State of California

AIR RESOURCES BOARD

PUBLIC HEARING TO CONSIDER THE PROPOSED HEAVY-DUTY ENGINE AND VEHICLE OMNIBUS REGULATION AND ASSOCIATED AMENDMENTS:

Proposed Amendments to the Exhaust Emissions Standards and Test Procedures for 2024 and Subsequent Model Year Heavy-Duty Engines and Vehicles, Heavy-Duty On-Board Diagnostic System Requirements, Heavy-Duty In-Use Testing Program, Emissions Warranty Period and Useful Life Requirements, Emissions Warranty Information and Reporting Requirements, and Corrective Action Procedures, In-Use Emissions Data Reporting Requirements, and Phase 2 Heavy-Duty Greenhouse Gas Regulations, and Powertrain Test Procedures

STAFF REPORT: INITIAL STATEMENT OF REASONS

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California Environmental Protection Agency
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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/ Abbreviation	Definition
°C	Degrees Celsius
°F	Degrees Fahrenheit
2016 State SIP Strategy	Revised Proposed 2016 State Strategy for the State Implementation Plan
3B-MAW	Three-Bin Moving Average Window
ABT	Averaging, Banking, and Trading
ACT	Advanced Clean Trucks
AESS	Automatic Engine Shutdown System
APU	Auxiliary Power Units
ARPA-E	Advanced Research Projects Agency-Energy
ASC	Ammonia Slip Catalyst
ASTM	American Society for Testing and Materials
ATCM	Airborne Toxic Control Measure
Ca	Calcium
CA-ABT	California-Averaging, Banking, and Trading
CA-VIUS	California Vehicle Inventory and Use Survey
Caltrans	California Department of Transportation
CARB or Board	California Air Resources Board
CCR	California Code of Regulations
CE-CERT	College of Engineering – Center for Environmental Research and Technology
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CI	Compression-Ignition
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2-FCL	CO2 Family Certification Level
DAAAC	Diesel Aftertreatment Accelerated Aging Cycle
DDP	Durability Demonstration Program
DEF	Diesel Exhaust Fluid
DMV	Department of Motor Vehicles
DOC	Diesel Oxidation Catalyst
DOT	Department of Transportation
DPF	Diesel Particulate Filter
EA	Environmental Analysis
ECU	Engine Control Unit
EGR	Exhaust Gas Recirculation
EIR	Emissions Information Report
EMA	Truck and Engine Manufacturers Association
EMD	Engine Manufacturer Diagnostic
EMFAC	Emission FACtors Inventory Model
EWIR	Emissions Warranty Information and Reporting
FCL	Family Certification Level
FEL	Family Emission Limit
FIR	Field Information Report

Acronym/ Abbreviation	Definition
FTP	Federal Test Procedure
g/bhp-hr	Grams Per Brake Horsepower-Hour
g/hr	Grams Per Hour
g/kW-hr	Grams Per Kilowatt-Hour
GEM	Greenhouse Gas Emissions Model
GHG	Greenhouse Gas
GSP	Gross State Product
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
HD	Heavy-Duty
HD I/M	Heavy-Duty Vehicle Inspection and Maintenance
HD OBD	Heavy-Duty On-Board Diagnostics
HDIUC	Heavy-Duty In-Use Compliance
HDIUT	Heavy-Duty In-Use Testing
HDO	Heavy-Duty Otto-Cycle
HDTT	Heavy-Duty Transient Test Cycle
HDVIP	Heavy-Duty Vehicle Inspection Program
Heavy-Duty Diesel Test Procedures	California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles
Heavy-Duty Otto-Cycle Test Procedures	California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines and Vehicles
HHDD	Heavy Heavy-Duty Diesel
hp	Horsepower
HSC	California Health and Safety Code
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
Hz	Hertz
ICCT	International Council on Clean Transportation
ISOR or Staff Report	Initial Statement of Reasons
ISR	Sacramento Institute for Social Research
ITR	Innovative Technology Regulations
K	Potassium
LEV III	Low-Emission Vehicle III
LHDD	Light Heavy-Duty Diesel
LLC	Low Load Cycle
LPG	Liquefied Petroleum Gas
MAW	Moving Average Window
MDDE	Medium-Duty Diesel Engine
MDOE	Medium-Duty Otto-Cycle Engine
MECA	Manufacturers of Emission Controls Association
MEMA	Motor & Equipment Manufacturers Association
Mg	Magnesium
MHDD	Medium Heavy-Duty Diesel
MIL	Malfunction Indicator Light
MOD NTE	Modified Not-to-Exceed
mph	Miles Per Hour
MY	Model Year
Na	Sodium

Acronym/ Abbreviation	Definition
NAAQS	National Ambient Air Quality Standards
NESCAUM	Northeast States for Coordinated Air Use Management
NHTSA	National Highway Traffic Safety Administration
NMHC	Non-Methane Hydrocarbons
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
NTE	Not-to-Exceed
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OOIDA	Owner-Operator Independent Drivers Association
PEMS	Portable Emissions Measurement System
PM	Particulate Matter
PM2.5	Fine Particulate Matter
ppb	Parts Per Billion
ppm	Parts Per Million
Proposed Amendments	Heavy-Duty Omnibus Low NOx Regulation
PSIP	Periodic Smoke Inspection Program
REAL	Real Emissions Assessment Logging
REMI	Regional Economic Models, Inc.
RMC-SET	Ramped Modal Cycle Version of the Supplemental Emission Test
SCAQMD	South Coast Air Quality Management District
SCR	Selective Catalytic Reduction
SCRF	Selective Catalytic Reduction Coated on Filter
SI	Spark-Ignited
SIP	State Implementation Plan
SRIA	Standardized Regulatory Impact Assessment
State Strategy	2016 State Strategy for the State Implementation Plan
SwRI	Southwest Research Institute
tpd	Tons Per Day
TWC	Three-Way Catalyst
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
UL	Useful Life
VIUS	National Vehicle Inventory and Use Survey
VMT	Vehicle Miles Traveled
ZEV	Zero-Emission Vehicle

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EXECUTIVE SUMMARY

Nearly seven years ago, in October 2013, the California Air Resources Board (CARB or Board) initiated a Low NOx Demonstration Program with Southwest Research Institute (SwRI) to evaluate the feasibility of attaining a 0.02 gram per brake horsepower-hour (g/bhp-hr) tailpipe oxides of nitrogen (NOx) emission standard on modern heavy-duty engines. That tailpipe standard corresponds to a 90 percent reduction in NOx emissions from the current 0.20 g NOx/bhp-hr emission standard for on-road heavy-duty engines. The Low NOx Demonstration Program, funded in partnership with the Manufacturers of Emission Controls Association (MECA), United States Environmental Protection Agency (U.S. EPA), South Coast Air Quality Management District (SCAQMD), and engine manufacturers, grew to $5 million and has demonstrated the feasibility of achieving significantly lower exhaust emissions from heavy-duty engines.

Relying in part on the work of SwRI, CARB staff has developed a proposed comprehensive update to the California emission standards and other emission-related requirements for heavy-duty engines and vehicles, hereinafter referred to as the "Heavy-Duty Omnibus Regulation" (HD Omnibus Regulation). The HD Omnibus Regulation is aimed at ensuring real-world emissions performance, not just in the laboratory, but also on the road. In June 2018, the Board approved amendments to the California on-road heavy-duty vehicle and engine warranty regulations (i.e., the Step 1 warranty amendments) to lengthen existing warranty periods to better reflect the longevity and usage of modern vehicles, and the HD Omnibus Regulation would lengthen those periods further.

This Staff Report describes the various components of the HD Omnibus Regulation which collectively comprise a significant set of revisions designed to ensure that NOx emissions from heavy-duty engines are significantly reduced from the time the vehicle/engine is first sold, until the end of its useful life.

A. Why does California need to further reduce emissions from on-road heavy-duty vehicles and engines?

On-road heavy-duty vehicles,[1] including long-haul trucks, drayage trucks, transit buses, refuse trucks, and other commercial work vehicles, operate throughout California and are an essential part of the state's economy. According to California's Emission FACtors (EMFAC) 2017 emissions inventory model, almost a million heavy-duty vehicles operate on California roads each year and are significant sources of NOx, particulate matter (PM), and greenhouse gas (GHG) emissions. In fact, on-road heavy-duty vehicles comprise the largest NOx emission source category in the state (as shown

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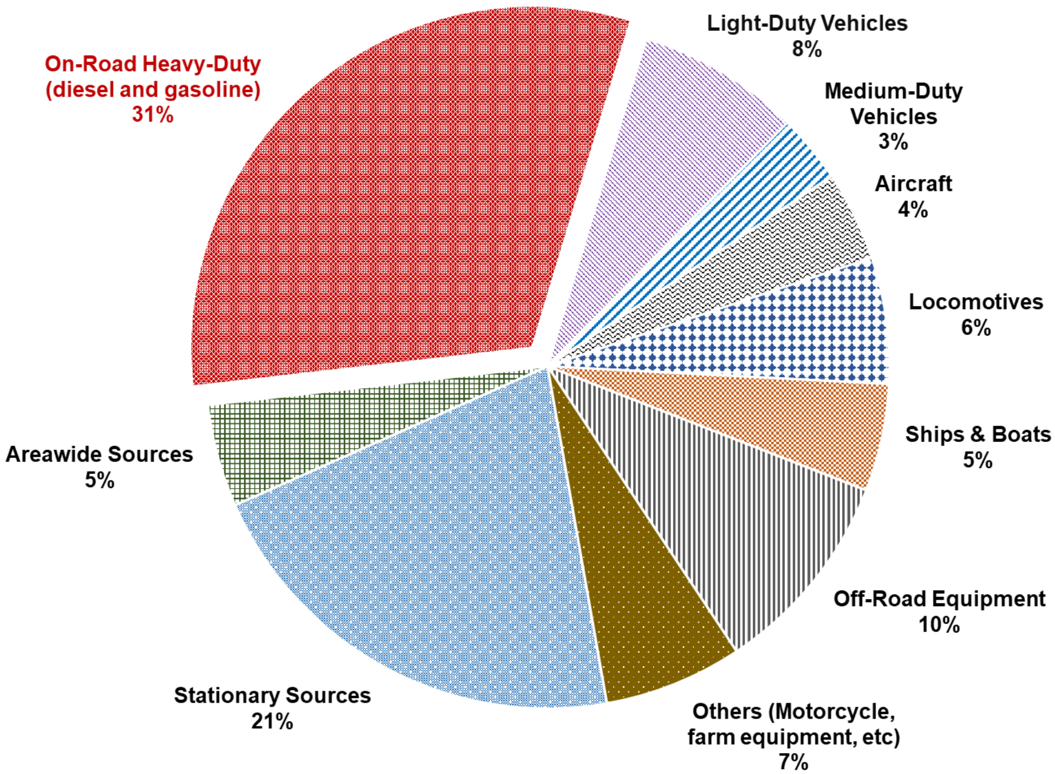
[1] Under California regulations, heavy-duty vehicles are those vehicles with a gross vehicle weight rating (GVWR) greater than 8,500 pounds, while medium-duty vehicles are a subcategory of heavy-duty vehicles with a GVWR between 8,501 and 14,000 pounds. Manufacturers have the option to certify medium-duty engines used in vehicles from 10,001 to 14,000 pounds GVWR to the engine standards specified for engines in vehicles over 14,000 pounds.

in Figure ES-1), contributing 31 percent of all statewide NOx emissions as well as 26 percent of total statewide diesel PM emissions.

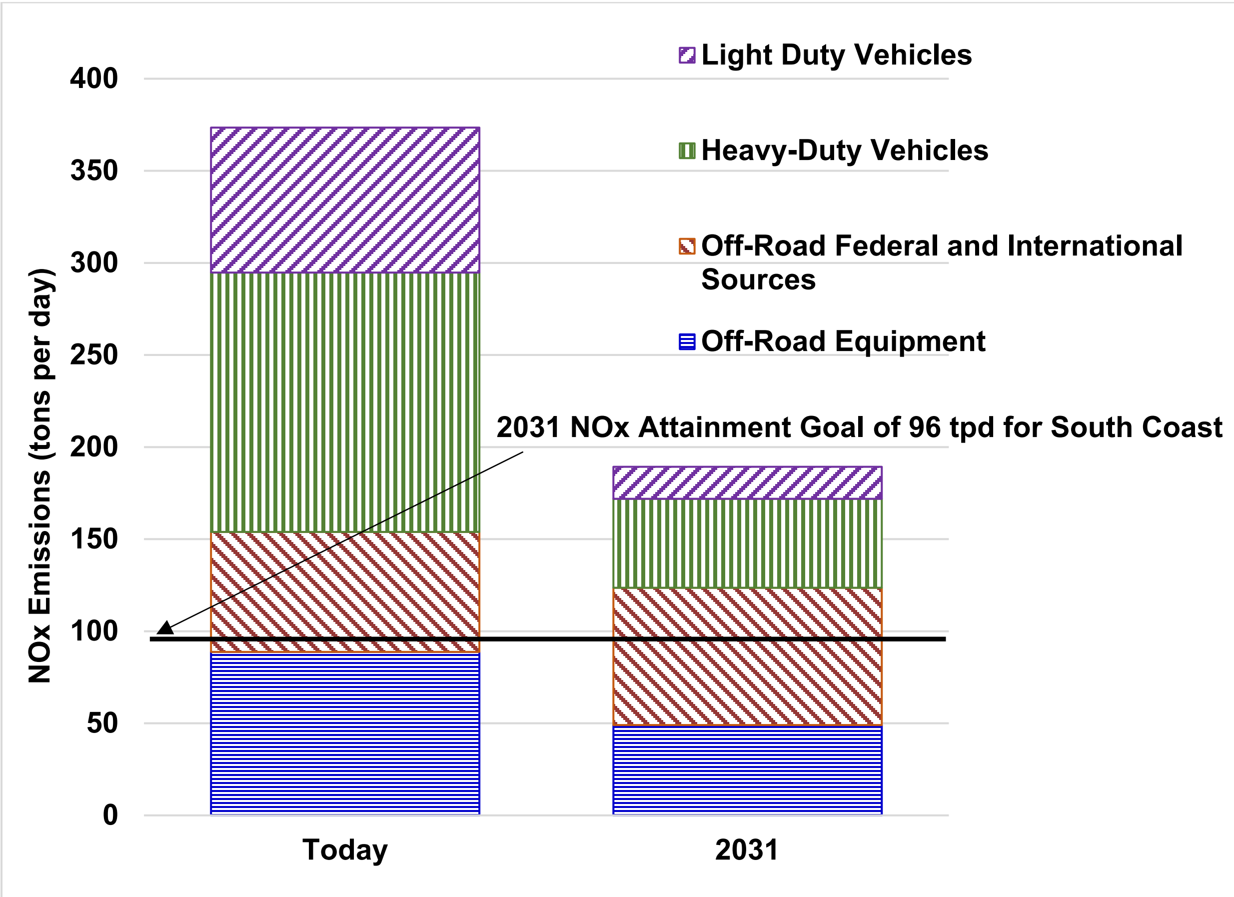
Figure ES-1. NOx Emission Source Categories in California – 2018



One element of the proposed rulemaking action, establishing an approximately 90 percent lower NOx standard for on-road heavy-duty engines, constitutes the most significant measure in CARB's 2016 State Strategy for the State Implementation Plan (SIP), California's official and legally binding plan of measures needed to meet the federal National Ambient Air Quality Standards. This measure is responsible for nearly half of the entire NOx emission reduction commitment in the entire plan, 52 tons per day (tpd) out of 111 total tpd NOx in 2031, and is therefore a critical component of California's strategy to achieve California's air quality goals, attain the National Ambient Air Quality Standards, and protect the health and well-being of Californians.

Figure ES-2 shows NOx emissions from mobile sources in the South Coast Air Basin for the current year 2020 and projected for 2031 (CARB, 2016c). As shown in Figure ES-2, existing mobile source programs are expected to reduce NOx emissions by over 50 percent of the needed emission reductions from mobile sources in the South Coast Air Basin. However, even with the expected emission reductions, on-road heavy-duty vehicles are projected to remain one of the largest contributors to the state's NOx emissions inventory, and significant additional NOx reductions are needed from these sources in order to meet the federal ambient air quality standards for ozone.

Figure ES-2. South Coast Mobile Source NOx Emissions With Existing Programs (CARB, 2018f)



Note: This figure is based on the 2016 State Strategy for the State Implementation Plan, which used CARB's EMFAC2014 inventory model to estimate on-road emissions. The more updated estimates in this document are based on EMFAC2017.

B. What are the current California emission standards and other emission-related requirements for on-road heavy-duty vehicles and engines?

Since 2010, in California and the rest of the United States, on-road heavy-duty engines have been subject to a PM standard of 0.01 g/bhp-hr and a NOx standard of 0.20 g/bhp-hr. California also requires engines to certify to a NOx idling emission standard of 30 grams per hour (g/hr).[2]

To legally sell new engines, manufacturers must certify that their engines will comply with applicable emission standards throughout a specified period called the regulatory useful life (which for the heaviest diesel engines is currently 10 years, 435,000 miles, or 22,000 hours, whichever first occurs). To simulate heavy-duty engine and emission-

[2] In lieu of compliance with the idling standard, manufacturers may use a non-programmable 5-minute engine shutdown system, but no manufacturers have chosen this option.

related control component aging throughout the applicable useful life period, manufacturers operate engines over test cycles as specified in a durability demonstration program (DDP). Manufacturers must demonstrate that the emissions from engines that have completed a DDP comply with applicable certification emission standards before those engines can be certified for use and sale. To demonstrate compliance, California and U.S. EPA require heavy-duty engine manufacturers to measure exhaust emissions generated when engines are operated over two test cycles, the heavy-duty transient Federal Test Procedure[3] (FTP) and the Supplemental Emission Test Ramped Modal Cycle[4] (RMC-SET). The FTP test cycle represents a transient medium load duty cycle. The RMC-SET simulates steady-state engine operation during suburban and highway truck speeds.

Manufacturers must also warrant emission-related components for a certain time period, currently 100,000 miles or 10 years, whichever first occurs. For components that fail under warranty, manufacturers may be required to report certain data to CARB. If failure rates are high enough, manufacturers are required to conduct corrective actions such as recalling faulty components.

Manufacturers are also required to test engines while they are operated on the road using portable emissions measurement systems. All heavy-duty engine manufacturers must conduct heavy-duty in-use testing (HDIUT) on a fraction of their engine families, with the specific engine families specified by U.S. EPA and CARB. The in-use test data are evaluated via the not-to-exceed (NTE) method and submitted to CARB and U.S. EPA. CARB also has the ability to independently test any engine family through CARB's in-house Heavy-Duty In-Use Compliance Program. Engine families that fail HDIUT requirements are subject to potential recall.

Diesel manufacturers have met the PM standard through use of diesel particulate filters (DPF) and the NOx standard via use of selective catalytic reduction (SCR) systems. SCR systems typically use a solution of urea and water called Diesel Exhaust Fluid (DEF) to supply the ammonia that converts NOx to nitrogen gas and water.

In 2016, CARB created and adopted the Innovative Technology Regulation with significant short-term certification flexibility to encourage development and introduction of hybrid technologies. To date, however, no hybrid certifications have used this flexibility.

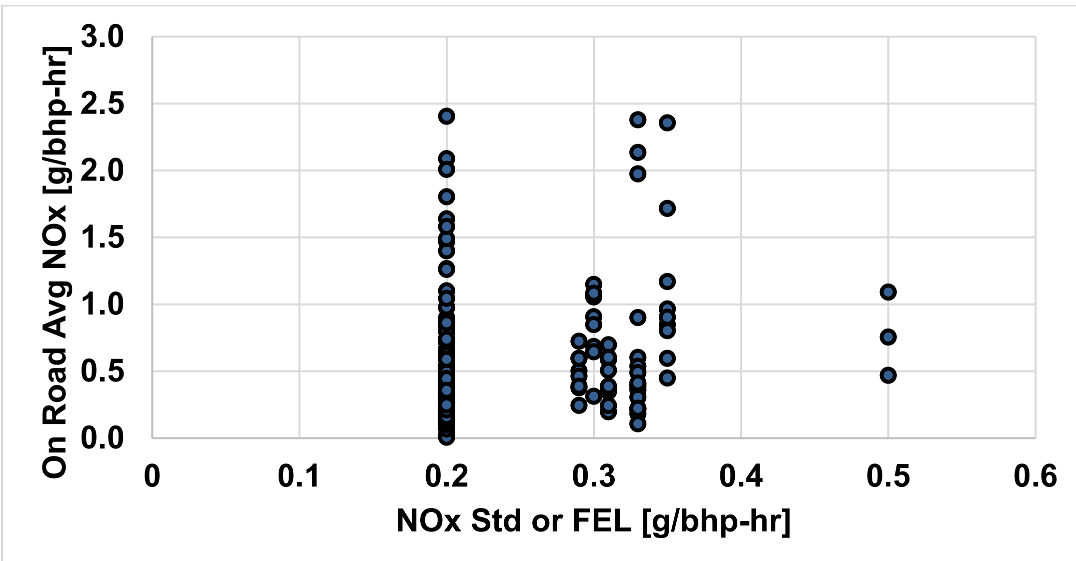
[3] "FTP" is the heavy-duty transient Federal Test Procedure duty cycle specified in 40 CFR 86.007-11(a)(2), as amended October 25, 2016.
[4] "RMC-SET" is the supplemental emission test procedure with the steady-state duty cycle specified in 40 CFR 86.1360, as amended October 25, 2016.

C. Why are changes needed to these existing programs?

Changes to these existing programs are needed for the following reasons:

(1) Some elements of the programs need improvement to better control real-world emissions performance. As shown in Figure ES-3 below, measured real-world NOx emissions far exceed the emission standards to which heavy-duty engines are certified. Figure ES-3 contains manufacturer-submitted HDIUT data for heavy-duty vehicles in real-world use, where average NOx emissions were many times higher than the certification standard or Family Emission Limit (FEL), in fact sometimes greater than ten times the standard.

Figure ES-3. Real-World vs. Certified NOx Emission Rates of Manufacturer-Submitted HDIUT Vehicles



(2) It is technically feasible and cost-effective to significantly reduce current emission standards to achieve needed NOx reductions, and

(3) Some provisions would benefit from clarification.

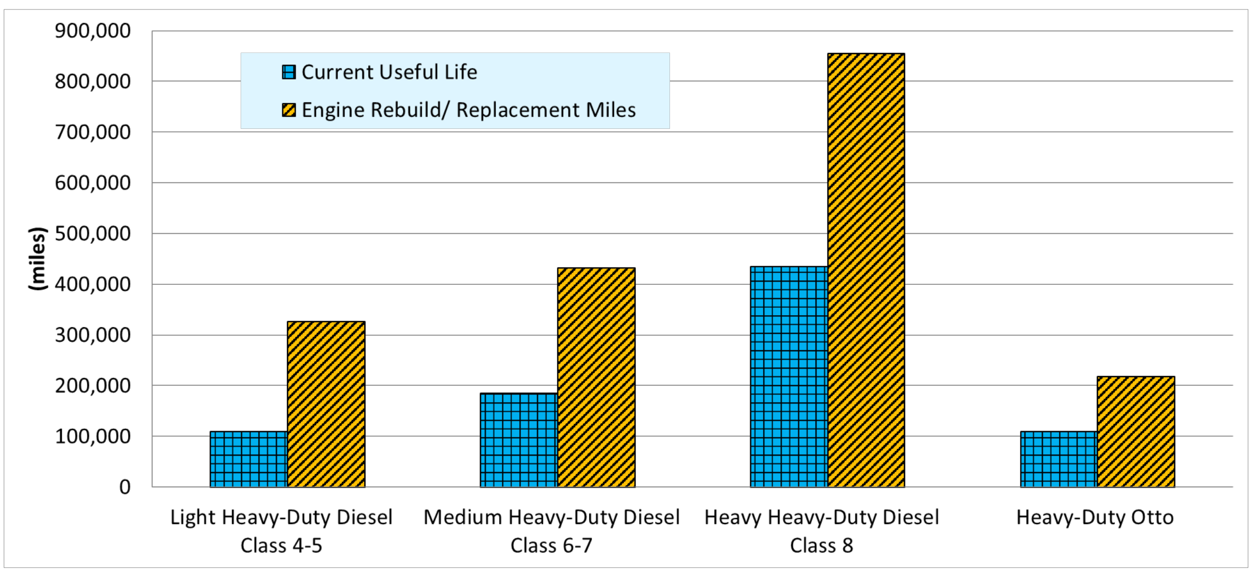
Elements of existing programs that need improvement include the following:

- SCR systems are highly effective at controlling NOx emissions at high engine exhaust temperatures but currently fail to function well at low temperature, low load conditions. Unfortunately, these low load conditions dominate actual operation of heavy-duty vehicles in urban stop-and-go operation in communities and on congested freeways where the reduction of NOx is most needed.

- The current NTE-based HDIUT program exempts nearly all of the vehicle operational conditions experienced by actual heavy-duty vehicles, and therefore does not accurately assess the true emissions performance of heavy-duty vehicles in terms of NOx emissions. An analysis of manufacturer-submitted HDIUT data for 2010 to 2014 model year (MY) engines equipped with SCR showed the average percent of data and percent of NOx emissions represented in NTE events was less than six percent in the HDIUT data set. In some cases, manufacturers have completed HDIUT requirements without obtaining any valid data, which clearly subverts the purpose of the program. The European Union has a superior Moving Average Window (MAW)-based approach that more accurately assesses emissions from actual heavy-duty vehicles, and CARB staff believes that adjustments to the MAW approach will also be beneficial for the HDIUT program.

- Current regulatory useful life mileages for heavy-duty engines are significantly lower than the mileages at which modern heavy-duty engines are rebuilt or replaced, as shown in Figure ES-4 below. This highlights the need for longer useful life periods to reduce emissions by: (1) better representing the longer modern service lives of heavy-duty engines, and (2) encouraging manufacturers to make parts more durable in order to avoid non-compliance with in-use testing requirements and inconvenient, costly recalls.

Figure ES-4. Current Heavy-Duty Useful Life Compared to Engine Rebuild/Replacement Mileages (MacKay, 2019)



Note: Class 4-5 is 14,001-19,500 lbs. GVWR, Class 6-7 is 19,501-33,000 lbs. GVWR, and Class 8 is >33,000 lbs. GVWR.

- Similarly, longer warranty periods for heavy-duty vehicles and engines are needed for three main reasons: (1) to better represent their longer modern service lives and ensure that the emission control systems remain operational throughout a greater portion of a vehicle's service life, (2) to reduce incidences of tampering and mal-maintenance, and (3) to encourage manufacturers to make parts more durable. For example, survey data shows Class 8 vehicles frequently operate upwards of 850,000 miles before engine rebuilds are conducted (MacKay, 2019). However, engines in such vehicles are currently only required to be warranted to 100,000 miles, and even under CARB's June 2018 Step 1 warranty amendments, these vehicles will still only be required to be warranted for 350,000 miles.

- CARB's current DDP requirements do not adequately predict actual emissions. Analysis of data from U.S. EPA's "2014-2017 Progress Report, Vehicle and Engine Compliance Activities," and CARB's recent investigation of excess emissions that led to a nationwide recall of more than 500,000 heavy-duty trucks indicate that the current laboratory aging process does not yield valid results for estimating full useful life deterioration factors. Hence, improvements that do a better job of demonstrating real-world durability are clearly needed.

- Amendments to CARB's Emissions Warranty Information and Reporting (EWIR) and corrective action procedures are needed to ensure that emission control component problems are corrected more expeditiously. Currently, identifying potentially defective emission control components by warranty reporting requirements and the process of negotiating corrective action with manufacturers and determining the emissions impact of a component failure is lengthy, which can delay corrective action and allow vehicles to operate with defective or faulty components with elevated emissions for years.

- Over the last few model years (MYs) some manufacturers have elected to certify some of their engine families to higher PM emission levels through use of less efficient (i.e., more porous) DPFs, resulting in higher PM emission rates, although still compliant with the current PM standard. To prevent manufacturers from using less efficient DPFs and thereby maintain the current robust PM emission control performance near 0.001 g/bhp-hr levels, there is a need for a lower PM standard.

D. What amendments are CARB staff proposing in this rulemaking action?

The proposed HD Omnibus Regulation would comprehensively overhaul emission standards and other emission-related requirements for California-certified on-road heavy-duty engines and contains the following primary elements.

1. Proposed NOx and PM Exhaust Emission Standards

The proposed exhaust emission standards would apply to heavy-duty Otto-cycle (HDO) and heavy-duty diesel engines intended for use in vehicle service classes with gross vehicle weight ratings (GVWR) greater than 10,000 pounds. The current and proposed standards for 2024 through 2026 MY engines are shown in Table ES-1.

CARB staff is also proposing to provide manufacturers the option to certify 2024 through 2026 model year engines to a less stringent NOx standard, if they meet that standard on a nationwide basis. The optional 50-state-directed engine standards are shown in parentheses in Table ES-1. To the extent the optional standards are used by manufacturers, they would provide air quality benefits to California since federal certified trucks that travel to California would be lower-emitting than they would have been absent this option.

The proposed standards for 2027 and subsequent MY engines are shown in Table ES-2. As shown in Table ES-2, CARB staff is proposing tiered standards for heavy heavy-duty diesel (HHDD) engines based on an intermediate useful life of 435,000 miles and full useful life of 600,000 miles and 800,000 miles, for 2027 through 2030 and 2031 and subsequent MYs, respectively.

Table ES-1. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards (MY 2024 to 2026)

MYs	**MDDE/LHDD/MHDD/HHDD[a]**				**MDOE/HDO[a]**
	FTP (g/bhp-hr)	RMC-SET (g/bhp-hr)	LLC (g/bhp-hr)	Idling (g/hr)	FTP (g/bhp-hr)
Current	0.20	0.20	---	30	0.20
2024 - 2026	0.050 (0.10)[b]	0.050 (0.10)[b]	0.200 (0.30)[b]	10 (10)[b]	0.050 (0.10)[b]

[a] MDDE: Medium-duty diesel engines 10,001-14,000 lbs. GVWR,
LHDD: Light heavy-duty diesel engines 14,001-19,500 lbs. GVWR,
MHDD: Medium heavy-duty diesel engines 19,501-33,000 lbs. GVWR,
HHDD: Heavy heavy-duty diesel engines >33,000 lbs. GVWR,
MDOE: Medium-duty Otto-cycle engines 10,001-14,000 lbs. GVWR, and
HDO: Heavy-duty Otto-cycle engines >10,000 lbs. GVWR.
[b] NOx standards in parentheses are optional 50-state-directed engine standards. Manufacturers may meet these less stringent standards in California if they do so for all engine families they produce nationwide.

Table ES-2. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards (MY 2027 and Subsequent)

Test Procedure	MDDE/LHDD/MHDD	MDOE/HDO	HHDD	
	MY 2027 and Subsequent		MY 2027 - 2030	MY 2031 and Subsequent
	(@Useful Life)	(@Useful Life)	(@435,000 miles)[a]	(@435,000 miles)[a]
FTP cycle (g/bhp-hr)	0.020	0.020	0.020	0.020
RMC-SET cycle (g/bhp-hr)	0.020	---	0.020	0.020
Low-load cycle (g/bhp-hr)	0.050	---	0.050	0.050
Idling (g/hr)	5	---	5	5

[a] For HHDD, the FTP, RMC-SET, and Low-load cycle standards at full useful life are higher to account for deterioration, as shown within the main document in Table III-4.

CARB staff is also proposing a PM standard of 0.005 g/bhp-hr beginning with the 2024 MY for all heavy-duty diesel and HDO engines.

2. Proposed Heavy-Duty In-Use Testing Program

CARB staff is proposing amendments that would replace the current NTE-based methodology with a new MAW-based methodology for 2024 and subsequent MY engines. For diesel engines, three bins related to the applicable standards would be used to determine compliance. The three diesel-cycle MAW-based bins represent idle, low load, and medium to high load operations based on average carbon dioxide emission rates. For Otto-cycle engines, a single bin encompassing all operation would be used. Compliance would be determined by comparing the average NOx emissions for each bin to the in-use threshold, defined as one and a half times the applicable NOx standard for the MY. These amendments to the HDIUT program would improve the coverage of engine operations and emissions.

The amendments would also ensure that adequate data is obtained to verify the condition of the test vehicle and sensors before, after, and during HDIUT, would provide clear criteria for engine family pass or fail compliance determinations, ensure that corrective action is taken in a timely manner, and clarify current provisions.

3. Proposed Amendments to Warranty and Useful Life Periods, and EWIR and Corrective Action Procedures

To help ensure that emission controls are sufficiently durable to control emissions over applicable useful life periods, and well-maintained and repaired when needed, CARB staff is proposing to lengthen the criteria pollutant emissions warranty and useful life period requirements for heavy-duty vehicles and engines. The Proposed Amendments would be phased-in beginning with 2027 MY engines, and would be fully implemented for 2031 and subsequent MY engines. The current and proposed warranty and useful life periods are shown in Table ES-3.

Table ES-3. Current and Proposed Warranty and Useful Life Periods

MY	LHDD	MHDD	HHDD	HDO
	Warranty (miles)			
June 2018 Step 1 Warranty 2022-2026	110,000 5 years	150,000 5 years	350,000 5 years	50,000* 5 years
2027-2030	150,000 7 years/ 7,000 hours	220,000 7 years/ 11,000 hours	450,000 7 years/ 22,000 hours	110,000 7 years/ 6,000 hours
2031 and Subsequent	210,000 10 years/ 10,000 hours	280,000 10 years/ 14,000 hours	600,000 10 years/ 30,000 hours	160,000 10 years/ 8,000 hours
	Useful Life (miles)			
Current-2026	110,000 10 years	185,000 10 years	435,000 10 years/ 22,000 hours	110,000 10 years
2027-2030	190,000 12 years	270,000 11 years	600,000 11 years/ 30,000 hours	155,000 12 years
2031 and Subsequent	270,000 15 years	350,000 12 years	800,000 12 years/ 40,000 hours	200,000 15 years

* Not included under Step 1 Warranty, but current periods are shown here for completeness.

The Proposed Amendments also include improvements to CARB's EWIR program and corrective action procedures to ensure that manufacturers take corrective action in a more timely manner when failure rates exceed corrective action thresholds. This will help speed up necessary recalls and ensure that defective parts are quickly identified and replaced.

4. Proposed Heavy-Duty Durability Demonstration Program Amendments

The Proposed Amendments would establish more stringent heavy-duty engine durability requirements. The amendments would increase the default break-in period for heavy-duty diesel engines from 125 hours to 300 hours, specify standardized certification cycles for engine and aftertreatment system aging in order to validate component durability and determine deterioration factors, and extend the durability testing period.

The amendments would also allow manufacturers to use accelerated aging cycles for a portion of the useful life demonstration for the aftertreatment system, provided they periodically submit emissions data from in-use heavy-duty diesel engines sold into commerce over the useful life of such engines.

5. Proposed Emissions Averaging, Banking, and Trading Program Amendments

Because the amendments would establish California heavy-duty engine emission standards and other emission-related requirements that are more stringent than the corresponding federal heavy-duty emission standards and other emission-related requirements, CARB staff is proposing to establish a separate California-only averaging, banking, and trading (CA-ABT) program starting with the 2022 MY engines. The proposed CA-ABT program would allow manufacturers to transfer a portion of any existing 2010 to 2021 MY credits from federal averaging, banking, and trading (ABT) accounts for 2010 to 2021 MYs, as adjusted by the fraction of California to 50-state sales volumes for 2019-2021 MY sales. The Proposed Amendments would also allow manufacturers that elect to produce and certify heavy-duty zero-emission vehicles (ZEV) to generate NOx credits, in order to incentivize the sales of heavy-duty ZEVs earlier than would be required by CARB's proposed Advanced Clean Trucks (ACT) Regulation.

6. Powertrain Certification Test Procedures for Heavy-Duty Hybrid Vehicles Amendments

The Proposed Amendments would provide manufacturers an option to certify hybrid powertrains to criteria pollutant emission standards using specified hybrid-powertrain testing procedures. The proposed hybrid-powertrain testing procedures would align with federal powertrain testing procedures and would be based on the U.S. EPA Phase 2 GHG technical amendments for powertrain testing.

7. Clean-up Items, Clarifications, and Corrections

The Proposed Amendments would make some minor but needed clarifications and corrections related to the Phase 2 GHG standards, diesel auxiliary power unit requirements, and medium-duty engine requirements. These amendments, which are described in further detail in this Staff Report, are needed to align better with federal requirements and clarify inadvertent ambiguities.

E. What technologies would be needed to meet the Proposed Amendments? How does CARB staff know the amendments are technically feasible?

In order to comply with the more stringent standards for 2024 and subsequent MYs, manufacturers would likely need to utilize a combination of emission control strategies that provide improved thermal management and improved SCR conversion efficiency during cold starts and at lower engine loads. Such strategies would likely include engine calibration strategies, such as higher exhaust gas recirculation rates to reduce engine-out NOx, and higher idle speeds to reduce engine warm-up time to better control cold start emissions. In addition, SCR system improvements such as a combination of larger SCR catalyst volumes and improved catalyst substrates would likely be needed. Improvements in thermal management of SCR systems would also likely be needed, such as improved packaging of the aftertreatment system and improved urea dosing strategies, such as heating urea dosing systems. The SwRI Low NOx Stage 1 testing program demonstrated 0.09 g/bhp-hr FTP NOx emission levels (a 36 percent reduction) solely through engine calibration strategies that reduced cold start emissions and with a stock aftertreatment system. In addition, modeling by MECA showed that improving engine calibration together with the use of currently available average SCR catalyst volume could reduce composite FTP NOx emission levels to 0.03 g/bhp-hr levels.

To meet the proposed 2027 and subsequent MY heavy-duty diesel engine NOx standards, manufacturers would likely need to utilize additional engine calibration strategies, engine hardware changes such as cylinder deactivation and variable valve actuation, as well as advanced aftertreatment systems such as dual SCR systems with dual dosing and a light-off catalyst close-coupled to the engine. In the SwRI Low NOx Stage 3 testing program, SwRI has demonstrated achieving the proposed 2027 emission levels utilizing these technologies (without reliance on variable valve actuation), along with improved engine calibration strategies for exhaust thermal management.

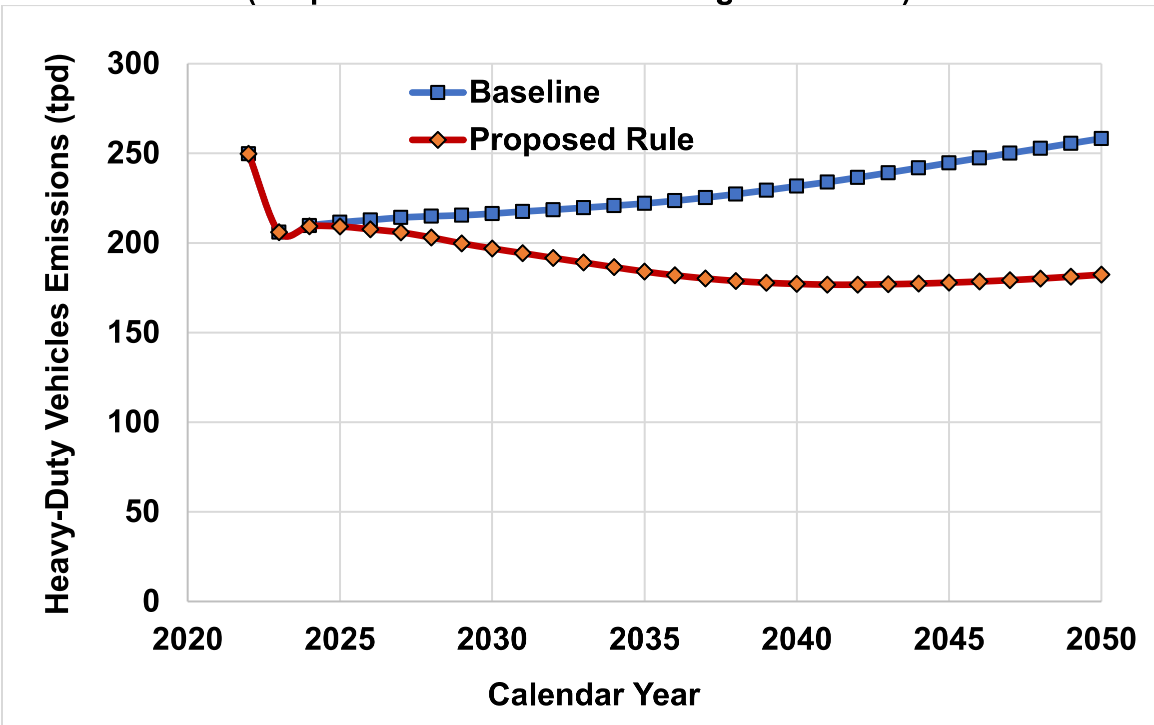
F. What emission reductions would the Proposed Amendments achieve?

Table ES-4 below shows the projected NOx reductions the Proposed Amendments would achieve. In 2031, the target SIP date to meet the 2008 ozone ambient air quality standards, NOx emission benefits are estimated to be approximately 23.2 tpd statewide and 7.0 tpd in the South Coast Air Basin. Figure ES-5 shows statewide NOx emissions trends from heavy-duty vehicles for baseline and with the Proposed Amendments.

Table ES-4. Projected NOx Emission Benefits from the Proposed Amendments (tpd)

Calendar Year	Statewide	South Coast	San Joaquin Valley
2024	0.4	0.1	0.1
2031	23.2	7.0	5.7
2040	54.5	16.3	13.6
2050	75.9	23.0	19.0

Figure ES-5. Statewide NOx Emissions from Heavy-Duty Vehicles (Proposed Amendments vs. Legal Baseline)[5]



The proposed PM standard of 0.005 g/bhp-hr is intended to encourage manufacturers to continue meeting the current PM emissions levels of 0.001 g/bhp-hr, and to prevent backsliding by using less efficient DPFs. Therefore, no additional direct PM benefits are expected from this requirement. However, since NOx is also a precursor to secondary PM2.5 formation, NOx emission reductions would also provide ambient PM2.5 emission benefits resulting in significant health benefits. The Proposed Amendments are not expected to have any significant impacts on GHG emissions. The emission reductions from the Proposed Amendments are expected to prevent nearly 3,900 deaths, as well as greater than 1,300 hospitalizations and 1,800 emergency room visits through the year 2050.

G. What would the cost impacts of the Proposed Amendments be?

<u>Total Cost Impact on Manufacturers</u>

The Proposed Amendments would require engine manufacturers to produce lower-emitting engines with new technologies and calibration strategies, which would require them to incur research and development costs and would also increase their upfront production and operational costs. Table ES-5 below summarizes the anticipated total costs of the Proposed Amendments on engine manufacturers. As Table ES-5 shows,

[5] Note that the inventory includes NOx emissions from all engine-certified heavy-duty vehicles (excluding chassis-certified medium-duty vehicles) with GVWR >10,000 pounds, including out-of-state vehicles that operate in California.

the majority of manufacturer costs would be due to meeting the new standards and covering the lengthened warranties.

Table ES-5. Projected Cost Impact of the Proposed Amendments to Manufacturers (2018$)

Engine MY[a]	Standards, Certification, and New Technology	In-Use Amendments	Lengthened Warranty	Durability Demonstration	EWIR Amendments	ABT	Total Costs on Manufacturers
2024	$45,200,000	$59,000	$0	$141,000	$10,237,000	$43,000	$55.7 million
2027	$109,540,000	$62,000	$13,611,000	$755,000	$21,017,000	$43,000	$145 million
2031	$134,784,000	$67,000	$41,449,000	$2,002,000	$7,445,000	$43,000	$186 million
Total Costs for Calendar Year 2022 to 2050	**$2.78 billion**	**$2.00 million**	**$933 million**	**$82.3 million**	**$276 million**	**$1.43 million**	**$4.07 billion**

[a] LHDD, MHDD, and HHDD MY engines will appear in the following year's vehicles.

The projected compliance costs are significant, $145 million for 2027 MY engines and approximately $4.07 billion in total costs for calendar year 2022 through 2050. However, these costs are small in comparison to the roughly $36.8 billion in expected monetized health benefits resulting from the Proposed Amendments, which largely stem from avoided premature mortality. As discussed further below, manufacturers would be expected to recoup their costs by passing them on to their customers.

The manufacturers would likely pass their costs on to engine and vehicle buyers in the form of increased engine and vehicle prices. However, engine and vehicle buyers would also receive benefits due to the Proposed Amendments. The Proposed Amendments would significantly lengthen the manufacturer's emissions warranty period, and vehicle owners would benefit by not having to pay out-of-pocket for vehicle repairs during that lengthened period. This benefit is particularly timely due to the recently signed Senate Bill 210 (Leyva; Chapter 298, Statutes of 2019), which directs CARB to develop and implement a comprehensive heavy-duty vehicle inspection and maintenance (HD I/M) program. The HD I/M program will make vehicle owners responsible for maintaining their engines and aftertreatment systems in order to register them in California. The longer warranty periods within the Proposed Amendments would help ensure that manufacturers, not vehicle owners, pay for problems caused by poor design and durability that the HD I/M program detects. In addition, the proposed longer useful life and proposed durability demonstration protocol would encourage manufacturers to produce more durable components, resulting in fewer failures and less downtime for vehicle owners. Finally, the EWIR amendments would result in cost savings for vehicle purchasers because components that they previously would have had to pay for out-of-pocket would now be repaired or replaced under an extended warranty or recall. Tables ES-6 thru ES-8 below show the net impact for the various vehicle classes covered by the Proposed Amendments. For a medium heavy-duty diesel (MHDD) vehicle with a 2031 MY engine, CARB staff expects the initial vehicle purchase price to be about $6,923 higher than it otherwise would be. A buyer of such a vehicle would receive savings of $1,641 over the life of the vehicle, and would pay an additional $532 for DEF, meaning that the net impact on the vehicle purchaser would be an increase of about $5,814 over the life of the vehicle. While not insignificant, in this example these costs are relatively modest when compared to the total purchase price of MHDD vehicles with 2031 and subsequent MY engines, representing about 5.6 percent of baseline vehicle purchase price. The overall net cost for all vehicle classes as a percent of baseline purchase price is expected to range from 0.4 percent to 9.5 percent, with an average in MY 2024 to 2026 of 2.6 percent, in MY 2027 to 2030 of 5.2 percent, and in MY 2031 and subsequent of 5.8 percent.

Table ES-6. Net Cost Impact of a Vehicle with Engine MY from 2024 to 2026 Under the Proposed Amendments (2018$)

	Increased Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$3,761	$898	$60	$4,599	$169,637	2.7%
MHDD	$2,469	$370	$0	$2,839	$103,165	2.8%
LHDD	$1,687	$366	$0	$2,053	$57,694	3.6%
HDO	$506	$0	$143	$363	$94,089	0.4%
MDDE-3	$1,554	$196	$0	$1,751	$52,040	3.4%
MDOE-3	$412	$0	$0	$412	$44,459	0.9%
Population Average	**$2,355**	**$453**	**$34**	**$2,776**	**$107,782**	**2.6%**

Table ES-7. Net Cost Impact of a Vehicle with Engine MY from 2027 to 2030 Under the Proposed Amendments (2018$)

	Increased Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$7,423	$1,186	$791	$7,819	$171,107	4.6%
MHDD	$6,063	$488	$1,234	$5,317	$104,217	5.1%
LHDD	$4,741	$527	$345	$4,923	$58,258	8.5%
HDO	$821	$0	$368	$453	$98,583	0.5%
MDDE-3	$3,916	$235	$0	$4,151	$52,424	7.9%
MDOE-3	$412	$0	$0	$412	$44,843	0.9%
Population Average	**$5,437**	**$617**	**$789**	**$5,264**	**$109,559**	**5.2%**

Table ES-8. Net Cost Impact of a Vehicle with Engine MY 2031 and Subsequent Under the Proposed Amendments (2018$)

	Increased Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$8,478	$1,294	$930	$8,841	$171,107	5.2%
MHDD	$6,923	$532	$1,641	$5,814	$104,217	5.6%
LHDD	$6,041	$659	$1,143	$5,557	$58,258	9.5%
HDO	$1,015	$0	$582	$433	$98,583	0.4%
MDDE-3	$4,354	$235	$0	$4,589	$52,424	8.8%
MDOE-3	$412	$0	$0	$412	$44,843	0.9%
Population Average	**$6,410**	**$700**	**$1,197**	**$5,912**	**$109,889**	**5.8%**

CARB staff estimated the overall cost-effectiveness of the Proposed Amendments, in terms of dollar spent per emission benefit, to be $5.45 per pound of NOx reduced. This is within the range of the cost-effectiveness of CARB's previously adopted measures.

H. How would CARB staff's Proposed Amendments interact with the ACT Regulation?

The ACT Regulation, which was proposed at the December 12, 2019 board hearing (CARB, 2019l), is intended to accelerate the widespread adoption of ZEVs in the medium- and heavy-duty truck sector. The regulation would require large truck manufacturers to sell zero-emission trucks in California to broaden the market and to send a clear signal that medium- and heavy-duty ZEVs will be a major part of California's overall strategy to reduce criteria emissions, reduce climate impacts, and reduce petroleum use. Information collected via ACT Regulation reporting requirements would also be used in developing future regulations designed to further accelerate the purchase and use of ZEVs in fleets. With both a manufacturer ZEV sales requirement and a requirement for ZEVs to be used, in combination with early market support from funding programs, it is envisioned that the market for ZEV technology will significantly increase.

Although the proposed ACT Regulation would broadly apply to the same category of on-road vehicles as those affected by the Proposed Amendments, within the same time period and impact the same manufacturers, it must be noted that the Proposed Amendments address different purposes and provide utility that is distinct and independent from the purposes and the utility provided by the proposed ACT Regulation. As previously described, the Proposed Amendments implement SIP measures that require CARB to reduce NOx emissions from new on-road heavy-duty engines and to ensure those emission reductions are maintained as those engines and vehicles are operated. In contrast, the primary goal of the proposed ACT Regulation is to accelerate the introduction of ZEVs in the medium- and heavy-duty truck sector in applications that are best suited to the use of such ZEVs - applications that do not require vehicle operations exceeding a few hundred miles a day, such as local delivery applications and buses, which is a much smaller subset of the engines and vehicles impacted by the Proposed Amendments. Moreover, neither the ACT Regulation nor the Proposed Amendments are dependent on the adoption or implementation of the other rulemaking. However, the Proposed Amendments will complement the ACT Regulation by ensuring that the portions of manufacturers' engine family lines that are powered by internal combustion engines will be emitting at the lowest NOx emission standards possible.

In developing the Proposed Amendments, CARB staff had to consider how compliance, as well as potential early or over compliance, with the proposed ACT Regulation should be credited. The Proposed Amendments establish a mechanism so that heavy-duty ZEVs would also be averaged in and would help with compliance with the emission standards within the Proposed Amendments. The Proposed Amendments would provide an incentive for manufacturers to comply early or over comply with the ACT Regulation's heavy-duty ZEV mandates. So, for example, a manufacturer could choose to make more heavy-duty ZEVs than required by the ACT Regulation and then also make diesel engines certified to emission levels higher than the proposed standards. The manufacturer would be in compliance as long the manufacturer meets the proposed standards via use of averaging, banking, and trading provisions.

I. How do the Proposed Amendments relate to U.S. EPA's Cleaner Truck Initiative and why is it necessary for California to act ahead of U.S. EPA?

Addressing heavy-duty engines certified for use in California alone is not sufficient to address California's air quality needs. Heavy-duty vehicles play an important role in the transport of goods for interstate commerce and frequently cross state borders, and many California fleets purchase used federally certified heavy-duty vehicles. Thus, California must rely on the federal government to adopt and enforce timely, rigorous standards as well. Indeed, federally certified heavy-duty vehicles are responsible for over half of the total vehicle miles traveled by heavy-duty vehicles in California. For the heaviest vehicles (Class 8 vehicles over 33,000 pounds GVWR), over 60 percent of vehicle miles traveled in California are by federally certified heavy-duty vehicles. Hence, no matter how comprehensive and effective California's own HD Omnibus Regulation is, without companion federal action, these federally certified heavy-duty vehicles will still be emitting excess NOx emissions, and will compromise California's ability to achieve clean air.

U.S. EPA is currently in the process of developing its own package of lower NOx emission standards called the Cleaner Trucks Initiative, which will likely take effect with the 2027 MY (FR, 2020). Due to federal statutory lead time constraints, the Cleaner Trucks Initiative will likely not establish new, more stringent NOx emission standards for 2024 or 2025 MY engines.

California cannot wait for the federal government to act. Although California has made significant strides towards improved air quality over the past five decades, over 12 million residents still breathe unhealthy air. California faces particularly extreme ozone attainment challenges in the South Coast and San Joaquin air basins. Further reduction of NOx emissions is critical for attaining federal ozone and PM2.5 standards.

In addition to working toward meeting the most recent federal ozone standard of 75 parts per billion (ppb) by 2031, the South Coast and San Joaquin Valley air basins must also continue to make progress towards attainment of earlier standards they have not yet achieved, including the 8-hour ozone standard of 80 ppb (with an attainment date of 2023). In order for the South Coast Air Basin to meet the federal ozone standards, overall NOx emissions would need to be reduced by 70 percent from today's level by 2023 and approximately 80 percent by 2031.

Because federally certified heavy-duty vehicles contribute significant in-use emissions while they operate in California, CARB staff is pleased that U.S. EPA is both developing the Cleaner Trucks Initiative rule and actively involved in related research studies. CARB staff is also encouraged to see that U.S. EPA has announced the goal of a "coordinated 50-state program" (FR, 2020). CARB staff has encouraged U.S. EPA to align its Cleaner Trucks Initiative provisions with CARB's proposed HD Omnibus Regulation, to the greatest extent possible (Corey, 2020). Nationally harmonized requirements would reduce the cost of compliance to the industry and improve the cost-effectiveness of both CARB's Proposed Amendments and U.S. EPA's Cleaner Trucks Initiative.

J. Were there any superior alternatives to the proposed Heavy-Duty Omnibus Regulation?

CARB staff encouraged public input on alternative approaches that could yield the same or greater benefits as the Proposed Amendments or may achieve the goals at a lower cost. CARB staff analyzed in depth two alternatives proposed by stakeholders. However, as explained below, no alternative proposed was found to be less burdensome and equally effective in achieving the purposes of the regulation.

Alternative 1, proposed by the SCAQMD, would include all the elements of the Proposed Amendments but be implemented approximately three years earlier than CARB staff's proposal (SCAQMD, 2019). Although Alternative 1 would achieve greater NOx reductions sooner, CARB staff believes the accelerated timeline of Alternative 1 would not provide enough lead time for engine manufacturers to conduct needed research, development, and durability testing. Hence, CARB staff believes Alternative 1 is not technically feasible and rejected it.

Alternative 2, submitted by the Truck and Engine Manufacturers Association (EMA), is a nationwide program alternative (EMA, 2019). Under Alternative 2, engine manufacturers would voluntarily certify all their engines nationally to a NOx standard less stringent than the standards in the Proposed Amendments. Alternative 2 would achieve about eight percent less benefits than the Proposed Amendments. Although Alternative 2 could be more cost-effective than the Proposed Amendments and would achieve nearly as many benefits, it was rejected for several reasons. First, Alternative 2 is projected to achieve less reductions of NOx emissions than the Proposed Amendments. Second, CARB staff believes there is an intrinsic advantage to the Proposed Amendments pushing manufacturers to deploy technically feasible, cost-effective technology with dramatically lower NOx emissions than today's truck engines as quickly as possible. The success of California's standards in 2024 and beyond would set a model for U.S. EPA to follow and make it more likely that federally certified trucks of the future are lower-emitting.

Although rejecting Alternative 2, CARB staff is cognizant of the advantages of nationally harmonized standards including simplicity, efficiency, and cost savings. Hence, to encourage manufacturers to make one set of 50-state clean vehicles, the Proposed Amendments include an option for manufacturers to voluntarily certify to the same standard nationally beginning in MY 2024. CARB staff is hopeful that many manufacturers will choose to use this option in the years that CARB's HD Omnibus Regulation is in effect but before the Cleaner Truck Initiative has been implemented.

K. What does CARB staff recommend?

CARB staff recommends that the Board approve the proposed regulation orders and test procedures in Appendices A and B. The main body of this Staff Report provides further discussion and justification for CARB staff's proposal.

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I. INTRODUCTION AND BACKGROUND

A. Introduction

This Initial Statement of Reasons (ISOR or Staff Report) presents the California Air Resources Board (CARB or Board) staff's Proposed Amendments to California exhaust emission standards and associated test procedures for heavy-duty engines to ensure they remain clean in-use and has been termed the proposed "Heavy-Duty Omnibus Regulation." CARB staff is additionally proposing other emission-related requirements for heavy-duty engines and heavy-duty vehicles, hereinafter referred to as the "Proposed Amendments." The Heavy-Duty Omnibus Regulation (HD Omnibus Regulation) and the Proposed Amendments encompass the following elements:

- New exhaust emission standards and test procedures for 2024 and subsequent model year (MY) engines;
- Amendments to on-board diagnostic (OBD) system requirements
- Amendments to the heavy-duty in-use testing (HDIUT) program;
- Amendments to the emissions warranty period and useful life requirements;
- Amendments to the emissions warranty information and reporting (EWIR) requirements and corrective action procedures;
- Amendments to the emissions averaging, banking, and trading (ABT) program;
- Amendments to durability demonstration requirements and new in-use emissions data reporting requirements;
- New powertrain test procedures for heavy-duty hybrid vehicles;
- Amendments to better align California heavy-duty vehicle greenhouse gas (California Phase 2 GHG) tractor auxiliary power unit (APU) certification requirements with California's off-road test procedures;
- Amendments to California Phase 2 GHG provisions; and
- Clarifications to medium-duty engine requirements.

This Staff Report is divided into fourteen chapters and nine appendices that describe the Proposed Amendments, and its associated costs and benefits. Chapter I presents an overview of the Proposed Amendments and relevant background information such as the current market, current emission control technologies, and existing regulations and test procedures. Chapter II describes the specific problems the Proposed Amendments would address. Chapter III presents CARB staff's proposed solutions to the specific problems. Chapter IV describes the specific purpose and rationale for each proposed amendment. Chapter V presents the benefits anticipated from the Proposed Amendments, i.e., benefits to the environment, public health, and businesses. Chapter VI discusses in further detail the expected air quality benefits associated with the Proposed Amendments. Chapter VII presents an environmental analysis of the Proposed Amendments, and Chapter VIII describes the environmental justice aspects. Chapter IX includes the economic impact analysis/assessment, including a cost-effectiveness determination, and its fiscal impacts. Chapter X contains an evaluation of the regulatory alternatives. Chapter XI presents the justification for the adoption of regulations that differ from federal regulations. Chapter XII includes a description of the public process used for developing the Proposed Amendments. Chapter XIII indicates the references for sources of information used to develop the Proposed Amendments. And finally, Chapter XIV list the appendices for this Staff Report. Appendix A includes the Proposed Amendments changes to the regulations; Appendix B includes the Proposed Amendments changes to the test procedures; Appendix C includes details on the economic analysis; Appendix D includes details on the emissions inventory analysis methods and results for the Proposed Amendments; Appendix E includes the estimated health benefits analysis; Appendix F provides further details on the purpose and rationale of the Proposed Amendments; Appendix G lists the meetings and discussions held with the public during development of the rulemaking; Appendix H discusses the contribution to regional haze and visibility protection by the Proposed Amendments; and Appendix I contains a description of current and advanced emission control strategies, as well as key findings of the work performed at Southwest Research Institute (SwRI) in support of the Proposed Amendments described in this Staff Report.

B. Background

On-road heavy-duty vehicles[6] operate throughout California in a wide range of vocations and are an essential part of the state's economy; they include long-haul trucks, transit buses, refuse trucks, and other commercial work vehicles. The current population of heavy-duty vehicles over 14,000 pounds gross vehicle weight rating (GVWR) operating in California is nearly 1 million, according to CARB's Emission FACtors (EMFAC)[7] 2017 inventory model. These vehicles are significant sources of oxides of nitrogen (NOx), particulate matter (PM), and GHG emissions.

Heavy-duty engines used in vehicles with GVWR greater than 14,000 pounds are required to certify to the heavy-duty engine certification standards and test procedures specified in title 13 of the California Code of Regulations, section 1956.8 (13 CCR 1956.8). Currently, medium-duty vehicles from 8,501 to 14,000 pounds GVWR are subject to the Low Emission Vehicle III (LEV III) chassis certification emission standards found in 13 CCR 1961.2, but manufacturers have the option to certify a subset of engines used in incomplete Otto-cycle and incomplete and complete diesel-cycle medium-duty vehicles, those from 10,001 to 14,000 pounds GVWR, to the engine dynamometer emission standards specified in 13 CCR 1956.8. Thus, the Proposed Amendments would only affect engines used in heavy-duty vehicles with GVWR greater than 14,000 pounds and engines used in medium-duty vehicles with GVWR between 10,001 and 14,000 pounds that optionally certify to the requirements in 13 CCR 1956.8. The Proposed Amendments would apply to diesel-cycle and Otto-cycle engines and vehicle classifications outlined in Table I-1.

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[6] Under California regulations, heavy-duty vehicles are vehicles with a GVWR greater than 8,500 pounds, while medium-duty vehicles are a subcategory of heavy-duty vehicles with a GVWR between 8,501 and 14,000 pounds. The regulatory classification and treatment of medium-duty engines and vehicles are discussed further below in Subsection 12.
[7] EMFAC is a modeling tool developed by CARB for estimating emissions in California (e.g., EMFAC2017 is the most recent update, adopted in 2017).

Table I-1. Applicable Heavy-Duty Engine and Vehicle Classifications

Engine Cycle	Vehicle Class	GVWR (lbs.)	Engine Category
Diesel-Cycle	8	>33,000	Heavy Heavy-Duty Diesel (HHDD)
	6-7	19,501 - 33,000	Medium Heavy-Duty Diesel (MHDD)
	4-5	14,001 - 19,500	Light Heavy-Duty Diesel (LHDD)
	3	10,001 - 14,000	Medium-Duty Diesel Engine (MDDE)
Otto-Cycle	4-8	>14,000	Heavy-Duty Otto (HDO)
	3	10,001 - 14,000	Medium-Duty Otto Engine (MDOE)

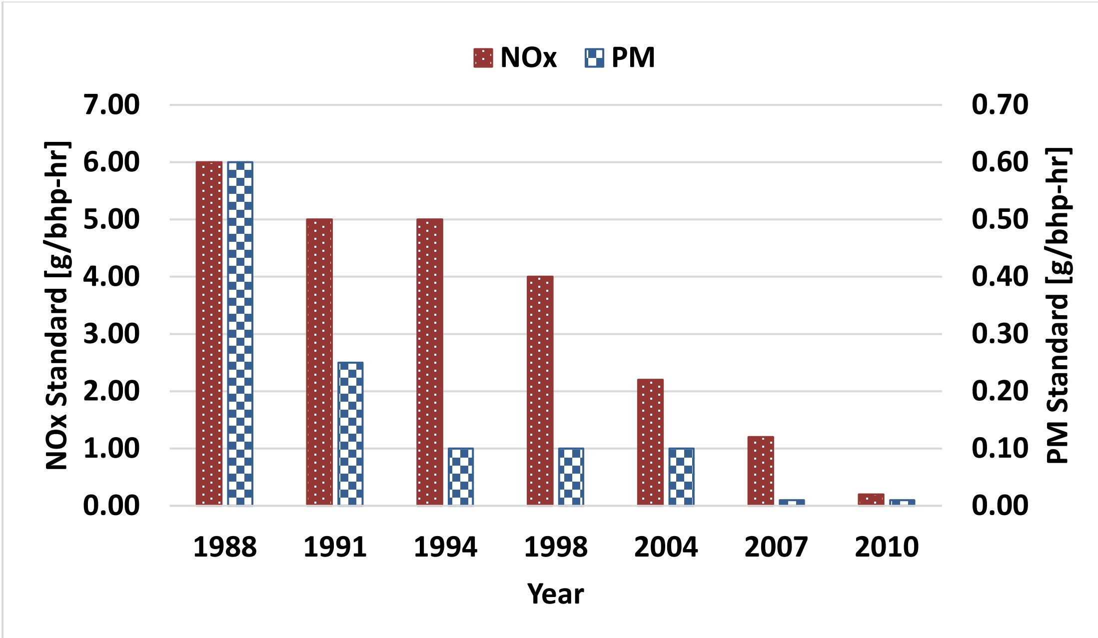
1. NOx and PM Emission Standards

1.1. History of Heavy-Duty Engine Emission Standards

The first heavy-duty engine emission standards that set limits on tailpipe carbon monoxide (CO) and combined hydrocarbons (HC) plus NOx emissions were adopted by CARB in 1970 and became effective in California in 1973. The same standards were implemented federally in 1974. The first regulations to control heavy-duty engine PM emissions were adopted in 1986 and became effective in 1988. Since the 1970s, regulations to control heavy-duty engine pollutant emissions have become more rigorous, continuing in the 1990s through 2010, with increasingly stringent standards and test procedures for CO, HC, NOx and PM emissions. In 2004, a combined standard for smog-forming emissions for HC and NOx was implemented to further reduce the combined emissions by 40 percent. In 2007, NOx and non-methane hydrocarbon (NMHC) standards of 0.20 and 0.14 grams per brake horsepower-hour (g/bhp-hr), respectively, were phased-in, reaching full compliance in 2010. An approximate reduction of 90 percent in NMHC and NOx emissions was achieved in 2010. Overall, heavy-duty engine emissions have been significantly reduced compared to uncontrolled levels.

Figure I-1 illustrates the evolution of NOx and PM emission standards for new on-road heavy-duty diesel engines adopted and implemented by CARB. In most cases, California’s heavy-duty engine emission standards were harmonized with the United States Environmental Protection Agency (U.S. EPA) standards, although in a few cases implementation in California began one or more years before the federal standards.

Figure I-1. California – On-Road Heavy-Duty Diesel Engine NOx and PM Standards



1.2. Emission Control Technologies

There are two main approaches for reducing engine emissions, namely engine controls and the use of exhaust aftertreatment systems. Engine controls comprise a number of strategies to achieve more efficient combustion and hence reduce engine-out emissions, while further reduction of pollutants can be achieved with exhaust aftertreatment before the exhaust leaves the tailpipe.

Most of the NOx and PM standards that were implemented prior to the 2007 and 2010 standards were met using only in-cylinder engine emission controls that reduced engine-out NOx emissions. For example, during the late 1980s and early 1990s, the main strategies used for NOx control were injection timing retard together with charge air cooling to reduce intake manifold temperatures. These strategies reduce NOx by lowering peak combustion temperatures and hence converting less atmospheric nitrogen to NOx. However, reducing NOx using injection timing control also tends to increase fuel consumption and PM emissions. Thus, other strategies such as increased fuel injection pressures and increased intake manifold pressures had to be used to offset the increased fuel consumption and PM.

The 1998 NOx standard of 4.0 g/bhp-hr was met with continued improvement of the previous engine control strategies and advances in electronic controls, which allowed for more flexible and accurate control of engine operating parameters including fuel injection timing, fuel injection pressures, fuel metering, and turbocharger control.

Manufacturers met the 2004 NOx standards with a type of engine control called cooled exhaust gas recirculation (EGR), coupled with higher fuel injection pressures to mitigate potential increases in PM and fuel consumption and the use of variable geometry turbochargers to control and ensure the required EGR flow for NOx control.

Beginning in 2007, heavy-duty diesel engines were subject to a PM standard of 0.01 g/bhp-hr, a NOx standard of 0.20 g/bhp-hr, and an NMHC standard of 0.14 g/bhp-hr. The PM standard took full effect beginning in 2007 which required for the first time the installation of a diesel particulate filter (DPF) exhaust aftertreatment in the tailpipe. The NOx and NMHC standards were phased-in on a percent of sales basis: 50 percent from 2007 through 2009 and 100 percent in 2010. Higher rates of cooled-EGR, variable geometry turbochargers, high pressure fuel injection and electronic controls were used to comply with the 2007 through 2009 fleet average NOx standard of 1.2 g/bhp-hr, and diesel oxidation catalysts (DOC) were used to meet the NMHC standard and promote passive DPF regeneration (oxidation of soot collected in the filter) by converting nitric oxide to nitrogen dioxide. Moreover, in addition to the continued use of existing engine control technologies, manufacturers introduced urea-based selective catalytic reduction (SCR) systems, a NOx aftertreatment control technology, to comply with the 2010 NOx standard of 0.20 g/bhp-hr. In an SCR aftertreatment system, ammonia is used as a NOx reductant as the exhaust gases react over the catalyst substrate. Typically, an aqueous urea solution made up of a mix of urea and water, also known as Diesel Exhaust Fluid (DEF), is stored on-board the vehicle. DEF injected into the hot exhaust stream thermally decomposes to form ammonia and carbon dioxide (CO2). The ammonia produced then reacts with NOx as the exhaust flows through the catalyst, converting the NOx to harmless nitrogen gas and water.

Because sulfur can poison and degrade the performance of aftertreatment catalysts, ultra-low sulfur diesel fuel with a sulfur content of less than 15 parts per million (ppm) was introduced prior to the implementation of the 2007 and 2010 heavy-duty engine NOx and PM standards. Section B.13 later in this chapter discusses in more detail the effects of sulfur and other contaminants in fuel on aftertreatment systems.

1.3. Optional Low NOx Standards

In 2013, California established optional low NOx standards (CARB, 2019k) with the most aggressive standard being 0.02 g/bhp-hr NOx, which is 90 percent below the current standard. The optional low NOx standards were developed to pave the way for more stringent mandatory standards by encouraging manufacturers to develop and certify low NOx engines. Financial incentives to potential customers were developed to encourage the purchase of these low NOx engines. For the 2019 MY, fifteen engine families, some using compressed natural gas (CNG) and others using liquefied petroleum gas (LPG), were certified to the optional low NOx standards (CARB, 2020a). All engine families currently certified to the optional low NOx standards for MYs 2016 through 2020 (as of January 2020) are listed in Table I-2.

Table I-2. Optional Low NOx Certified Heavy-Duty Engines

Low NOx Engine	Engine Family	Displacement (Liters)	NOx Certification Standard (g/bhp-hr)	NOx Reduction %	Fuel	Intended Service Class
2020 MY as of 1/9/2020						
Cummins 6.7	LCEXH0408BBC	6.7	0.02	90%	CNG	MHDD
Cummins 8.9	LCEXH0540LBN	8.9	0.02	90%	CNG	HHDD
Cummins 8.9	LCEXH0540LBL	8.9	0.02	90%	CNG	MHDD
Cummins 8.9	LCEXH0540LBM	8.9	0.02	90%	CNG	UB
Cummins 11.9	LCEXH0729XBC	11.9	0.02	90%	CNG	HHDD-UB
Roush (LPG) 6.8	LRIIE06.8BW2	6.8	0.02	90%	LPG	HDO
Roush (LPG) 6.8	LRIIE06.8BWL	6.8	0.05	75%	LPG	HDO
2019 MY						
Agility Powertrains 6.8	KAGIE06.8BW6	6.8	0.02	90%	CNG	HDO
Agility Powertrains 6.8	KAGIE06.8BWZ	6.8	0.02	90%	CNG	HDO
Agility Powertrains 6	KAGIE06.0584	6.0	0.05	75%	CNG	HDO
Cummins 8.9	KCEXH0540LBL	8.9	0.02	90%	CNG	MHDD
Cummins 8.9	KCEXH0540LBM	8.9	0.02	90%	CNG	UB
Cummins 8.9	KCEXH0540LBN	8.9	0.02	90%	CNG	HHDD
Cummins 11.9	KCEXH0729XBC	11.9	0.02	90%	CNG	HHDD-UB
Cummins 6.7	KCEXH0408BBB	6.7	0.10	50%	CNG	MHDD
Encore Tec 6.8	KEL3E06.8BWZ	6.8	0.02	90%	CNG	HDO
Encore Tec 6.8	KEL3E06.8BW6	6.8	0.02	90%	CNG	HDO
Encore Tec 6	KEL3E06.0584	6.0	0.05	75%	CNG	HDO
Roush (CNG) 6.8	KRIIE06.8BC2	6.8	0.02	90%	CNG	HDO
Roush (CNG) 6.8	KRIIE06.8BC1	6.8	0.10	50%	CNG	HDO
Roush (LPG) 6.8	KRIIE06.8BW2	6.8	0.02	90%	LPG	HDO
Roush (LPG) 6.8	KRIIE06.8BWL	6.8	0.05	75%	LPG	HDO
2018 MY						
Agility Powertrains 6	JAGIE06.0584	6.0	0.05	75%	CNG	HDO
Cummins 6.7	JCEXH0408BBB	6.7	0.10	50%	CNG	MHDD
Cummins 8.9	JCEXH0540LBN	8.9	0.02	90%	CNG	HHDD
Cummins 8.9	JCEXH0540LBL	8.9	0.02	90%	CNG	MHDD
Cummins 8.9	JCEXH0540LBM	8.9	0.02	90%	CNG	UB
Cummins 11.9	JCEXH0729XBC	11.9	0.02	90%	CNG	HHDD-UB
Encore Tec 6	JEL3E06.0584	6.0	0.05	75%	CNG	HDO
Encore Tec 6.8	JEL3E06.8BWZ	6.8	0.02	90%	CNG	HDO
Encore Tec 6.8	JEL3E06.8BW6	6.8	0.02	90%	CNG	HDO
Roush (LPG) 6.8	JRIIE06.8BWL	6.8	0.05	75%	LPG	HDO
Roush (LPG) 6.8	JRIIE06.8BW2	6.8	0.02	90%	LPG	HDO
2017 MY						
Cummins 8.9	HCEXH0540LBK	8.9	0.02	90%	CNG	HHDD
Cummins 8.9	HCEXH0540LBJ	8.9	0.02	90%	CNG	MHDD
Cummins 8.9	HCEXH0540LBI	8.9	0.02	90%	CNG	UB
Cummins 6.7	HCEXHO408BBA	6.7	0.10	50%	CNG	MHDD
Encore Tec 6.8	HEL3E06.8BWZ	6.8	0.02	90%	CNG	HDO
Encore Tec 6	HEL3E06.076P	6.0	0.05	75%	CNG	HDO
GreenKraft (LPG) 8	HGKTE08.0GL8	8.0	0.02	90%	LPG	HDO
GreenKraft (CNG) 8	HGKTE08.0GC8	8.0	0.02	90%	CNG	HDO
Roush (LPG) 6.8	HRIIE06.8BWL	6.8	0.05	75%	LPG	HDO
Roush (CNG) 6.8	HRIIE06.8BWC	6.8	0.10	50%	CNG	HDO
Westport Dallas 6.8	HBAFE06.8BW6	6.8	0.05	75%	CNG	HDO
2016 MY						
Cummins 8.9	GCEXH0540LBJ	8.9	0.02	90%	CNG	MHDD
Roush 6.8	GRIIE06.8BWC	6.8	0.10	50%	CNG	HDO

UB - Urban Bus
HDO - Heavy-Duty Otto-Cycle
MHDD - Medium Heavy-Duty Diesel Cycle
HHDD - Heavy Heavy-Duty Diesel Cycle
CNG - Compressed Natural Gas
LPG - Liquefied Petroleum Gas

No diesel engines have yet been certified to the optional low NOx standards. CARB staff believe manufacturers have chosen not to certify diesel engines to the optional standards even though certification data indicates doing so would be feasible for several existing engine families for several reasons. First, certifying the first diesel to the optional standards could be perceived as support for a lower mandatory standard, which engine manufacturers oppose. Second, because diesels have the existing market share, diesel engine manufacturers have not been motivated to differentiate themselves on the basis of improved NOx emissions performance, like their CNG- and LPG-fueled competitors.

The emissions control challenges are different for diesel-fueled engines compared to CNG and LPG engines certified to these standards. For example, the nature of lean-burn fuel combustion, such as with diesel fuel, prevents the use of traditional three-way catalysts (TWC) to reduce CO, HC, and NOx in diesel engines; instead, SCR systems are used. As discussed at greater length later in this Staff Report, thermal management has not been addressed across duty cycles in today's SCR-equipped diesel engine systems especially when the engine is operated at lower engine loads or at idle for extended periods of operation. However, improved thermal management is one of the key strategies CARB staff expects manufacturers to use for complying with the standards proposed in this Staff Report.

1.4. Idling Restrictions and Optional Idle Certification Standard

In addition to establishing increasingly stringent exhaust emission standards for new engines, California has also adopted programs that provide substantial in-use emission reductions, such as vehicle idling restrictions (CARB, 2019h). In 2008, CARB adopted clean idle standards that limit idle operation to five minutes before the engine must be shut off. CARB's clean idle standards require new engines to be equipped with a 5-minute non-programmable automatic engine shutdown system (AESS) or to optionally certify to a clean idle NOx standard of 30 grams per hour (g/hr). To certify engines to the clean idle standards, manufacturers must demonstrate that idling emissions do not exceed the clean idle standard under curb idle and elevated idle with accessory and hoteling loads. To date, all heavy-duty engine manufacturers have elected to comply with the idle emission standard rather than install an AESS.

CARB's idling regulations currently exempt some vehicle applications from the clean idle standards. Exempted vehicle applications include buses,[8] school buses, recreational vehicles, medium-duty vehicles, armored vehicles, workover rigs, emergency vehicles, and military tactical vehicles. Emergency vehicles and military tactical vehicles are currently exempt from any emission control device requirements according to California Vehicle Code section 27156.2 and 13 CCR 1905, respectively.

Buses were exempted because of the need for climate control of the large volume of the passenger compartment and the use of APUs was considered not practical and

[8] "Buses" are defined in California Vehicle Code, section 233, 612, and 642.

effective enough to meet the desired hoteling loads (CARB, 2005b). The other vehicle applications were exempted because installation of the nonprogrammable AESS was considered not practical either for safety reasons or because it would interfere with the operation of the vehicle for which it is designed to perform.

The need for low NOx and lower PM emission standards is discussed in Chapter II, Sections C.1 and C.2. Chapter III, Sections A.1 and A.2 describe the Proposed Amendments to the standards and their feasibility.

1.5. On-Board Diagnostics Requirements

On-board diagnostic (OBD) systems are self-diagnostic systems incorporated into a vehicle's on-board computer. They are comprised mainly of software designed to detect emission-control system malfunctions as they occur. This is done by monitoring virtually every component and system that can cause increases in emissions, thus maintaining low emissions throughout the vehicle's life. The OBD system continuously works in the background during vehicle operation to monitor emission-related components and alerts the vehicle operator of detected malfunctions by illuminating the malfunction indicator light (MIL) on the vehicle's instrument panel. Additionally, the OBD system stores important information, including identification of the faulty component or system and the nature of the fault, which allows for quicker diagnosis and proper repair of the problem by technicians. This helps vehicle owners experience less expensive repairs, and promotes repairs being done correctly the first time.

OBD systems also influence and interact with other CARB emission requirements. For example, the detection of faults during the emission warranty period provides a clear notification to the vehicle operator that a warranty repair is needed. In turn, this provides further motivation to engine manufacturers to design durable emission controls to minimize warranty costs and avoid perceptions by the vehicle operator of the need for frequent repairs. OBD systems have also become the basis for emission inspection programs in California and throughout the nation. For light-duty vehicles, all 2000 and newer MY vehicles are inspected nearly exclusively by accessing the OBD system to verify that no emission-related faults are present. For heavy-duty vehicles, research is still ongoing to develop such a program, but it is likely that OBD information will play a vital role in the inspection process.

The first generation of OBD systems intended for passenger cars, light- and medium-duty vehicles with TWCs and feedback control (referred to as OBD I) was implemented by CARB in 1988, and required monitoring of only a few of the emission-related components on the vehicle (CARB, 1985). In 1989, CARB adopted regulations requiring a second generation of OBD systems (referred to as OBD II) that standardized the system and addressed the shortcomings of the OBD I requirements. OBD II required all 1996 and newer passenger cars, light-duty trucks, and medium-duty vehicles and engines to be equipped with OBD II systems (CARB, 1989).

In 2004, CARB adopted regulations requiring OBD systems for heavy-duty vehicles and engines (i.e., vehicles with a GVWR greater than 14,000 pounds). CARB first adopted the Engine Manufacturer Diagnostic (EMD) regulation, which required manufacturers of heavy-duty engines and vehicles to implement diagnostic systems on all 2007 and subsequent MY on-road heavy-duty engines. The EMD regulations were much less comprehensive than the OBD II regulations and were intended for heavy-duty manufacturers to achieve a minimum level of diagnostic capability (CARB, 2004). In 2005, CARB adopted heavy-duty OBD (HD OBD) requirements for 2010 and subsequent MY heavy-duty engines and vehicles, which phased in with full implementation required for the 2013 MY (CARB, 2005a).

1.5.1. OBD Component Monitoring

Table I-3 lists the heavy-duty engine emission control components that can contribute to an increase in emissions if they malfunction and hence must be monitored by HD OBD systems. Monitoring requirements for medium-duty vehicles utilizing engines certified to the heavy-duty engine emission standards are essentially identical. For the components shown in regular font (not in italics) in Table I-3, the OBD system is required to monitor the components and indicate a fault code when emissions exceed the emission standards by a certain amount. Emission "thresholds" for these faults are typically either a multiple of the exhaust emission standard (e.g., 2.0 times the applicable standard, etc.), or an additive value above the standards (e.g., 0.2 g/bhp-hr above the applicable standards, etc.). The components and/or systems whose monitors are calibrated to a threshold limit include the fuel system, the EGR system, the boost pressure control, and other aftertreatment devices (e.g. catalysts, PM filters, etc.).

Table I-3. Components for Heavy-Duty OBD System Monitoring[a]

• Fuel System	• *Misfire Detection*	• EGR System
• Boost Pressure Control	• NMHC Catalyst	• NOx Catalyst
• NOx Adsorber	• PM Filter	• Exhaust Gas Sensors
• Variable Valve Timing/Control	• Cold Start Strategies	• *Crankcase Ventilation*
• *Engine Cooling System*	• *Comprehensive Component*[b]	• Secondary Air System
• Catalyst Monitoring	• Evaporative System	• *"Other Controls"*[c]

[a] Components in *italics* are not correlated to an emission threshold limit. The components not in italics are correlated to a threshold limit that can be a multiple of, or additive to, the emission standards.
[b] Electronic powertrain component/system that affects emissions or is used to monitor the major emission-related components.
[c] Any other emission control systems that are either: (1) not identified or addressed by other systems, or (2) are identified but are not compensated for by an adaptive control system.

For other components like those in italics in the table above, the OBD system is required to comprehensively detect malfunctions that indicate the component or system is no longer properly functioning. This can include failures that cause sensors used for emission control and/or other OBD monitors to read erroneously, emission-related electronic output components like solenoids or valves that fail to operate as commanded, and other system failures that prevent proper emission control of the engine.

1.5.2 OBD Standardization

The MIL serves as a visual communication method through which the OBD system alerts the vehicle operator that an emission-related fault or malfunction has occurred. If a component is detected as malfunctioning by the OBD system, in addition to illuminating the MIL, the system stores key information to assist repair technicians in diagnosing and repairing the fault.

The OBD system also includes statistical safeguards to ensure robust detection of faults. This includes requirements that the system utilize sufficient time to ensure a fault is actually present and to validate the presence of the fault on two separate trips before alerting the driver. The system contains additional safeguards to ensure the MIL is not prematurely extinguished and that the system stores sufficient information for a repair technician to understand the operating conditions under which the fault was stored and fault information to isolate and pinpoint the malfunctioning component or system as much as possible.

In addition to information to assist repair technicians, the OBD system stores data that facilitates emission inspections and assists CARB in verifying compliance with emission requirements. For instance, the system is able to communicate information during an inspection regarding not only the current status of the emission controls but also information that confirms the correct vehicle is being inspected and whether there have been recent attempts to erase or tamper with fault information. Likewise, the system stores critical information such as verification that OBD monitors run frequently during in-use operation and data for how often certain auxiliary emission control devices are active and how much NOx and CO2 are emitted in various engine operating conditions.

Lastly, standardization is an important part of the OBD requirements to ensure common interpretation and usage of the information. For example, the HD OBD regulations require that all manufacturers use the same symbol and color for the MIL and that the MIL be used exclusively for emission-related faults. OBD systems are also required to store and communicate all of the information with off-board repair or inspection tools through a standardized network and message protocol to ensure ready access by all technicians to the information.

2. Certification Test Cycles

For an engine to be certified, the manufacturer must demonstrate that its exhaust emissions do not exceed specified standards. A standardized test procedure is prescribed for each emission standard, to allow for objective, repeatable, and comparable measurement of emissions for different engines and vehicles. An engine test cycle specifies a sequence of test points, each with a defined engine speed and torque to be followed on an engine dynamometer.

As described in greater detail below, for heavy-duty engine certification, California and U.S. EPA require heavy-duty engines to be tested on the heavy-duty transient Federal Test Procedure[9] (FTP) and the Supplemental Emission Test Ramped Modal Cycle[10] (RMC-SET). The FTP test cycle represents a transient medium load duty cycle. The RMC-SET simulates steady-state engine operation during suburban and highway truck speeds. The FTP and RMC-SET have the same numerical standard.

Since 1985, the transient FTP has been the primary cycle used for the emissions certification of all heavy-duty on-road engines with GVWR greater than 10,000 pounds in California (8,500 pounds federally). The cycle was developed in the 1970s and was based on data collected on 44 trucks and four buses in New York, and 44 trucks and three buses in Los Angeles (Smith, 1978). The truck sample in each city included gasoline-fueled and diesel-fueled engines. Two versions of the FTP cycle exist, one for diesel-cycle engines, and one for Otto-cycle engines.

The FTP test cycle is run with both a cold- and a hot-start condition. For the cold start, the engine is typically “soaked” overnight, and a cold-start test is performed in the morning. The cold-start test is followed by a minimum of three consecutive hot-start tests. Before each hot start test, there is a 20-minute soak period. The FTP standard is a composite of the cold- and hot-start FTP test results and is weighted 1/7 and 6/7 for the cold- and hot-start tests, respectively, as specified in title 40, Code of Federal Regulations (CFR), section 86.007-11 (40 CFR §86.007-11).

The average load factor of the diesel FTP cycle is approximately 26 percent of the maximum engine power available at a given engine speed. Heavy-duty diesel engines tested on the FTP cycle for the most part produce medium to high temperature (250-350 degrees Celsius (°C)) exhaust.

The RMC-SET, specified in 40 CFR §86.1362, simulates steady-state engine operation during suburban and highway truck speeds. It consists of a 40-minute ramped modal cycle version of the 13-mode steady-state Supplemental Emissions Test.

As mentioned above in Section B.1.5, in California, 2008 and subsequent MY engines have the option to certify to a NOx idling emission standard of 30 g/hr. The idling test is 60 minutes long and includes a curb idle mode and an elevated idle speed and engine load mode.

Chapter II, Section C.1.1 discusses the need for revised test cycles. Chapter III, Section A.1 describes the Proposed Amendments and their rationale.

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[9] “FTP” is the heavy-duty transient Federal Test Procedure duty cycle specified in 40 CFR 86.007-11(a)(2), as amended October 25, 2016.

[10] “RMC-SET” is the supplemental emission test procedure with the steady-state duty cycle specified in 40 CFR 86.1360, as amended October 25, 2016.

3. Heavy-Duty In-Use Test (HDIUT) Procedures

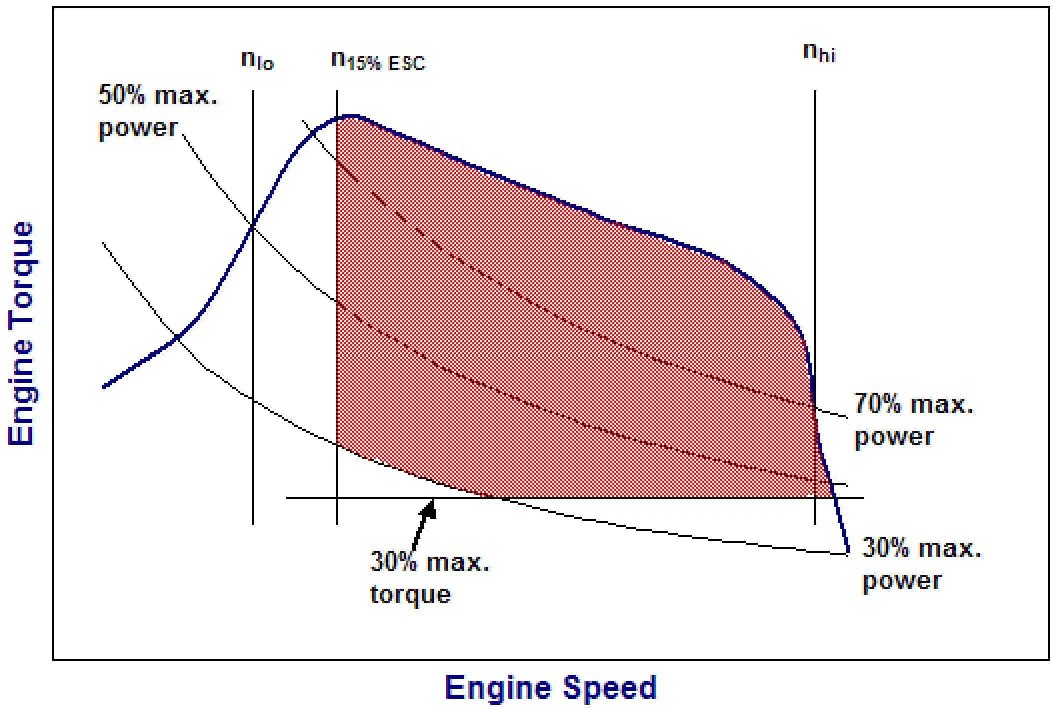
3.1. Manufacturer-Run HDIUT with Not-To-Exceed (NTE) Method

In the 1990s, seven large heavy-duty diesel engine manufacturers calibrated their engines so that fuel economy was improved at the expense of excess NOx emissions above the standards during high speed cruise operation. This calibration strategy was considered a violation of the regulations because the emissions impact was not assessed or accounted for when the vehicles were originally certified over the FTP test cycle. To address these violations, the Department of Justice, U.S. EPA, CARB, and the settling manufacturers signed consent decrees. In the consent decrees, the settling manufacturers were required, among other things, to produce heavy-duty diesel engines that complied with prescribed emission standards that were lower than required by the state and federal regulations at the time. Additionally, the manufacturers were required to certify to new test procedures: the Not-to-Exceed (NTE) method and the Euro III European Stationary Cycle for two years, 2003 and 2004. The majority of settling manufacturers agreed to produce engines by October 1, 2002 that would meet those supplemental test procedures. In December 2000, California adopted the NTE and the European Stationary Cycle requirements for 2005 and subsequent MY engines (CARB, 2000).

In 2003, U.S. EPA, CARB, and the engine manufacturers worked on further defining the NTE requirements in a settlement agreement (U.S. EPA, 2003). In the settlement agreement, engine manufacturers agreed to self-test a portion of their engine families in the field, by using Portable Emission Measurement Systems (PEMS), via what has come to be known as the HDIUT Program. There was a mandatory two-year pilot program focusing on gaseous emissions in 2005 and 2006, and a 2006 and 2007 pilot program focusing on PM emissions. A fully enforceable program was initiated with 2007 and subsequent MY engines for gaseous emissions and 2008 and subsequent MY engines for PM emissions. CARB also has the ability to independently test any engine family through CARB's in-house Heavy-Duty In-Use Compliance (HDIUC) Program, but with current resources, CARB staff is only able to test a small fraction of the heavy-duty engines that CARB certifies.

The HDIUT requirements are set forth in the CFR (part 86, subpart T: Manufacturer In-Use Testing) and in the California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles (Heavy-Duty Diesel Test Procedures). All heavy-duty engine manufacturers are required to participate in the HDIUT program by testing a fraction of their engine families every year, as specified by U.S. EPA and CARB. The testing is conducted based on NTE protocols as defined in 40 CFR §86.1370-2007, which establishes, among other things, the NTE control area over a range of engine torque and speeds where emissions are assessed. A graphical representation of the NTE control area (DieselNet, 2019) is shown in Figure I-2. Current NTE procedures allow data to be excluded from the evaluation of compliance, such as data generated under extreme ambient temperatures and altitudes. Valid NTE events must comply with operation within the NTE control area over 30 or more continuous seconds. Because of the continuous operation requirements and the allowable exclusions using the NTE method, only a small portion of engine operation is actually evaluated.

Figure I-2. NTE Control Area Schematic



3.2. Problems with Data Coverage of the NTE Methods

An analysis of the manufacturer submitted HDIUT data set for 2010 to 2014 MY engines equipped with SCR showed that the NTE method and exclusions reduce valid data to a small fraction of total operation and hence fail to adequately measure or control real-world emissions performance. In some cases, manufacturers completed their annual HDIUT requirements without submitting any valid data, which clearly subverts the purpose of the program. In fact, for the 2010 to 2014 HDIUT data submitted by manufacturers, 24 percent of the tests included no valid NTE events at all, meaning they passed HDIUT by default. The average percent of data and percent of NOx emissions represented in NTE events was less than six percent in the HDIUT data set. Overall, the NTE method does not capture the operation of the heavy-duty fleets in terms of test time or NOx emissions (Bartolome et al., 2018).

In Europe under the Euro VI Regulation (OJ, 2011) similar in-use testing is required for their program utilizing a Moving Average Window (MAW) approach. A window is a short period within the data set over which emissions are averaged. In the Euro VI MAW method, a window is defined by a constant work output by the engine. The width of the box is a fixed value based on the engine's power output over the certification cycle, in this case the European World Harmonized test cycle. Windows begin at the start of the test, and every second, a new window begins.

Because the MAW method utilizes fewer exclusions to invalidate windows compared to the NTE method, the Europeans are able to evaluate a broader range of engine operations. In an evaluation of U.S. and European heavy-duty diesel engine products, the International Council on Clean Transportation (ICCT) has concluded that European-certified heavy-duty diesel engines have lower emissions over the full range of engine operation, despite having a NOx emission standard that is 72 percent greater than the U.S. EPA standards (Posada et al., 2019). The lower emissions are attributed to their Euro VI in-use testing program that covers a broader range of operation and requires engine manufacturers to design towards the NOx emission standard over a greater portion of engine operation. The Proposed Amendments to the HDIUT program would evaluate compliance over the full duty cycle to discourage manufacturers from using cheating calibration strategies as was done in the past, as well as control emissions throughout the entire operation range of the engine.

Chapter II, Section C.3 below discusses the need to revise the HDIUT program, including the need to ensure more real-world emission reductions, and Chapter III, Section A.3 describes the proposed HDIUT amendments in further detail.

4. Emissions Warranty Periods

California has emissions warranty and durability provisions for on-road heavy-duty engines to help ensure adequate durability and proper maintenance of the engine and emission controls. The emissions warranty is used to cover any repairs needed to correct defects in materials or workmanship that would cause an engine or vehicle to not meet its applicable emission standards. From the vehicle owner's viewpoint, the inclusion of an emissions warranty provides a level of assurance that the engine and its associated emission control system are free from defects that would cause warranted parts not to be identical to the parts as described in the manufacturers' applications for certification, and that the components will perform as required. If such defects do occur during the warranty period, the manufacturers are liable for fixing them. From an air quality regulatory agency perspective, emission-related warranties help control emissions and protect air quality.

CARB and U.S. EPA require that heavy-duty manufacturers offer minimum warranties for emission-related parts to reduce emissions by (1) helping ensure that emission control systems are well-designed and properly built, and will function as intended during the warranty period, and (2) making it more likely that, during the warranty period, any needed emission-related repairs will be completed because they are paid for by the manufacturer. Also, vehicle owners are less likely to tamper with emission aftertreatment systems during the warranty period because the cost of repairs are covered by the manufacturer and tampering can allow a manufacturer to void emissions warranty coverage.

4.1. History of Heavy-Duty Emissions Warranty

The history and development of the heavy-duty emissions warranty provisions can be followed by tracking the regulatory amendments that have occurred for the emission standards and the heavy-duty useful life periods. Starting in 1978, CARB initially adopted emissions warranty regulations for California-certified 1979 and subsequent MY motorcycles, passenger cars, light-duty trucks, medium-duty vehicles, and heavy-duty vehicles, registered in California, regardless of their original point of registration, and California-certified motor vehicle engines used in such vehicles, to clarify the rights of individual motor vehicle and engine owners, motor vehicle and engine manufacturers, and the service industry (CARB, 1978). It was not until the early 1980s that U.S. EPA promulgated heavy-duty vehicle warranty and useful life requirements identical to those adopted in California (FR, 1982; FR, 1984).

Since then, in the 1990s, CARB has typically aligned California's heavy-duty engine emission standards with U.S. EPA standards (AWMA, 2006). In 1997, U.S. EPA adopted lower NOx+NMHC emission standards, to be effective in 2004, along with changes to the existing federal ABT program, for heavy-duty diesel engines sold in the other 49 states, and requirements for durability, maintenance intervals, recordkeeping, warranties, certification test fuel, and engine useful life. In 1998, CARB adopted similar amendments that harmonized with U.S. EPA's provisions, with the exception of the ABT program (CARB, 1998). The amendments also made changes to the emission-related maintenance intervals beginning with the 2004 MY that were the same as federal intervals, and were specified in miles or hours, whichever occurs first. In addition, a definition of "add-on emission-related component"[11] was included in the maintenance interval amendments.

More recently, on June 28, 2018, the Board approved amendments (i.e., the June 2018 Step 1 warranty amendments) to the California on-road heavy-duty vehicle and heavy-duty engine warranty regulations to lengthen existing warranty periods and maintenance provisions to better reflect the longevity and usage of modern vehicles. The amended warranty periods apply to California-certified diesel-fueled engines used in California-registered on-road heavy-duty vehicles weighing greater than 14,000 pounds GVWR and would increase the mileage of warranty coverage beginning with the 2022 MY.

4.2. Current and Recently Amended Heavy-Duty Engine and Vehicle Emissions Warranty Periods

Both CARB and U.S. EPA require that heavy-duty engines demonstrate compliance with emission standards throughout their useful lives, and both CARB and U.S. EPA have separate requirements for minimum emission warranties as well (13 CCR 1956.8, 1971, and 1976; 40 CFR §86.004-2). California's emissions warranty period requirements for heavy-duty diesel vehicles and heavy-duty engines are codified in 13 CCR 2036.

As indicated in Table I-4, California's existing regulations (valid through the 2021 MY) specify that the emissions warranty period must cover 5 years, 100,000 miles, or 3,000

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[11] An "add-on emission-related component" is a component whose sole or primary purpose is to reduce emissions or whose failure will significantly degrade emissions control and whose function is not integral to the design and performance of the engine.

hours, whichever occurs first, for heavy-duty diesel engines and the vehicles in which they are used, and 5 years or 50,000 miles, whichever occurs first, for all other heavy-duty vehicles and the engines in which they are used (e.g., Otto-cycle engines, etc.). The 3,000-hour provision was intended to apply to heavy-duty vehicles with diesel engines that idle for many hours or that are driven very few miles at low speeds. Under the current emissions warranty provisions, a manufacturer is only required to honor warranty obligations up to 3,000 hours regardless of age or miles traveled, if the hour period is reached before the mile or year periods.

However, under the June 2018 Step 1 warranty amendments, the 3,000-hour limit will no longer be applicable. This elimination was done to align with existing federal requirements because the 3,000-hour provision does not exist in federal heavy-duty warranty regulations (40 CFR §86.004-2). In Table I-4, in addition to indicating the elimination of the 3,000-hour period under the June 2018 Step 1 warranty amendments, other amendments adopted under that rulemaking are also indicated. Specifically, the warranted year period remains at 5 years for all heavy-duty engines, but beginning with the 2022 MY the emissions warranty mileages will increase to 350,000 miles for heavy-duty vehicles with heavy heavy-duty diesel (HHDD) engines, 150,000 miles for heavy-duty vehicles with medium heavy-duty diesel (MHDD) engines, and 110,000 miles for heavy-duty vehicles with light heavy-duty diesel (LHDD) engines. Lastly, the June 2018 Step 1 warranty amendments did not apply to either heavy-duty Otto-cycle (HDO) engines nor to heavy-duty vehicles that are propelled by battery electric systems, fuel cells, hybrid-electric systems,[12] or other hybrid systems.

[12] Beginning with model year 2022, under the June 2018 Step 1 warranty amendments, the warranty required for engine families that have concurrent applications in both dedicated diesel-fueled vehicles and hybrid vehicles will be 5 years/350,000 miles, whereas for engine families certified for use in hybrid vehicles exclusively, the warranty will remain 5 years/100,000 miles.

Table I-4. Current and Amended Heavy-Duty Engine and Vehicle Emissions Warranty Periods (13 CCR 2036)

Engine / Vehicle Category (GVWR)	Current Warranty (miles)	June 2018 Step 1 Warranty Amendments Effective MY 2022 (miles) (CARB, 2018c)
HHDD / Class 8 >33,000 lbs.	100,000 5 years/3,000 hours	350,000 5 years
MHDD / Class 6-7 19,501 - 33,000 lbs.	100,000 5 years/3,000 hours	150,000 5 years
LHDD / Class 4-5 14,001 - 19,500 lbs.	100,000 5 years/3,000 hours	110,000 5 years
HDO >14,000 lbs.	50,000 5 years	N/A

Although the California emissions warranty provisions specify required periods of coverage with respect to accumulated mileage, time in service, and operational hours, the provisions also state that in no case may the emissions warranty period be less than the “basic mechanical” warranty that the manufacturer provides to the purchaser of the engine (13 CCR 2036; 40 CFR §1037.120). “Basic mechanical” warranties, which are also known as “commercial” warranties, cover defects of the “basic” or “major” engine components (e.g., cylinder block, cylinder head, camshafts, rocker arms, manifolds, etc.) but not necessarily any of the emission control system components. If the basic mechanical warranty provides greater coverage than that specified by the emissions warranty regulations, then the emission control system components are then required to be provided the same amount of coverage specified by the basic mechanical warranty.

Another aspect relating to the heavy-duty emissions warranty periods and the applicability for coverage is the pairing of the heavy-duty engine to the heavy-duty vehicle. Usually, heavy-duty engine and heavy-duty vehicle combinations are straightforward. For example, a heavy heavy-duty engine is usually installed in a Class 8 heavy-duty vehicle that weighs greater than 33,000 pounds GVWR. However, sometimes a medium heavy-duty engine is installed in a Class 8 heavy-duty vehicle, such as when a purchaser uses an engine downsizing strategy to enhance fuel efficiency and reduce the purchase price. Currently, the emissions warranty requirements are the same for all heavy-duty vehicles with a GVWR greater than 14,000 pounds, thus, there is currently no need to differentiate between heavy-duty engine service classes. However, beginning with the 2022 MY, the warranty periods will be different, and so while the warranty coverage will remain applicable to the vehicle, the length of the new warranty periods will be based on the “primary intended service class” of the engine installed in the vehicle (40 CFR §1036.140). Therefore, a heavy heavy-duty engine installed in a Class 8 heavy-duty vehicle greater than 33,000 pounds GVWR will have a warranty period of 5 years/350,000 miles. However, in the instances where a medium heavy-duty engine is installed in a Class 8 heavy-duty vehicle, the warranty period will be limited to the medium heavy-duty engine requirement of 5 years/150,000 miles. This warranty period will be applicable because the warranty period is dependent on the certified primary intended service class of the engine (i.e., a medium heavy-duty engine).

Additionally, as heavy-duty engine technology develops, the warranty coverage for engines used in heavy-duty hybrid vehicles requires special consideration. Currently, heavy-duty hybrid vehicles, if certified through CARB’s heavy-duty hybrid vehicles interim certification procedures, must comply with the same warranty and useful life requirements as the certified combustion engine that is installed in the hybrid vehicle. For example, if the installed engine is a MY 2019 heavy-duty diesel engine, both the engine and the hybrid system have to comply with the 5-year/100,000 miles warranty requirement. For hybrid vehicles funded through the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), the warranty requirements in HVIP also apply to vehicles receiving funding. The HVIP warranty requirements, 3 years/50,000 miles, apply to the hybrid system, but do not shorten the warranty of the internal combustion engine, which is still covered by the warranty requirements specified in 13 CCR 2036.[13]

[13] Beginning with model year 2022, the warranty required for engine families that have concurrent applications in both dedicated diesel-fueled vehicles and hybrid vehicles will be 5 years/350,000 miles, whereas for engine families certified for use in hybrid vehicles exclusively, the warranty will remain 5 years/100,000 miles.

4.3. Heavy-Duty Engine/Vehicle Maintenance Intervals

Routine maintenance is required for a heavy-duty engine to function properly throughout its useful life, including not exceeding applicable emission standards. Routine maintenance may include any type of adjustment, cleaning, repair, or replacement that needs to be performed on components or systems at the owner's expense. Some examples of routine maintenance are oil, oil filter, and air filter changes at pre-defined mileage intervals.

Modern heavy-duty engines are complex systems that require fine-tuned calibration of engine operations in tandem with downstream aftertreatment systems. With more system complexity and upstream-downstream interactions, a rigorous maintenance schedule becomes even more critical for proper engine and aftertreatment system functionality (CCDET, 2016). In the owner's manual for an engine, the manufacturer identifies a maintenance schedule with the recommended maintenance intervals for adjustments, cleaning, repairs, replacements, etc., that can be needed for different components.

4.3.1. Emissions Maintenance Intervals for Heavy-Duty Diesel and Otto-Cycle Engines

Under the Step 1 warranty amendments for diesel engines, the minimum maintenance repair/replacement intervals were determined from a survey of the owner's manuals for all 2016 California-certified on-road heavy-duty diesel engines. Specifically, all of the owner's manuals for these engine families were reviewed, and the shortest (i.e., most frequent) repair/replacement maintenance interval specified for emission-related components, by any manufacturer, was selected as the new minimum repair/replacement interval for that component. Further, if all manufacturers did not recommend any required maintenance for a component or system, then the minimum repair/replacement maintenance interval for that component or system was set to the current applicable useful life of the engine. These minimum repair/replacement intervals are effective beginning in MY 2022 and are shown in Table I-5 below for heavy-duty diesel engines. The current minimum maintenance repair/replacement intervals for Otto-cycle engines are shown in Table I-6.

Table I-5. Minimum Maintenance Repair/Replacement Intervals for Heavy-Duty Diesel Engines for Criteria Pollutant Emissions Effective MY 2022

Component or System	Minimum Repair/Replacement Interval for Heavy-Duty Diesel Engines		
	Light Heavy-Duty Diesel Engine 14,001 - 19,500 lbs. GVWR	**Medium Heavy-Duty Diesel Engine** 19,501 - 33,000 lbs. GVWR	**Heavy Heavy-Duty Diesel Engine** >33,000 lbs. GVWR
Exhaust Gas Recirculation (EGR) System (valves & cooler - not including hoses)	Not Replaceable[a,b]	Not Replaceable[a,b]	Not Replaceable[a,b]
Exhaust Gas Recirculation (EGR) System (other than valves & cooler)	110,000 miles, or 3 years	185,000 miles	435,000 miles
Crankcase Ventilation System	50,000 miles	60,000 miles, or 2,000 hours, or 1 year	60,000 miles, or 2,000 hours, or 1 year
Diesel Exhaust Fluid (DEF) Filter	110,000 miles, or 2 years	125,000 miles, or 3,000 hours, or 10 years	125,000 miles, or 3,000 hours
Fuel Injectors	110,000 miles	185,000 miles	435,000 miles
Turbochargers	Not Replaceable[a,b]	Not Replaceable[a,b]	Not Replaceable[a,b]
Electronic Control Unit, Sensors, and Actuators	100,000 miles, or 3,000 hours	150,000 miles, or 4,500 hours	150,000 miles, or 4,500 hours, or 5 years
Diesel Particulate Filter System (element only)	Not Replaceable[a]	Not Replaceable[a]	Not Replaceable[a]
Diesel Particulate Filter System (other than element)	110,000 miles	185,000 miles, or 3 years	435,000 miles, or 3 years
Catalytic Converter (bed only)	Not Replaceable[a]	Not Replaceable[a]	Not Replaceable[a]
Catalytic Converter (other than catalyst bed)	110,000 miles	185,000 miles	435,000 miles
Any other add-on or new technology emission-related component or system whose primary purpose is to reduce emissions or whose failure will significantly degrade emissions control	110,000 miles, or 3,300 hours[c]	185,000 miles, or 5,550 hours[c]	435,000 miles, or 13,050 hours[c]

[a] For components or systems designated in the table as “Not Replaceable,” manufacturers shall not schedule any repair/replacement maintenance intervals throughout the applicable useful life of the heavy-duty diesel engine unless the manufacturer pays for it.

[b] Sensors and actuators are included only if they are integral to these assemblies and cannot be repaired without removing or replacing the assembly. Otherwise sensors and actuators are subject to the maintenance intervals specified in the table for Electronic Control Units, Sensors, and Actuators.

[c] Manufacturers may request more frequent repair/replacement maintenance intervals for add-on or new technology emission-related components provided that the manufacturer demonstrates to the Executive Officer’s satisfaction that such intervals are technologically necessary and appropriate.

Table I-6. Current Minimum Maintenance Repair/Replacement Intervals for Heavy-Duty Otto-Cycle Engines for Criteria Pollutant Emissions

Component or System	California & Federal Minimum Maintenance Repair/Replacement Interval for Heavy-Duty Otto-Cycle Engines specified in 86.004-25
Exhaust Gas Recirculation (EGR) System (filters & cooler – not including hoses)	50,000 miles or 1,500 hours
Crankcase Vent. Valve & Filter	50,000 miles or 1,500 hours
Fuel Injectors	100,000 miles or 3,000 hours
Turbocharger	100,000 miles or 3,000 hours
Engine Control Unit (ECU), Sensors, Actuators	100,000 miles or 3,000 hours
Exhaust Gas Recirculation (EGR) System (including all related control valves and tubing)	100,000 miles or 3,000 hours
Catalytic Converter (other than catalyst bed)	100,000 miles or 3,000 hours
Catalyst bed only	Not Replaceable[a]
Oxygen Sensor	80,000 miles or 2,400 hours
Carburetors	100,000 miles or 3,000 hours
Evaporative Emission Canisters	100,000 miles or 3,000 hours
Air Injection System Components	100,000 miles or 3,000 hours
Emission-related Hoses and Tubes	50,000 miles or 1,500 hours
Ignition Wires	50,000 miles or 1,500 hours
Any other add-on or new technology emission related component or system whose primary purpose is to reduce emissions or whose failure will significantly degrade emissions control	NA

[a] For components or systems designated in the table as “Not Replaceable,” manufacturers shall not schedule any repair or replacement maintenance intervals throughout the applicable useful life.

4.3.2. How the Maintenance Intervals are Established

As discussed further in Section B.8 of this chapter, before a manufacturer can sell or offer for sale a new heavy-duty engine in California, it must first receive an Executive Order from CARB for that engine by demonstrating through an emission certification process that the engine complies with all applicable new engine certification requirements. One of the key components of the certification process includes conducting a durability demonstration to provide assurances that engine and aftertreatment system components are durable and that the engine and aftertreatment system will comply with the applicable emission standards at the end of useful life. The demonstration also requires information on the required maintenance (both emission-related and non-emission-related[14]) that is needed for proper engine and aftertreatment system operation.

While the durability demonstration ensures that the engine and its emission control systems are durable over the engine's useful life, a manufacturer sometimes determines that a particular durability demonstration may require the repair or replacement of some components during the durability demonstration period. A manufacturer is allowed by the current California and federal regulations to schedule the repair or replacement of some components at specific intervals during the durability demonstration, as long as they similarly schedule such repairs or replacements into the allowable maintenance schedules for vehicle owners. This maintenance schedule becomes the "official" maintenance schedule (13 CCR 2036(e)) instructions for the engine family, and subsequent to approval by CARB's Executive Officer, is required to be distributed to the initial vehicle purchaser (e.g., via the owner's manual). The maintenance schedule includes all emission-related and non-emission-related maintenance requirements for each specific engine and aftertreatment system.

4.3.3. Relationship Between Scheduled Replacement Intervals and Warranty Coverage

The maintenance provisions specify the minimum allowable (i.e., shortest allowed) maintenance intervals for specific emission-related components. Currently, the minimum maintenance intervals for heavy-duty diesel engines, with the exception of non-emission-related scheduled maintenance requirements, occur at or after the end of the current 100,000-mile warranty period. Similarly, the heavy-duty Otto-cycle engine minimum maintenance intervals occur at or after the current 50,000-mile warranty period. Hence, a manufacturer cannot schedule emission-related maintenance in the owner's manual before the end of the current 100,000-mile warranty for heavy-duty diesel engines, or before the end of the current 50,000-mile warranty for heavy-duty Otto-cycle engines. Therefore, for both diesel- and Otto-cycle heavy-duty engines, the

[14] Maintenance can be designated as either "emission-related" or as "non-emission-related." Emission-related maintenance means maintenance of a component which substantially affects emissions. For example, an oil change at the manufacturer-specified interval is considered non-emission-related, whereas the ash cleaning of a diesel particulate filter at the manufacturer-specified interval is considered emission-related.

current minimum maintenance intervals have little effect on current warranty requirements.

However, during the rulemaking process for the June 2018 Step 1 warranty amendments, CARB staff noticed that the existing maintenance provision in 13 CCR 2036(d)(3) had the potential to truncate the lengthened warranty periods. Specifically, it would allow the warranty coverage to end after the first scheduled replacement, even if the warranty period for that component has not yet been exceeded. CARB accordingly modified 13 CCR 2036(d)(3) to require that any component repaired or replaced during the lengthened warranty period would continue to remain subject to the warranty requirements throughout the remainder of the proposed warranty period.

Chapter II, Section C.4 below discusses the need to revise heavy-duty warranty provisions further. Chapter III, Section A.4 describes the proposed warranty amendments and the rationale for them.

5. Useful Life Periods

The regulatory useful life period is the period of time or engine operation during which manufacturers are liable for emissions compliance. Specifically, manufacturers must ensure that their engines meet emission standards not only at the time of certification (via the Durability Demonstration Program procedures discussed later), but also for production engines for their regulatory useful life. CARB's current useful life provisions parallel the useful life provisions of U.S. EPA, and are meant to ensure adequate durability of both the engine and the vehicle emission control systems.

Under the current regulations the period of time for the useful life is measured in miles, years, and in some cases in hours. Originally, the mileage values were chosen to roughly correspond to the average engine life before retirement (for smaller engines), or major engine rebuilds (for larger engines). Section 202(d) of the Federal Clean Air Act specifies these useful life periods for the various heavy-duty engine classes and further authorizes U.S. EPA to adopt longer useful life periods, which U.S. EPA has done. See e.g., 40 CFR §86.004-2.

5.1. History of Heavy-Duty Useful Life

5.1.1. How Heavy-Duty Useful Life was First Established

Prior to the 1984 MY, U.S. EPA defined useful life periods as fixed intervals that represented a period that was somewhat less than half the service life of the vehicles and engines (U.S. EPA, 1983). These fixed intervals had values of 10 years, 100,000 miles, or 3,000 hours of operation, whichever occurred first, for heavy-duty diesel engines, and 5 years, 50,000 miles, or 1,500 hours of operation for heavy-duty Otto-cycle engines. However, beginning with the 1984 MY, U.S. EPA changed the useful life definition from the fixed intervals to manufacturer-determined periods that represented the average of the then-currently recognized full-life period of use up to engine retirement or rebuild (FR, 1980).

However, industry still had concerns about these useful life periods. So in response, U.S. EPA, in its final ruling, adopted provisions beginning with the 1985 MY, that established useful life periods for an engine subclass based on its primary intended service class application.[15] The breakdown for the heavy-duty diesel engine class then became three subclasses: the LHDD engine subclass that consists of lighter duty engines sold primarily for use in pickups, delivery vehicles, and recreational vehicles; the MHDD engine subclass that was comprised of engines typically used for short-haul intra-city vehicles; and the HHDD engine subclass consisting of engines primarily used in long-haul inter-city operations.

The 1985 and subsequent heavy-duty useful life periods were derived from an analysis of a combination of engine rebuild survey data, scrappage data, and stakeholder estimates. Accordingly, the useful life periods for heavy-duty diesel engines were categorized based on the three subclasses where a HHDD[16] engine was 8 years/290,000 miles, a MHDD engine was 8 years/185,000 miles, and a LHDD engine was 8 years/110,000 miles (U.S. EPA, 1983). The useful life period for LHDD engines was chosen to be the same as for heavy-duty Otto-cycle engines because, at the time, they were a relatively new diesel application being used in a field that was dominated by Otto-cycle engines, and the reasoning was that they should last as long as the Otto-cycle engines they were designed to replace.

5.1.2. Development over the Years

Since the mid-1980s, manufacturers have significantly increased the mechanical durability of heavy-duty diesel engines, thereby allowing the engines to accumulate many more miles before requiring rebuild. In addition, by the late 1990s, U.S. EPA reported in 1997 that the annual vehicle miles traveled (VMT) for line-haul trucks had increased, resulting in HHDD engines reaching the end of their 1985-defined useful life of 290,000 miles more quickly, and then continuing to accumulate many more miles beyond that useful life period before needing to rebuild the engine (U.S. EPA, 1997a). U.S. EPA's finding was corroborated by published warranty information and the commonly accepted understanding at the time in the trucking industry, that with sound maintenance practices, the HHDD engines lasted much longer than 290,000 miles before requiring a rebuild (HDT, 2006).

Therefore, in 1997, when U.S. EPA adopted the 2004 emission standards for heavy-duty diesel engines, it also amended the HHDD engine useful life period. While U.S. EPA considered proposing an increase of the HHDD engine useful life period to 500,000 miles or more, U.S. EPA ultimately determined that a somewhat lower value was appropriate because engine manufacturers stated that they would be challenged to meet the proposed new emission standards, and that an extremely long useful life could affect the feasibility of the 2004 standards. In response, U.S. EPA acknowledged that the length of the useful life could affect the feasibility of the standards and lengthened

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[15] The primary intended service class application is the application group for which a heavy-duty diesel engine is designed and marketed.
[16] Vehicle classes are indicated with respect to their applicable GVWR in Table I-7.

the useful life period to 435,000 miles for the HHDD engines. The 435,000-mile value was selected because it represented a 50 percent increase from the previous useful life of 290,000 miles and was intended to help ensure durable emissions control designs without compromising the feasibility or cost-effectiveness of the 2004 standards (U.S. EPA, 1997a).

In its 1997 rulemaking, U.S. EPA stated that the "time in service" denoted in years for the useful life period was much less critical than the mileage because the time in service in years was not generally the limiting period. At the time, it was estimated that a LHDD engine[17] required an average of about 8 years to reach the point where it needed to be rebuilt or retired. In addition, engine manufacturers had stated that LHDD engines are not typically rebuilt. In fact, the vast majority of rebuilding occurred with the heavy-duty engines used in vehicle classes 6-8,[18] which were designed and built to last for a longer time. Consequently, U.S. EPA adopted the useful life period of 10 years for all heavy-duty diesel engines beginning with the 2004 MY.

Lastly, due to concerns that 435,000 miles would be inappropriately long for urban buses, which had a much lower average speed than line-haul trucks, U.S. EPA adopted an "operational hour" limit of 22,000 hours that was calculated using the 290,000-mile value (i.e., the then-current accepted projected life-to-rebuild mileage for urban bus engines) and a 13 miles per hour (mph) speed value (the average speed for urban buses).

Thus, beginning with the 2004 MY for heavy-duty engines, the current useful life periods for heavy-duty engines were defined as 10 years or 110,000 miles for LHDD engines and heavy-duty Otto-cycle engines, 10 years or 185,000 miles for MHDD engines, and 10 years or 435,000 miles or 22,000 hours for HHDD engines, whichever comes first. Table I-7 indicates these useful life periods for heavy-duty diesel engines and heavy-duty Otto-cycle engines that are certified to criteria emission standards.

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[17] Light heavy-duty engine means an engine used in a vehicle that is normally at or below 19,500 pounds GVWR.

[18] Vehicle classes 6 and 7 weigh between 19,501 pounds - 33,000 pounds GVWR, and Class 8 vehicles weigh greater than 33,000 pounds GVWR.

Table I-7. Useful Life Periods for Heavy-Duty Diesel-Cycle and Heavy-Duty Otto-Cycle Engines for Criteria Pollutant Emissions

Engine / Vehicle Category (GVWR)	Useful Life for Engines Certified to Criteria Emission Standards miles or years or hours (whichever first occurs)
HHDD / Class 8 >33,000 lbs.	435,000 miles 10 years/22,000 hours
MHDD / Class 6-7 19,501 - 33,000 lbs.	185,000 miles 10 years
LHDD / Class 4-5 14,001 - 19,500 lbs.	110,000 miles 10 years
HDO >14,000 lbs.	110,000 miles 10 years

5.1.3. Useful Life Relationship to Engine Certification and Engine Rebuilds

Both U.S. EPA and CARB require certified engines to meet emission standards throughout their useful life periods. As an engine ages, its engine-out emissions tend to increase due to many factors, including normal wear. Manufacturers must take into account this deterioration in emissions performance in the initial design of the engine.

To certify an engine, an engine manufacturer demonstrates an engine's durability by conducting durability testing on the engine with all emission control systems installed and operating, including any aftertreatment devices (e.g., SCR for NOx control, a DPF for PM control). The durability tests demonstrate that the engine and its associated emissions control systems are sufficiently durable to comply with the emission standards over the engine's full useful life. However, this represents an ideal situation because it assumes that the vehicle, engine, and aftertreatment devices are properly designed, well-maintained, and not subject to tampering.

The mileage values for the useful life period were set based on the average mileage at which engines get rebuilt or retired. An engine rebuild commonly involves the disassembly of the engine to a point where high-wear components are checked and measured against the original equipment manufacturer (OEM) specifications, replaced or reconditioned as necessary, and reassembled. Some MHDD engines and most HHDD engines are designed so that many core components that are subject to high wear and tear, such as pistons and cylinder walls, facilitate an easy replacement. Generally, at the end of both MHDD and HHDD engine useful lives, the vehicle owner usually rebuilds the engine to obtain additional service at lower cost than through the purchase of a new engine. In 1982, the average rebuild mileage for heavy-duty diesel engines used in vehicles weighing greater than 33,000 pounds GVWR was 276,000 miles (Rondini, 2015), but today, a HHDD engine can, on average, operate upwards of 850,000 miles before rebuild (MacKay, 2019).

5.2. Current Heavy-Duty Useful Life Requirements for Diesel and Otto-Cycle Engines

5.2.1. Criteria Pollutant-Related Useful Life Requirements

As stated above, both CARB and U.S. EPA require that heavy-duty engines meet emission standards throughout their useful life periods. As previously shown in Table I-7, for heavy-duty criteria emissions-certified diesel-cycle engines, the current useful life accumulated mileage periods range from 110,000 miles up to 435,000 miles depending on a vehicle's GVWR. The "time in service" period is 10 years, and the "operational hour" period is 22,000 hours for HHDD engines.

Table I-7 also indicates the useful life for criteria emissions-certified Otto-cycle engines as either 110,000 miles or a "time in service" period of 10 years, for all vehicle GVWRs greater than 14,000 pounds.

5.2.2. Useful Life Requirements for GHG Emissions-Certified Engines (Diesel- and Otto-Cycle) and Vehicles

Under the federal Phase 1 GHG Regulations, the useful life periods for engines and vehicles with respect to the GHG emissions were set equal to the respective useful life periods applicable for criteria pollutants (FR, 2016).

Under the federal Phase 2 GHG Regulations, however, U.S. EPA adopted a useful life period of 150,000 miles or 15 years for both diesel- and Otto-cycle engine-equipped vocational vehicles at or below 19,500 pounds GVWR beginning with the 2021 MY. However, in the case of engine dynamometer-based certifications performed under 40 CFR, part 86, subpart A, the 150,000 mile/15-year useful life period was not adopted. For vehicles greater than 19,500 pounds, U.S. EPA retained the Phase 1 GHG useful life periods.

5.3. Comparison Between Useful Life and Actual Heavy-Duty Vehicle Usage

As mentioned earlier, the engine rebuild data that was used to determine the current useful life mileage periods originated from the late 1980s. Since then the advances in vehicle and engine technology have allowed heavy-duty vehicles to remain in service longer than the required mileages under the current useful life provisions. In fact, by 2006, the average mileage for an engine rebuild or replacement was 600,000-700,000 miles, and the newer engines could operate close to a million miles if properly maintained (HDT, 2006). This is evidenced by comparing the mileages seen in real-world vehicle usage coming from CARB's EMFAC inventory model, recent heavy-duty vehicle survey data, as well as from tracking the odometer mileages from vehicles undergoing their biennial inspection and maintenance checks.

EMFAC can be used to provide an average odometer mileage based on the vehicle age for the different vehicle categories. EMFAC utilizes vehicle data from the California Department of Motor Vehicles (DMV) registrations and builds it into the model to track how vehicles operate throughout the state. EMFAC models the average odometer as a function of both a mileage accrual rate and a vehicle survival rate. The mileage accrual rate in the latest version of EMFAC came directly from the federal National Vehicle Inventory and Use Survey (VIUS) data that provided the odometer mileage as a function of vehicle age. The survival rate is affected by initial new sales, migration of new vehicles out of California, migration of used vehicles into California, and also scrapping of vehicles (e.g., totally destroyed in an accident, etc.). Therefore, the average odometer value coming from EMFAC is a good representation of the real mileages for heavy-duty vehicles in California. Table I-8 compares the EMFAC mileage values to the current regulatory useful life mileages for different vehicle and engine categories. As indicated in the table, the EMFAC values greatly exceed the mileages for the current useful life, and although they do not reflect engine rebuilds or replacements, they show that the vehicles that are currently in use are operating on the roads for periods much longer than their respective regulatory useful lives would indicate.

Another comparison of the regulatory useful life and real-world usage is possible with heavy-duty vehicle survey data from two sources: one is based on national surveys, and the other is based on a California-specific survey. The national survey data comes from the DataMac database developed and maintained by MacKay & Company which has been in the business of conducting marketing research for the commercial trucking, construction, and agricultural equipment industries since 1968. MacKay & Company specializes in delivering market analysis of vehicle and engine components, distribution channels and market trends. By utilizing their DataMac database to explore current and projected components replacement for the on-road heavy-duty vehicle sector, it is possible to determine an average mileage at which the engine rebuilds/replacements are occurring for the engines used in the different vehicle classes. These values for the mileages at which the engine rebuilds/replacements actually occur are also shown in Table I-8 and, like the EMFAC values, show that the average miles greatly exceed the current applicable regulatory useful life values.

The California-specific survey is the California Vehicle Inventory and Use Survey (CA-VIUS) that shows current mileage trends within the state. This survey was modeled after the now-discontinued VIUS and began in early 2016 and was completed in 2018. It was a collaborative effort by CARB, the California Energy Commission, and the California Department of Transportation (Caltrans), but it was led by Caltrans. The goal of CA-VIUS was to collect data on the physical and operational characteristics of California's commercial vehicle population. The odometer mileages based on the vehicle's age are readily obtained from this data set, and so it is useful in observing current heavy-duty vehicle mileage trends. The CA-VIUS mileages listed in Table I-8 show the maximum average odometer values for the different vehicle classes being considered. Comparing the mileages from CA-VIUS to the regulatory useful life reveals that, like the EMFAC and MacKay & Company mileages, they are also much higher than current useful life. Regardless, the general trend still holds that the real-world use of heavy-duty vehicles has increased since the early 1980s to longer periods of time out on the road, and consequently demonstrates that the current useful life period requirements are no longer representative of real-world operations.

Table I-8. Comparison of Current Heavy-Duty Vehicle Useful Life Mileages with Real-World Vehicle Information from Various Sources

Heavy-Duty Category (GVWR)	Current Useful Life (Miles)	EMFAC 2017 Useful Life (Miles)	MacKay & Co. Weighted Average Engine Rebuild/ Replacement from 2012-2018 (Miles)	CA-VIUS Maximum Odometer (Miles)*	B-Life (Miles)
HHDD / Class 8 >33,000 lbs.	435,000	800,000	854,616	703,772	1,000,000- 1,200,000[A,B,C,D]
MHDD / Class 6-7 19,501 - 33,000 lbs.	185,000	400,000**	432,652	235,624**	500,000- 550,000[E,F]
LHDD / Class 4-5 14,001 - 19,500 lbs.	110,000 150,000[a]	400,000**	326,444	235,624**	250,000- 550,000[G,H,I,J]
HDO >14,000 lbs.	110,000 150,000[b]	300,000	217,283	153,810	N/A

* The second to the rightmost column is the maximum predicted odometer mileage, based on CA-VIUS survey data. CARB staff fitted a polynomial function to the plot of the average odometer mileage versus vehicle age; where the maximum value of the average odometer mileage is assumed to remain constant for all older vehicles. That maximum odometer mileage is shown.

** Values obtained from the data source were grouped for vehicles weighing between 14,001- 33,000 pounds GVWR.

[a] 40 CFR §1037.105 and §1037.106

[b] 40 CFR §1036.108(d)

[A] (DDC, 2017) https://detroitads.azureedge.net/9276-detroit_dd13_ghg17_product_ove-2017-04-20.pdf

[B] (Fletcher & Lyden, 2009) http://www.worktruckonline.com/fc_resources/wt0109engines.pdf

[C] (International, 2016) https://www.internationaltrucks.com/-/media/navistar/trucks/spotlight/engine-detail-pages/navistar-n13/enginedetailgallery_n13_1.pdf

[D] (Paccar, 2019) https://paccarpowertrain.com/MX-13-Spec-Sheet.pdf

[E] (Ford, 2017) http://www.fleet.ford.com/resources/ford/general/pdf/brochures/2018/19314%20InternationalDuraStar%20wo%20crops.pdf

[F] (International, 2018) https://www.internationaltrucks.com/engines/navistar-n9

[G] (Cummins Hub, 2018) http://www.cumminshub.com/67.html

[H] (Diesel Hub, 2018b) http://www.dieselhub.com/tech/truck-classifications.html

[I] (Ram Trucks, 2018) https://www.ramtrucks.com/ram-chassis-cab.html

[J] (International, 2018) https://www.internationaltrucks.com/engines/navistar-n9

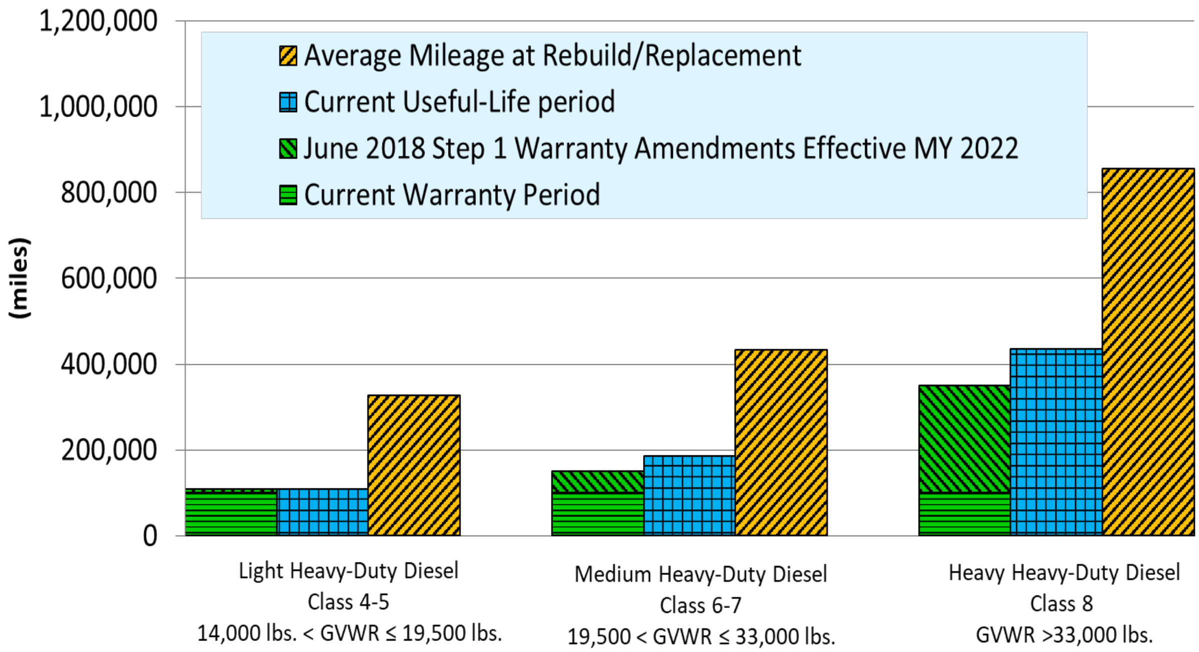
To describe some of the improvements for engine durability, engine manufacturers use the “B-life” value. The “B-life” value for an engine is an industry standard metric used to statistically predict when a certain percentage of the units in the engine family will fail. In essence, the values can give a measure of the life expectancy of an engine. Typical “B-life” values for heavy-duty diesel engines are shown in Table I-8 for vehicle classes 4-8. Generally, the values indicate that the engines are capable of operating anywhere from 250,000 up to 1.2 million miles before requiring a rebuild (Paccar, 2019; DDC, 2017; Isuzu, 2017; Kenworth, 2013). However, it may be possible that B-life values are not the best metric on which to base decisions for the engine useful life if they are considered to be applicable to only the main engine block components (e.g., valves, pistons, cylinders, etc.), and not to the emissions control and aftertreatment systems that are later incorporated onto the engine. Regardless, the “B-life” periods can be used to illustrate that the current useful life periods, of which Class 8 engines have the highest value at 435,000 miles, are substantially inadequate when compared to the expected design life for these heavy-duty engines. Additionally, when also considering the implications for the warranty periods, the emissions warranty would have ceased to apply long before the engine block is rebuilt, leaving a large opportunity for emission-related components to fail and emissions to degrade.

Comparing the data sources in Table I-8, the engine rebuild/replacement data obtained from MacKay & Company (MacKay, 2019) most accurately illustrates the inadequacies of the current useful life periods. The goal of the engine rebuild is to bring the engine back to OEM specifications and, according to MacKay, this may include the replacement of some engine components such as the cylinder liners, piston rods, gaskets; or the re-grinding of the crankshaft; or the machining of the non-lined engine cylinders. So, unlike the statistically obtained “B-life” value that assumes an idealized usage of the vehicles, the MacKay rebuild/replacement data are based on survey responses from fleet and shop owners and so they are more indicative of real-world truck usage. The MacKay rebuild/replacement data is also superior to the CA-VIUS data because the CA-VIUS data does not contain an indication of when an engine has been rebuilt. So, for example, CA-VIUS survey data might indicate a mileage for a vehicle of 500,000 miles but would not indicate whether the engine in that vehicle was original or had recently been rebuilt back to OEM specifications.

Figure I-3 illustrates a comparison of values of the current and the June 2018 Step 1 warranty amendments, and the current useful life periods for on-road heavy-duty diesel vehicle classes 4 through 8 based on the engine rebuild/replacement miles. The current heavy-duty engine emission warranty period of 100,000 miles is reached relatively early in the service life of many vehicles, and well before engine rebuild typically occurs. And although the June 2018 warranty amendment values are longer than the current warranty periods, they are still much lower than the rebuild mileages, and therefore remain inadequate to protect air quality.

Chapter II, Section C.5 below discusses the need to revise the useful life requirements. Chapter III, Section A.5 describes the proposed useful life amendments and the rationale for them.

Figure I-3. Comparison of Warranty and Useful Life to Mileage at Engine Rebuild/Replacement



6. Emissions Warranty Information and Reporting and Corrective Action Procedures

In 1988, CARB adopted a program for light-duty and heavy-duty vehicles and engines, to identify and recall vehicles with defective emission-related parts and systems. This program is called the "Emissions Warranty Information Reporting" (EWIR) program (1988 EWIR Regulation). The program requires vehicle manufacturers to keep records of emission control components[19] that are replaced or repaired under warranty, report if the number exceeds a certain threshold, and then determine the actual failure rate (e.g., some returned parts replaced under warranty can be excluded because they may not actually be defective due to mechanics having misdiagnosed the problem). When the validated failure rate of an emissions component exceeds four percent within the warranty period, CARB requires corrective action (CARB, 1988).

Manufacturers track the number of warranty claims for each emission control component during the emissions warranty period. Once a component reaches a warranty claim rate of one percent or 25 claims, whichever is greater, manufacturers are required to submit quarterly reports tracking the warranty claims rate. Once the

[19] In this Staff Report's discussion of warranty provisions, "component" is used to mean a category of hardware such as turbocharger or fuel injector; "part" is used to mean an individual piece of hardware. So, for example, if 100% of turbochargers for an engine family with a sales volume of 50 engines failed and the manufacturer had to conduct a recall, that would constitute recall of one component, and the manufacturer would need to recall 50 parts.

warranty claims rate reaches four percent or 50 claims, whichever is greater, a field information report (FIR) must be submitted. The main purpose of the report is to determine the root cause of the failure and the true failure rate. This allows manufacturers an opportunity to screen out warranty claims for parts that were found not to be defective and to assess the projected failure rate of a given emission control component.

Once a warranty claims rate exceeds a valid failure rate of four percent or 50 failures, whichever is greater, manufacturers are required to submit an emissions information report (EIR) for the defective component that may launch the process of corrective action. Manufacturers are required to take corrective action for components that have a true failure rate greater than four percent or 50 failures, whichever is greater, per 13 CCR 2143.

Chapter II, Section C.6 below discusses the need to revise the EWIR program and corrective action procedures. Chapter III, Section A.6 describes the proposed EWIR and corrective action amendments.

7. Emissions ABT Program

7.1. Background and National Program

The heavy-duty engine ABT program was first established for 1991 MY engines. At that time, U.S. EPA and CARB adopted separate ABT programs applicable to heavy-duty engines sold outside of California (the other 49 states) and to heavy-duty engines sold in California, respectively. The intent of the program was to provide manufacturers with flexibility in complying with applicable emission standards on a corporate-wide basis instead of requiring compliance for each individual certified engine family. Manufacturers were also given the ability to trade or bank the emission credits under the banking and trading provisions of the program.

The original federal-ABT program is described in 40 CFR §86.091-15, last amended November 5, 1990.[20] Under this program, credits had a three-year credit life. Based on feedback from stakeholders (U.S. EPA, 1997b), U.S. EPA removed the three-year credit life limit from the regulations with 2004 and subsequent MY engines.

In California, only an averaging program was initially introduced for 1991 MY heavy-duty engines (i.e., no banking or trading).[21] The California regulations were later amended to include banking and trading of credits with 1998 and subsequent MY engines

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[20] The federal-ABT program was subsequently modified for the 1992 MY (40 CFR §86.092-15, last amended March 25, 1994), 1994 MY (40 CFR §86.094-15, last amended September 30, 1994), 1998 MY (40 CFR §86.098-15, last amended October 21, 1997), 2004 MY (40 CFR §86.004-15, last amended October 6, 2000), and 2007 MY (40 CFR §86.007-15, last amended January 18, 2001) engines.
[21] The program was described in the California Exhaust Emission Standards and Test Procedures for 1985 through 2003 Model Heavy-Duty Diesel Engines and Vehicles, amended December 12, 2002, §86.091-11.

(86.098-15).[22] California regulations were further amended beginning with 2004 and subsequent MY engines so that the California and federal-ABT programs were merged into a national pool of ABT credits for heavy-duty engines sold nationally.[23]

The key advantage of the ABT program is to provide flexibility to manufacturers in meeting the emission standards. Under the ABT program, manufacturers can produce and sell some engines with emission levels above the applicable standards so long as they balance that by selling other engines that have emission levels below the applicable standards. Basically, compliance with the emission standards can be demonstrated through corporate averaging of all certified products. The regulations define four separate ABT averaging sets (pools) of credits for heavy-duty engines. These pools include:

1. HDO averaging set which includes medium-duty and heavy-duty Otto-cycle engines,
2. LHDD averaging set which includes medium-duty and light heavy-duty diesel engines,
3. MHDD averaging set which includes medium heavy-duty diesel engines, and
4. HHDD averaging set which includes heavy heavy-duty diesel engines.

For the HDO averaging set, ABT is available for NOx and NMHC. For the LHDD, MHDD, and HHDD averaging sets, ABT is available for NOx and PM. It should be noted that prior to the 2007 MY, the ABT program defined a combined ABT averaging set for NOx+NMHC. For 2007 and subsequent MYs (post-2007), the NOx+NMHC ABT averaging set was eliminated, but manufacturers were allowed to transfer the pre-2007 credits into post-2007 credits subject to a specific discounting mechanism.

Cross trading of emission credits between different ABT averaging sets is prohibited. This prevents manufacturers from producing high-emitting engines in a specific service class and counterbalancing that with production of lower-emitting engines in another service class. In order to ensure that sufficient credits are available, manufacturers are required to submit a preliminary ABT report to CARB and U.S. EPA at the beginning of the MY along with their certification applications. End-of-year ABT reports are required within 90 days after the end of the MY.

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[22] Refer to footnote 20.

[23] The regulatory framework for the current ABT program is described in the California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines and Vehicles, section 86.xxx-15 (Heavy-Duty Otto-cycle Test Procedures §86.xxx-15), last amended December 19, 2018, and California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles, section 86.xxx-15 (Heavy-Duty Diesel Test Procedures §86.xxx-15), last amended April 18, 2019.

Emission credits/deficits for each engine family are calculated using the following equation:

$$Emission\ Credits = (Std\ - FEL) \times CF\ \times UL \times Production \times 10^{-6}$$ (Equation I-1)

where:

Emission Credits = Calculated emission credits for each engine family in Megagrams.

Std = the current and applicable heavy-duty engine NOx, NMHC or PM emission standard in g/bhp-hr or grams per Megajoule.

FEL = the NOx, NMHC, or PM family emission limit (FEL) for the engine family in g/bhp-hr or grams per Megajoule.

CF = a transient cycle conversion factor in brake horsepower-hour or Megajoules per mile. The transient cycle conversion factor is the total (integrated) cycle brake horsepower-hour or Megajoules, divided by the equivalent mileage of the applicable transient cycle. For Otto-cycle heavy-duty engines, the equivalent mileage is 6.3 miles. For diesel heavy-duty engines, the equivalent mileage is 6.5 miles.

UL = the useful life for the given engine family in miles.

Production = the number of engines produced for sales in the United States within the given engine family during the MY. Quarterly production projections are used for initial certification. Actual production is used for end-of-year compliance determination.

As mentioned earlier, current ABT calculations and accounting are done at the federal level using 50-state production volumes. There is only one pool of credits that covers California and the remaining 49 states. Given the harmonization of standards between CARB and U.S. EPA, manufacturers have been certifying the same products as 50-state engine families with both agencies for many years.

7.2. Interaction Between the ABT Program and Advanced Clean Trucks Regulation

The Advanced Clean Trucks (ACT) Regulation was proposed at a December 12, 2019 board hearing (CARB, 2019l). The purpose of the ACT Regulation is to accelerate the widespread adoption of zero-emission vehicles (ZEV) in the medium- and heavy-duty truck sector and reduce the amount of harmful emissions generated from on-road mobile sources.

The proposed ACT Regulation is focused on requiring large truck manufacturers to sell zero-emission trucks in California to broaden the market and to send a clear signal that medium- and heavy-duty ZEVs will be a major part of California's overall strategy to reduce criteria emissions, reduce climate impacts, and reduce petroleum use. The proposed ACT Regulation would also require one-time reporting from large entities to report information about their contracting practices in meeting their transportation needs and how truck and bus owners currently use their vehicles. Information collected from these companies would help CARB structure future end-user regulatory strategies including whether large entities that hire truck fleets could become the point of regulation, help ensure a level playing field, and help CARB determine any appropriate exemptions or flexibilities. This information would be used in developing future regulations designed to further accelerate the purchase and use of ZEVs in fleets. With both a manufacturer ZEV sales requirement and a requirement for ZEVs to be used, in combination with early market support from funding programs, it is envisioned that the market for ZEV technology will significantly increase.

Although the proposed ACT Regulation would broadly apply to the same category of on-road vehicles as those affected by the Proposed Amendments, within the same time period and impact the same manufacturers, it must be noted that the Proposed Amendments address different purposes and provide utility that is distinct and independent from the utility provided by the proposed ACT Regulation. As previously described, the Proposed Amendments implement SIP measures that require CARB to reduce NOx emissions from new on-road heavy-duty engines and to ensure those emission reductions are maintained as those engines and vehicles are operated. In contrast, the primary goal of the proposed ACT Regulation is to accelerate the introduction of ZEVs in the medium- and heavy-duty truck sector in applications that are best suited to the use of such ZEVs - applications that do not require vehicle operations exceeding a few hundred miles a day, such as local delivery applications and buses, which is a much smaller subset of the engines and vehicles impacted by the Proposed Amendments. Moreover, neither the ACT Regulation nor the Proposed Amendments are dependent on the adoption or implementation of the other rulemaking. However, the Proposed Amendments will complement the ACT Regulation by ensuring that the portions of manufacturers' engine family lines that are powered by internal combustion engines will be emitting at the lowest NOx emission standards possible.

In developing the Proposed Amendments, CARB staff had to consider how compliance, as well as potential early or over compliance, with the ACT Regulation should be credited in the ABT program.

Chapter II, Section C.7 below discusses further the need for revisions to the ABT program, and Chapter III, Section A.7 describes proposed revisions to the ABT program intended to provide incentives for manufacturers to make more heavy-duty ZEVs than required by the ACT Regulation.

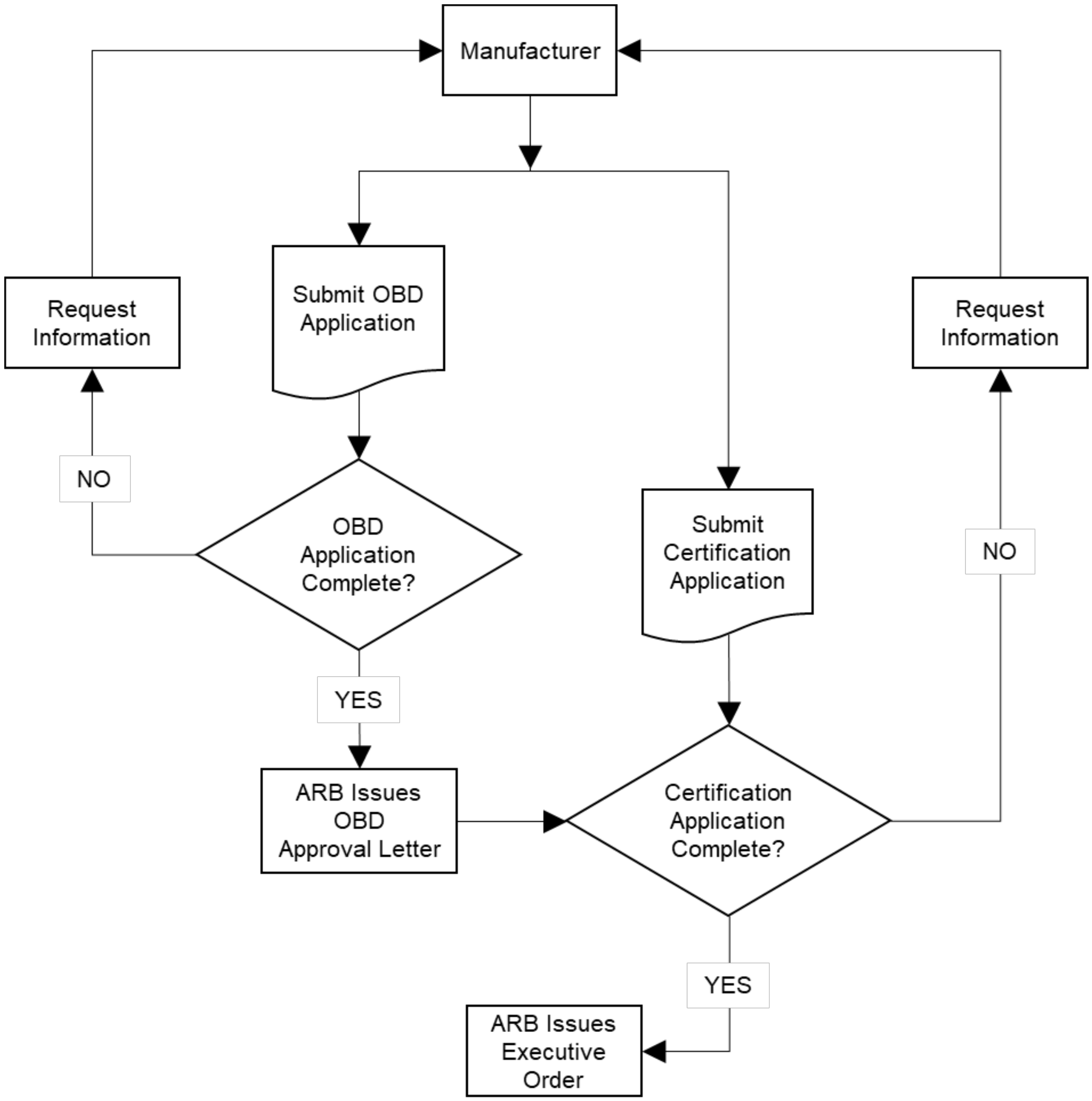
8. Heavy-Duty Engine Durability Demonstration Program and In-Use Emissions Data Reporting

8.1. Background and Regulatory Citations

The goods movement sector is one of many commercial sectors that relies heavily on the efficiency and durability of the modern-day diesel engine. Agriculture, construction, and commercial shipping sectors also use diesel engines as the primary source of power. One of the key advantages of the diesel engine is the longer useful life compared to an Otto-cycle engine. Diesel engines operate at high compression ratios, and therefore, higher operating combustion pressures compared to Otto-cycle engines. This means that the diesel engine block and other engine components must be designed to be more robust than their heavy-duty Otto-cycle counterparts. These design changes have resulted in a more durable heavy-duty engine with a longer service life. Given the improvements for heavy-duty diesel engine design, other engine and aftertreatment system components are similarly designed to last longer in comparison to heavy-duty Otto-cycle engines.

Heavy-duty engine manufacturers must go through a rigorous certification and OBD approval process in California to demonstrate that each certified engine family will be fully compliant with applicable regulations (Figure I-4) before distributing products into the California market. At the end of the approval process, CARB issues an Executive Order for each certified engine family allowing the manufacturer to sell their products in California. The approval process to obtain an Executive Order includes many elements. The durability demonstration program (DDP) is one of the components of the on-road heavy-duty engine certification process.

Figure I-4. On-Road Heavy-Duty Certification and OBD Review Processes



The purpose of the DDP is twofold. First, manufacturers must demonstrate that emission-related components are durable through the full useful life of the engine subject to the specified maintenance intervals. Second, manufacturers use the DDP data to calculate deterioration factors[24] for various pollutants to estimate the full useful life emissions. Manufacturers must demonstrate that the deteriorated emissions test results at the end of the useful life periods do not exceed applicable emission standards before a certification Executive Order is issued.

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[24] Deterioration factors are parameters that are either added (additive deterioration factors) or multiplied (multiplicative deterioration factors) to the low hour emission test results to simulate the impacts of full useful life aging on the engine and aftertreatment system.

The DDP requirements depend on a number of parameters including the production volume and the combustion cycle. There are four unique pathways to satisfy certification durability requirements. These are each described in the following subsections.

8.1.1. Heavy-Duty Small Volume Manufacturers

Manufacturers with aggregated national sales of less than 301 vehicles and vehicle engines per year may use assigned deterioration factors[25] to satisfy the certification DDP requirements. Assigned deterioration factor values are provided for each specific pollutant and are referenced in U.S. EPA's guidance document CCD-00-12 (U.S. EPA, 2000).

Using assigned deterioration factors significantly reduces the testing burden and costs to small volume manufacturers. However, such manufacturers are still required to conduct certification emissions tests demonstrating that the emissions test levels with the applied deterioration factors are at or below the applicable emission standards.

8.1.2. Heavy-Duty Otto-Cycle Engines

Due to the vast level of experience with Otto-cycle engines in the light-duty sector, the component durability and deterioration behavior of Otto-cycle engine and aftertreatment systems are well known and have been correlated with data from in-use vehicles. Based on historical data, U.S. EPA and CARB have determined that the Otto-cycle emissions deterioration is primarily a function of the TWC performance over time and have established bench aging procedures that simulate TWC deterioration. It should be noted that the emission control technologies and useful life periods are similar for both light-duty (15 years/150,000 miles for LEV III) and heavy-duty (10 years/110,000 miles) Otto-cycle engines.

The regulatory framework for the durability process is provided in the Heavy-Duty Otto-cycle Test Procedures §86.001-24(c)(3) and §86.004-26(c)(2). Manufacturers are not required to age the combined engine and aftertreatment system on a dynamometer. Instead, a representative engine family, which includes the engine and TWC, performs an initial emissions test (after going through a 125-hour engine operation break-in period). Then, the aftertreatment system is removed from the engine and bench aged to simulate aging to full useful life. The aftertreatment is then reinstalled on the engine and the final emissions test is performed. The results from both tests are used to calculate the deterioration factor values for that engine family.

Bench aging of other components such as natural gas regulators and fuel injectors are usually performed by the parts or engine manufacturer for demonstrating component

[25] Heavy-Duty Diesel Test Procedures §86.xxx-14(A)(1.4) and Heavy-Duty Otto-cycle Test Procedures §86.xxx-14(1.4)

durability. Manufacturers include a statement of compliance verifying that all parts are durable to full useful life of the engine in their certification applications.

8.1.3. Heavy-Duty Diesel-Cycle Engines

Since the implementation of the 2007 and subsequent MY heavy-duty engine emission standards, manufacturers have relied heavily on aftertreatment systems such as DOCs, DPFs, and SCR systems to produce compliant engines. The overall performance and durability of these complex aftertreatment systems over time is an area that is still under investigation. Catalyst manufacturers are continuously reformulating the SCR substrate and wash-coat materials to improve performance and durability.

There is also a great deal of concern regarding the actual durability of other emission-related components such as EGR valves, coolers, and sensors, which are critical to the proper operation of the engine and aftertreatment system. Therefore, conducting whole system aging is the preferred option.

Another area of concern is the interaction between downstream aftertreatment systems with the upstream engine hardware. During an active DPF regeneration,[26] engine operational parameters such as ignition timing, air-to-fuel ratio and EGR rate are modulated to assist the DPF regeneration process. Many manufacturers also have periodic SCR regeneration strategies to restore SCR performance by removing sulfur, hydrocarbons and ammonia crystals from the SCR surface. These upstream/downstream interactions make the process of decoupling the engine aging process from the aftertreatment aging process difficult.

Due to these complexities, U.S. EPA and CARB have relied on actual engine and aftertreatment system aging on an engine dynamometer to verify system durability and to calculate the engine family's deterioration factors.[27]

CARB staff has been cognizant of the significant time and costs associated with running a full useful life DDP of the engine and aftertreatment system on an engine dynamometer. In order to establish unified procedures for durability demonstration, CARB staff conducted a durability workshop on March 24, 2010 (CARB, 2010). Some of the key topics covered in the workshop included:

- Minimum service accumulation requirements for the DDP were declared as 50 percent of useful life, or optional 35 percent of useful life for manufacturers participating in the Truck and Engine Manufacturers Association (EMA) cooperative test program (EMA deterioration factor test program),

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[26] Active regenerations are periodic engine and aftertreatment system events/strategies that are deployed to restore the aftertreatment system performance. Emissions characteristics of the engine and aftertreatment system change during active regeneration events and are adjusted using infrequent regeneration adjustment factors.
[27] Heavy-Duty Diesel Test Procedures §86.xxx-24(c)(3) and §86.004-26(c)(2)

- Scheduled and unscheduled maintenance requirements during DDP,
- Ash cleaning protocol during DDP,
- Carryover and carry across of deterioration factor data,
- Use of engine cycles based on observed in-use data,
- Pre-approval process for alternate and accelerated aging cycles which consider many operational parameters including:
    - Fuel consumption
    - Number of active regenerations
    - Acceleration factor/load factor
    - Steady-state and transient engine speed and load behavior of the aging cycle

A typical DDP may take anywhere from several months to a year to complete. Manufacturers are also required to seek pre-approval of their proposed DDP from CARB's Executive Officer prior to performing any aging on the engine and aftertreatment system. The approval process is typically done on a case-by-case basis jointly between CARB and U.S. EPA so that a single DDP satisfies the requirements of both agencies.

8.1.4. Innovative Technology Regulation

CARB adopted the Innovative Technology Regulation (ITR) (13 CCR 2208.1) procedures to encourage technology innovation by streamlining the certification process for low NOx and hybrid heavy-duty engines. The ITR also includes provisions for both Otto-cycle and diesel-cycle heavy-duty engines.

One component of the ITR includes provisions that allow manufacturers to forgo the DDP and instead use assigned deterioration factors to satisfy the certification requirements for some products. In order to be eligible for participation, manufacturers must meet the specific requirements outlined in 13 CCR 2208.1(b).

It should be noted that the ITR is applicable to all engine manufacturers including small and large volume manufacturers.

8.2. Introduction of In-Use Emissions Data Reporting

As discussed earlier, state and federal ambient air quality standards continue to be exceeded in major regions throughout California even though there have been significant improvements to California's air quality. Requiring new engines to meet the proposed lower NOx certification standards, establishing a new low load test cycle as part of certification, strengthening the HDIUT program, and lengthening the useful life and warranty requirements would collectively make progress towards meeting California's clean air attainment goals, but there is still uncertainty regarding the extent to which strict certification standards are met in-use.

To address this issue, CARB approved amendments to the on-road HD OBD regulations in 13 CCR 1971.1(h)(5) in November 2018 that require engines and vehicles to incorporate additional data stream parameters that can be used to characterize the engine's NOx control performance in the real world. These tracking parameters are collectively referred to as "Real Emissions Assessment Logging," or REAL. These amendments were approved by the Office of Administrative Law on October 3, 2019. Under these requirements, 2024 and subsequent MY on-road heavy-duty diesel-fueled engines are required to store emissions data including NOx emissions data for the vehicle's lifetime and over the past 100 hours within the vehicle's engine control module.

While the HD OBD regulations described the mechanism to store the REAL data within the engine control module, no reporting requirements were included in the regulations. Given the wide use of telematics (Teletrac Navman, 2019) currently used by fleets, CARB staff believes that the capability to transmit the REAL data via telematics to engine manufacturers from each new 2024 and subsequent MY on-road heavy-duty diesel-fueled truck would be feasible in the 2024 MY. Additionally, the required data can also be downloaded every time the vehicle is being serviced at an authorized repair facility.

CARB staff believes that periodic reporting of all REAL parameters for each engine family could be used as a tool to verify the durability of on-road heavy-duty diesel-fueled engines in real-time. Therefore, as part of the DDP amendments, as described later in this Staff Report, CARB staff is including an option to streamline the proposed DDP process if manufacturers agree to periodically submit REAL data on their California-certified heavy-duty diesel-fueled engine families. The submittal of this information is projected to become even more critical in the post-2027 MY period, when the useful life periods of heavy-duty engines are proposed to be increased.

Chapter II, Section C.8 discusses the need for strengthening the durability requirements as part of the certification process and the need for emissions data reporting in-use. Chapter III, Section A.8 describes the Proposed Amendments for these program elements.

9. Powertrain Certification Test Procedures for Heavy-Duty Hybrid Vehicles

Conventional heavy-duty engines are certified on an engine dynamometer. Heavy-duty hybrid vehicles are typically manufactured by coupling a conventional engine with a hybrid (e.g., battery electric) system. Generally, three separate entities are involved in the manufacture of a heavy-duty hybrid vehicle: manufacturers of the conventional engine, the hybrid system, and the vehicle manufacturer. Currently, there is only one vertically-integrated heavy-duty hybrid vehicle available in California, where the engine, the hybrid system and the vehicle were designed and manufactured as an integrated unit by a single manufacturer.

In 2014, the Board adopted amendments to the California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric and Other Hybrid Vehicles in the Urban Bus and Heavy-Duty Vehicle Classes (CARB, 2014a). The interim procedures allow for the testing and certification of heavy-duty hybrid vehicles on a chassis dynamometer, which provide a way to reflect advances in technology that could not be captured in CARB's existing heavy-duty certification procedures. The 2014 amendments were intended to expand the applicability of the certification procedures to allow more vocational vehicles, such as beverage, package, and linen delivery vehicles, to certify. However, the interim procedures have not been utilized by heavy-duty hybrid vehicle manufacturers to certify hybrid vehicles, possibly because the interim procedures are more involved than traditional certification in that they require testing of both the hybrid vehicle and an equivalent conventional vehicle.

In 2018, as discussed further below, CARB adopted the California Phase 2 GHG Regulation, largely aligning with the federal Phase 2 GHG standards. Both the California and federal Phase 2 GHG Regulations contain a provision allowing a manufacturer the option to certify hybrid vehicles to the GHG emission standards using powertrain testing.

Powertrain testing provides an alternative to testing just the engine of a vehicle and enables manufacturers to quantify the impact of vehicle technologies such as hybridization that cannot be easily tested on an engine dynamometer. CARB's current Phase 2 GHG powertrain test procedure is identical to U.S. EPA's, and it can only be used for GHG certification and does not constitute a certification process for NOx or other criteria pollutant emission standards. CARB staff's proposal addresses this, and is discussed in more detail in Chapter II, Section C.9 and Chapter III, Section A.9.

10. Heavy-Duty Vehicle GHG Tractor APU Certification

In commercial long-haul trucking, heavy-duty trucks typically have cabs equipped with a sleeper berth so that the driver can rest during mandatory rest periods. These sleeper berth cabs require power to operate cab comfort equipment such as a heating and air conditioning system, refrigerator, and microwave oven. Traditionally, the needed power was obtained by idling the vehicle's engine during the duration of the rest period, resulting in significant NOx and PM emissions. To address these emissions, in 2004, CARB adopted an airborne toxic control measure (ATCM) to limit idling from in-use diesel-fueled commercial motor vehicles (13 CCR 2485) that requires the operator to manually turn off the vehicle's engine within five minutes of operating the engine at idle.

Since the adoption of the idling ATCM, other regulations and amendments, as previously discussed, have been adopted that require new heavy-duty engines to be equipped with a non-programmable engine shut-down system or to certify the engine to an optional low NOx idling emission standard. Another alternative allows in-use heavy-duty vehicles to use alternative idle reduction technologies to provide power to the vehicle's on-board equipment. Such alternative idle reduction technologies include a diesel-fueled APU that either routes its exhaust through the vehicle's DPF or through a separate DPF devoted strictly to the APU itself.

Chapter II, Section C.10 below discusses the need for amendments to the APU certification requirements and Chapter III, Section A.10 describes the Proposed Amendments in detail.

11. California Phase 2 GHG Regulation Clean-up Items

In 2011, the U.S. EPA and the National Highway Traffic Safety Administration (NHTSA) adopted the first national GHG and fuel-efficiency standards for new medium- and heavy-duty engines and vehicles, the Phase 1 Regulation (U.S. EPA, 2011). Specifically, the Phase 1 Regulation established emission standards for CO2 and other GHGs (nitrous oxide, methane, and hydrofluorocarbons). CARB harmonized with the federal Phase 1 standards beginning with the 2014 MY (CARB, 2013b; CARB, 2014b). These standards were established for three regulatory categories:

1. Class 7 and Class 8 combination tractors,

2. Class 2b[28] to 8 vocational vehicles, and

3. Class 2b and 3 large pickups and vans.

In 2016, the U.S. EPA and the NHTSA adopted the second phase of the GHG and fuel-efficiency standards for new medium- and heavy-duty engines and vehicles (U.S. EPA, 2016c). The federal Phase 2 standards build upon the federal Phase 1 standards and established more stringent CO2 emission standards for tractors, vocational vehicles, and large pickups and vans. Separate engine standards were also established for the engines used in tractors and vocational vehicles. The Phase 2 CO2 emission standards were more technology-forcing than the Phase 1 standards, requiring manufacturers to improve existing technologies or develop new technologies to meet the standards. The Phase 2 CO2 emission standards get progressively more stringent for 2021 through 2027 MY tractors, vocational vehicles, and large pickups and vans. The emission standards for the other GHGs (nitrous oxide, methane, and hydrofluorocarbons) remained at their Phase 1 numeric values. The Phase 2 Regulation also defined trailers as a newly regulated class of heavy-duty vehicles and established CO2 emission standards for certain trailers used in combination with tractors. The standards were intended to make trailers more efficient and lower the GHG emissions associated with their use. Affected trailer types include box-type trailers (dry van and refrigerated van trailers of all lengths), flatbed trailers, tank trailers, and container chassis.

In 2018, California largely aligned with the federal Phase 2 Regulation in structure, timing (except the initial trailer standards), and stringency, but with some minor California differences (CARB, 2017d; CARB, 2019b). These differences were

[28] Class 2b vehicles are 8,501 to 10,000 pounds GVWR.

necessary to facilitate enforcement, align with existing California programs, and provide additional incentives for manufacturers to bring advanced technologies to market. This also allowed manufacturers to continue to build a single fleet of vehicles and engines for the United States market.

In addition to meeting GHG emission standards, the California Phase 2 GHG Regulation also requires manufacturers of engines and vehicles (including trailers) to meet California warranty requirements (13 CCR 2035 et seq.), in which the GHG warranty periods and the GHG components under warranty are identical to the federal requirements. As an example, trailer manufacturers must warrant to the ultimate purchaser and each subsequent purchaser that, when registered in California, the trailer is designed, built, and equipped so it conforms to the standards of 13 CCR 2035 et seq. and is free from defects in materials and workmanship for a period of five years (except for tires, which have a warranty period of one year).

Additionally, these same manufacturers are subject to California-specific emissions warranty reporting requirements and in-use vehicle (including trailers) compliance and recall requirements. These include EWIR requirements (13 CCR 2144), FIR requirements (13 CCR 2145), EIR requirements (13 CCR 2146), and the in-use vehicle compliance testing and voluntary, influenced, and ordered recall requirements (13 CCR 2111 et seq.).

Chapter II, Section C.11 discusses the need for clean-up of some minor Phase 2 provisions, and Chapter III, Section A.11 describes the proposed clean-up items in detail.

12. Medium-Duty Engines

The terminology used in California and federal regulations to describe various classifications of heavy-duty vehicles and engines is similar but not identical. Table I-9 provides the California and federal weight classifications for heavy-duty vehicles and engines. The main difference is the use of the terms medium-duty vehicles and medium-duty engines. In California, medium-duty engines are used in vehicles from 8,501 to 14,000 pounds GVWR (called medium-duty vehicles) as defined in 13 CCR 1900, and are a subcategory of heavy-duty engines, which are defined, in 13 CCR 1900 as engines used in vehicles greater than 8,500 pounds GVWR. For criteria emissions, heavy-duty engines used in vehicles greater than 14,000 pounds GVWR must demonstrate compliance with emission standards on an engine dynamometer. The heavy-duty vehicles in which these certified engines are installed do not require separate vehicle certification for criteria emissions other than evaporative emissions for Otto-cycle vehicles and refueling emissions. For criteria emissions of medium-duty vehicles from 10,001 to 14,000 pounds GVWR, the California LEV III Regulation provides the option for the vehicle to be either chassis-certified according to 13 CCR 1961.2 or to be engine-certified according to 13 CCR 1956.8 (used in incomplete Otto-cycle medium-duty vehicles, or incomplete and complete diesel medium-duty vehicles).[29] If a manufacturer chooses the latter engine-certified option, the medium-duty vehicle manufacturer must obtain a vehicle Executive Order by providing the certified engine information but does not have to conduct additional emission testing to demonstrate compliance with vehicle emission standards (in the case of refueling emissions, the manufacturer's engineering analysis must sufficiently indicate that vehicle testing is not necessary).

Table I-9. California and Federal Heavy-Duty Vehicle and Engine Classifications

<table>
<tr><th>Weight Class (lbs. GVWR)</th><th colspan="3">CARB</th><th colspan="3">U.S. EPA/U.S. Department of Transportation (DOT)</th></tr>
<tr><td colspan="7">Diesel Engines</td></tr>
<tr><td>8,501-10,000</td><td rowspan="7">Heavy-duty engine/ vehicle</td><td rowspan="2">Medium-duty engine[a]/vehicle</td><td rowspan="4">Light heavy-duty engine</td><td rowspan="7">Heavy-duty engine/ vehicle</td><td rowspan="4">Light heavy-duty engine</td><td>Class 2b</td></tr>
<tr><td>10,001-14,000</td><td>Class 3</td></tr>
<tr><td>14,001-16,000</td><td rowspan="5"></td><td>Class 4</td></tr>
<tr><td>16,001-19,500</td><td>Class 5</td></tr>
<tr><td>19,501-26,000</td><td rowspan="2">Medium heavy-duty engine</td><td rowspan="2">Medium heavy-duty engine</td><td>Class 6</td></tr>
<tr><td>26,001-33,000</td><td>Class 7</td></tr>
<tr><td>>33,000</td><td>Heavy heavy-duty engine</td><td>Heavy heavy-duty engine</td><td>Class 8</td></tr>
<tr><td colspan="7">Otto-Cycle Engines</td></tr>
<tr><td>8,501-14,000</td><td rowspan="2">Heavy-duty engine/ vehicle</td><td>Medium-duty engine[a]/vehicle</td><td rowspan="2"></td><td rowspan="2">Heavy-duty engine/ vehicle</td><td rowspan="2"></td><td>Classes 2b-3</td></tr>
<tr><td>>14,000</td><td></td><td>Classes 4-8</td></tr>
<tr><td>Reference</td><td>13 CCR 1900</td><td>13 CCR 1900; certification test procedures</td><td>13 CCR 1956.8; certification test procedures</td><td>40 CFR 86.082-2</td><td>40 CFR 86.085-2 (primary intended service class)</td><td>U.S. DOT 40 CFR 1037.801</td></tr>
</table>

[a] The term, medium-duty engine, is not defined in 13 CCR 1900 but is defined in the certification test procedures incorporated by reference in 13 CCR 1956.8.

When a medium-duty engine is engine certified, all the certification, testing, and in-use requirements that pertain to heavy-duty engines apply to medium-duty engines unless a specific restriction on vehicle weight range is given, e.g., heavy-duty engines used in vehicles greater than 14,000 pounds GVWR. The emission standards for Otto-cycle medium-duty engines are contained in 13 CCR 1956.8(c), where different sets of

[29] As of the 2020 MY, medium-duty engines for use in vehicles from 8,501 to 10,000 pounds GVWR must be chassis certified (13 CCR 1961.2).

emission standards may apply depending on the engine MY. Note that only Otto-cycle engines used in incomplete medium-duty vehicles may be engine certified; complete medium-duty Otto-cycle vehicles are required to be chassis certified. The emission standards for diesel medium-duty engines are contained in 13 CCR 1956.8(h). Engine-certified diesel engines may be used in both incomplete and complete medium-duty vehicles.

Chapter II, Section C.12 discusses the need for clarifications made to the regulations for medium-duty engines and Chapter III, Section A.12 describes the specific amendments to accomplish this.

13. Fuels Topics

The emissions profile and long-term emissions performance of heavy-duty vehicles are dependent on proper integration of the engine, exhaust aftertreatment, and fuel as a combined system. CARB, U.S. EPA, and ASTM International (formerly known as American Society for Testing and Materials), and others have set standards to promote successful operation and emissions control durability. Fuel constituents such as sulfur and metals can degrade aftertreatment performance by binding to or covering active sites, thereby progressively reducing chemical reactivity of catalysts.

Diesel fuel composition has been regulated to reduce tailpipe emissions even before diesel exhaust aftertreatment was introduced. For example, sulfur in diesel fuel was reduced to low sulfur standards which greatly reduced sulfate PM (CARB, 2003). Further, California reformulated diesel fuel has reduced aromatic content to incrementally improve NOx and diesel PM emission rates. When the diesel engine tailpipe standards for 2007 and subsequent years were being considered, it was recognized that achieving these standard levels would require exhaust aftertreatment systems. It was also recognized that sulfur accumulation on catalytic surfaces is a potential impediment (although reversible using a desulfation process) to catalyst activity. But as mentioned above, diesel sulfur for on-road applications was reduced in 2006 to ultra-low sulfur diesel levels of 15 ppm sulfur (CARB, 2003). This enabled catalytic exhaust aftertreatment strategies by minimizing the number and duration of high temperature desulfation events potentially detrimental to both catalyst longevity and fuel economy. Thus, the 2006 introduction of ultra-low sulfur diesel fuel allowed for the introduction of on-road heavy-duty catalyzed diesel exhaust aftertreatment systems for PM in 2007 and for NOx in 2010.

Metals levels in fuel are also important. Alkali (sodium [Na] and potassium [K]) and alkaline earth (calcium [Ca] and magnesium [Mg]) metals can be present in biodiesel as residues from the production process or enter the diesel fuel stream from a number of other sources. The limits on metals are key quality assurance metrics for biodiesel and its blends. ASTM International (ASTM) Specification D6751 for B100 blend stock limits the concentrations of sodium + potassium (Na+K) and calcium + magnesium (Ca+Mg) to 5 ppm maximum and phosphorus to 10 ppm maximum. Alkali and alkaline earth metals are controlled because of their contribution to engine component wear, filter clogging and injector deposits. They also could have an impact on diesel emission control systems by reducing the catalyst durability.

CARB staff has evaluated sulfur and metals levels in today's fuel supply for diesel engines versus the needs of the aftertreatment that staff projects to meet the new engine standards expected as part of the Proposed Amendments.

To better understand sulfur content and variability in the California fuel supply for diesel engines, CARB collected over 400 fuel samples from California producers, importers and distribution terminals during 2017 to 2019 calendar years. These samples included diesel and some biodiesel and renewable diesel blends with maximum sulfur content observed of 13 ppm and an average sulfur content of 4 ppm with a standard deviation of 3 ppm, without any applied corrections for volumes represented or market share of producers (Corey, 2020). Based on the system performance in demonstrations funded by CARB and data on current fuel sulfur levels, CARB staff have concluded that sulfur levels in current ultra-low sulfur diesel are adequate, and changes to the sulfur standards are not needed and are not included in the Proposed Amendments in this Staff Report.

For metals, an OEM has raised concern regarding risks from lifetime exposures to trace metals, particularly Na, K, Mg, and Ca in biodiesel. The four (4) California-sourced fuel samples in the OEM's data set contained both biodiesel as well as levels of metals that if attributed solely to a B100 blend stock, would be sufficient to put such a blend stock at or beyond the ASTM specification limits (Recker, 2019).

Staff believes the metals levels the OEM has reported may have large associated analytical uncertainties inconsistent with the OEM's own demonstrated analytical capabilities (Trick et al., 2016) and the fuel sampling protocol may not be representative of the general fuel pool. In response to the OEM concerns, CARB staff arranged for the collection and analysis of 437 diesel and biodiesel blend samples collected at retail pumps across California in 2019. The findings of the 2019 California sampling campaign are summarized in a February 2020 transmittal from CARB to U.S. EPA (Corey, 2020). As discussed in detail in that transmittal, the phosphorus and metal contents of biodiesel were significantly lower than current ASTM limits, and overall, staff does not expect the impact of biodiesel metals and phosphorus on the full useful life durability of diesel exhaust aftertreatment systems to be in excess of expectations based on current fuel specifications. CARB staff also arranged for analysis of 27 U.S. EPA collected B100 samples collected from biodiesel production facilities nationally and again did not identify metals contamination problems to corroborate the OEM claims (CARB, 2020g). This finding is generally consistent with trends seen in national biodiesel fuel surveys conducted by the National Renewable Energy Laboratory (NREL) (McCormick et al., 2005; Alleman et al., 2007; Alleman et al., 2008; Barnitt et al., 2008; Alleman et al., 2010; Alleman et al., 2013; Alleman et al., 2019; Alleman 2020a; Alleman 2020b; Lopes et al., 2013) as well as the performance seen in survey history from the European biodiesel market (AGQM, 2020; EBB, 2020).

A number of studies have examined current 0.2 g/bhp-hr NOx engine performance and fuel metal exposure, including studies run to full useful life on fuels at the metals limit. As noted above, many fuel surveys indicate typical metal concentrations are much less than the recommended limit. Deutz points out that they do not find metals accumulating in their SCRs at the full rate one would calculate from the maximum allowable biodiesel limit concentrations and also indicate that biodiesel derived metal exposures could be comparable or less than engine lubricant derived metal sources (Wilharm & Stein, 2011).

Studies at NREL have examined emissions control performance and other parameters after a full useful life worth of metal exposure equivalent to continuous fueling with biodiesel at the maximum allowable metals limit. These studies have included light-duty truck (Williams et al., 2013; Williams et al., 2014) and heavy heavy-duty diesel engine applications (Williams et al., 2011; Lance et al., 2016).

Although the aforementioned data and studies are reassuring, because advanced aftertreatment has not been tested on biodiesel out to the longer useful lives recommended, and because current biodiesel blend stock recommendations are less protective than current DEF standards, CARB staff plans to continue to seek information on lifetime exposure/emissions impact relationships, prevailing fuel metals levels and to evaluate the potential need for future changes to biodiesel standards.

II. THE PROBLEM THAT THE PROPOSAL IS INTENDED TO ADDRESS

The goal of this proposal is to achieve the maximum technologically feasible and cost-effective reductions in real-world NOx emissions from heavy-duty engines and vehicles. This is critical for California to attain the National Ambient Air Quality Standards (NAAQS) for ozone in 2031 in the South Coast and San Joaquin Valley air basins, as well as fine particulate matter (PM2.5) standards in the next decade.

This proposal includes amendments to the exhaust emission standards and test procedures for 2024 and subsequent MY engines and vehicles, OBD system requirements, the HDIUT program, emissions warranty period and useful life requirements, EWIR requirements and corrective action procedures, the emissions ABT program, durability demonstration requirements, and new in-use emissions data reporting requirements.

The Proposed Amendments also include associated revisions to the heavy-duty hybrid powertrain test procedures, heavy-duty vehicle GHG tractor APU certification procedures, and California Phase 2 GHG Regulations to provide clarity to manufacturers and harmonize certain requirements with the federal Phase 2 heavy-duty GHG Regulations. As discussed further below, the South Coast needs significant reductions in NOx emissions by 2024, and thus several elements of the proposed rulemaking are aimed at incentivizing early emission reductions. For example, the Proposed Amendments include a mechanism to provide incentives for manufacturers to earlier comply with future emission standards, and credits for manufacturers that produce zero-emission heavy-duty vehicles as early as MY 2022.

Section A below describes in further detail the significance of emissions from heavy-duty engines and the need for emission reductions from this very important source. Section B describes CARB's authority to adopt the Proposed Amendments. Section C describes the need for the Proposed Amendments, with subsections providing further justification of the need for each of the main regulatory elements, such as lower NOx standards, amendments to the HDIUT program, etc.

A. Need for Emission Reductions

1. State Implementation Plan Requirements

Exposure to ozone and PM has serious health effects and is associated with increased risk of premature deaths, emergency room visits, and hospital stays. A range of respiratory effects are linked to these pollutants such as asthma, respiratory inflammation, and decreased lung function and growth. In particular, PM2.5 poses the greatest health risk as the fine particles can get deep into the lungs and possibly into the bloodstream, causing irregular heartbeat, heart attacks, as well as increased risk of lung cancer.

Although California has made significant strides towards improved air quality over the past five decades, over 12 million residents still breathe unhealthy air. California faces particularly extreme ozone attainment challenges in the South Coast and San Joaquin air basins, where the unique topography and weather pattern of these regions result in the accumulation of emissions and sustained high pollution levels. Climate change is further complicating the efforts to reach attainment, as rising temperatures lead to air stagnation, increased ozone pollution due to faster reaction rates, and an increased frequency of wildfires that cause the release of gaseous and particulate pollutants.

Further reductions of NOx and PM2.5 emissions are critical for attaining federal ozone and PM2.5 standards. This is described in detail in the 2016 State Strategy for the State Implementation Plan (State Strategy), the State of California's official and legally binding plan to meet the NAAQS requirements over the next fifteen years. In addition to working towards attaining the most recent federal ozone standard of 75 parts per billion (ppb) by 2031, the South Coast and San Joaquin Valley must also continue to make progress towards attaining earlier standards they have not yet achieved, including the 8-hour ozone standard of 80 ppb (with an attainment date of 2023). In order for the South Coast to meet the federal ozone standards, overall NOx emissions need to be reduced by 70 percent from today's levels by 2023, and approximately 80 percent by 2031. In 2037, a lower NAAQS ozone standard will take effect at 70 ppb, driving the need for even greater reductions in NOx emissions from all sources including heavy-duty engines.

The current 2010 NOx emission standard for heavy-duty engines established a limit of 0.2 g/bhp-hr, which represents a 90 percent reduction from the previous standard of 2.0 g/bhp-hr. Nevertheless, it is projected that even in 2023 when almost the entire on-road fleet of heavy-duty vehicles operating in California are certified to the 2010 standard, the 2031 and the more stringent 2037 NAAQS requirements for ambient ozone will not be attained in California without further reductions.

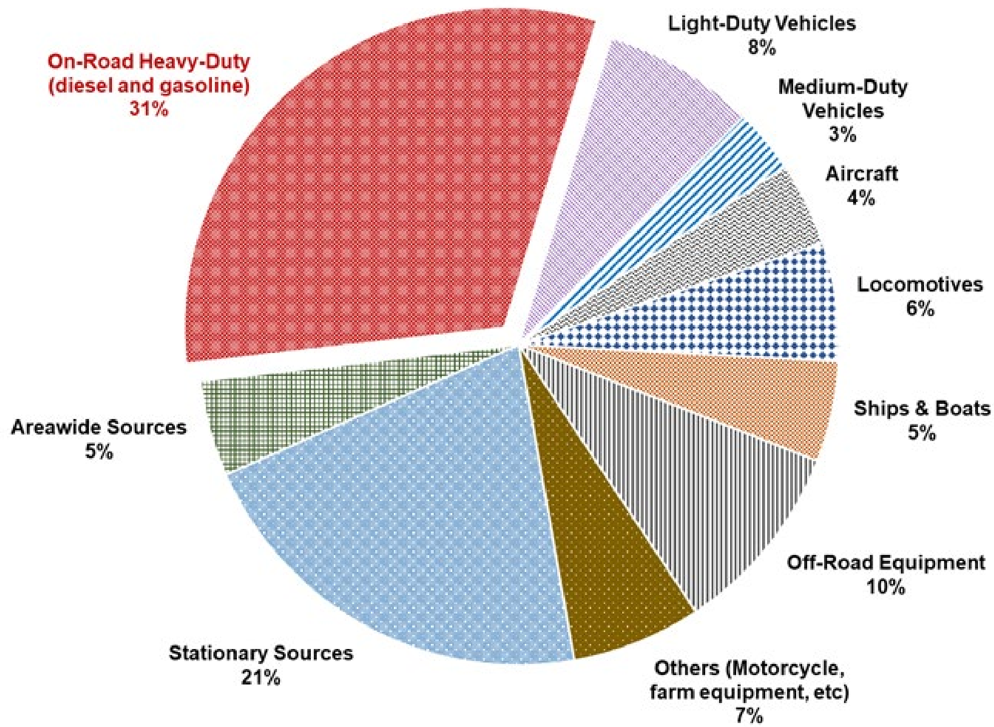
The Proposed Amendments would implement two on-road heavy-duty measures in the 2016 State Strategy for the State Implementation Plan (SIP) (CARB, 2017b) – "Low-NOx Engine Standard" and "Lower In-Use Emission Performance Level." The "Low-NOx Engine Standard" measure would reduce tailpipe NOx emissions from new heavy-duty engines by 90 percent below current NOx levels. The "Lower In-Use Emission Performance Level" would revise the HDIUT program, lengthen the warranty and useful period requirements, and revise the DDP procedures and EWIR requirements. These actions would help ensure heavy-duty vehicles remain at their cleanest possible level in use and decrease engine and aftertreatment system deterioration.

The proposal to establish a new NOx standard for on-road heavy-duty engines that is effectively 90 percent lower than the current standard constitutes the largest measure in the entire State Strategy, responsible for 52 tons per day (tpd) of NOx emission reductions, nearly half of the entire NOx emission reduction commitment in the entire plan (52 out of 111 tpd NOx in 2031). Additional actions in the proposed Mobile Source Strategy involve requirements to ensure in-use performance and the durability of emissions control equipment, as well as include incentives to accelerate the deployment of near-zero and zero-emission technologies.

2. Heavy-Duty Engine and Vehicle Emissions Inventory

On-road heavy-duty vehicles comprise the largest NOx emission source category in the state, contributing to 31 percent of all statewide NOx emissions, as shown in Figure II-1 below, as well as 26 percent of total statewide diesel PM emissions.

Figure II-1. NOx Emission Source Categories in California[30] - 2018



Most of the NOx emissions from heavy-duty engines come from diesel-cycle engines, especially in the higher weight classes. Gasoline and natural gas Otto-cycle spark-ignited (SI) engines are also a source of NOx emissions but to a much lesser extent, comprising only two to three percent of the total heavy-duty NOx emissions.

3. Regional Haze and Visibility Protection

In addition to helping California meet its SIP commitments and reduce the health impacts from unhealthy air, the emission benefits from the Proposed Amendments would help reduce regional haze and help improve visibility. The Clean Air Act Amendments of 1977 included a goal for "prevention of any future, and the remedying of existing, impairment of visibility"[31] in Class I Areas in the United States and its territories. Class I Areas are specially designated federal lands managed by the

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[30] CEPAM: 2016 SIP – Standard Emission Tool, BY2012, Oxides of Nitrogen, Annual Average, Year: 2018, grown and controlled.
[31] Section 169A of the Clean Air Act.

U.S. Department of the Interior or the U.S. Forest Service (in the U.S. Department of Agriculture). There are 29 of these treasured national parks, forests, monuments, and seashores in California, more than in any other state or territory. A series of federal rules have been developed since 1977, in furtherance of reducing emissions that cause regional haze that impairs visibility in these Class I Areas. The regulatory focus is on reducing emissions from human-caused (anthropogenic) sources of visibility impairment. Every state must identify and implement pollution control strategies to make continuous progress towards a long-term goal of visibility comparable to "natural conditions" by 2064. Further discussion of regional haze and visibility requirements, and how the Proposed Amendments would help improve visibility and reduce haze is included in Appendix H.

B. Regulatory Authority

CARB has been granted both broad and extensive authority under the Health and Safety Code (HSC) to adopt the Proposed Amendments. The California Legislature has placed the responsibility of controlling vehicular air pollution on CARB, and has designated CARB as the state agency that is "charged with coordinating efforts to attain and maintain ambient air quality standards, to conduct research into the causes of and solution to air pollution, and to systematically attack the serious problems caused by motor vehicles, which is the major source of air pollution in many areas of the State" (HSC 39002 and 39003). CARB is authorized to adopt standards, rules and regulations needed to properly execute the powers and duties granted to and imposed on CARB by law (HSC 39600 and 39601). HSC 43013 and 43018 broadly authorize and require CARB to achieve the maximum feasible and cost-effective emission reductions from motor vehicles, including the adoption and implementation of vehicle emission standards and in-use performance standards (HSC 43013(a)) and by improving emission system durability and performance (HSC 43018(c)(2)), resulting in an expeditious reduction of NOx emissions from diesel vehicles, "which significantly contribute to air pollution problems" (HSC 43013(h)).

CARB is further authorized to adopt and implement emission standards for new motor vehicles and new motor vehicle engines that are necessary and technologically feasible (HSC §43101), to adopt test procedures and any other procedures necessary to determine whether vehicles and engines are in compliance with the emissions standards established under Part 5 of the Health and Safety Code (HSC §43104), and to not certify a new motor vehicle or motor vehicle engine unless the vehicle or engine meets the emission standards adopted by CARB pursuant to Part 5 of the Health and Safety Code under test procedures adopted pursuant to section 43104. (HSC § 43102).

The California Global Warming Solutions Act of 2006, Assembly Bill 32, Chap. 488, Stats. 2006 (Nunez), requires CARB to enact regulations to achieve the level of statewide GHG emissions in 1990 by 2020, authorizes and directs CARB to monitor and regulate sources of GHG emissions, (HSC 38510), and specifically directs CARB to "adopt rules and regulations … to achieve the maximum technologically feasible and cost-effective greenhouse gas emission reductions from sources … subject to the criteria and schedules set forth in this part." HSC 38560. In 2016, California's

Legislature adopted, and California's Governor Brown signed Senate Bill 32, Chap. 249, Stats. 2016 (Pavley), which requires CARB to ensure that California's statewide emissions of GHG emissions are reduced to at least 40 percent below the level of statewide greenhouse gas emissions in 1990, no later than December 31, 2030. HSC 38566. Key to meeting the Assembly Bill 32 and Senate Bill 32 GHG emission reduction goals is the reduction of GHG emissions from medium- and heavy-duty trucks.

C. Need for Proposed Amendments

Section A above documented the need in California for significant NOx emission reductions from heavy-duty engines. Each of the subsections below provides further justification of the need for each of the main regulatory elements.

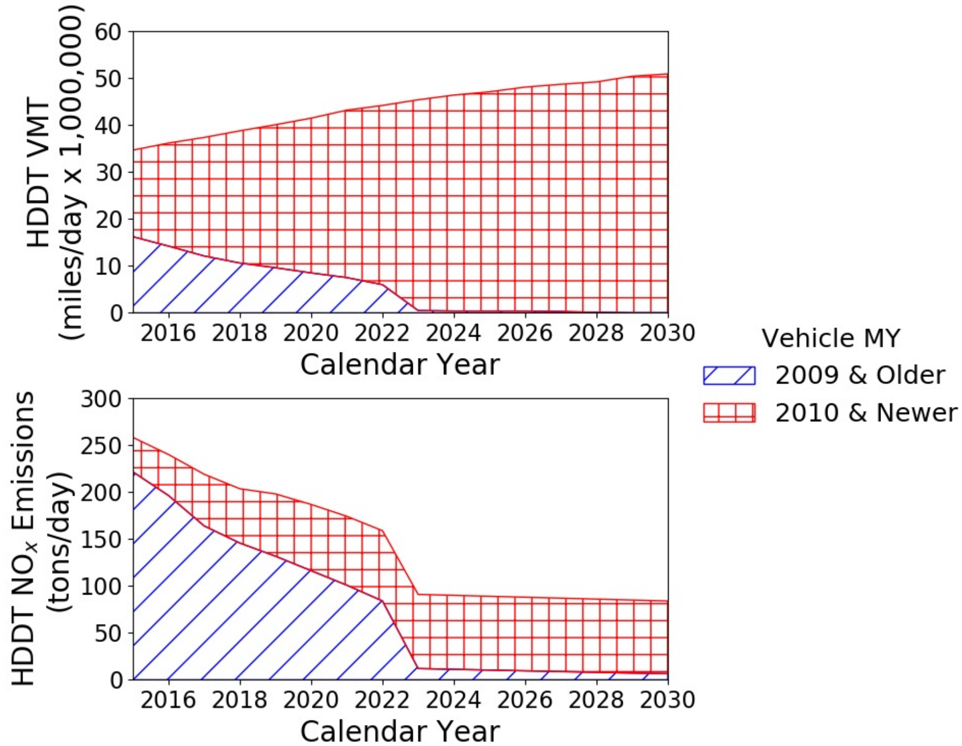
1. Need for New Low NOx Standards

As described above in Section A, on-road heavy-duty vehicles are significant contributors to criteria pollutant and GHG emissions, with about 31 percent of all statewide NOx emissions coming from heavy-duty vehicles. Reducing the emissions from heavy-duty vehicles is a key part in meeting SIP requirements and attaining federal ambient air quality standards. Without the proposed low NOx standards, the 2031 and 2037 NAAQS requirements for ambient ozone will not be attained. The proposed low NOx emission standards are discussed in further detail in Chapter III, Section A.1.

1.1. Shortcomings of Current Test Cycles

Examining the projected emissions inventory in California in Figure II-2 below, it can be observed that there is a rapid transition to 2010 and newer MY trucks and the associated VMT and NOx emissions due to turnover driven by California's existing Truck and Bus Regulation. Beginning in 2023, the NOx emission inventory is projected to be dominated by trucks with today's 2010 technology engine. Beginning in 2023, because emissions from older trucks will have been greatly reduced, it therefore becomes increasingly important to reduce emissions from the newest trucks.

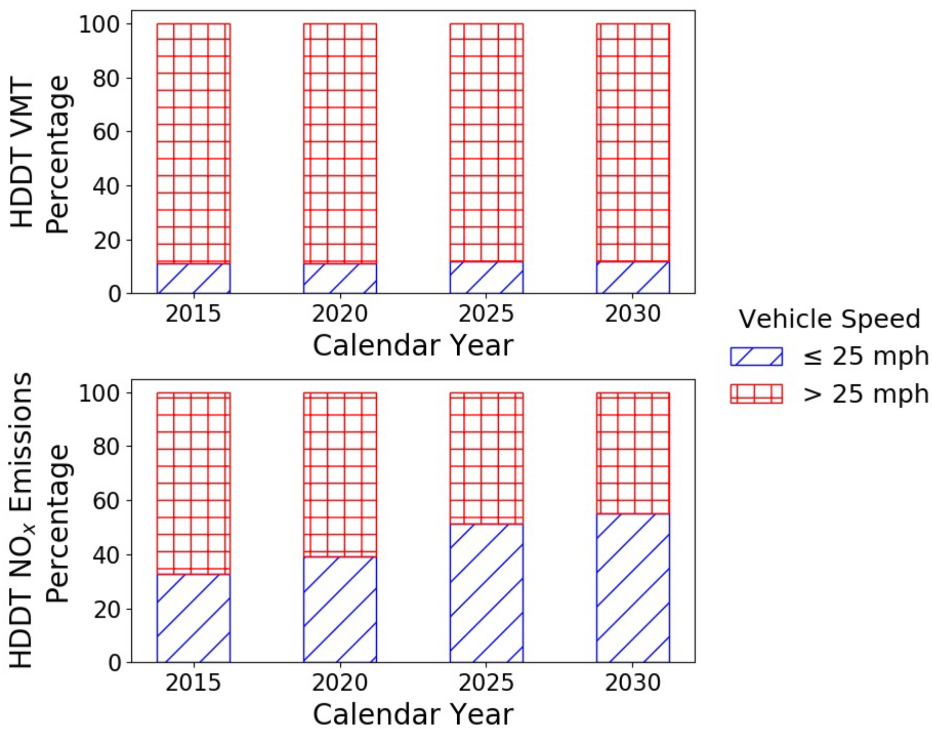
Figure II-2. Time Trend in VMT and NOx Emissions from Pre-2010 and 2010+ MY Heavy-Duty Diesel Trucks



All recent MY engines complying with the current 2010 NOx standard of 0.2 g/bhp-hr on the FTP and RMC-SET are equipped with SCR NOx aftertreatment systems. A notable characteristic of the SCR system is that it has a limited effective operational temperature range, below which its NOx conversion efficiency drops precipitously.

Current heavy-duty engine certification cycles, namely the FTP and RMC-SET, inadequately assess the emissions performance of SCR-equipped engines, as they do not account for sustained low load operations, when exhaust temperatures would fall below the minimum effective operational temperature of SCR systems. As higher emitting pre-2010 engines become a smaller and smaller portion of the California fleet, the emissions at low load contribute a greater and greater share of the emissions. Unless addressed, NOx emissions coming from low speed operations are projected to increase at a disproportionate rate compared to the VMT coming from such operations (Yoon et al., 2017), as can be observed in Figure II-3 below.

Figure II-3. Percent Contribution of Vehicle Speeds Below and Above 25 MPH to VMT and NOx Emissions



In addition, the FTP is not representative of current heavy-duty vehicle operation for a number of reasons. First, because it was developed from vehicle activity data in the 1970s when VMT was much lower, it likely does not represent today's traffic conditions characterized by more congestion and more frequent low-load operation. A 2019 study targeting gathered activity data from dozens of diesel Class 6 to 8 vehicles operating in California found all vehicles, even long-haul trucks, spending a significant portion of their operation idling (Pondicherry et al., 2019). Idling accounted for over 30 percent of operation for nearly all trucks instrumented, with some trucks with power take-off units idling over 60 percent of their operating hours. The study concluded that California's congested roads were evident, with idling and stop-and-go operation dominating the data set and most trucks spending over half their operating hours in such operation. Second, when the FTP was developed, the vast majority of diesel engines had less horsepower, were naturally aspirated, or if turbocharged, had much lower boost pressure than current engines. Fuel and air management were also done quite differently on the older mechanical engines. Due to these differences in today's engines, the FTP engine loads are not fully representative of the low-load operation experienced by modern engines.

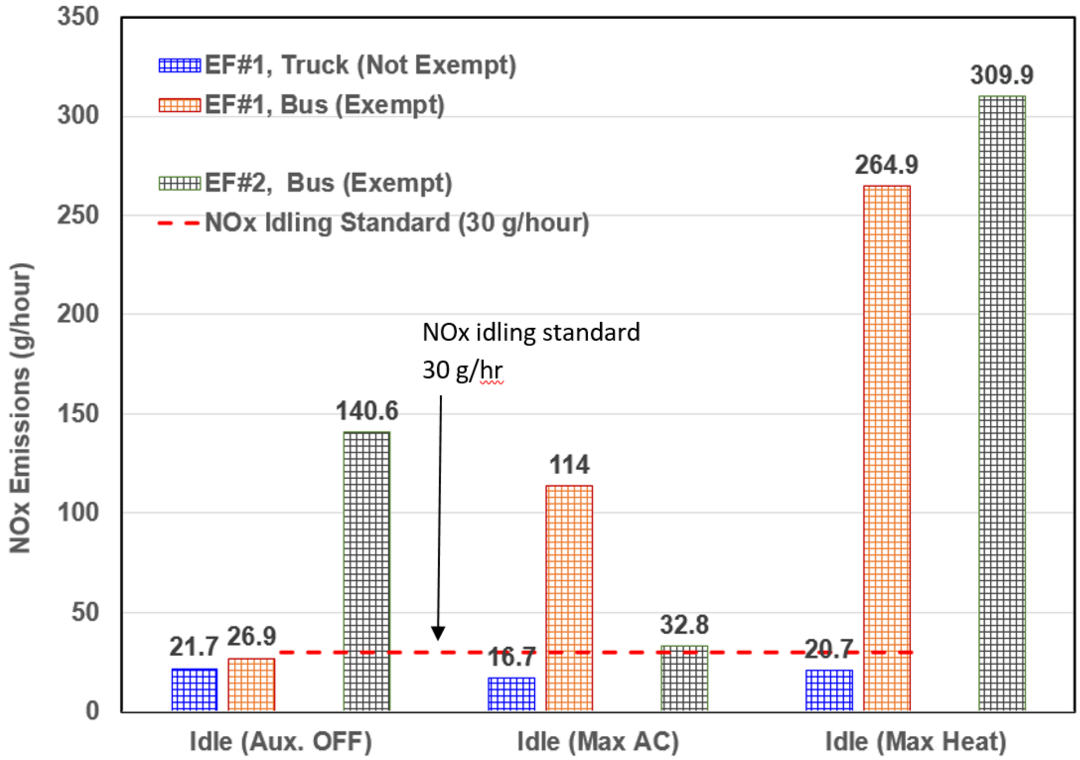
Thus, there is a need to ensure that manufacturers design and calibrate their engines and aftertreatment systems to control emissions at low load, as well as a need for a certification test cycle representative of today's low-load heavy-duty truck operation. There is a need for a cycle with operation at low average engine power for long enough duration to demonstrate that engine and aftertreatment hardware and controls needed to deal with low load operation challenges are present and functional. As described in further detail later in this Staff Report, in addition to certifying on the FTP, CARB staff is proposing that future MY engines meet an emission standard over an additional new supplemental cycle, namely the low load cycle, or LLC.

1.2. Need for Changes to Clean Idle Standards

As mentioned above in Chapter I, Section B.1.4, CARB's idling regulations currently exempt buses, school buses, recreational vehicles, medium-duty vehicles, armored vehicles, workover rigs, emergency vehicles, and military tactical vehicles. When the idling regulations were adopted in 2005, CARB staff expected that manufacturers would generally meet them through use of AESS, and exempted these vehicles because AESS were not appropriate for them. However, in practice, manufacturers have instead met the idling regulations by certifying to clean idle standards of less than 30 g/hr NOx by using EGR and air-fuel ratio controls. EGR and air-fuel ratio controls are feasible for buses, recreational vehicles, medium-duty vehicles, armored vehicles, and workover rigs, just like for any heavy-duty vehicle, and so the rationale for exempting these vehicles that existed in 2005 no longer exists.

CARB staff believes that removing the idling regulation exemption for these vehicles would result in meaningful emission reductions based on recent testing of vehicles via CARB's Truck and Bus Surveillance Program. Figure II-4 shows CARB's Truck and Bus Surveillance Program testing of 3 engines, two of which are tour bus engines that are exempt from the clean idle requirement and one is a truck engine subject to the clean idle requirement (Corey, 2020). The truck engine EF#1 is the same engine family as the bus engine EF#2. Figure II-4 shows that NOx idling emission rates from the exempted bus engines are substantially higher than emission rates from the clean idle certified truck engine and in fact nearly 10 times higher than the 30 g/hr NOx clean idle standard, which highlights the emission reductions that could be achieved via removing these exemptions.

Figure II-4. Exemption Effect on NOx Idling Emissions



1.3. Need for Amendments to Optional Low NOx Standards

Because the proposed mandatory NOx standards for 2024 and subsequent MYs would be as low as or lower than the current optional low NOx standards, there is a need to amend the existing optional low NOx standards. In order to continue to incentivize manufacturers to develop and certify engines that are even cleaner than the engines required by the Proposed Amendments in the future, the current optional low NOx standards should be made more stringent than the proposed mandatory standards.

1.4. Need for Amendments to OBD Requirements

As mentioned above in Chapter I, Section B.1.5, the emission "thresholds" for faults that must be detected by OBD systems are typically either a multiple of the exhaust emission standard (e.g., 2.0 times the applicable standard), or an additive value above the standards (e.g., 0.2 g/bhp-hr above the applicable standards). For the most important emission control systems such as the PM filter and SCR system, the OBD regulation specifies malfunction criteria and emission thresholds for detecting a malfunction and illuminating the MIL based on emission increases (defined by additive and multiplicative factors) relative to the emission standard. For example, on 2016 and subsequent MY diesel engines, the OBD system must be designed to detect an SCR catalyst malfunction when the catalyst has deteriorated to the point that the engine's emissions are exceeding the NOx standard by more than 0.2 g/bhp-hr (e.g., cause NOx emissions to exceed 0.4 g/bhp-hr if the exhaust emission standard is 0.20 g/bhp-hr).

Using EGR as another example, the OBD system must be designed to detect an EGR system malfunction when the EGR flow rate has decreased to the point that NMHC, CO, or NOx emissions are exceeding 2.0 times any of the applicable standards, or PM emissions are exceeding the applicable PM standard by more than 0.02 g/bhp-hr.

Under the Proposed Amendments, NOx emission standards would ultimately be reduced to a tenth of today's 0.2 g/bhp-hr standard and PM standards to one half of today's standard. Because the OBD emission thresholds are often defined as an additive or multiplicative function of the standard, without amendments to the OBD threshold requirements, the OBD thresholds would similarly be reduced along with the proposed standards (e.g., the NOx threshold would become 2.0 times the new lower emission standard). While detection of faults at these proportionally lower levels will likely be required in the future as it will be necessary to ensure the maximum benefits of the proposed standards are maintained in-use, the engine manufacturers have expressed concern about not knowing with certainty what impact the lower standards will have on their OBD monitoring capability. As such, the engine manufacturers have requested interim relief until they have more certainty on what emission thresholds are achievable, and CARB staff concurs that the requested relief is reasonable and needed.

2. Need for New Lower PM Standards

Diesel exhaust PM is composed of carbon particles and numerous organic compounds, including over 40 known cancer-causing organic substances. The majority of diesel PM is small enough to be inhaled into the lungs and deposits in the deepest regions of the lungs where the lung is most susceptible to injury.

In 1998, CARB identified diesel PM as a toxic air contaminant based on published evidence of a relationship between diesel exhaust exposure and lung cancer and other adverse health effects. In 2012, additional studies on the cancer-causing potential of diesel exhaust published since CARB's determination led the International Agency for Research on Cancer (IARC, a division of the World Health Organization) to list diesel engine exhaust as "carcinogenic to humans." It is estimated that about 70 percent of total known cancer risk related to air toxics in California is attributable to diesel PM (CARB, 2020f).

Therefore, it is important to reduce the public's exposure to diesel PM emissions, and reducing diesel PM has been one of CARB's top priorities for the last several decades. Part of CARB's strategy for reducing diesel PM has been to impose strict PM emission standards for heavy-duty engines that require manufacturers to install DPFs. The current PM standard for heavy-duty engines is 0.01 g/bhp-hr on the FTP and RMC-SET test cycles. As mentioned above in Chapter I, Section B.1, on-road heavy-duty engine manufacturers began installing DPFs with new engines starting in the 2007 MY.

Certification data indicate most engines have PM certification levels well below the current 0.01 g/bhp-hr PM standard and certify close to 0.001 g/bhp-hr. However, over the last few MYs some manufacturers have elected to certify some of their engine families to higher PM emission levels. CARB staff discovered that the increase in some PM emission certification levels is due to some engine manufacturers choosing to use less efficient (more porous) DPFs to reduce engine backpressure, resulting in higher PM emission rates, although still compliant with the current PM standard. Thus, to prevent manufacturers using less efficient, more porous DPFs and maintain current robust PM emission control performance near 0.001 g/bhp-hr levels, there is a need for a lower PM standard.

3. Need for Heavy-Duty In-Use Test Procedures Amendments

As discussed above in Chapter I, Section B.3, there are severe shortcomings associated with today's NTE-based HDIUT program. Many manufacturers currently comply without submitting any valid data, and, on average, the NTE-based protocol captures less than six percent of actual real-world operation. In addition, the current regulatory language sometimes leads to misinterpretation of in-use compliance testing results. This means the current HDIUT program is in need of a major overhaul to ensure it is controlling emissions during real-world operation. Subsection 3.1 below describes why a full revamping of the HDIUT program is needed. Subsection 3.2 describes the need for obtaining OBD and REAL data during HDIUT.

3.1. Need for Revamping HDIUT Program and Replacing NTE Methodology

An assessment of the current HDIUT program using the NTE methodology shows that the vast majority of operating conditions are not evaluated and go unchecked for in-use compliance. Of the 207 tests analyzed, 24 percent of manufacturer-submitted in-use tests for the HDIUT program had zero valid NTE events and passed the test by default, as shown in Figure II-5. In the analysis, valid NTE events represented only 5 percent of the total data (Bartolome et al., 2018). An extensively modified NTE (MOD NTE) method was explored which included more than intake manifold and exhaust temperature revisions. A summary of these changes to the exclusions in the MOD NTE are summarized in Table II-1. In the analysis, it was found that even with extreme modifications, the NTE would only be able to increase the percentage of data in terms of time and mass of NOx emissions to approximately 30 percent, as shown in Figure II-6. An analysis of the HDIUT data set with Europe's Euro VI (d) MAW procedure was able to yield approximately 60 percent of valid data compared to the entire test in terms of time and total mass NOx emissions. In-use emissions from European heavy-duty engines are better controlled over the span of operating speeds when compared to the United States products (Posada et al., 2019). The improvement in emissions control performance in the low and medium speed operations is likely due to the differences in the in-use requirements in Europe that require control over a broader range of operations when compared to the current NTE-based HDIUT program in the United States. Based on the comparison of the NTE, MOD NTE, and Euro VI MAW, CARB staff concluded that modifying the NTE would be insufficient. Instead, a MAW type approach would be superior for developing a future in-use method capable of capturing most of the test time and most of the NOx emissions during real-world testing.

Figure II-5. Percent of Valid Test Time of the 207 SCR Equipped 2010 to 2014 MY Engines from the Manufacturer-Submitted HDIUT Program

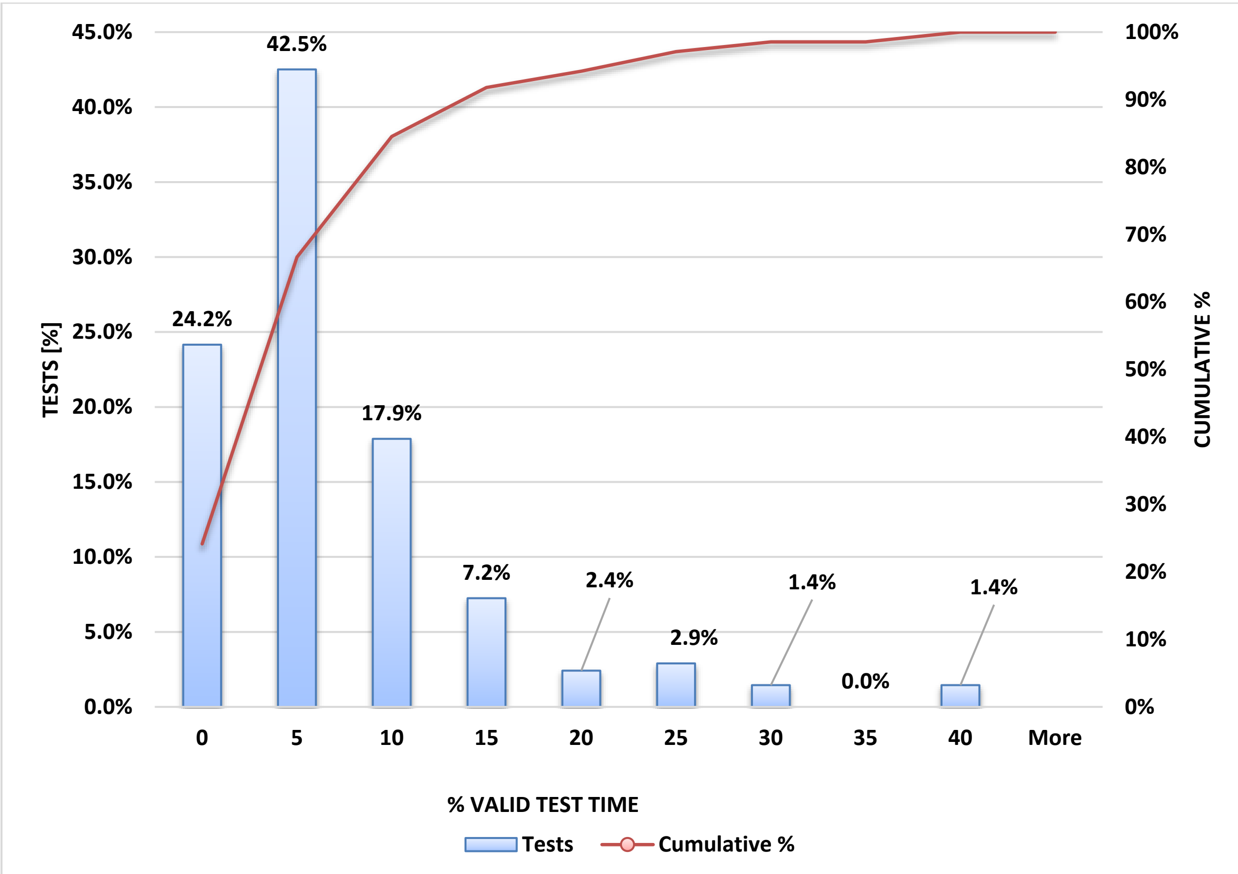
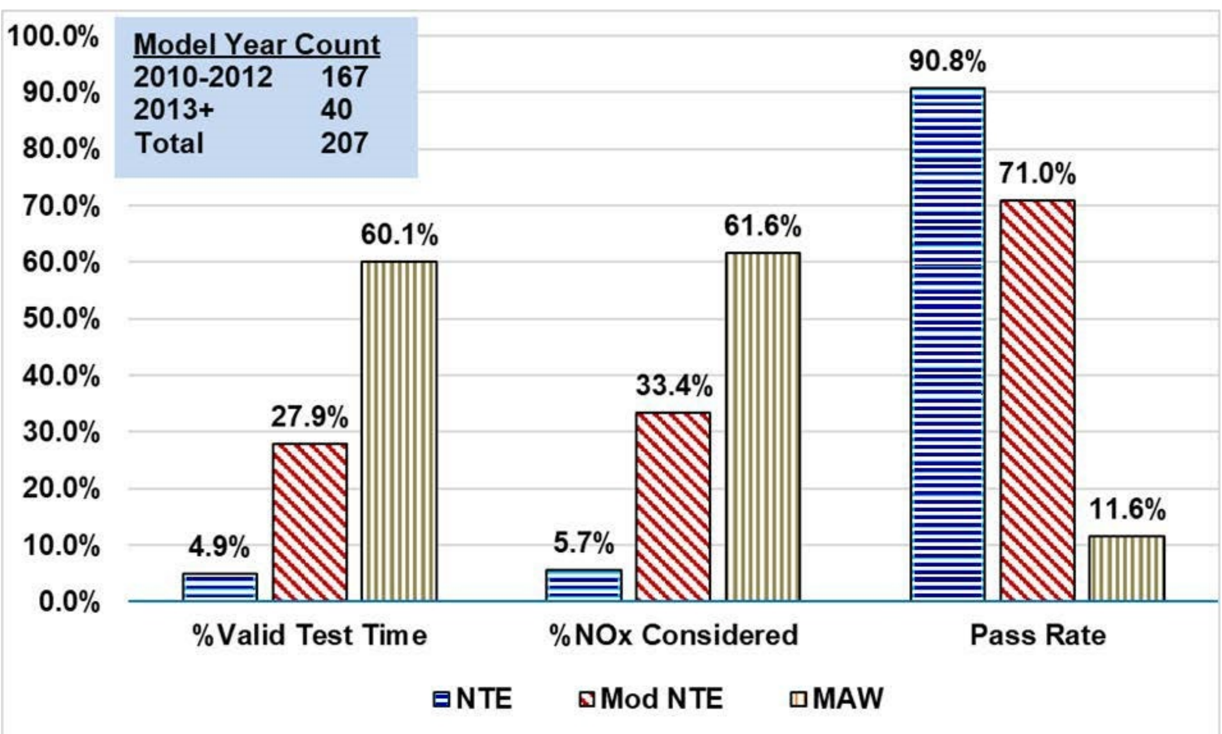


Table II-1. Summary of Data Exclusion for the NTE and MOD NTE Methods

NTE Data Exclusions	MOD NTE Data Exclusions
rpm < $n_{15\%}$	Same rpm < $n_{15\%}$
Torque < 30% Max Torque	Reduced: Torque < 10% Max Torque
Power < 30% Max Power	Reduced: Power < 10% Max Power
$T_{intake\ manifold}[oF] > \frac{IMP[bar] + 7.75}{0.0875}$	Removed
$T_{engine\ coolant}[oF] > \frac{IMP[bar] + 9.889}{.0778}$	Removed
$T_{exhaust} < 250$ [ºC]	Reduced: $T_{exhaust} < 200$ [ºC]
$h_{altitude} > 5{,}500\ ft$	Removed
$T_{amb} > -0.00254\ h_{altitude} + 100$	Removed
Consecutive time < 30 seconds	Reduced: Consecutive time < 10 seconds

Figure II-6. Performance Comparison of the NTE, MOD NTE, and the MAW Based on Euro VI on the HDIUT Data Set



3.2. Need for OBD/REAL Data During HDIUT

Since the initial implementation of NTE testing, emission control systems have advanced to using more electronic controls and measured parameters. Examination of OBD emission control system data stream parameters and REAL data are crucial to verify the condition of the test vehicle before, after, and during heavy-duty in-use testing, and to verify all sensors and tracking information are properly responding and in agreement with data collected through the PEMS equipment. However, there are currently no requirements for engine manufacturers to submit such data during HDIUT.

4. Need for Lengthened Warranty Periods

As mentioned previously, longer warranty periods help both to encourage manufacturers to produce more durable emission control systems and components that improve the emissions performance of their engines and vehicles, and give vehicle owners greater incentive to fix non-performance-related malfunctions that otherwise might not get repaired if the owner had to bear the cost for the repair. Both of these outcomes result in emission control systems that properly operate for longer periods of their usage.

Subsection 4.1 below describes current problems with heavy-duty engine and vehicle emission warranties. Subsection 4.2 details why regulatory amendments requiring longer warranties are needed. Finally, Subsection 4.3 explains why warranty-related amendments concerning optionally certified hybrid powertrains are needed.

4.1. Current Problems with Heavy-Duty Engine and Vehicle Emission Warranties

Evidence generated by CARB testing of in-use heavy-duty vehicles (CARB, 2017a) and recent emissions warranty claim data for heavy-duty vehicles (CARB, 2018f) together point to current shortcomings with heavy-duty engine and vehicle emission warranty requirements. CARB’s test programs have identified numerous heavy-duty vehicles with mileages within their applicable regulatory useful life periods, but beyond their emissions warranty periods, that had NOx emission levels significantly above the applicable certification standards. Also, CARB staff’s review of manufacturer emissions warranty claims showed high warranty claim rates for major heavy-duty diesel engine components. Statements at public meetings with fleet owners, retrofit installers, and equipment dealers confirmed these findings, and suggested that some fleets are experiencing significant vehicle downtime due to parts failures. A survey conducted in 2017 of California truck owners/operators by the Sacramento Institute for Social Research (ISR) found over half of respondents reported having experienced downtime because of repairs for their California heavy-duty vehicles manufactured between 2007 and 2017 (ISR, 2017). Further, over 15 percent of these respondents experienced downtime events lasting over a month per vehicle (on average).

4.2. Why Longer Emissions Warranties are Needed

Longer emissions warranty periods for heavy-duty vehicles and engines are needed for three main reasons: (1) to better represent their longer modern service lives and ensure that the emission control systems remain operational throughout a greater portion of a vehicle's service life, (2) to reduce incidences of tampering and mal-maintenance, and (3) to encourage manufacturers to make parts more durable. As an added benefit, the lengthened emissions warranty periods would protect heavy-duty vehicle owners from having to pay to replace emission-related components that are supposed to remain durable throughout the useful life of the engine.

Truck dealers and owners support the need for longer emissions warranty requirements. The American Truck Dealers Division of the National Automobile Dealers Association has stated recently they believe that longer emissions warranty periods should be required because they offer potential benefits for commercial motor vehicle purchasers (NADA, 2020). Similarly, the Owner-Operator Independent Drivers Association (OOIDA), the largest trade association representing small-business truckers and truck drivers, recently told U.S. EPA they support longer emissions warranty requirements. OOIDA noted that the current federal warranty lengths for heavy-duty engines (5 years, 100,000 miles) have not been updated for 40 years and are "insufficient for real-world operations" because OOIDA members regularly drive more than 100,000 miles in less than a year (OOIDA, 2020).

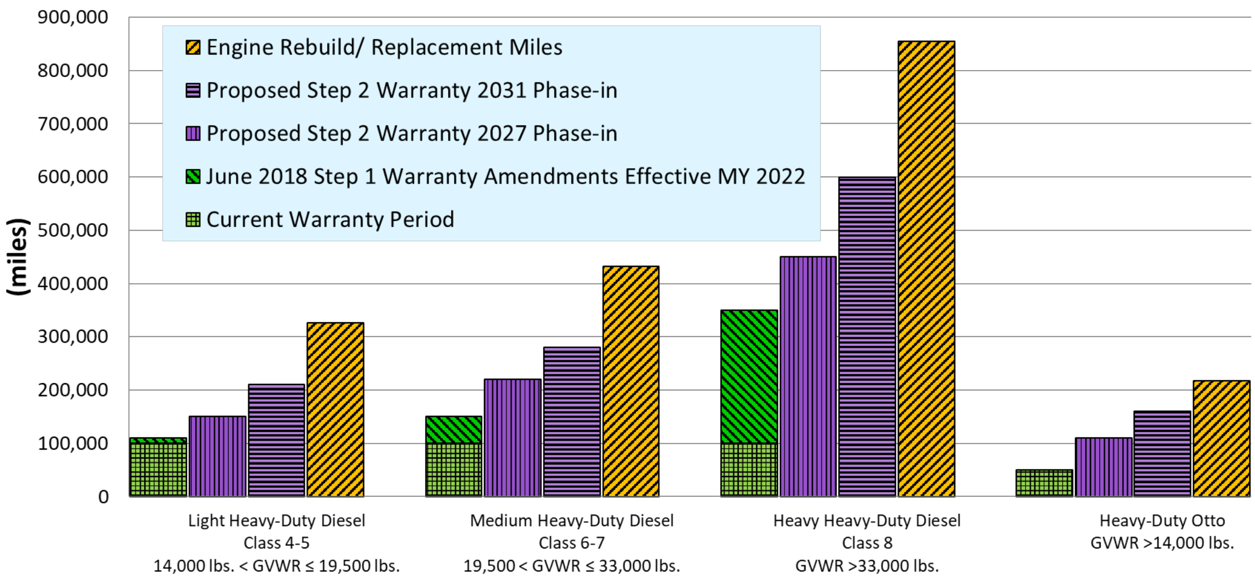
<u>Better Representation of Longer Modern Service Lives</u>

As described above in Chapter I, Section B.5, and shown in Table I-8, real-world survey data indicate that, depending on the primary intended service class, heavy-duty engines are currently being used anywhere from 217,000 to 855,000 miles before getting rebuilt or replaced. Therefore, because modern heavy-duty engines have longer service lives, it is reasonable that their warranty periods should also be longer to provide warranty coverage for a greater portion of that increased time in operation.

For example, survey data shows Class 8 vehicles frequently operate upwards of 850,000 miles before rebuilds are needed (MacKay, 2019). However, under the June 2018 Step 1 warranty amendments, these vehicles will be required to be warranted for only 350,000 miles. This demonstrates that the June 2018 Step 1 warranty amendments still fall short of reflecting the real-world longevity of heavy-duty vehicles. Similarly, engines used in vehicle classes 4-7 also have relatively short warranty periods (i.e.,110,000 miles for engines used in vehicle classes 4-5, and 150,000 miles for engines used in vehicle classes 6-7, both of which are much shorter than the approximately 236,000 mile maximum predicted odometer mileage for vehicle classes 4-7 from the CA-VIUS data (CARB, 2019g). Therefore, these differences support the argument that longer warranty periods beyond those adopted under the June 2018 Step 1 warranty amendments are needed. The June 2018 Step 1 warranty amendments were the first step in advancing warranty coverages that were more closely matched to the useful life period.[32] Subsequently, these proposed warranty amendments in this rulemaking are the second step that would work in conjunction with the proposed lengthened useful life amendments to provide a more reasonable warranty coverage for modern heavy-duty vehicles.

The Proposed Amendments to warranty periods are depicted in Figure II-7, along with the upcoming (adopted) Step 1 warranties in 2022 for the heavy-duty diesel vehicle classes 4-8, and the current warranty period for the heavy-duty Otto-cycle engine category (shown for completeness). For comparison, the engine rebuild/replacement miles are also shown. In particular, the discrepancy in the mileages for the June 2018 Step 1 warranty amendments and the rebuild/replacement mileages highlights the need for the lengthened phased-in warranty coverage.

Figure II-7. Current, Step 1 and Proposed Step 2 Heavy-Duty Warranties Compared to Engine Rebuild/Replacement Mileages



Reducing Incidences of Tampering and Mal-maintenance

Lengthened warranty periods may also reduce incidences of tampering and mal-maintenance. For example, there would be little incentive for a vehicle owner to tamper with the vehicle's emission control system, such as coring out or removing a DPF, or bypassing a catalyst, when the manufacturer is obligated to pay for any defect-related repairs, and especially since a manufacturer can disclaim warranty coverage for defects caused by tampering. Further, vehicle owners would also have more of an incentive to perform scheduled maintenance on time so as not to void their lengthened warranty. CARB staff estimates that only 30 percent of heavy-duty vehicle owners repair emission-related problems that do not significantly affect a vehicle's fuel economy or

[32] The period over which the engine is required to emit no more than the applicable emission standards for criteria pollutants.

performance outside of the warranty period (CARB, 2015a). One of the main observations of CARB's 2017 heavy-duty vehicle inspection and maintenance (HD I/M) Research Contract with the University of California Riverside: Center for Environmental Research and Technology also noted that many heavy-duty vehicle owners decline emission-related repairs if they are not crucial for keeping the vehicle operating (Durbin et al., 2017). Lengthening the warranty period might help to incentivize the many owners who do not currently repair emission-related part malfunctions outside of the warranty period to now seek such repairs in a timely manner.

Encourage Development of More Durable Parts

Third, the proposed lengthened warranty periods may encourage manufacturers to develop more durable parts should the cost of frequent part replacements outweigh the cost to redesign and produce more durable parts.

Additional Benefit to Vehicle Owners

Lengthening warranty periods would also protect heavy-duty vehicle owners from paying out-of-pocket expenses to replace emission-related components that are supposed to remain durable throughout the useful life of the engine. In particular, lengthened warranty periods are needed to protect heavy-duty vehicle owners from having to pay for repairs that are required by CARB's recently amended Periodic Smoke Inspection Program (PSIP), and Heavy-Duty Vehicle Inspection Program (HDVIP), and the future HD I/M program.

Recently adopted amendments to PSIP and HDVIP include much stricter opacity limits, which could result in more vehicle owners seeking to make timely engine repairs and replace DPFs (CARB, 2019d). Under the planned HD I/M program, emission reductions would be achieved when failing heavy-duty diesel vehicle emission control systems are repaired. Many of these HD I/M related repairs would occur under the proposed lengthened warranty periods.

Lengthening the warranty period would benefit vehicle owners. Under the current shorter warranty period, these owners would end up paying the repair costs for defective parts that fail after the warranty expires but well before the engine reaches its useful life. In some instances, the repair for the same defective part can occur multiple times over the life of the engine. Without a lengthened warranty period requirement, even vehicle and engine owners who perform required maintenance as scheduled would be required to pay out-of-pocket costs for any repairs due to defective emission-related parts that cause a failure under the PSIP, HDVIP, or the HD I/M program after the Step 1 warranty is passed. The lengthened warranties will shift some of these repair costs to the manufacturer and, as previously mentioned, may encourage manufacturers to make parts more durable, thereby reducing the repairs needed to comply with HD I/M.

4.3. Why Warranties are Needed for Optionally Certified Hybrid Powertrains

Heavy-duty diesel engines are certified with a stipulation for the intended service class of vehicles the engines will be installed in. As shown in Table I-4 above, once CARB's Step 1 warranty amendments take effect, warranty requirements will be different for LHDD, MHDD and HHDD engines, with longer warranties for heavier rated engines. As such, beginning with MY 2022, a Class 8 heavy-duty vehicle with a HHDD engine would typically come with a longer warranty than LHDD and MHDD vehicles.

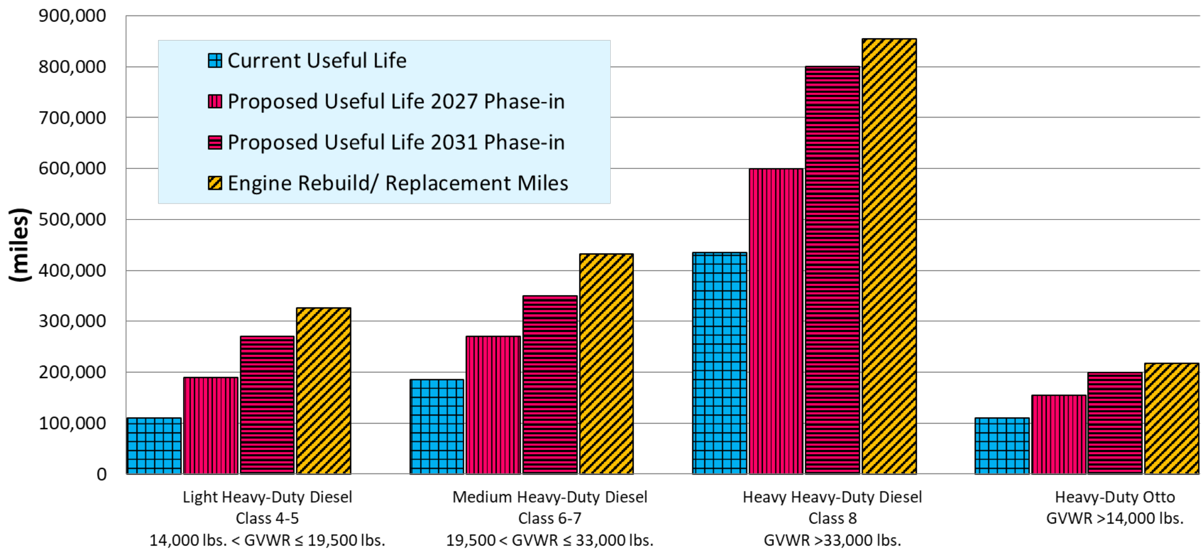
Hybrid powertrains are comprised of more than one source of power, typically a combustion engine and an electric motor and batteries in the case of an electric-hybrid system. Hence, a hybrid powertrain could be designed to have a combustion engine of various displacements and power ratings coupled with an electric system. One possible hybrid configuration could involve a combustion engine sized to be smaller than would otherwise be needed for the intended vehicle service class, e.g., a MHDD engine, or even a LHDD engine, in a Class 8 vehicle, if its intended design is to perform as a range extender, such as in a series hybrid architecture. In another configuration, a hybrid system could be designed with a fully-sized combustion engine, coupled with a much smaller electric system, such as used in a 48-volt system mild hybrid set up. If the hybrid powertrains from both of these scenarios were certified for use for the same Class 8 vehicle (with the same duty cycle and usage), it is reasonable to expect that both hybrid powertrain systems would need the same warranty requirements. Without this equivalence, purchasers of a vehicle that employs an undersized combustion engine hybrid powertrain would be exposed to a shorter warranty period than appropriate.

Currently, as discussed above in Chapter I, Section B.4, heavy-duty hybrid vehicles certified through CARB's existing procedures must comply with warranty requirements determined by the certified combustion engine that is installed in the hybrid vehicle. Beginning with MY 2022, when warranty requirements will differ for various classes of heavy-duty vehicles, the possibility of warranties mis-matched to the hybrid vehicles and engines exists. For example, under current requirements, a LHDD engine in a MY 2022 Class 8 hybrid vehicle would only be required to have a 5-year/110,000 miles warranty even though comparable conventional vehicles would be required to have a 5-year/350,000 miles warranty. Therefore, CARB staff believes it is necessary to propose amendments along with the new hybrid powertrain certification test procedures that base the warranty period for such systems on the warranty that would normally be required for the engines that are typically installed in the same class of vehicles. In other words, amendments are needed to ensure for the example above, that the MY 2022 HHDD hybrid system is covered for 350,000 miles warranty, just like a typical HHDD engine in a HHDD vehicle.

5. Need for Lengthened Useful Life Periods

Manufacturers are responsible for making sure their engines meet emission standards for the applicable regulatory useful life. However, as shown in Figure II-8, the current mileages for useful lives are significantly lower than the mileages at which modern heavy-duty engines get rebuilt or replaced. This highlights the need for longer useful life periods to reduce emissions by: (1) better representing the longer modern service lives of heavy-duty engines, and (2) encouraging manufacturers to make parts more durable in order to avoid non-compliance with in-use testing requirements and inconvenient, costly recalls.

Figure II-8. Current and Proposed Heavy-Duty Useful Life Compared to Engine Rebuild/Replacement Mileages (MacKay, 2019)



Also, similar to the reasons discussed above for needing warranties for optionally certified hybrid powertrains, ensuring that the emission standards for these hybrid vehicles are met throughout their useful lives is also important.

6. Need for Amendments to the Emissions Warranty Information and Reporting Program and Corrective Action Procedures

The intent of the EWIR program and associated corrective action procedures is to ensure that defective emission control components are expeditiously identified and remedied through corrective action. However, manufacturers, particularly heavy-duty engine manufacturers, have generally not corrected problems for emission control components experiencing failure rates (CARB, 2016d). This is likely due to the limited amount of HDIUC testing conducted by CARB, the cost of recall and/or other factors such as bad publicity over faulty quality. Additionally, the process of negotiating corrective actions with manufacturers and determining the emissions impact of a component failure is a lengthy process that can delay implementation of a corrective action for years. Consequently, heavy-duty vehicles can operate with defective components for extended periods of time, thereby emitting excessive levels of emissions over those time periods. Subsections 6.1 and 6.2 below describe in further detail why amendments to the current EWIR program and corrective action procedures are needed.

6.1. Existing EWIR Program and Corrective Action Procedures Unduly Restrict CARB's Ability to Require Recalls

Under the existing EWIR regulation, if a manufacturer contests the need for a recall, even if CARB has identified a defective emissions control component, CARB then has the burden of proving that defective component could cause a substantial number of the vehicles or engines containing that defective component to exceed applicable emission standards over their useful lives. This would then require CARB to expend excessive time and resources to conduct numerous emissions tests to prove that substantial numbers of vehicles or engines are exceeding emission standards over their useful lives. Procuring and testing a sufficient number of test engines and defective parts to test can be very difficult, leading to delays in corrective action, and also increases the cost of conducting the testing. Without the ability to require the timely repair of defective emission control components, excess emissions will adversely impact air quality. Hence, amendments to the current EWIR requirements are needed to make it easier for CARB to force necessary recalls.

6.2. Examples of Manufacturers Failing to Comply with Warranty Triggers

Over the years, many heavy-duty engine manufacturers have been recalcitrant in conducting corrective actions when their true failure rate was over four percent. In fact, several heavy-duty engine manufacturers have had component failure rates over 100 percent, which means the same component was replaced several times during the warranty period. CARB has been in negotiations with several heavy-duty manufacturers to correct defects in emission control components with such high failure rates. Some of these negotiations have been ongoing for years and consume enormous amounts of CARB staff resources to resolve these cases and initiate corrective action. This lengthy process is repeated whenever a new defective component is discovered. Thus, to pursue remedial action based on failure rates, amendments to the current EWIR requirements and corrective action procedures are needed to clarify manufacturer responsibilities when corrective action triggers are reached and streamline the overall remedial action process.

7. Need for Emissions Averaging, Banking, and Trading Program Amendments

Amendments to California's ABT requirements are needed because under staff's proposal, California's emission standards would be different from U.S. EPA's corresponding emission standards, and consequently the current ABT accounting mechanism would no longer accurately account for credits generated under California's heavy-duty engine emissions program. Beginning with MY 2024, California can no longer utilize credits in the federal ABT bank. If California did not establish its own ABT bank and instead continued to use U.S. EPA's bank, it could inappropriately award windfall credits to manufacturers. For example, consider a case where the NOx emission standard remains at the current 0.20 g/bhp-hr level under federal requirements, while California adopts a more stringent NOx emission standard of 0.05 g/bhp-hr for 2024 MY engines. If a manufacturer chose to certify an engine to both sets of standards, it would certify a 50-state engine family with an FEL value of 0.05 g/bhp-hr with U.S. EPA. Using Equation I-1, shown in Chapter I, Section B.7.1, this engine family would generate emission credits in the federal-ABT program based on being certified 0.15 g/bhp-hr below the federal standard. In California, the same product would meet the emission standards without generating any credits. Hence, to have a functioning ABT program, California must set up its own ABT bank.

A functioning ABT is needed, first, so that California can provide an incentive for manufacturers who voluntarily certify engines to the standards proposed within this Staff Report earlier than required. For example, a manufacturer certifying to a 0.05 g/bhp-hr diesel emission standard in MY 2022 or 2023 should be able to generate credits.

Second, a functioning ABT is needed so that California can provide appropriate incentives for heavy-duty ZEVs. In order to encourage manufacturers to comply early with the ACT ZEV sales percentage requirements, which begin with MY 2024, California needs to create a pathway for Class 4-8 heavy-duty ZEV manufacturers to generate NOx credits starting with the 2022 MY.

8. Need for Heavy-Duty Engine Durability Demonstration Program and In-Use Emissions Data Reporting Amendments

In order to evaluate the efficacy of current DDP practices, CARB staff reviewed the information from the 2014 through 2017 vehicle and engine compliance activities report (U.S. EPA, 2019) which was recently published by U.S. EPA. The report provides detailed information regarding the recall activities and defects reporting for the heavy-duty sector. Analysis of this information is essential because it examines the overall status of emission-related component durability for the industry as a whole during several calendar years. CARB staff also examined the information from the recent recall of Cummins engines, a nationwide recall of more than 500,000 engines (CARB, 2018g).

It should be noted that one of the key objectives of the DDP is to verify emission-related component durability. Without durable emission-related components, the engine and aftertreatment system cannot achieve emissions compliance throughout its useful life. A robust DDP would include modes of operation that would expose the engine and aftertreatment system components to the types of vibration, temperature, pressure, and transient operations that are representative of real-life, in-use operations. Therefore, the presence of any defective components in the durability engine should be detected through the DDP process.

CARB staff compared the data from 2014 through 2019 MY durability reports for the California-certified on-road heavy-duty manufacturers, the information mentioned above from the U.S. EPA compliance activities report, and the data from the Cummins recall program. Comparison of the data revealed that none of the problems identified in the field (either component defects or recalls) were observed through the existing DDP process. The lack of any correlation between the results from the laboratory aging process versus real-life, in-use operations strongly suggests that the current DDP program is not accurately simulating the factors contributing to engine and emission control deterioration. Engine manufacturers have also recently stated that the current laboratory aging process does not yield valid results for estimating full useful life deterioration factors. There are many factors that contribute to this discrepancy including:

- Some manufacturers may not be using proper dynamometer hardware to age the engine and aftertreatment system in the laboratory as part of the DDP. Recent communication from EMA (EMA, 2019b) indicates that some manufacturers are using "less expensive engine dynamometers" that are not capable of simulating motoring conditions as part of the aging cycle. Motoring conditions are essential in simulating transient operations (over 14 percent of the FTP cycle contains motoring operation), and the absence of motoring conditions during the aging process means that meaningful transient operations were not properly simulated in the laboratory. CARB staff believes that inclusion of transient conditions is essential in validation of engine and aftertreatment system durability.

- No standardized aging cycles are currently being used by engine manufacturers. A more robust approach would require the manufacturers to use standardized aging cycles/processes so that results from different laboratory aging programs could be compared.

- The current equivalent fuel-burned approach used by all manufacturers, which correlates the amount of fuel burned to VMT, does not rely on a systematic and scientific approach. U.S. EPA has developed a new tool, Greenhouse Gas Emissions Model (GEM) (U.S. EPA, 2016b), which uses specific vehicle and engine parameters to establish a relationship between VMT and hours of engine operation over standardized heavy-duty chassis cycles.

- Acceleration factors are being used by manufacturers as a tool to decrease the amount of laboratory aging time. No standardized or scientific methodology has been proposed by the industry to verify the validity of the acceleration factors in estimating deterioration factors.

- Emission-related component deterioration and failure mechanisms are not fully captured by the current aging process. This was discussed earlier as part of U.S. EPA's 2014-2017 vehicle and engine compliance activities review. The discrepancy between component failure rates in the laboratory and in the field means that the current aging process is not representative of real-life operations.

There is a strong need to find a new enhanced process which is more representative of the real-life aging of on-road heavy-duty diesel engines. This process is described in more detail in Chapter III, Section A.8.

9. Need for Powertrain Certification Test Procedures for Heavy-Duty Hybrid Vehicles Amendments

Before manufacturers can legally sell or offer for sale new engines or new motor vehicles in California, manufacturers must certify those engines or vehicles with CARB in accordance with CARB test procedures. Current heavy-duty engine certification testing procedures were designed to assess emissions of conventional combustion engines using engine dynamometers. These procedures are intended to test only the engine and are not able to test and capture the overall impact of a hybrid system that is integrated with the engine. Heavy-duty hybrid vehicles operate over a broad range of duty cycles, through intricate interactions between the hybrid system and the combustion engine, creating a significant testing challenge for accurately capturing their overall emission and fuel economy characteristics. As such, heavy-duty hybrid vehicles are unable to be certified to criteria pollutant emission standards using existing heavy-duty engine certification test procedures, except through the added step of using CARB's interim hybrid certification procedures, which is conducted on a chassis dynamometer.

Because the current interim hybrid certification procedures have not been utilized by manufacturers, CARB staff believes that the development of new powertrain test procedures for criteria pollutants emissions based on existing powertrain testing procedures for GHG emissions is warranted. CARB staff's proposal is discussed more in detail in Chapter III, Section A.9.

10. Need for Heavy-Duty Vehicle GHG Tractor APU Certification Amendments

In 2016, new federal GHG requirements were adopted for diesel-fueled APUs used in new 2024 and subsequent MY on-road tractors in U.S. EPA's Phase 2 rulemaking. That rulemaking requires diesel APUs installed on tractors to be certified to a PM emission standard of 0.02 grams per kilowatt-hour (g/kW-hr) rather than the 0.40 g/kW-hr PM standard required for similar off-road diesel engines not used in APU applications. This new lower PM standard is specified in a new section, 40 CFR §1039.699, and will become effective in the 2024 MY.

In 2018, CARB adopted its own Phase 2 GHG Regulation for California, which is closely aligned with the U.S. EPA's Phase 2 rulemaking, including the diesel APU certification requirement specified in 40 CFR §1039.699. However, 40 CFR §1039.699 was not specifically incorporated into the California off-road diesel test procedures.[33] Therefore, amendments are needed to align with the federal requirements by incorporating 40 CFR §1039.699 into California's off-road test procedures.

[33] California Exhaust Emission Standards and Test Procedures for New 2011 and Later Tier 4 Off-Road Compression-Ignition Engines, PART I-D

11. Need for California Phase 2 GHG Regulation Clean-up Items

CARB staff has become aware that several minor clarifications and corrections are needed in the California Phase 2 GHG Regulation. As detailed further in Chapter III, Section A.11, CARB staff's proposal mostly involves clean-up modifications that include amendments on the definition of medium-duty vehicle and the end-of-year reporting requirements, and updates to the environmental performance label specifications as well as typographical error revisions and correction of regulatory text references. Additionally, CARB staff is proposing trailer specific revisions such as clarifications that warranty, in-use compliance, and emissions warranty reporting regulations also apply to trailers.

The proposed minor modifications are necessary to improve implementation of the original regulation, for clarify and consistency among regulated entities, as well as correction of typographical errors. These proposed trailer-specific amendments are also necessary to explain specifically the original California Phase 2 GHG regulatory intent that this section applies to trailers certified to the California Phase 2 GHG emission standards.

12. Need for Medium-Duty Engine Clarifications and Amendments

When California's LEV III Regulation was adopted in 2012, the regulatory useful life of emission standards for passenger cars, light-duty trucks, and medium-duty vehicles was increased from 10 years or 120,000 miles, whichever first occurs, to 10 years or 150,000 miles, whichever first occurs. However, when these changes were made to 13 CCR 2112, where the useful life periods of emission standards for motor vehicles are identified, the regulatory text inadvertently did not mention engines used in medium-duty vehicles, whereas the LEV program requirements have always applied to medium-duty vehicles and engines used in such vehicles. By default, the existing useful life of 120,000 miles continued to remain in effect for medium-duty engines. When a vehicle manufacturer chooses to certify its medium-duty vehicle with an engine-certified medium-duty engine, it has to apply for a vehicle Executive Order with the certified engine information. In this case, the engine would be certified to 120,000 miles while the vehicle would be certified to 150,000 miles according to LEV III regulations. Thus, a discrepancy in engine and vehicle useful life exists, and regulatory clarification for useful life consistency to 150,000 miles is needed.

Another issue pertains to the use of medium-duty engines and heavy-duty engines used in certain vehicles. Currently, the regulation sets out separate emission standards for engines used in medium-duty vehicles from 8,501 to 14,000 pounds GVWR and for engines used in vehicles greater than 14,000 pounds GVWR. Consequently, engine and vehicle Executive Orders specifically mention the vehicle weight ranges in which engines may be installed. For example, an engine certified as part of a medium-duty engine family is for use in medium-duty vehicles from 8,501 to 14,000 pounds GVWR. Thus, the regulations direct the use of medium-duty engines in medium-duty vehicles only. Although the existing regulations prohibit installing a medium-duty engine into a heavy-duty vehicle over 14,000 pounds GVWR, CARB staff believes that more clearly expressing this prohibition in the Proposed Amendments will reinforce this prohibition to the regulated industry, to ensure that medium-duty engines, which would have a significantly shorter useful life and warranty requirements, would not be installed in heavy-duty vehicles greater than 14,000 pounds GVWR.

Additionally, a provision adopted in the LEV III Regulation in 2012 allowed heavy-duty vehicles greater than 14,000 pounds GVWR to be certified in a medium-duty vehicle certification test group, which are chassis-certified, if the vehicles are certified to the most stringent standards of that test group. Without this provision, the engines used in heavy-duty vehicles greater than 14,000 pounds GVWR would be certified to a separate certification family and require a separate Executive Order than their medium-duty vehicle counterparts. Since the proposed low NOx standards are significantly more stringent than the current medium-duty vehicle chassis standards, the use of this provision should be limited to 2023 and earlier MYs, before the proposed low NOx standards take effect.

III. OVERVIEW OF PROPOSED REGULATION AND ASSOCIATED AMENDMENTS

This chapter provides an overview of the Proposed Amendments. Section A describes each main element of the Proposed Amendments, with subsections regarding each of the following elements:

1. New NOx standards for 2024 and subsequent MY heavy-duty engines, including standards on a new LLC;
2. New PM standards for 2024 and subsequent MY heavy-duty engines;
3. Amendments to CARB's heavy-duty in-use test procedure;
4. Warranty period amendments;
5. Useful life period amendments;
6. Emissions warranty information and reporting and corrective action procedure amendments;
7. Emissions Averaging, Banking, and Trading program amendments;
8. Heavy-duty engine durability demonstration program and in-use emissions data reporting amendments;
9. Powertrain certification test procedure amendments;
10. Heavy-duty vehicle GHG tractor APU certification amendments;
11. California Phase 2 GHG Regulation clean-up amendments; and
12. Medium-duty engine amendments.

Section B describes areas where related amendments are likely needed in future rulemakings.

A. Summary of Proposed Action

The primary goal of the Proposed Amendments is to achieve the greatest degree of NOx and PM emission reductions that are technologically feasible and cost-effective. To achieve this, CARB staff has developed proposals that would require new heavy-duty engines to meet stringent NOx and PM emission standards during certification. The proposed new heavy-duty engine emission standards would include lower NOx and PM standards on existing certification cycles such as the heavy-duty transient FTP,[34] the

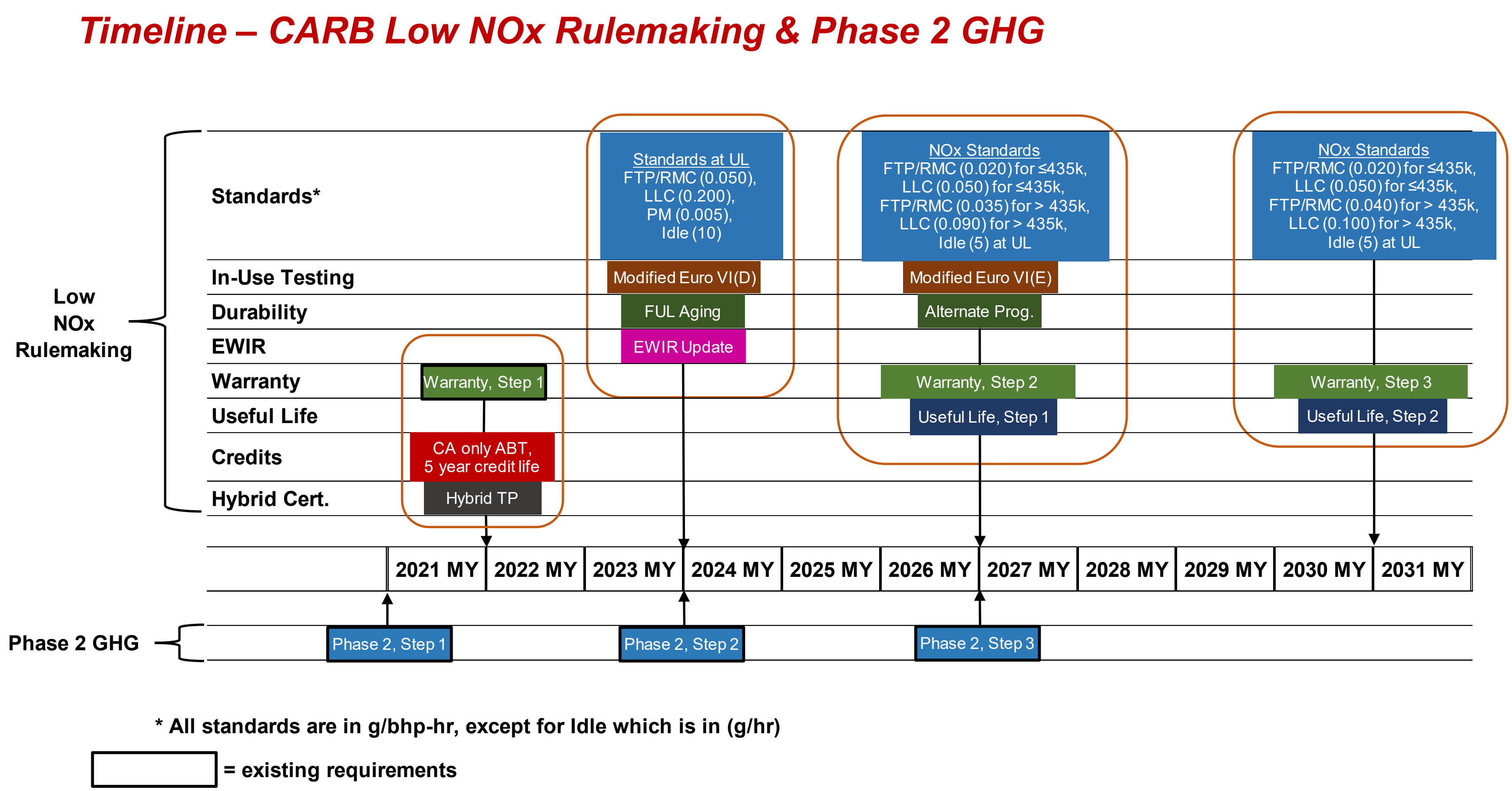
[34] "FTP" is the heavy-duty transient Federal Test Procedure duty cycle specified in 40 CFR §86.007-11(a)(2), as amended October 25, 2016.

RMC-SET,[35] idling test procedures,[36] and on a new LLC cycle developed to demonstrate emissions are controlled under low load and low speed urban driving operations. The proposed new emission standards and associated test procedures are applicable to heavy-duty diesel-cycle and Otto-cycle engines primary intended for use in the service classes outlined in Table I-1 of Chapter I, Section B.

The amendments would implement more stringent NOx and PM emission standards for heavy-duty engines in three phases. A tiered approach would achieve NOx and PM emission reductions while minimizing the impacts on the engine manufacturers' product development cycle. The implementation timeline for the various elements of the Proposed Amendments is shown in Figure III-1 below:

[35] "RMC-SET" is the supplemental emission test procedure with the steady-state duty cycle specified in 40 CFR §86.1360, as amended October 25, 2016.
[36] Idling test procedure is the duty cycle specified in Part 86, Subpart A, section 11.B.6 of the California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles, as amended on April 18, 2019. https://ww3.arb.ca.gov/msprog/onroadhd/documents/hddtps_warranty_10-19.pdf

Figure III-1. Proposed Amendments Timeline



The first phase of the proposed emission standards starts with the 2024 MY and remains in effect until the 2026 MY. CARB staff is proposing emission reduction levels that can be achieved through improved engine and aftertreatment system calibration, engine hardware modifications using existing commercially available technologies, larger SCR catalyst bed volume with an improved catalyst substrate, and optimized placement and packaging of the exhaust aftertreatment system. This phase is intentionally harmonized with the second stringency step of the Phase 2 GHG requirements, thereby allowing the manufacturers to introduce GHG and low NOx technologies at the same time to reduce the overall product development and design costs.

The second set of the proposed emission standards are more stringent and would go into effect with the 2027 MY. The useful life period for all classes of heavy-duty engines would also increase at the same time. CARB staff believes that the proposed standards would require major engine control strategy changes as well as implementation of known engine hardware and incremental aftertreatment architecture improvements. This phase of the emission standards would also be synchronized with the last stringency step of the Phase 2 GHG Regulations. Again, the intent is to provide an aligned pathway to implement low NOx and GHG requirements simultaneously.

The final phase of the emission standards would go into effect with the 2031 MY. While CARB staff is not proposing implementation of new NOx control technologies in this phase, the useful life and warranty periods would be increased further with the 2031 MY. The revised useful life and warranty periods would require the engine and aftertreatment system to maintain emissions compliance for a longer period of time.

1. New NOx Standards for 2024 and Subsequent MY Heavy-Duty Engines

Subsection 1.1 below describes amendments to the NOx emission standards. Subsection 1.2 explains why CARB staff concluded the proposed standards are technically feasible and describes the technology packages staff believes would be used to meet the proposed standards.

1.1. Amendments to the NOx Emission Standards (FTP, RMC-SET, LLC, and Idling Test Cycle)

The proposed heavy-duty engine NOx emission standards would be implemented in two steps, the first step applicable to 2024 through 2026 MY engines, and the second step applicable to 2027 and subsequent MY engines. Subsection 1.1.1 below describes the proposed standards for MYs 2024 to 2026; Subsection 1.1.2 describes the proposed optional 50-state-directed engine standards for MYs 2024 to 2026; Subsection 1.1.3 describes the proposed MY 2027 and subsequent medium- and heavy-duty engine standards; Subsection 1.1.4 describes the proposed optional low NOx standards for MY 2024 and subsequent heavy-duty diesel and Otto-cycle engines; and Subsection 1.1.5 describes related amendments to the OBD requirements.

1.1.1. MY 2024 through 2026 Heavy-Duty and Medium-Duty Engines

Table III-1, below, shows the proposed NOx emission standards for MY 2024 to 2026.

Table III-1. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards (MY 2024 to 2026)

MY	Heavy-Duty Diesel-Cycle				Heavy-Duty Otto-Cycle
	FTP (g/bhp-hr)	RMC-SET (g/bhp-hr)	LLC (g/bhp-hr)	Idling (g/hr)	FTP (g/bhp-hr)
2024-2026	0.050	0.050	0.200	10	0.050

1.1.2. Optional 50-State-Directed Engine Standards for MYs 2024 to 2026

CARB staff is also proposing to provide manufacturers the option to certify 2024 through 2026 model year engines to a less stringent NOx standard, if they meet that standard on a nationwide basis. The optional 50-state-directed engine standards are shown in Table III-3.

Table III-2. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards (Optional 50-State-Directed Engine Standards)[a]

MY	Heavy-Duty Diesel-Cycle				Heavy-Duty Otto-Cycle
	FTP	RMC-SET	LLC	Idling	FTP
	(g/bhp-hr NOx)			(g/hr NOx)	(g/bhp-hr NOx)
2024-2026	0.10	0.10	0.30	10	0.10

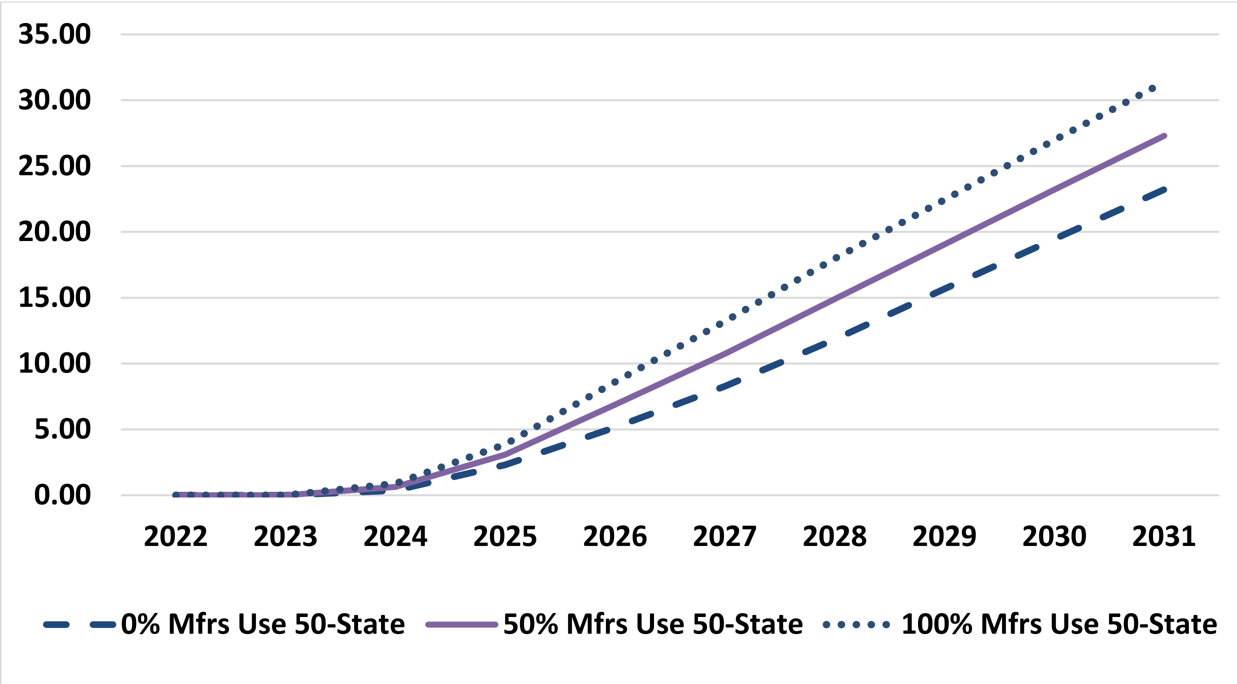
[a] Manufacturers opting into the optional 50-state-directed standards would also need to meet a PM standard of 0.005 g/bhp-hr on the FTP, RMC-set, and LLC for diesel-cycle and FTP for Otto-cycle.

The proposed optional 50-state-directed engine standards would allow engine manufacturers to meet California's requirements at a lower per engine cost, since the standards are less stringent and the technologies and strategies needed to meet those standards are less complex. Furthermore, this option would allow a manufacturer to make one set of national 50-state certified engines, thereby spreading the manufacturer's research and development costs over a larger number of engines that are sold nationwide.

To the extent that manufacturers elect to utilize this option, it would provide air quality benefits to California, since the affected trucks that travel to California would be much lower-emitting than they otherwise would be, absent this option. As shown in Figure III-2 below, the greater the fraction of manufacturers that participate in the 50-state-directed program, the greater the emission benefits. If all manufacturers participate in the 50-state-directed program (as shown in the dotted dark blue line in Figure III-2), emission benefits in 2031 would be 31.4 tpd versus 23.2 tpd if no manufacturers participate (as shown in the dashed blue line in Figure III-2). This represents a 35 percent increase in benefits in that year, which is clearly a significant increase. However, because it is unclear how many, if any, manufacturers would participate, the primary emission benefit analysis described in Chapter V and elsewhere in this Staff Report assumes no manufacturers participate.[37]

[37] Given that the Truck and Engine Manufacturers Association has stated that the 50-state-directed standards are not workable and that manufacturers would not certify to them, assuming no manufacturers participate in the primary emission benefit analysis seems prudent (EMA, 2020).

Figure III-2. Emission Benefits of Proposed Amendments Over Time With Various Levels of Manufacturer Participation in 50-State-Directed Standards [Statewide tpd NOx]



Manufacturers would be able to meet the proposed optional 50-state-directed engine standards with improved engine calibration strategies that are aimed at reducing emissions during cold start and low load operations, and with current generation aftertreatment systems. As discussed extensively above, a number of heavy-duty engine families currently certify at a much lower emissions level than the proposed optional 50-state-directed engine standards (see Figure III-11 and III-12), and at the same time meet the 2024 Phase 2 GHG standards. This indicates that the proposed optional 50-state-directed engine standards are technically feasible.

Manufacturers that opt to certify engines to the proposed optional 50-state-directed engine standards would also be required to comply with the same certification and in-use requirements for engines meeting the 2024 California standards. This means engines certified to the proposed optional 50-state-directed engine standards would also need to comply using the same durability test procedures, idling standard, in-use testing (HDIUT) requirements, warranty, and other requirements that apply to 2024 California-certified engines.

1.1.3. MY 2027 and Subsequent Medium- and Heavy-Duty Engines

Table III-4 shows the proposed NOx emission standards for MYs 2027 to 2030 and 2031 and subsequent.

Table III-3. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards for 2027 and Subsequent

Test Procedure	Medium-Duty, Light Heavy- and Medium Heavy-Duty Diesel Engines	Medium-Duty and Heavy-Duty Otto-Cycle Engines
	MYs 2027 and Subsequent	
	(@Useful Life)	(@Useful Life)
FTP cycle (g/bhp-hr)	0.020	0.020
RMC-SET cycle (g/bhp-hr)	0.020	---
Low-load cycle (g/bhp-hr)	0.050	---
Idling (g/hr)	5	---

Test Procedure	Heavy Heavy-Duty Diesel Engines			
	MYs 2027 - 2030		MYs 2031 and Subsequent	
	(@435,000 miles)	(@Useful Life)	(@435,000 miles)	(@Useful Life)
FTP cycle (g/bhp-hr)	0.020	0.035	0.020	0.040
RMC-SET cycle (g/bhp-hr)	0.020	0.035	0.020	0.040
Low-load cycle (g/bhp-hr)	0.050	0.090	0.050	0.100
Idling (g/hr)	5	5	5	5

As discussed further in Section A.2 below, the PM emission standards for MY 2027 and subsequent diesel- and Otto-cycle heavy-duty engines is 0.005 g/bhp-hr at the applicable full useful lives for those heavy-duty engines.

1.1.4. Optional Low NOx Standards

Table III-5 and Table III-6 show proposed optional low NOx emission standards for 2024 and subsequent MY for Otto-cycle and diesel heavy-duty engines.

Otto-Cycle heavy-duty engines: Table III-5 shows proposed optional low NOx standards for Otto-cycle heavy-duty engines. For 2024 to 2026 MY Otto-cycle heavy-duty engines, CARB staff is proposing an optional low NOx emission standard of 0.020 g/bhp-hr over the FTP test cycle, which would be 60 percent below the proposed 0.050 g/bhp-hr NOx emission standard for 2024 MY engines. Many CNG- and LPG-fueled stoichiometric SI heavy-duty engines are already certified to the current optional 0.02 g/bhp-hr NOx standard (Table I-2). It has been demonstrated that these engines perform well under low load driving conditions. For example, the University of California Riverside's College of Engineering – Center for Environmental Research and Technology (CE-CERT) testing of an optional low NOx certified 12-liter Cummins CNG engine showed that NOx emissions were well controlled to below 0.02 g/bhp-hr NOx under low loads and cruise conditions (CE-CERT, 2018). In addition, in the SwRI Low NOx Stage 1 testing program, a 12-liter Cummins CNG engine that was developed to meet a 0.02 g/bhp-hr NOx standard on the FTP and RMC-SET test cycles, was tested under various vocational cycles and showed NOx emissions to be well controlled under these operations (Sharp et al., 2017b).

For 2027 and subsequent MY Otto-cycle heavy duty engines CARB staff is proposing a more stringent optional low NOx emission standard of 0.010 g/bhp-hr over the FTP test cycle, which would be 50 percent below the proposed 0.020 g/bhp-hr NOx emission standard for 2027 MY engines. Most of the Otto-cycle heavy-duty engines currently certified to the 0.02 g/bhp-hr optional low NOx standard (Table I-2) have NOx certification levels of 0.01 g/bhp-hr. This indicates that with further incremental improvements to TWCs and air-fuel ratio controls, it would be technically and cost-effectively feasible for Otto-cycle heavy-duty engines to meet the proposed 2027 optional low NOx standard.

Heavy-duty diesel engines: Table III-6 shows proposed optional low NOx standards for heavy-duty diesel engines. For 2024 to 2026 MY heavy-duty diesel engines, CARB staff is proposing an optional low NOx emission standard of 0.020 g/bhp-hr over the FTP and RMC-SET test cycles, which would be 60 percent below the proposed 0.050 g/bhp-hr NOx emission standard for 2024 MY engines. An optional 0.02 g/bhp-hr low NOx standard is currently in place but to-date no heavy-duty diesel engine has been certified to this standard. If a manufacturer chooses to certify its engines to the proposed optional 0.020 g/bhp-hr NOx standard, the engines would also be required to certify to a 0.080 g/bhp-hr NOx standard over the LLC test cycle. To meet these optional low NOx standards, CARB staff believes diesel engines would require similar technologies and strategies identified in Subsection 1.1.3 above to meet the proposed mandatory standards for 2027 MY engines.

For 2027 and subsequent MY engines, CARB staff is proposing an optional low NOx standard of 0.010 g/bhp-hr on the FTP and RMC-SET test cycles at full useful life. The corresponding proposed optional low NOx standard under the LLC would be 0.025 g/bhp-hr. CARB staff believes that diesel engines would require similar technologies and strategies identified in Subsection 1.1.3 above but with incremental improvements over and above the improvements needed to meet the proposed mandatory standard for 2027 MY engines.

Table III-4. Proposed Optional Low NOx Standards for 2024 and Subsequent Heavy-Duty Otto-Cycle Engines Used in Vehicles >14,000 lbs. GVWR

Optional Low NOx Exhaust Emission Standards for Heavy-Duty Otto-Cycle Engines (g/bhp-hr)			
MY	**Test Procedure**	**NOx**	**PM**
2024 - 2026	FTP	0.020	0.005
2027 and Subsequent	FTP	0.010	0.005

Table III-5. Proposed Optional Low NOx Exhaust Emission Standards for Heavy-Duty Diesel Engines Used in Vehicles >14,000 lbs. GVWR

Optional Low NOx Exhaust Emission Standards for 2024 and Subsequent MY Heavy-Duty Diesel Engines Used in Vehicles >14,000 lbs. GVWR (g/bhp-hr)			
MY	**Test Procedure**	**Full Useful Life NOx**	**PM**
2024 - 2026	FTP and RMC	0.020	0.005
	LLC	0.080	0.005
2027 and Subsequent	FTP and RMC	0.010	0.005
	LLC	0.025	0.005

1.1.5. Amendments to OBD Requirements

To address engine manufacturers' concerns regarding not knowing with certainty at what emission levels their OBD systems will be able to detect faults, CARB staff is proposing amendments to both the HD OBD Regulation and the OBD II Regulation (for engines used in medium-duty vehicles) to provide an interim level of relief by maintaining OBD thresholds for NOx and PM effectively at the same levels as required for today's standards. With this relief, engine manufacturers can first focus on the necessary emission control solutions to meet the proposed standards before turning to improvements that may be necessary to ensure robust detection of faults at the lower emission levels. However, these higher OBD thresholds could allow emissions to exceed existing malfunction thresholds before detecting a fault, which could reduce the benefits of the proposed emission standards by allowing affected engines to operate without an indication of the need for repair. Accordingly, it will be imperative that these thresholds are monitored and, if needed, adjusted to ensure the benefits of the proposed standards are protected.

Based on past experience, staff expects that the majority of monitors will already be capable of detecting faults at emission levels lower than the proposed thresholds with minimal revision as changes to improve the emission controls generally also improve the resilience of such controls to degradation. For example, many EGR systems can be designed with adaptive controls such that, as exhaust gas passages become restricted and reduce the flow, the system automatically adjusts to command more flow until it achieves the desired flow amount. In such a system, essentially no degradation in emissions occurs until the system is so restricted that the system reaches its maximum control authority and can no longer achieve the desired flow. Appropriate sizing of the EGR system could then allow a fault to be detected at this same point of reaching the control limits, whether the engine meets a 0.20 or 0.020 g/bhp-hr standard and result in emission levels that are proportionally similar such as 2.0 times the standard itself. From the information submitted during OBD certification, staff would be able to verify both the emission level at which faults are actually being detected and the level of degradation of the component being detected. If manufacturers are able to calibrate the system to delay detection of faults until even more component degradation occurs than is typical of today's OBD systems, it will be a clear indication that the malfunction threshold relief is not needed and will support an immediate further tightening of the threshold. Accordingly, staff expects to track manufacturers' progress at these lower emission standards and pursue adoption of more appropriate malfunction emission thresholds at a future OBD regulatory update.

1.2. Technical Feasibility of the Proposed Standards

Overview of Existing Strategies: As discussed in Chapter I, current heavy-duty engines are required to meet a NOx standard of 0.20 g/bhp-hr, a PM standard of 0.10 g/bhp-hr and an NMHC standard of 0.14 g/bhp-hr. To meet these standards, manufacturers are utilizing both engine and aftertreatment system control strategies for both compression-ignition (CI) and spark-ignited (SI) combustion engines. Specifically, for CI engines, manufacturers are using engine controls such as cooled EGR, variable geometry turbochargers, high pressure fuel injection, and other associated electronic controls, as well as aftertreatment system controls such as DOCs, DPFs, urea-based SCR, urea injection control, and ammonia slip catalysts (ASC). For SI engines, manufacturers are using engine controls such as EGR rate control, air-fuel ratio control, and other associated electronic controls and aftertreatment strategies such as TWCs. With better air-fuel ratio controls and increased catalyst volume, manufacturers have been certifying SI engines to the optional low NOx standards of 0.02 g/bhp-hr NOx, 90 percent below current standards (see Table I-2).

Advanced Strategies: There are two main approaches for reducing emissions further at the tailpipe: engine controls and aftertreatment system controls. Engine control strategies comprise software and hardware-based controls designed to achieve more efficient combustion and reduced engine out emissions as well as enable improved thermal management of the exhaust emissions for more effective aftertreatment system performance over a wide range of the vehicle operations. For CI engines, exhaust aftertreatment system control strategies include improvements to the catalyst formulations, urea injection controls, exhaust system thermal insulation, supplemental heat addition to the exhaust, and placement of the aftertreatment system close to the engine. It is not expected that a single strategy or technology would enable NOx emission reductions necessary to achieve the levels of the proposed NOx standards. However, adequate NOx emissions reductions to meet the proposed standards can be realized from improved integration of engine control with advanced aftertreatment system control strategies. A discussion of the individual technologies and strategies that could be implemented to further reduce NOx emissions at the tailpipe are discussed in Appendix I.

Some of the engine control strategies and supplemental energy sources designed to add heat to the exhaust may require additional fuel consumption during cold starts or low temperature operations. However, the integration and calibration of these technologies is expected to achieve significant NOx reductions with minimal or no impact on GHG emissions over the vehicle's entire duty cycle. In some cases, the selection of certain engine technologies like cylinder deactivation can achieve desired NOx emissions reductions while reducing GHG emissions to help support attaining Phase 2 GHG requirements. For SI stoichiometric combustion engines, emission control strategies are less complex but can significantly reduce NOx emissions with improved TWC formations and advanced air-fuel ratio controls.

Subsection 1.2.1 below summarizes why CARB staff believes the 2024 to 2026 standards are technically feasible. Subsection 1.2.2 summarizes why CARB staff believes the 2027 and subsequent standards are technically feasible. Descriptions of the technology packages that staff expects would be used to meet the proposed standards are included in Subsection 1.2.3 for MY 2024 to 2026 and in Subsection 1.2.4 for MY 2027 and subsequent. An analysis of diesel certification data that provides additional support for why the proposed standards are feasible is provided in Subsection 1.2.5.

1.2.1. Summary of Technical Feasibility Rationale for 2024 to 2026 MY Standards

The proposed 0.05 g/bhp-hr NOx emission standard on the FTP and RMC-SET and 0.2 g/bhp-hr NOx emission standard on the LLC shown for the 2024 to 2026 MYs are technically feasible and cost-effective based on the following:

- <u>Several potential strategies are commercially available today.</u>
    - CARB staff's assessment of the current state and anticipated near-term development of diesel engine technologies in 2015 identified many possible strategies and technologies (CARB, 2015b). An updated list of the strategies and technologies is discussed in Appendix I. Subsection 1.2.3 below describes the technology packages staff expects will be used.
    - The SwRI Low NOx Stage 1 testing program identified dozens of potential technology packages that could significantly reduce NOx emissions from today's diesel engines (Sharp et al., 2017b) with minimal impact on GHG emissions.
    - As described further in Subsection 1.2.3 below, CARB staff believes the most likely approach for meeting the proposed 2024 FTP and RMC-SET NOx standards would require a combination of strategies that provide

improved thermal management and improved SCR conversion efficiency during cold starts and at lower engines loads. Strategies such as engine calibrations that increase EGR rates, higher idle speeds, and intake or exhaust throttling, reduce engine warm-up time to better control cold start emissions. In addition, SCR system improvements such as a combination of larger SCR catalyst volume or improved catalyst substrates would likely be needed. Improvements in thermal management of the SCR system could also be achieved with improved packaging of the aftertreatment system and improved urea dosing strategies, such as heated urea dosing or other active ammonia producing systems.

- Demonstration program and modeling results support the feasibility of a 0.05 g/bhp-hr NOx standard. The SwRI Low NOx Stage 1 testing program demonstrated 0.09 g/bhp-hr FTP NOx emission levels (a 36 percent reduction) solely through engine calibration strategies that reduced cold start emissions and with a stock aftertreatment system. Further description of the SwRI Low NOx Stage 1 testing program is provided in Appendix I. In addition, modeling by the Manufacturers of Emission Controls Association (MECA) showed that improving engine calibration together with average-sized SCR catalysts, available in the market today, could reduce composite FTP NOx emission levels to 0.03 g/bhp-hr levels (MECA, 2019a). These modifications are currently commercially available and could be implemented on 2024 MY products.

- Current certification data show many manufacturers are certifying well below today's standards and nearly meeting the 0.05 g/bhp-hr standard already. As described further below in Subsection 1.2.5, currently there are certified diesel engines in the market with 0.06 g/bhp-hr NOx exhaust emission levels that also meet the 2024 and subsequent MY GHG CO2 emission standards.

- Staff's proposal would give manufacturers the option of certifying to 0.1 g/bhp-hr NOx as long as they certify all their engine families to that standard nationally. Based on the certification data cited in the previous bullet, meeting 0.1 g/bhp-hr NOx is clearly feasible today, as many manufacturers already are certifying below that level.

- Manufacturers could comply by pursuing hybrid or heavy-duty ZEV technologies. Starting with the 2022 MY, manufacturers would be allowed to generate NOx credits from heavy-duty ZEV sales in the California-only averaging, banking, and trading,(CA-ABT) program. The credits generated from heavy-duty ZEV sales in the CA-ABT program could be used to offset emissions from engines that have been certified to FELs above the applicable emissions standards. Manufacturers could also consider using existing diesel engine technology coupled with mild hybrid systems as a way to cut emissions with relatively few changes to today's engine products. As discussed later in Section A.9 of this chapter, the Proposed Amendments would provide a new path for certification for hybrid powertrains.

- Test data on current engines in low load operation, along with the known effectiveness of currently available minor hardware modifications, support the feasibility of a 0.20 g/bhp-hr LLC standard. As part of the ongoing research work at SwRI, LLC emissions testing was conducted on several heavy-duty engines that are currently being sold in the U.S. and European Union markets. The intent was to establish baseline LLC emission test profiles for current production engines without any hardware or software modifications. The tailpipe NOx emissions from current production engines on the LLC ranged from 0.34 to 1.5 g/bhp-hr (Sharp, 2019). The information from the SwRI emissions tests was also shared with MECA for further analysis. MECA subsequently used the LLC emissions test data to perform modeling to analyze the impacts of heated urea dosing on baseline production engine emissions performance. The modeling results showed that currently available emission controls, together with heated urea dosing, can achieve tailpipe NOx emissions down to 0.18 g/bhp-hr over the LLC (MECA 2019a). Given the benefits of the heated urea dosing system and the fact that it would require minimal hardware modifications to current engine and aftertreatment architecture, CARB staff believes that a 0.20 g/bhp-hr standard for the LLC is technically feasible and cost-effective for the 2024 MY timeframe.

CARB staff believes the proposed 10 g/hr NOx idle emissions standard shown in Table III-1 for the 2024 to 2026 MYs is feasible based on the following assessment. In Stage 2 of the SwRI Low NOx testing program, SwRI evaluated the emission reductions achievable by changing calibrations during idle (Sharp, 2020a). The LLC contains two long idle segments that can cool the aftertreatment system temperature on current products to the point where SCR control is no longer available. One way to impede this cooling is to increase the EGR rate and reduce exhaust flow during idling events. As shown in Table III-2, SwRI demonstrated that reducing exhaust flow at idle significantly reduces NOx emissions during idle.

Table III-6. Low NOx Calibration Idle Comparison

Calibration	Speed [rpm]	Torque [N-m]	Power [kW]	Exhaust Flow Rate [kg/hr]	Engine Out NO_X Mass Rate at Idle [g/hr]	CO_2 Mass Rate [kg/hr]	Fuel Flow Rate [kg/hr]
Baseline	550	0	0	105	26	327	1.02
Reduced exhaust flow (curb idle)	550	0	0	48	2.8	283	0.91
Reduced exhaust flow (3.5 kW load)	550	61	3.5	50	1.6	451	1.42

rpm – revolutions per minute; N-m – Newton-meter; kW – kilowatt; kg/hr – kilograms per hour; g/hr – grams per hour

As shown in Table III-6, at curb idle speeds (no load), reducing exhaust flow cut idle emissions on the MD13TC engine[38] by almost 90 percent (from 26 g/hr to 2.8 g/hr), at the same time fuel efficiency and CO2 emissions were improved. When SwRI added a 3.5 kW load, equivalent to heavy heavy-duty engine loads that would result from auxiliaries such as an alternator and brake air compressor, idle emissions were further reduced (to 1.6 g/hr). Acknowledging idle loads in the test cycle adds heat energy to the exhaust flow, which assists the aftertreatment in maintaining better emission control during sustained idle or low load operation, and makes the test cycle more representative of in-use vehicles and their operation.

CARB staff is not proposing to set the standard as low as the 1.6-2.8 g/hr idle rates that SwRI achieved, as described above. This is to leave a compliance margin and avoid potential issues such as fouling the EGR valve and impacts on DOC or DPF durability. CARB staff is proposing a 10 g/hr NOx idle emission standard for 2024, which is approximately four times the levels demonstrated by SwRI. Figure III-3 below shows idling certification data for 2019 model year engines certified to CARB's Clean Idle standards. As shown in Figure III-3, several 2019 model year engines already certify with idle emissions below 10 g/hr, so meeting a 10 g/hr level is clearly feasible.

CARB staff is proposing to remove the idling standard exemptions for buses, school buses, recreational vehicles, medium-duty vehicles, armored vehicles, and workover rigs because there are technologies and strategies that enable them to meet the proposed standards which are shown in Tables III-1 and III-4. Manufacturers would be able to meet the standards using EGR and air-fuel ratio controls. Other strategies for meeting the proposed standards would include raising the exhaust temperature to enable SCR operation using cylinder deactivation, mild hybrid systems, stop-start systems, or a combination of all of these strategies.

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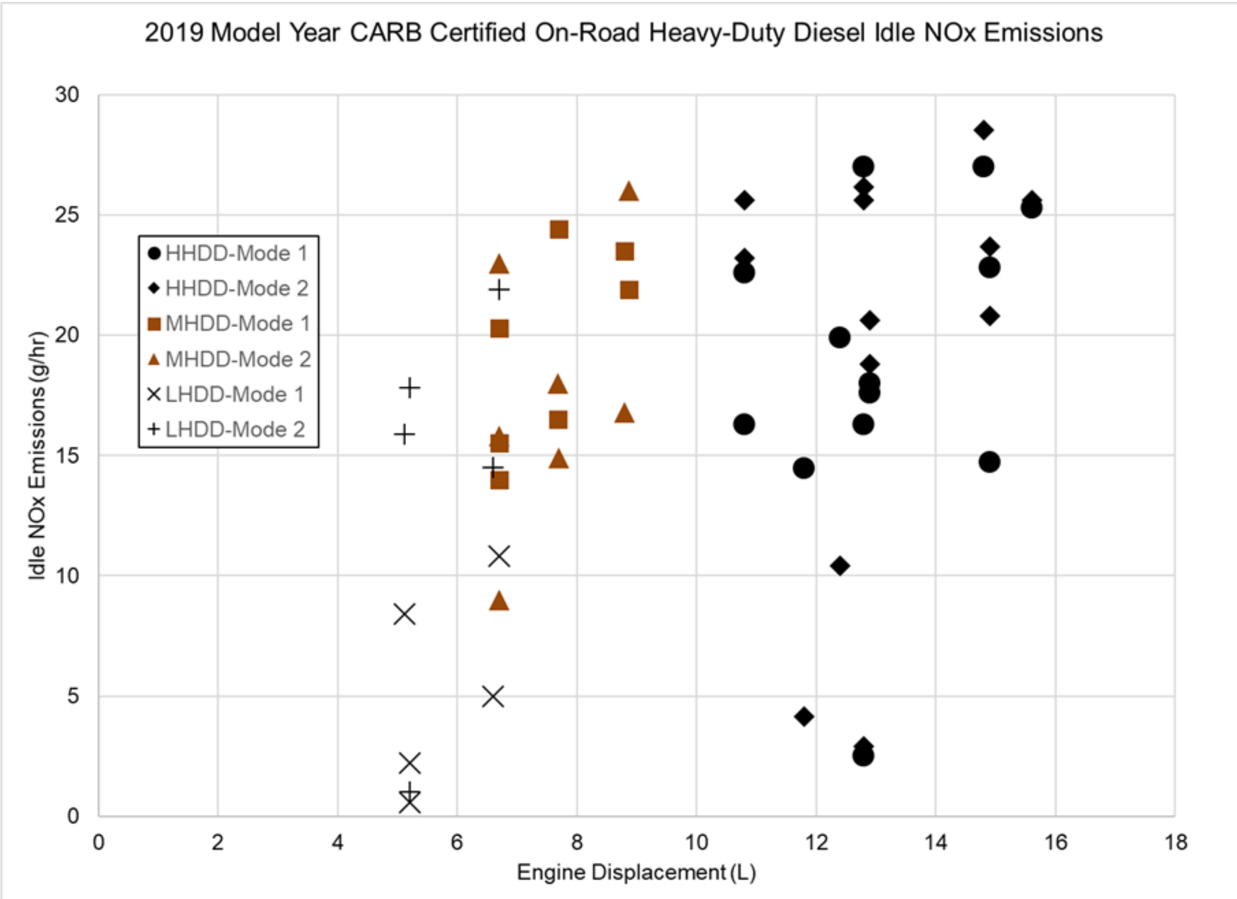
[38] The 2014 Volvo MD13TC engine was designed for use in a Class 8 Line Haul Tractor application. It has a nominal maximum power of 361 kW at 1477 rpm, a nominal peak torque of 3050 N-m at 1000 rpm (Sharp et al., 2017b).

Figure III-3. 2019 MY Idle Emission Levels for On-Road Heavy-Duty CARB Certified Clean Idle Engines

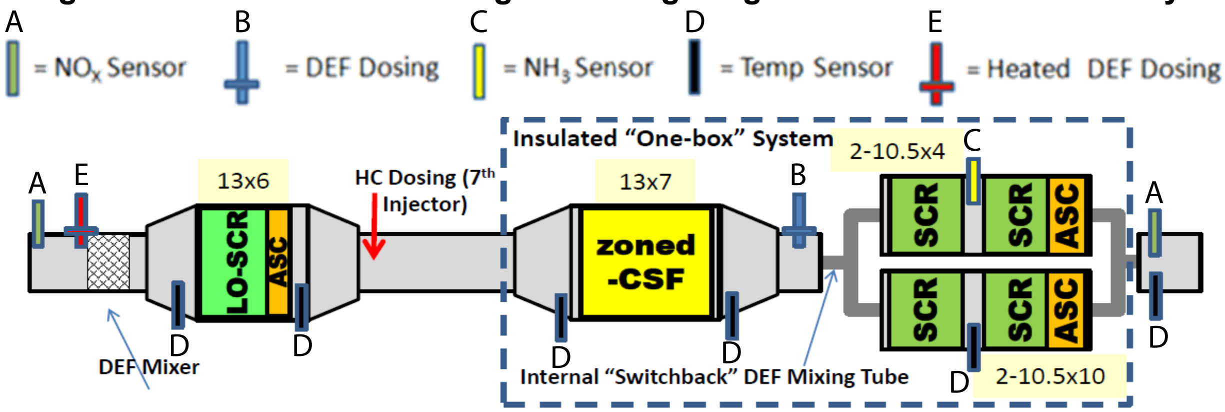


1.2.2. Summary of Technical Feasibility Rationale for 2027 and Subsequent Standards

CARB staff believes the 2027 NOx standards proposed are technologically feasible for the following reasons:

- Technologies exist today that are capable of meeting the proposed standards. Meeting the proposed 2027 FTP, RMC-SET, and idle NOx standards would be feasible using the same strategies identified for 2024 through 2026 above, including improved calibration, improved SCR conversion efficiency during cold starts and at lower engine loads, along with some additional engine hardware improvements such as cylinder deactivation and architectural changes to the aftertreatment system. The SwRI demonstration program identified many potential aftertreatment designs that could meet a 0.02 g/bhp-hr standard. The SwRI Low NOx Stage 3 testing program final aftertreatment system is shown below in Figure III-4. The technology packages staff believes manufacturers would use to meet the proposed 2027 standards are described in Subsection 1.2.4 below.

Figure III-4. SwRI Low NOx Stage 3 Testing Program Final Aftertreatment System



- <u>Demonstration program results and related work by manufacturers support the feasibility of a 0.020 g/bhp-hr NOx standard</u>.
    - SwRI Low NOx Stage 3 testing program results are shown in Figure III-5 and described in more detail in Appendix I. The SwRI Low NOx Stage 3 testing program subjected aftertreatment to an accelerated thermal and chemical aging protocol equivalent to the current useful life of 435,000 miles. Because the Proposed Amendments include lengthened useful life, CARB staff determined appropriate emissions standards at the proposed lengthened useful lives by extrapolating the SwRI test results, as described more fully in Appendix I. CARB staff also adjusted the proposed standards to account for infrequent DPF regeneration and to add a compliance margin.
    - Substantial work by OEMs, suppliers and researchers has examined a range of low NOx technologies for reducing NOx by about 90 percent from today's levels and their implementation in the context of the Phase 2 GHG standards. Overviews of GHG and NOx issues and approaches include those contributed by Corning (Joshi, 2019), FCB Research and Consulting (Barbosa, 2019), and Michigan Technological University (Chundru et al., 2020). Recent technical studies have also explored individual technologies such as various methods of introducing externally supplied exhaust heat (Continental, 2015), Miller cycle valve timings (Guan et al., 2019), electrified turbochargers (Wu et al., 2019), and catalyst shapes for tight packaging (Continental, 2019).
    - FEV has looked at how a high EGR rate engine strategy could pair with waste heat recovery to meet both GHG and NOx targets (Jeihouni et al., 2016). They have also examined variable compression ratio, downspeeding, downsizing, cylinder deactivation, and turbocompounding in combination with a wide variety of advanced aftertreatment configurations. They concluded "with appropriate selection of engine and [single dosing] aftertreatment technology packages, the 2027 Phase 2 GHG emission standards and the proposed 2027 ultra-low NOx [0.02

g/bhp-hr] can be achieved simultaneously" (Dahodwala et al., 2018). FEV has also published results for cold start and continuous low load performance of a 2.0L platform using dual dosing SCR coated on filter (SCRF)/SCR approaches with and without passive NOx adsorbers in combination with a range of engine technology and active heating options that support the feasibility of the proposed standards (Deppenkemper et al., 2019).

- AVL Powertrain Engineering published an assessment of impacts of low NOx and Phase 2 GHG on base powertrain configurations. They stated in 2017, "…0.02 or 0.05 g/bhp-hr is expected." They examined various engine and powertrain efficiency technologies including downspeeding, variable valve actuation, low and high pressure EGR, friction reduction, high peak firing pressure, light weight structure, high efficiency charging, waste heat recovery, mild hybridization, and electrified engine and vehicle accessories to meet these constraints. They concluded, "Although, this reduction seemed unrealistic from a first point of view, it has been shown in this paper, that technologies to achieve such an improvement are already developed. Still, OEMs need to find their specific technology road maps to achieve the legislation steps, and need to develop the said technologies to series production. Additionally, with the implementation of these technologies, the vehicle will have a benefit by an improvement in the [total cost of ownership]" (Walter et al., 2017).
- Cummins presented a technology outlook for heavy-duty engines that acknowledges the widespread regulatory interest in 90 percent lower NOx standards for on-road and "…a possibility for construction and agriculture sectors as well." They anticipate, in the context of optional low NOx gaseous-fueled engines, that "Advanced gasoline engines will use similar technologies to reach 0.02 g/bhp-hr." For diesel engines their outlook includes catalyst formulation, improved ammonia delivery at low temperatures, better ammonia management controls and sensors, active thermal management, NOx storage catalysts, aftertreatment design for fast warmup, engine technologies for fast warmup including bypasses, high idle and passive thermal design, and engine technologies for lower engine-out NOx options including various EGR and advanced combustion strategies. They also discussed integration opportunities at the engine/powertrain level (Eckerle et al., 2017).
- TNO Automotive examined the interplay of low NOx and Phase 2 GHG constraints for a number of valvetrain, thermal management, dual dosing split SCR and waste heat recovery technology packages and found, "Main conclusions from simulation study presented in this paper regarding the advantages and disadvantages of the different aftertreatment system configurations are in line with the observations from the extensive measurement program commissioned by CARB" (Seykens, et al., 2018). They further state that "2-10% fuel consumption benefit is available across the full low load operating range." The emission reductions below 0.05 g/bhp-hr FTP composite level they present did not rely on engine

calibration optimization, which would be an expected part of any commercialization effort that would additionally improve performance.

- IAV examined technology options for heavy-duty off-road diesel engines including EGR, variable valve timing, electrified turbochargers, engine firing pressure, and SCRF single dosing, and evaluating impacts on packaging. They demonstrated NOx reduction improvements that can be made without resorting to dual dosing split SCR systems and active exhaust heating strategies (Rauch et al., 2018).
- Tenneco and IAV examined various locations for close-coupled SCR in a dual dosing split SCR configuration and concluded, “Taken together, these simulations indicate that the ccSCR/LoSCR concept has the potential to meet the cold-start challenge of the proposed CARB low-NOx standard” (Harris et al., 2019). They have provided modeling for the benefits of air gap manifolds, various bypasses and variable valve actuation strategies (Kovacs et al., 2019). In addition, Tenneco modeled interplay among engine-based strategies, passive exhaust thermal management strategies and active exhaust thermal management options for a conventional DOC/DPF/SCR system. They note that even with an aggressive fuel fired heater, there is need for engine calibration assistance to limit NOx during the initial cold start warmup. They also highlight that control of the aftertreatment ammonia storage condition at shutdown can greatly reduce technology demands required to control cold start NOx, which presents another engine/aftertreatment integration opportunity (Harris & Gardner, 2019).
- Navistar stated their “expectation is for the EPA to continue to impose stringent NOx emissions decreasing allowable concentrations to ultra-low levels (≤0.02 g/bhp-hr),” which motivated their exploration of rapid simulation techniques for assessing the many options for meeting such standards. They propose a method using a dual dosing split SCR system returning a tailpipe FTP composite below 0.015 g/bhp-hr to meet such standards (Singh et al., 2019).
- Bosch has reported 0.023 g/kW-hr NOx FTP results, which is nearly low-emitting enough to meet the proposed 2027 standard, on an engine with calibration improvements and aftertreatment technology similar to what SwRI is demonstrating but without cylinder deactivation (Freitag, 2019). Bosch used a close-coupled light-off SCR.
- Navistar demonstrated a 0.04 g/bhp-hr composite NOx FTP on a 2019 model year 12.4-liter “stock” A26 Navistar diesel engine using engine calibration and dual SCR system with a close-coupled light-off SCR. The system showed NOx conversion efficiencies of about 96.9 percent on the cold FTP and 99.7 percent on the hot FTP (Adelman et al., 2020).
- Commercialized versions of dual dosing split SCR systems exist in the market today and at opposite ends of the displacement and unit volume per year extremes. Deutz employs a dual dosing series SCR/SCR system on their 12L/16L CARB and U.S. EPA off-road engine family to bring a Tier 3 product in Tier 4 compliance (Deutz, 2020). With the onset and

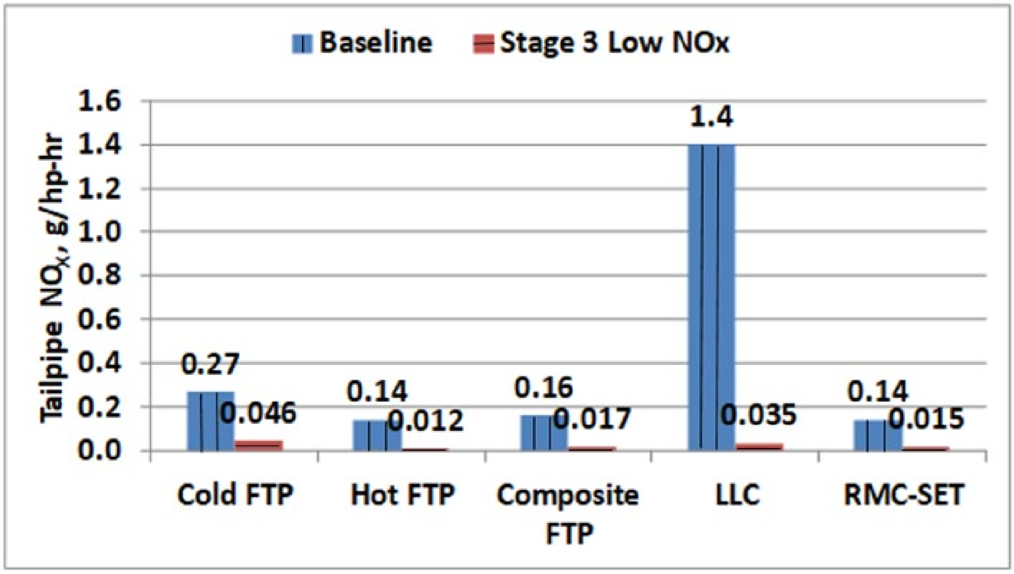
subsequent tightening of Real Driving Emissions regulations in Europe and related markets, Volkswagen has announced a close-coupled SCRF/underbody SCR dual dosing system for their mass market 2L diesel engine with plans to extend the strategy to their 3L diesel engine as well (VW, 2019).

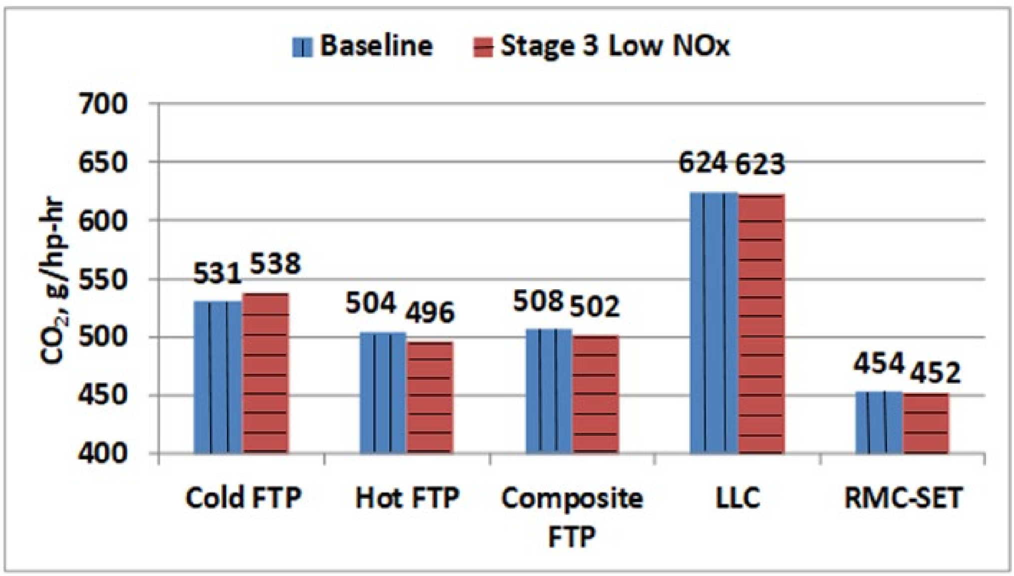
- Hino Motors has experimentally examined the significant benefits of heated DEF dosing to improve SCR performance by decoupling ammonia delivery from exhaust temperature. Their simple implementation consisting of 420 watts of glowplug-heated pre-chamber receiving the spray from a typical DEF injector enabled 60 percent NOx conversion efficiency at 160°C, where normally the conversion efficiency would be essentially zero (Okada et al., 2019).
- Other low power approaches to heated DEF dosing have been described, including pre-treatment of the DEF solution prior to conventional injection (Wilson & Hargrave, 2018) and a “biomimetic effervescent injector” approach (Larsson et al., 2019). Researchers had success avoiding deposits and aiding evaporation, atomization and the decomposition of urea to ammonia across much wider exhaust temperature ranges, using only limited amounts of waste heat or electrical energy.
- Continental Automotive is investigating applying heated dosing to the full exhaust flow using injection onto a high power electrically heated catalyst substrate using an assembly of existing proven injection and heating components. They offer this as a potential approach for light-duty and on- and off-road heavy-duty applications. This approach would provide a way to warm catalysts faster during critical situations within an overall duty-cycle (Continental Automotive, 2020).
- Cummins and Watlow have shown that a 24-volt exhaust heater with controls can enable more efficient engine operation sooner and maintenance of SCR efficiency at low loads (Culbertson et al., 2018). This technology provides an alternative to fuel-fired exhaust heating.
- Researchers are also investigating strategies combining full flow heated dosing and electrically heated catalyst concepts with 48-volt vehicle power architectures that also enable mild hybridization, electrified engine accessories and vehicle systems, stop/start, electric APUs, electric power take-off and zero-emission creep modes. These technology packages have the potential to reduce total cost of ownership while enabling active exhaust thermal management when it is critically needed for NOx control (Dorobantu, 2019).
- Cylinder deactivation, which is a common technology in light-duty and gasoline applications, is being actively marketed for use in heavy-duty diesel engines as a way to provide both active exhaust thermal management and fuel savings. Two suppliers applying their technology to different brand heavy-duty engines have reported experimental test data showing 86 percent NOx reductions in low load applications while reducing fuel consumption over those same duty cycles by 3 to 10 percent (Eaton, 2019; Jacobs, 2020). Additional study of the thermal management

and fuel economy benefits (Neely et al., 2019; Ramesh et al., 2017; Gehm, 2018) include its use to minimize active regenerations (Lu et al., 2015), the practical implementation implications for noise, vibration and harshness (Archer & McCarthy, 2018), first fire readiness after deactivation (Halbe et al., 2017), torque response in dynamic operation (Gosala et al., 2017), use at idle (Vos et al., 2019), and low load (Allen et al., 2019).

- Advanced engine architectures offer promise for meeting the proposed 2027 NOx standards with significantly lower GHG than today's engines. CARB is sponsoring demonstration of a promising advanced engine architecture, the Achates multi-cylinder opposed-piston engine, which is aimed at achieving low NOx and GHG emissions with engine dynamometer testing and Class 8 vehicle integrated testing (California Climate Investments, 2020; Patil et al., 2018; Abani et al., 2017). Testing has also been conducted to validate lubricant control and durability (Chown, et al., 2019) with further validation work ongoing. This architecture controls exhaust flows and temperatures that can potentially enable smaller catalyst sizes as well (Patil et al., 2019). The U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-E) is also sponsoring this opposed piston engine technology for smaller engine applications in light commercial vehicles and pickup trucks (Fromm & Redon, 2017; Salvi et al., 2018) with a drivable demonstrator in an F150 pickup chassis (Achates, 2018). ARPA-E and Nissan are sponsoring plug-in electric vehicle range extender concepts enabled by the low vibration characteristics of opposed pistons leveraged to maximize all swept volume into a single large cylinder (PR Newswire, 2019). Cummins is running a 1,000-horsepower opposed piston engine in a $47.4 million Army design-for-production program (Cummins, 2019; Green Car Congress, 2017). The Army plans call for potential production in fiscal year 2023 (National Defense, 2020). For Class 8 applications, the potential production cost savings include elimination of mechanical systems such as valvetrains and complex parts like cylinder heads. The analysis shows a production cost savings of 6 to 11 percent for engine and aftertreatment systems with lower GHG emissions and 0.02 g/bhp-hr NOx compared to equivalent MY 2017 diesel products meeting today's 0.2 g/bhp-hr standard (Kessler, 2020).

Figure III-5. Comparison of FTP, RMC-SET and LLC NOx and GHG Emissions - Baseline versus Advanced Engine and Aftertreatment System





- <u>Simulation modeling supports the feasibility of a 0.020 g/bhp-hr NOx standard.</u> MECA's modeling showed that 0.014 to 0.016 g/bhp-hr NOx on the FTP is feasible with engine calibration and hardware changes such as cylinder deactivation and advanced aftertreatment systems such as dual SCR systems with close-coupled light-off SCR and dual dosing, and exhaust system insulation. These results would also allow a compliance margin of about 20 percent relative to a 0.02 g/bhp-hr FTP NOx standard (MECA, 2020).

- SwRI Stage 3 Low NOx testing on thermally aged development parts demonstrated 0.025 g/bhp-hr NOx on the LLC, which is significantly below the proposed standard of 0.050 g/bhp-hr. Furthermore, testing on chemically and thermally aged parts to two thirds of the useful life of 435,000 miles (290,000 miles or 667 hours) showed 0.040 g/bhp-hr NOx on the LLC, supporting the feasibility of the proposed standard.

- Manufacturers could comply by pursuing heavy-duty ZEV technologies. Starting with the 2022 MY, manufacturers would be allowed to generate NOx credits from heavy-duty ZEV sales in the CA-ABT program. The credits generated from heavy-duty ZEV sales in the CA-ABT program could be used to offset emissions from engines that certify to FELs above the applicable emission standards.

The proposed idling NOx standard of 5 g/hr could be achieved using engine calibration strategies and the same engine and aftertreatment hardware systems used to meet the LLC standards. Since the LLC also consists of long idle segments, calibration to optimize idling emissions to meet the proposed idling standard could be incorporated together with the calibration work to optimize NOx emissions under the LLC.

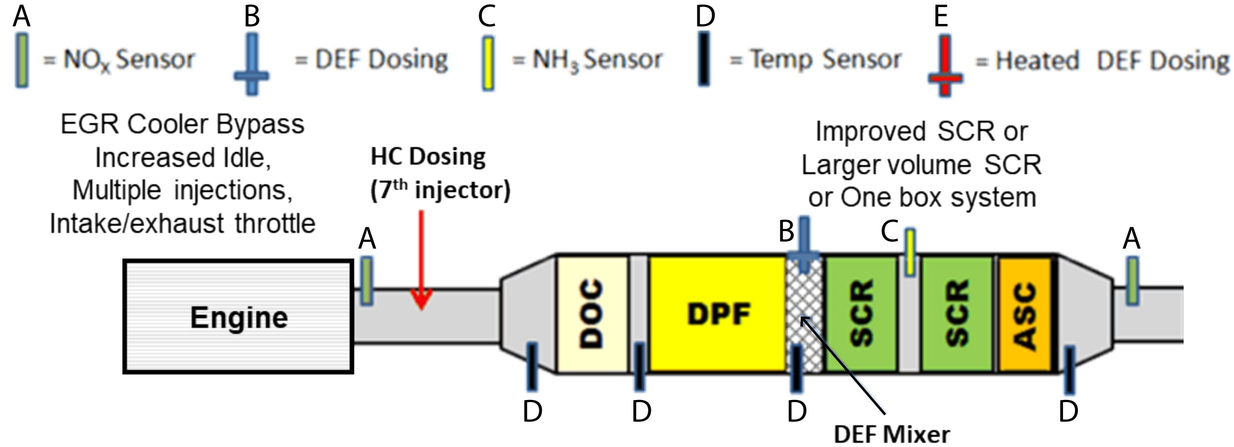
1.2.3. Technology Packages for the Proposed 2024 to 2026 MY NOx Standards

CARB staff believes a NOx standard of 0.05 g/bhp-hr on the FTP and the RMC-SET and a 0.20 g/bhp-hr on the LLC are feasible for MY 2024 through 2026 engines without significant changes to the engine and aftertreatment architecture. Several technology packages would enable meeting the 2024 NOx standards.

1) Meeting the proposed 2024 MY requirements will be feasible using engine calibration strategies and improved catalysts with larger volume than current generation catalysts or thin-walled high cell density catalyst substrates to provide rapid warm-up of the exhaust and reduce cold start emissions and EGR cooler bypass to keep the exhaust warm. Additionally, the DPF, SCR, and ASC can be packaged in a “one box system” to insulate the aftertreatment system and keep it warm over longer periods of time.

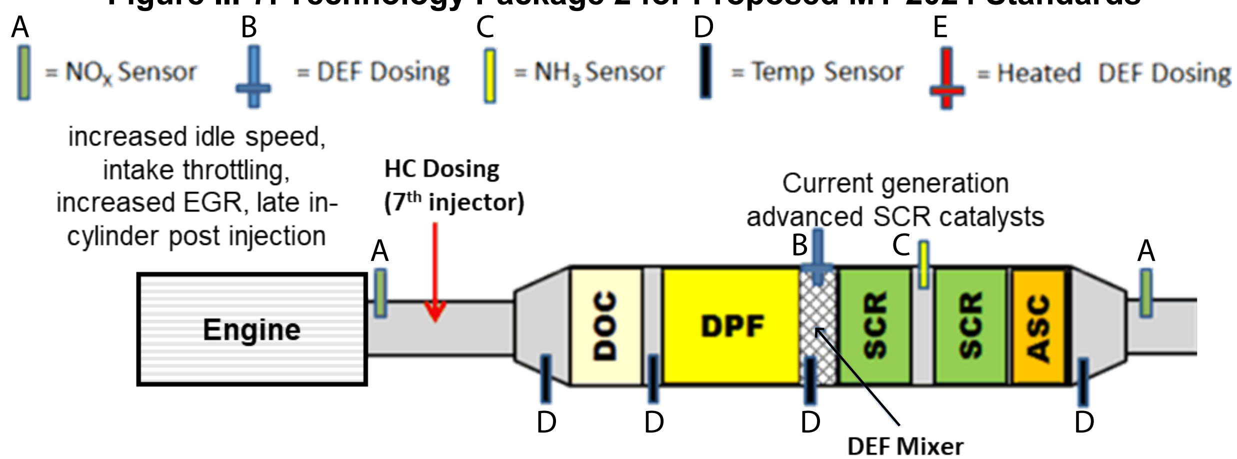
   Engine calibration strategies that may be used for rapid exhaust warm-up and reduced engine-out NOx may include increased idle speed, intake and exhaust throttling, post injection, and increased EGR rates. These strategies have been shown to accelerate catalyst light-off as well as reduce engine-out NOx emissions during cold starts (see Figure III-6).

Figure III-6. Technology Package 1 for Proposed MY 2024 Standards



2) As mentioned earlier, the SwRI Stage 1 Low NOx testing program demonstrated 0.09 g/bhp-hr FTP NOx emission levels (a 36 percent reduction) solely through engine calibration strategies that included increased idle speed, intake throttling, EGR, and late in-cylinder post injection (this calibration was referred to as CC1 by SwRI) (Sharp et al., 2017a). In addition, MECA, in its modeling study, used as input the engine-out emissions characteristics from the CC1 calibrated SwRI Stage 1 Low NOx engine (without EGR cooler bypass) together with the use of current generation SCR catalyst aged to full useful life of 435,000 miles to generate tailpipe NOx emissions of 0.03 g/bhp-hr on the FTP (MECA, 2019a) (see Figure III-7).

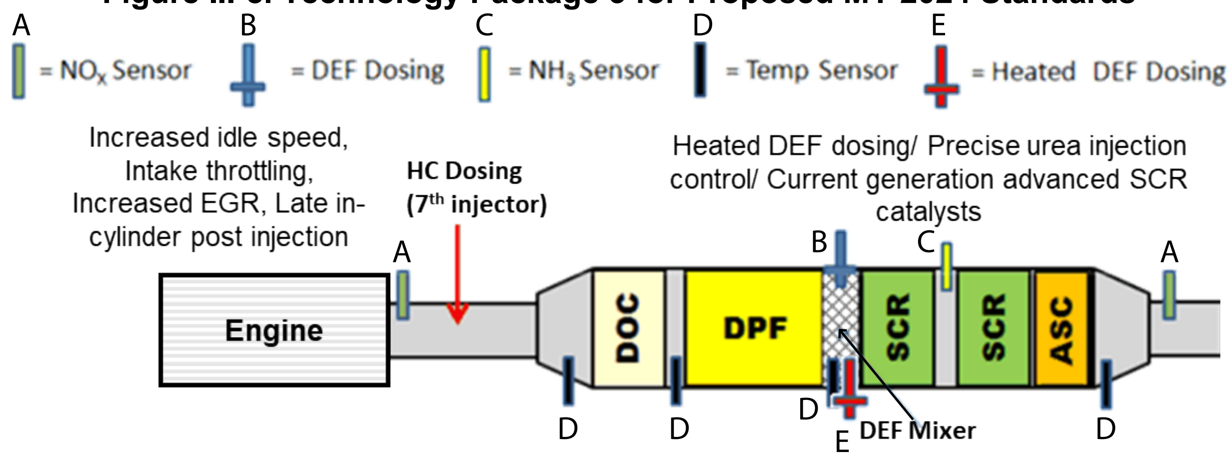
Figure III-7. Technology Package 2 for Proposed MY 2024 Standards



3) The above described technology packages are not the only options available for manufacturers to meet the MY 2024 to 2026 standards. Manufacturers could use a mix of off-the-shelf technologies to meet the proposed standards. For example, manufacturers could use heated dosing (which can replace EGR cooler bypass) to enable injection of urea at lower exhaust temperatures (150°C to 170°C) (MECA, 2019a), well below current SCR operating temperature without heated dosing. This may be combined with precise DEF injection controls as well as ammonia storage

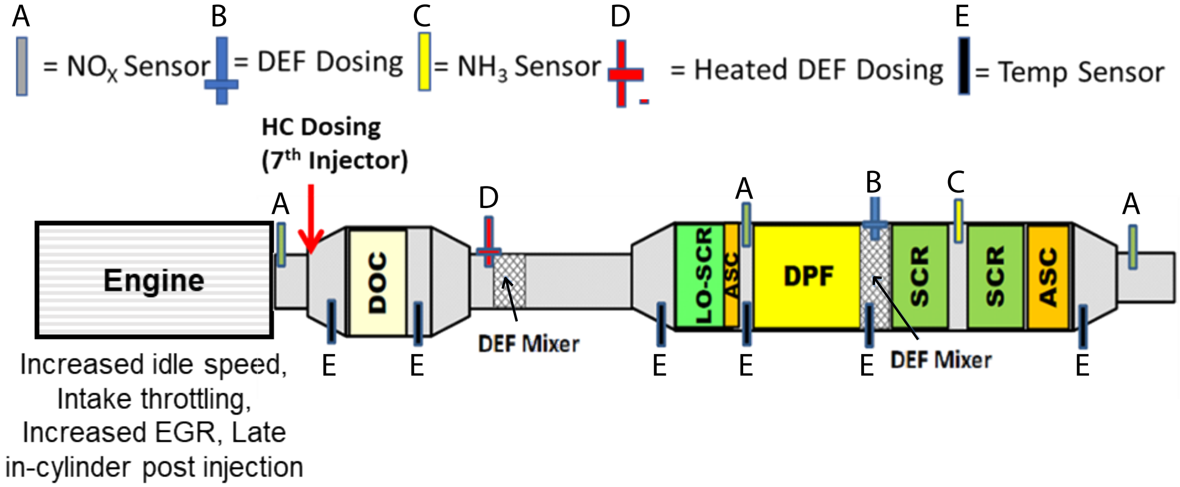
management of the SCR to meet the proposed FTP, RMC-SET and LLC standards. For example, in MECA's modeling study, they also evaluated the feasibility level of standards for the LLC. In addition to using as input engine-out emissions characteristics from the CC1 calibrated SwRI Stage 1 Low NOx engine, inputs to the model also included the use of improved, yet commercially available, DPF, SCR, ASC, and heated dosing technologies (again, no EGR cooler bypass) to generate tailpipe NOx emissions of 0.18 g/bhp-hr on the LLC (MECA, 2019a) (see Figure III-8).

Figure III-8. Technology Package 3 for Proposed MY 2024 Standards



4) Another possible package configuration is to place an additional SCR upstream of the DPF to take advantage of the hot exhaust coming out of the DOC. This configuration can be packaged as a compact, one box system. This configuration, together with the CC1 calibration and/or heated dosing, could meet the proposed FTP, RMC-SET, and LLC standards (see Figure III-9), based on the demonstrated performance of the CC1 calibration and known efficacy of heated dosing. This configuration has packaging advantages over the close-coupled light-off SCR approaches because it requires less space. Dual SCR-dual dosing aftertreatment technology is currently being introduced in passenger car applications, which illustrates the near-term feasibility of this technology (Dieselnet, 2020b). In addition, major diesel engine technology and control supplier, Bosch, has reported publicly on applying dual dosing SCR systems to heavy-duty applications (Freitag, 2019; Dieselnet, 2020a).

Figure III-9. Technology Package 4 For Proposed MY 2024 Standards



5) *Otto-cycle heavy-duty engines*: a number of natural gas- and propane-fueled Otto-cycle engines have been certified to the optional low NOx standards of 0.02 g/bhp-hr. These engines are currently using improved TWCs and better air-fuel ratio controls to meet the standards. Thus, CARB staff believes Otto-cycle engines will easily meet the proposed standards.

CARB staff believes that manufacturers could meet the proposed 2024 MY NOx standards using the above mentioned strategies without any significant impacts to GHG emissions. It is possible that a manufacturer may find it more difficult to comply with the 2024 GHG standards because of the Proposed Amendments. In that case, the manufacturer may need to add additional GHG technologies to bring its engine families into compliance with the 2024 Phase 2 GHG standards. As described more fully in Chapter IX, CARB staff has considered costs for the additional technology that a manufacturer may potentially incur to mitigate any GHG penalties for MYs 2024 to 2026.

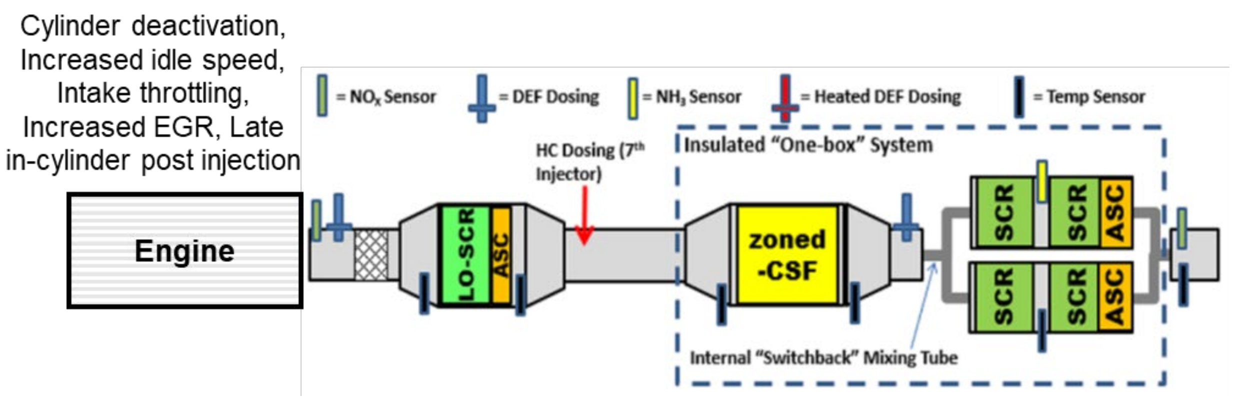
1.2.4. Technology Packages for the Proposed 2027 and Subsequent MY NOx Standards

CARB staff believes a NOx standard of 0.020 g/bhp-hr on the FTP and RMC-SET and a 0.050 g/bhp-hr standard on the LLC are feasible for 2027 and subsequent MY engines. Specifically, to meet the proposed 2027 MY standards manufacturers would need to employ engine software and hardware technologies that accelerate catalyst light-off and keep the aftertreatment system warm under sustained low load operations as well as also remain neutral or provide GHG emission reductions. As mentioned above, the SwRI Stage 3 Low NOx testing program is currently demonstrating a technology package with a target emission rate of 0.020 g/bhp-hr NOx on the FTP and RMC-SET and 0.050- g/bhp-hr NOx on the LLC. The system being demonstrated consists of:

i. Engine calibration strategies such as increased idle, increased EGR rate, and multiple fuel injection to accelerate catalyst light-off;

ii. Cylinder deactivation for rapid warm-up and to keep the exhaust warm under sustained low temperature operation
iii. Advanced aftertreatment system that includes dual SCR catalysts with dual dosing with the upstream light-off SCR catalyst close-coupled to the engine upstream of the DOC/zoned CSF (Shown in Figure III-10).

Figure III-10. Technology Package For Proposed MY 2027 and Subsequent



Testing conducted on hydrothermally aged development parts achieved significant emissions reductions resulting in 0.017 g/bhp-hr NOx on the FTP, 0.015 g/bhp-hr NOx on the RMC-SET, and 0.025 g/bhp-hr NOx on the LLC. The system is also being aged thermally and chemically aged to full useful life on a 2017 Cummins X15 engine to simulate real-world mileage accumulation. To date the parts have accumulated 667 hours or 290,000 miles (2/3 of full useful life, or 435,000 miles). Testing on these parts achieved NOx emission levels of 0.022 g/bhp-hr on the FTP, 0.019 g/bhp-hr on the RMC-SET and 0.040 g/bhp-hr NOx on the LLC (Sharp, 2020b).

1.2.5. Current Certified Diesel-Fueled Engine Assessment

Baseline certification emission levels for all CARB certified 2019 MY heavy-duty engines support the feasibility of the proposed 2024 to 2026 standards (CARB, 2019j). CARB staff reviewed the Executive Orders for all diesel-cycle and Otto-cycle heavy-duty engines to determine what type of emission levels are feasible with current technologies.

Figure III-11 to III-13 show the baseline 2019 MY FTP NOx certification levels versus the CO2 family certification levels (CO2-FCL) for LHHD, MHHD, and HHDD engines, respectively. Each blue dot represents an engine family. The FTP NOx certification levels represent the deteriorated emission levels at the end of useful life and are adjusted for infrequent regeneration adjustment factors. The CO2-FCL is a CO2 emission level declared by the manufacturer that is at or above emission test results for all emission-data engines. The CO2-FCL serves as the emission standard for the engine family with respect to certification testing.

Figure III-11. 2019 MY CARB Certified On-Road Light Heavy-Duty Diesel Certification Data

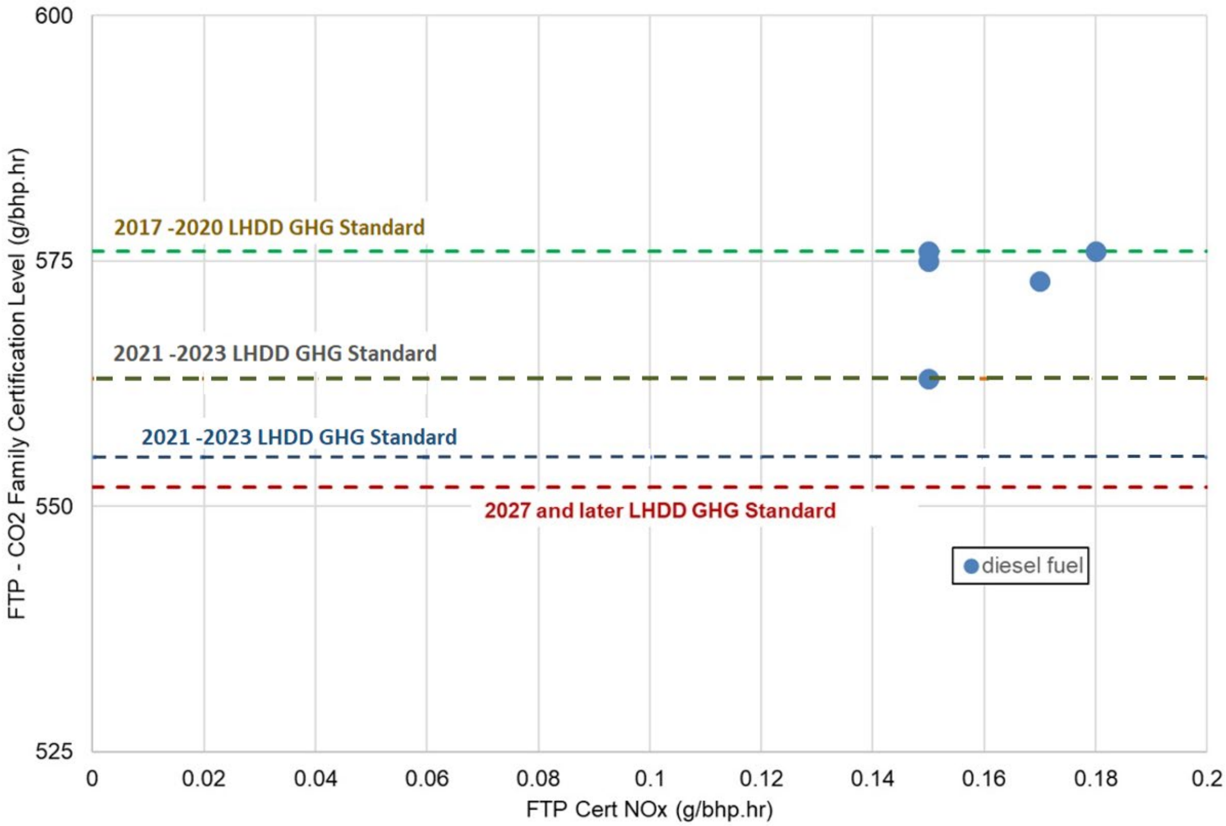


Figure III-12. 2019 MY CARB Certified On-Road Medium Heavy-Duty Diesel-Fueled Engines Certification Data

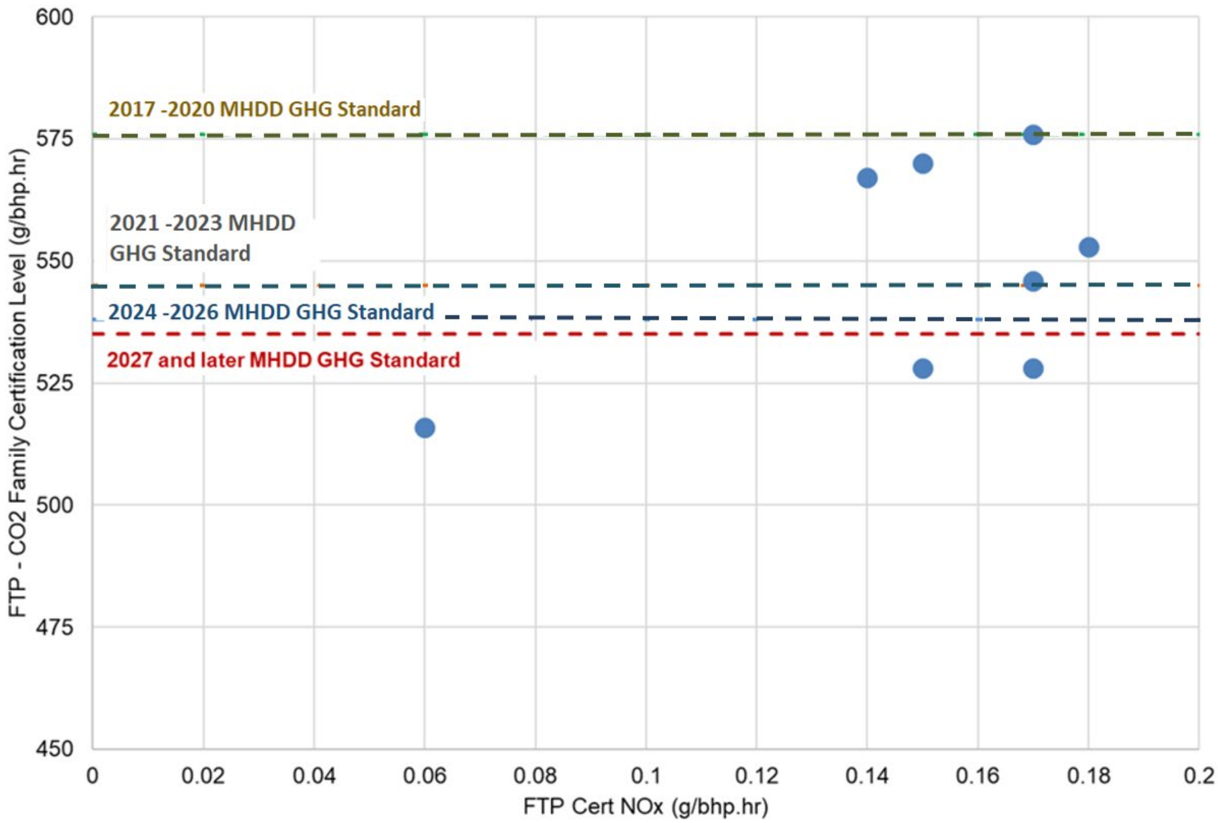
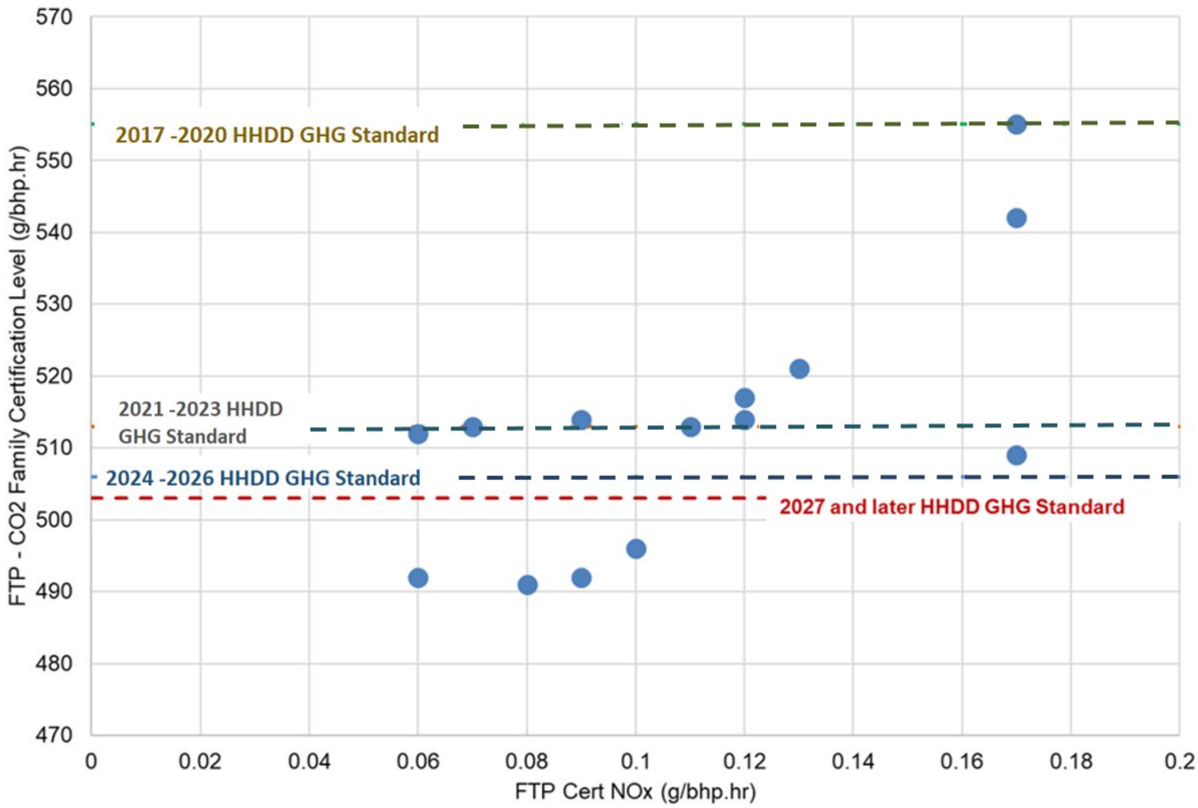


Figure III-13. 2019 MY CARB Certified On-Road Heavy Heavy-Duty Diesel-Fueled Engines Certification Data



It should be noted that engine and aftertreatment system architecture for medium-duty diesel, LHDD, MHDD, and HHDD engines are essentially identical. That is, all diesel classes use a combination of DOC, DPF, and SCR aftertreatment systems to reduce the exhaust emission levels. Thus, in CARB staff's view, it is unexpected that the FTP NOx levels as shown in Figure III-11 for LHDD engines tend to be somewhat higher than what is observed for HHDD engines. CARB staff does not have sufficient data to accurately explain the reasons for this trend. One possible explanation is that products in the LHDD class have a shorter useful life (110,000 miles) versus 435,000 miles for HHDD. Therefore, manufacturers may be using smaller and less expensive aftertreatment components that have shorter useful life and possibly lower catalyst conversion efficiencies. Nevertheless, CARB staff believes that given the same engine and aftertreatment system architecture, LHDDs can be designed to achieve the same type of NOx emission levels as their counterparts in the HHDD sector. In addition, as Figure III-3 above shows, the CO2 performance of all current LHDDs is not adequate to meet the 2024 CO2 standards, which indicates they are in need of an upgrade regardless of NOx standard changes. The engineering for this planned upgrade to meet 2024 GHG standards could and should be leveraged to simultaneously implement needed NOx performance improvements.

As Figure III-11 and III-12 indicate, currently there are certified products in the market capable of achieving 0.06 g/bhp-hr NOx exhaust emission levels while also meeting the 2024 and subsequent MY GHG CO2 emission standards. Therefore, reaching a 0.06 g/bhp-hr exhaust NOx emissions level is certainly currently feasible at no additional cost to manufacturers. Because manufacturers are certifying so close to 0.05 g/bhp-hr NOx already, the certification data support the feasibility of manufacturers meeting a 0.05 g/bhp-hr NOx standard in 2024 with minor technology and calibration improvements.

2. New PM Standards and Technology Packages for 2024 and Subsequent MY Heavy-Duty Engines

The current PM standard for heavy-duty engines is 0.01 g/bhp-hr on the FTP and RMC-SET test cycles. Certification data indicate most engines have PM certification levels well below the current 0.01 g/bhp-hr PM standard and certify close to 0.001 g/bhp-hr. However, over the last few MYs some engine families have certified at PM emission levels much higher, about 0.005 g/bhp-hr (CARB, 2020b). CARB staff suspects that the reason for the increase in PM emission levels was due to engine manufacturers choosing to use less efficient (more porous) DPFs to reduce engine backpressure and improve fuel economy but resulting in higher PM emission levels, although still compliant with the current PM standard. Thus, to prevent backsliding and maintain current robust PM emission control performance at 0.001 g/bhp-hr levels, the Proposed Amendments would lower the PM standard to 0.005 g/bhp-hr starting with the 2024 and subsequent MY engines. The CARB sponsored low NOx engine demonstration has monitored for any PM standard compliance implications of the strategies employed to simultaneously meet NOx and GHG targets and none were found (Khalek, 2018). This anti-backsliding change is feasible with existing DPF aftertreatment systems and would ensure that the best DPF technologies continue to be utilized for the maximum control of toxic diesel PM emissions.

3. Heavy-Duty In-Use Test Procedure Amendments

As discussed above in Chapter I, Section B.3 and Chapter II, Section C.3, the purpose of the manufacturer conducted HDIUT program and CARB’s HDIUC program is to ensure that emissions from diesel engines in vehicles greater than 8,500 pounds GVWR are controlled under real-world conditions, i.e., during normal vehicle operation in the field, throughout their useful life. Under the HDIUT program, CARB and U.S. EPA jointly select engine families to be tested and manufacturers recruit fleets and conduct the testing. Under the companion HDIUC program, CARB and U.S. EPA can conduct independent testing of any engine family. These programs utilize PEMS for measuring emissions and are currently based on the NTE test procedure.

As described above in Chapter II, Section C.3, assessments of the NTE testing protocol show it to be deficient in that it does not evaluate the vast majority of operating conditions (Bartolome et al., 2018; Posada et al., 2019). The reason for this is that the procedure incorporates a large number of test point exclusions, whereby test points that do not meet a strict set of requirements are dropped from consideration. For example, operations under certain temperatures or under certain loads are completely excluded. These limitations and inadequacies have compelled CARB staff to propose a new test procedure based on MAWs for 2024 and subsequent MY engines, as well as clarifications to the criteria for engine family pass or fail compliance determination consistent with the new test procedure.

Subsection 3.1 below describes Proposed Amendments for MY 2024 to 2026. Subsection 3.2 describes Proposed Amendments for MY 2027 and subsequent. Subsection 3.3 describes amendments that would add an additional method to verify compliance with the proposed idling emission standards to today's HDIUC testing program. Finally, Subsection 3.4 describes the amendments that would require OBD/REAL data to be collected during the HDIUT.

3.1. 2024 to 2026 HDIUT Program Amendments

CARB staff has been evaluating the best parts of the U.S. and European in-use testing programs to develop a significantly more effective in-use test procedure that evaluates all types of in-use operations to better control real-world emissions. CARB staff has been working with technical representatives of OEMs and U.S. EPA staff in the development of a new moving-average window (MAW) approach that evaluates almost all real-world operation for both diesel and Otto-cycle engines. As described further below, the three bin MAW (3B-MAW) approach for diesel engines distinguishes modes of operation and categorizes them into three separate operational bins, one for idle operation, one for low load operation (similar to LLC), and one for medium and high load operation (similar to FTP/RMC-SET). The 3B-MAW method allows idle and low load emissions to be compared to an appropriate emissions standard instead of to an FTP-RMC-SET-based emission standard intended for operations where it is easier to achieve high efficiency NOx control. Having three bins makes it reasonable to expect compliance for vehicles in any type of operation. Without such bins, a vehicle operated predominantly in idling or low-load conditions would likely fail HDIUT or HDIUC. Thus, the structure of the 3B-MAW approach essentially provides "guard rails" protecting manufacturers from inappropriately failing if such vehicles are selected for HDIUT.

The heavy-duty Otto-cycle engines are currently not subject to PEMS-based HDIUT or HDIUC testing, but they would become subject to HDIUC testing starting with 2024 MY engines. However, heavy-duty Otto-cycle engines are not required to certify to idle, LLC, or RMC-SET standards, and thus would not be evaluated using the 3B-MAW approach. Instead, heavy-duty Otto-cycle engines would be evaluated based on the FTP cycle standards alone.

The Proposed Amendments would replace the current NTE-based test procedures with the MAW test procedures for the manufacturer-run HDIUT program and for CARB's HDIUC testing beginning with 2024 and subsequent MY engines, with some modifications between 2026 and 2027 and subsequent MY engines, as described below.

Based on CARB staff's review of previous manufacturer test data submissions for the HDIUT program, it appears that some manufacturers have selected routes and times for testing specifically to ensure passing results, rather than to provide a rigorous evaluation of real-world emissions. For example, of the tests submitted, 24 percent did not have any valid NTE events for analysis, thus the tests passed by default as discussed in Chapter II, Section C.3. As another example, many tests focused only on highway driving, thereby limiting the ability to look at emissions performance at lower loads under which emissions compliance is much more challenging. To ensure submitted HDIUT program tests include a representative mix of real-world operation during weather conditions that will not invalidate or exclude data, the Proposed Amendments would require manufacturers to submit test plans for approval by CARB prior to testing. The submitted test plan would need to include the information listed below in Table III-7. CARB staff would have 30 calendar days after a manufacturer submits a complete test plan submission to approve or disapprove that test plan.

Table III-7. Test Plan Information Checklist

Vehicle Information	
	Manufacturer Model Model year Vehicle identification number (VIN) Vehicle/fleet vocation Expected percent of operation at highway speeds Expected percent of operation on surface streets Expected percent of operation at idle Trailer type if applicable Mileage
Engine Information	
	Engine family Engine model number Displacement Power rating Model year Engine serial number
OBD/MIL	
	History of OBD/MIL illuminating events History of owner actions for OBD/MIL illumination OBD/MIL codes experienced after accepting for in-use testing
Test Day	
	Expected date Expected test time Expected duration Test number Number of shift days Location Route Expected weather
PEMS	
	Make Model Certification

The MAW Test Procedure

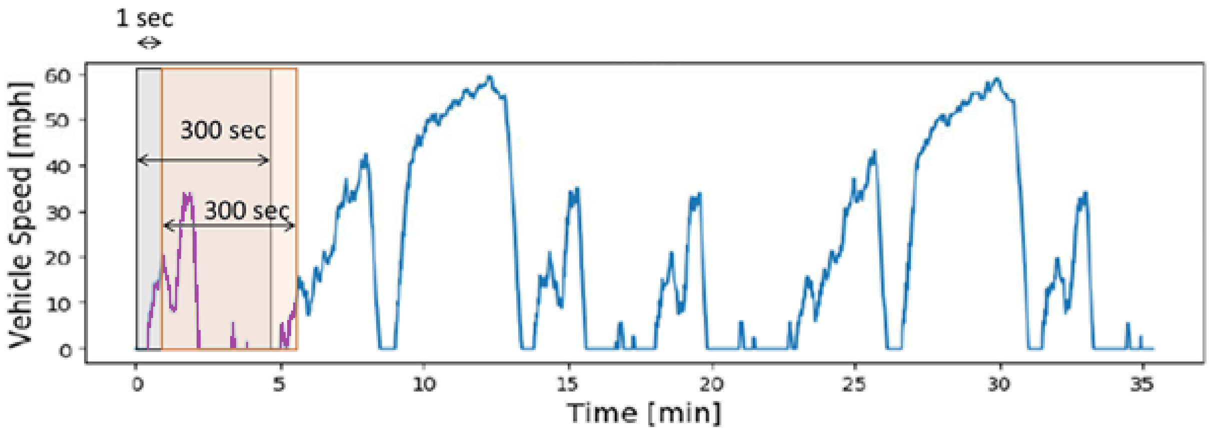
Just as for current NTE testing, in-use evaluation with the 3B-MAW test procedure would require on-road vehicle testing of heavy-duty vehicles with PEMS installed on the vehicle. The PEMS unit would measure and record emissions data from the engine tailpipe exhaust outlet. PEMS would also record engine and vehicle operation parameters via connection with the vehicle's OBD system. PEMS units also record ambient temperature, humidity, and have global positioning system capabilities. All data recording elements currently required when conducting HDIUT utilizing the NTE method would be required for testing under the MAW method as well.

Testing would begin with the engine coolant temperature under ambient conditions or less than 86°F (30°C), similar to the cold start conditions in 40 CFR §1065.530. The PEMS system would need to be active and collecting data prior to engine ignition. In the European In-Service Conformity testing, the test vehicles are driven by a manufacturer-hired driver over a prescribed route meeting operation targets for speed in urban, rural, and highway driving speeds. By contrast, the HDIUT program in the United States uses fleet drivers delivering cargo over varied test routes depending on the cargo's delivery location. To continue capturing and evaluating real-world operation rather than only specific known test routes, the Proposed Amendments would continue to require the vehicle to be driven by the regular fleet operator over its normal driving route for an entire shift day. A valid test would require a minimum of 3 hours of non-idle operation. A valid test day would also need to have an average load factor at or above 10 percent of the engine's maximum rated power. If these conditions are not met, an additional shift day of testing would be required.

In the MAW test procedure, emission windows are evaluated using a moving average. As mentioned, the windows are segregated based on engine operation into bins for diesel engines, based on the CO2 emissions or average power over the window. The emissions in the bins are evaluated against appropriate certification cycles and emission standards.

The mass emissions would be evaluated using a MAW method based on a reference time of 300 seconds. The mass emissions are not calculated for the complete data set, but for subsets of the complete data set. The length of these subsets are 300 seconds in length, with each 300-second segment referred to as a window. Windows would be overlapping with a time increment equal to the data sampling period of one Hertz (Hz) or greater. A schematic of the overlapping windows is provided in Figure III-14. The 300 second window would provide a longer averaging period than the current NTE program's minimum of 30 seconds to smoothen variability. The 300 second window is short enough, however, to be sensitive to emissions performance. CARB staff considered longer window lengths, but such longer window lengths could allow too much averaging and thereby average out emissions perturbations that should be controlled.

Figure III-14. Representation of the 300 Second Overlapping Windows of the 3B-MAW Method



Under certain conditions, data would be excluded from evaluation, such as extreme ambient temperature, ambient pressure, and altitude exclusions currently used in the NTE procedures and in Euro VI In-Service Conformity testing. Additionally, data collected during the PEMS unit's zero drift checks would also be excluded. The data collected during a cold start prior to warm engine operation would also be excluded initially for 2024 through 2026 MY engines but recorded. Warm engine operation would be defined as either of two conditions where the coolant temperature has reached 158°F (70°C) or coolant temperature stabilized within ±3.6°F (2°C) for a minimum of 5 minutes. Failure to meet the warm engine operation criteria within 20 minutes from test start would make the test invalid and would require the vehicle to be retested once cold start requirements are met.

Staff recognizes that diesel emissions cannot currently be controlled as efficiently during low load and idle operation as during higher loaded operation. Hence, as discussed further below, CARB staff is proposing the 3B-MAW for diesel engines and would have three bins: idle bin, low load bin, and the medium/high load bin. The multi-binning procedure described here would not apply to Otto-cycle engines. Instead Otto-cycle engine operations would be in a single bin encompassing the full range of real-world operation. CARB staff initially considered binning the windows into idle, low load and medium/high load according to the average power or work performed over each 300-second window. However, CARB staff ultimately decided against proposing the use of average power or work because engine broadcast power at low loads is inaccurate, especially at loads less than 20 percent power. CARB staff therefore investigated using fuel consumption or CO_2 emissions to bin windows because they would both be accurate surrogates for work performed. CARB staff finally selected a CO_2 emission rate for determining the binning windows because it would be independent of engine broadcast data and accurately measurable via PEMS.

The process of binning the windows would be based on the normalized average CO_2 emissions rate. During the industry workgroup development process for this rulemaking, some industry representatives voiced concerns that a NOx standard based on a CO2 metric would penalize more fuel-efficient engines. To address this, the Proposed Amendments would normalize the emissions with the Family Certification Level (FCL), the CO2 emission rate at the maximum power output defined in 40 CFR §1065.510. Similar to the emissions standards for criteria pollutants, the FCL value is the certified CO2 emissions value over an FTP test cycle. The window normalized average CO2 rate is calculated by dividing the average CO2 emissions rate in g/hr over the 300 second window by the product of the engine's FTP FCL and the maximum power output of the engine, as defined in 40 CFR §1065.510.

$$window\ normalized\ \text{average}\ CO2\ rate = \frac{\left(\sum_{t=1}^{n} \dot{m}_{CO2}(t)\right)}{FCL \times \left(P_{max} \times \frac{n}{3600}\right)} \qquad \text{(Equation III-1)}$$

where:

t is the time index of the window

$\dot{m}_{CO2}(t)$ is the mass flow rate of CO2 at time t (grams per second)

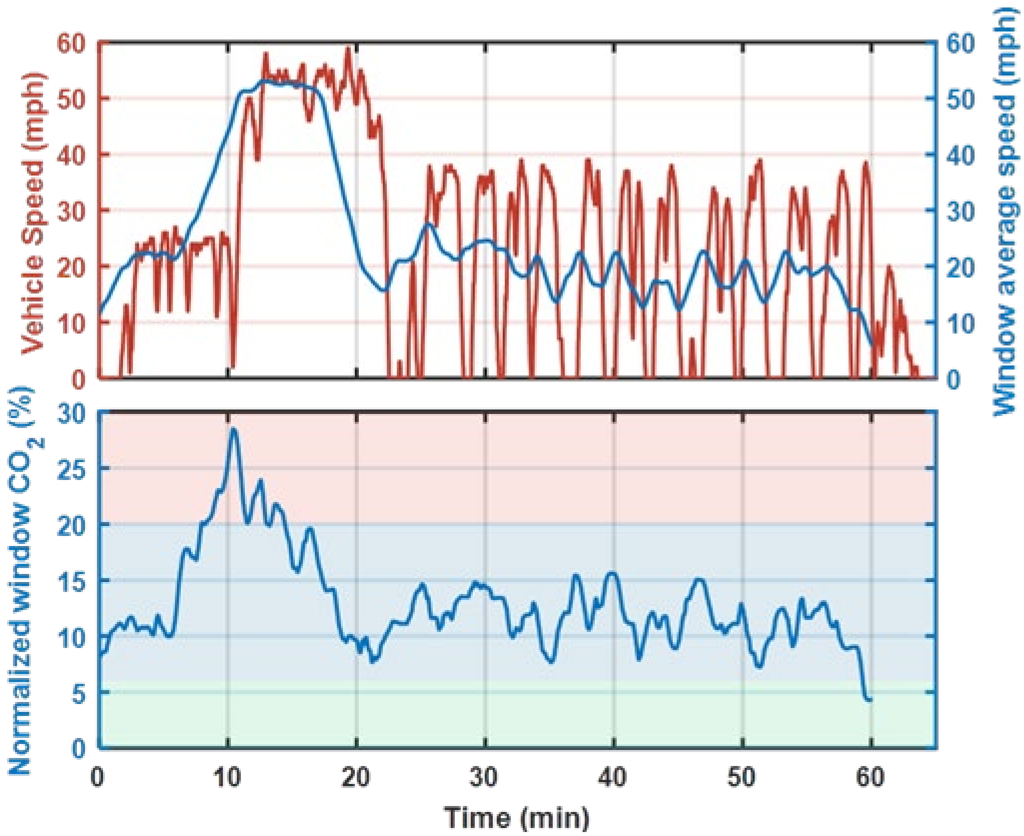
FCL is the family certification limit of the engine over the FTP cycle (g/bhp-hr CO2)

P_{max} is the maximum rated engine power (bhp)

n is the length of the bin in seconds

The engine's CO2 and criteria emissions can differ greatly under different engine loads and operating conditions, and thus a single emission standard appropriate at the higher load factors in the FTP and RMC-SET test cycles may not be appropriate for the entire span of potential operation. Hence, as mentioned, CARB staff is proposing three bins of operation, one comparable to the idling standard, one to the LLC standard, and one to the FTP/RMC-SET standard. Figure III-15 shows an example of how on-road test data would be analyzed. The normalized window CO2, a surrogate for power output, for each of the moving windows is used to determine bin placement.

Figure III-15. Vehicle Operation Moving Between the Bins of the 3B-MAW Method



The idle bin is intended to capture events of idling or extremely low load events. The emissions of the idle bin would be compared to the idle emission standards for in-use compliance. Windows will be placed into the idle bin if the window's normalized average CO2 rate is less than or equal to 6 percent.

The low load bin is intended to capture operation similar to operation found during development of the LLC by SwRI in the Low NOx Stage 2 testing program. Such operation is characterized by a decreased load on the engine after previous high load conditions, sustained low load operation, and increased load from engine idling to a well-loaded event (i.e., "return to service"). The emissions within the low load bin would be compared to the LLC emission standards for in-use compliance. Windows would be placed into the low load bin if the window's normalized average CO2 rate is greater than 6 percent and less than or equal to 20 percent. The 6 percent normalized average CO2 rate is chosen as a lower boundary because this is equivalent to the value of an engine tested on the LLC. Operation above 6 percent normalized average CO2 is expected to comply with the LLC emission standards.

The medium/high low load bin is intended to capture higher loaded operation, such as that found in the FTP and the RMC-SET cycles. The emissions within the medium/high bin would be compared to the FTP and the RMC-SET standards for in-use compliance. Windows would be placed into the medium/high load bin if the window's normalized average CO2 rate is greater than 20 percent. Operation above 20 percent normalized average CO2 is expected to comply with both the FTP and RMC-SET emission standards.

In the Euro VI MAW method, the 90th percentile emissions are compared with an emissions threshold to determine compliance. In the Euro VI method, the top 10 percent of windows are totally unaccounted for. Emissions in this top 10 percent of windows can be very significant, sometimes greater than one hundred times the standards for NOx. The 90th percentile evaluation method also does not account for operation and emissions below the standard; for example, an engine with no emissions at all in 89 percent of windows but slightly over the standard in the 90th percentile window would still be considered non-compliant. To avoid the weaknesses of using the 90th percentile to determine compliance, CARB staff is instead proposing a sum-over-sum approach, after discussing the approach with manufacturer representatives and U.S. EPA staff. A sum-over-sum approach would account for the emissions in all the windows at both the highest and lowest emission rates compared to the percentile method that focuses on a single value at the 90th percentile. In the proposed 3B-MAW method, the sum-over-sum emissions within each of the three bins would need to be at or less than their threshold values in Table III-8. The sum-over-sum window emissions would be calculated with Equation III-2a for the idle bin, and Equation III-2b for the low and medium high bin operation:

$$e_{sos\ NOx,idle} = \frac{\sum_{k=1}^{n} \dot{m}_{NOx} \times \Delta t}{\sum_{k=1}^{n} \Delta t} \times \frac{3{,}600\ sec}{1\ hr} \qquad \text{(Equation III-2a)}$$

$$e_{sos\ a,b} = \frac{\sum_{k=1}^{n} \dot{m}_{a} \times \Delta t}{\sum_{k=1}^{n} \dot{m}_{CO2} \times \Delta t} \times e_{CO2,FTP,FCL} \qquad \text{(Equation III-2b)}$$

where:

$e_{sos\ NOx,idle}$ is the sum over sum emissions for the idle bin for NOx

$\dot{m}_{NOx}$ is the mass of NOx per second emission

$e_{sos\ a,b}$ is the sum-over-sum emissions

a is the criteria pollutant. Example (HC, CO, NOx, and PM)

b is the bin. Example (idle, low load, and medium high load)

$\dot{m}_{a}$ is the mass criteria pollutant per second emission

$\dot{m}_{CO2}$ is the mass CO2 per second emission

$e_{CO2,FTP,FCL}$ is the engine family FTP FCL work specific CO2 [g/bhp-hr CO2]

n is the length of the bin in seconds

Δt is equal to 1 second

To determine if the tested engine is in compliance, each bin's sum-over-sum criteria emission for each of the three bins must be less than the in-use thresholds in Table III-8.

Table III-8. Table of Bin Structure Definitions, Applicable Standards, and In-Use Thresholds

Bin	Engine Type	Normalized Average Window CO2 Rate	The Sum-Over-Sum Emissions In-Use Threshold[39]
Idle	Diesel Cycle	$CO2_{normalized} \leq 6\%$	$e_{sos\ a,Idle} \leq 1.5$ x Idle standard
Low	Diesel Cycle	$6\% < CO2_{normalized} \leq 20\%$	$e_{sos\ a,Low} \leq 1.5$ x LLC standard
Med/High	Diesel Cycle	$20\% < CO2_{normalized}$	$e_{sos\ a,MedHigh} \leq 1.5$ x FTP/RMC-SET standard
All Operation	Otto-Cycle	na	$e_{sos\ a} \leq 1.5$ x FTP standard

3.2. 2027 and Subsequent HDIUT Amendments

For 2027 and subsequent MY engines, the Proposed Amendments would adjust the exclusions in the MAW test procedure to include cold start emissions and eliminate any minimum coolant temperature exemptions. Specifically, engines would have to demonstrate emissions control during cold start operation for in-use compliance. A cold start exclusion would be allowed for 2024 to 2026 MY engines to give manufacturers more time to refine any needed hardware or calibration changes needed for the 2027 MY. Strategies manufacturers may pursue include improving catalyst efficiency under these cold start conditions, or reducing the time engines remain cold by improving thermal management. Engine testing for the Low NOx Demonstration project at SwRI has shown quick aftertreatment response and controlled emissions within 70 seconds after a key on start, when the calibration and hardware is available. In addition, a valid test day would no longer need to have an average load factor at or above 10 percent maximum rated engine power. Thus, testing engines that operate exclusively in certain types of operation that result in less than 10 percent maximum rated engine power would be a valid test event for the same reasons stated above for removing the cold temperature exclusion.

3.3. Heavy-Duty In-Use Compliance Testing for Idling Emissions

The Proposed Amendments would provide CARB staff an additional method to verify compliance with the proposed idling emission standards. Under the Proposed Amendments, CARB staff could conduct an emissions test for a minimum of 30 minutes at an engine idle speed equal to the curb idle speed set by the manufacturer or at any other elevated idle speed up to 1100 revolutions per minute. The test would be conducted on a chassis dynamometer or using PEMS.

Compliance would be determined by calculating the average NOx emissions from the test and comparing them to the NOx idling emission standard applicable to the engine MY specified in Tables III-2 and Tables III-5. For compliance, the calculated average

[39] The applicable standards can be found in 13 CCR 1956.8.

NOx emissions would have to be less than or equal to the NOx idling emission standard.

3.4. Collection of OBD/REAL Data During HDIUT

Under the Proposed Amendments, manufacturers would be required to record and report two types of OBD parameters from the engine control unit (ECU) during in-use testing. The first type includes data stream parameters, all service mode data, and tracked data per CCR 1971.1(h)(4) and (h)(5). These parameters would be required to be collected at the beginning of testing, before engine shut off during the day, and at the end of the test. The second type of data required is 1Hz real-time data collected during the entire time of in-use testing. The list of required 1Hz data parameters is shown in Table III-9. The two OBD parameter types gathered would need to be reported in a separate file from the PEMS data in a comma-separated value file format.

Table III-9. 1 Hertz OBD Data Parameters to Be Collected During In-Use Testing

Category	Parameters
Engine	Engine speed, engine torque (actual, friction, and reference maximum), fuel rate, modeled exhaust flow, fuel injection timing, boost pressure, commanded/target boost pressure, and variable geometry turbo position
Aftertreatment	EGR mass flow rate, commanded EGR valve duty cycle/position, actual EGR valve duty cycle/position, EGR error between actual and commanded, PM filter inlet and outlet temperature, NOx mass emission rate (engine out and tailpipe), SCR intake and outlet temperature, corrected NOx sensor output, stability of NOx sensor reading, DEF dosing mode, commanded DEF dosing, DEF usage for current driving cycle, DEF dosing rate, modeled actual ammonia storage level on SCR, target ammonia storage level on SCR, and hydrocarbon doser flow rate
Others	Engine coolant and oil temperature, intake air/manifold temperature, air flow rate (from mass air flow sensor), exhaust gas temperature sensor output, charge air cooler outlet temperature, vehicle speed, and engine run time

4. Warranty Period Amendments

The main elements of CARB staff's proposal for the Step 2 warranty amendments are listed below, followed by a detailed discussion of each:

1. Phasing in longer warranty periods to better match the longer service lives of modern heavy-duty vehicles. This will result in emission reductions by incentivizing better vehicle maintenance by vehicle owners and encouraging manufacturers to make more durable parts.

2. Including an hourly warranty period limit for heavy-duty vehicles to account for vocational vehicles that do not accumulate a great number of miles because they are mostly used in low speed or idle operations.

3. Updating the heavy-duty Otto-cycle engine minimum maintenance intervals so that these intervals do not inadvertently truncate the proposed lengthened warranty periods. Further, expanding the applicability of the heavy-duty diesel minimum maintenance intervals to diesel-fueled engines used exclusively in hybrid vehicles, optionally certified hybrid powertrains, and engines that are fueled by gasoline and alternative fuels.

4. Explicitly linking HD OBD to the definition of warranted parts for non-diesel heavy-duty vehicles, as was done for heavy-duty diesel vehicles under the June 2018 Step 1 warranty amendments.

5. Restricting the allowable scheduled repair or maintenance for catalytic converter beds used on heavy-duty Otto-cycle engines because of their high cost and severe emission impacts upon failure.

6. Revising existing heavy-duty regulatory language that unintentionally shortens warranty periods, and other clarifications.

7. Removing the California vehicle registration requirement for warranty applicability to help ensure that any heavy-duty vehicles, with California-certified engines, that are registered outside of California but may travel within the state in their normal operations, continue to remain in compliance with the California emission requirements.

8. Expanding the warranty applicability to include heavy-duty hybrid vehicles that are equipped with optionally California-certified hybrid vehicle powertrains and certified engine families that are used exclusively in hybrid vehicles.

4.1. Longer Warranty Periods for Heavy-Duty Engines Used in Heavy-Duty Vehicles

To help ensure emission controls are well-maintained and repaired when needed and to help ensure more durable emission control systems, the criteria pollutant warranty regulations in 13 CCR 2036 for California-certified heavy-duty vehicles and engines would be amended by phasing in lengthened minimum warranty mileage periods beginning with the 2027 MY, with the final phase-in occurring with the 2031 MY.

Subsection 4.1.1 describes the proposed lengthened warranties. Subsection 4.1.2 describes why lengthened warranties are needed. Subsection 4.1.3 describes CARB staff's determination of the feasibility of the proposed lengthened warranties. Subsection 4.1.4 provides further information regarding the applicability of the proposed lengthened warranties.

4.1.1. Proposed Lengthened Warranties

Table III-10 below shows the warranty periods that were last amended under the June 2018 Step 1 warranty amendments rulemaking, and the proposed Step 2 warranty amendments for heavy-duty engines used in heavy-duty vehicles weighing greater than 14,000 pounds GVWR.

Table III-10. Current and Proposed Heavy-Duty Diesel Warranty Periods

Engine / Vehicle Category (GVWR)	Current Warranty (Miles)	June 2018 Step 1 Warranty Amendments Effective MY 2022 (Miles)	Proposed Phase-in for Step 2 Warranty Effective MY 2027 (Miles)	Proposed Phase-in for Step 2 Warranty Effective MY 2031 (Miles)
HHDD / Class 8 >33,000 lbs.	100,000 5 years 3,000 hours	350,000 5 years	450,000 7 years 22,000 hours	600,000 10 years 30,000 hours
MHDD / Class 6-7 19,501 - 33,000 lbs.	100,000 5 years 3,000 hours	150,000 5 years	220,000 7 years 11,000 hours	280,000 10 years 14,000 hours
LHDD / Class 4-5 14,001 - 19,500 lbs.	100,000 5 years 3,000 hours	110,000 5 years	150,000 7 years 7,000 hours	210,000 10 years 10,000 hours
HDO >14,000 lbs.	50,000 5 years	50,000[a] 5 years	110,000 7 years 6,000 hours	160,000 10 years 8,000 hours

[a] Not included under Step 1 Warranty, but current periods shown here for completeness.

Under the Step 1 warranty amendments, the mileage periods were set to reflect approximately 80 percent of the current useful life of the vehicles. Following this approach, the Step 2 warranty mileage periods were also selected to represent approximately 75-80 percent of the corresponding useful life mileage period. Useful life periods are discussed below in Section A.5 of this chapter.

Table III-10 also shows the proposed inclusion of operating hours for warranty for all heavy-duty categories. This would make the warranty period equal to the first occurring of either the mile, year, or hour limits. The Proposed Amendments to the operational hours are a result of manufacturer comments and to ensure warranty periods are reasonable for vocational vehicles that are used mainly in start/stop operations or with a substantial amount of idle operation. Further discussion of the need for hour provisions is provided in below in Subsection 4.2.

As explained in Chapter I, Section B.4, although heavy-duty engine and heavy-duty vehicle combinations are usually consistent, there are instances when they are not, such as when a medium heavy-duty engine is installed in a Class 8 heavy heavy-duty vehicle. The warranty scope and coverage for vehicle-engine combinations were addressed in the June 2018 Step 1 warranty amendments. Under the Step 1 provisions, the period of warranty coverage is determined according to the primary intended service class of the engine family installed in the heavy-duty vehicle, regardless of the GVWR of the vehicle in which it is installed. The scope of warranty coverage (i.e., which components are covered) is based on the vehicle and linked to which components trigger the vehicle's MIL to illuminate. This warranty scope/coverage approach for the heavy-duty engine and heavy-duty vehicle combinations generally remains in effect for the Step 2 warranty proposal.

However, there is an exception to this approach when considering the engines used in an optionally certified heavy-duty hybrid powertrain. The determination of the warranty period for a heavy-duty hybrid vehicle would be based on the GVWR of the vehicle in which the optionally certified hybrid powertrain is used. For example, in 2031, an optionally certified hybrid powertrain used in a vehicle with a GVWR between 19,501 and 33,000 pounds would have the warranty period of a MHDD engine, (i.e., the first occurring of 280,000 miles, 10 years, or 14,000 hours), even if the engine in the hybrid powertrain is a certified LHDD engine that typically would have a shorter warranty (i.e., the first occurring of 210,000 miles, 10 years, or 10,000 hours).

4.1.2. Feasibility of Longer Warranties

It is clear to CARB staff that longer warranties than those that will be required under the Step 1 warranty amendments are feasible because such longer warranties are already offered, both by manufacturers and by third party warranty providers. Many vehicle buyers already choose to buy such longer warranties for their vehicles. Some of the manufacturer extended warranty options available range up to 7 years or 700,000 miles (Paccar, 2020; International, 2020; DDC, 2020). Extended warranties are also provided by independent third-party businesses with mileages offered as high as 1,000,000 miles, provided that the vehicles satisfy certain initial inspection requirements and continue to be maintained in accordance with OEM recommendations (Truck Master Plus, 2020; Premium 2000, 2020).

CARB staff's assessment of currently available warranties for heavy-duty vehicles is based on the Sacramento ISR survey conducted for the June 2018 Step 1 warranty amendment rulemaking, and from consultations with heavy-duty vehicle and engine manufacturers, emission control system manufacturers, U.S. EPA, and independent third-party warranty providers. Table III-11 below summarizes the warranties that will be in place for heavy-duty vehicles after the June 2018 Step 1 warranty amendments take effect.

For example, CARB staff estimates that 40 percent of Class 8 vehicles will have a warranty out to 500,000 miles, well beyond the Step 1 requirement of 350,000 miles. Likewise, 40 percent of Class 6 and 7 vehicles are expected to have a warranty out to 185,000 miles (i.e., 35,000 miles above the Step 1 requirement of 150,000 miles).

Table III-11. Warranty Mileage Periods That Will Be in Place by Vehicle Service Classes After Step 1 Warranty Periods Take Effect

Vehicle Class	Miles Warranted	Percent Vehicle Population
Class 8	500,000	40%
Class 8	350,000 (Step 1 requirement)	60%
Class 6-7	185,000	40%
Class 6-7	150,000 (Step 1 requirement)	60%
Class 4-5	110,000 (Step 1 requirement)	100%
HDO	50,000 (Current requirement)	100%

Sources: (Cummins, 2017; Truck Master Plus, 2020; CARB, 2018c; and ISR, 2017)

Published durability information from the parts suppliers have proven difficult to obtain, but CARB staff received valuable input from MECA, the trade group representing leading manufacturers of emission control equipment for automobiles, trucks, and buses, and Motor & Equipment Manufacturers Association (MEMA), the trade group representing manufacturers of motor vehicle components and systems for the original equipment and aftermarket segments of the light- and heavy-duty motor vehicle manufacturing industry. Based on an analysis of NREL's Fleet DNA heavy-duty truck activity data (assuming a 10-year useful life), and these trade groups members' knowledge of the applicable components and systems they manufacture, MECA and MEMA recommended useful life mileages at 800,000 miles and warranty periods ranging between 450,000-600,000 miles for Class 8 vehicles provided they are phased-in from 2027 and 2031 (MECA, 2019b; MEMA, 2019).[40] Both trade groups agree that a phased-in approach would allow the industry more lead time to review field data and validate more durable designs to confirm these longer durability and warranty periods. In consultations with the suppliers during the June 2018 warranty rulemaking regarding their DPFs and SCR systems, many verbally stated that these major emission control components are typically designed for 1,000,000 miles of operation. Additionally, at least one supplier has stated on their product webpage that their turbochargers are expected to last as long as the engine, but in order to ensure that happens, the maintenance instructions must be strictly observed (BorgWarner, 2020). Continuing to perform maintenance as recommended by OEMs is commonly required for extended warranty coverage. These businesses' willingness to offer coverage out to these longer mileages depends on vehicle owners continuing the recommended maintenance; otherwise, the extended warranties are typically not honored. Continuing to properly perform all of the maintenance helps to ensure that the engine and emission control system, as a whole, will properly operate throughout their designed useful lives.

4.1.3 Scope of CARB Staff's Proposal and Applicability of Lengthened Warranties

The Step 2 warranty amendments proposed in this Staff Report would apply to heavy-duty vehicles greater than 14,000 pounds GVWR that are equipped with 2027 and subsequent MY heavy-duty engines. The proposed warranty amendments would first take effect with the 2027 MY and would be revised further with the 2031 MY. The warranty amendments would be applicable to California-certified heavy-duty vehicles and engines, regardless of whether they are registered in California. Federally certified heavy-duty vehicles operating in California would not be subject to the new warranty period requirements.

The Proposed Amendments would base the initial date for the applicability of the amended warranty periods on the MY of the engine, and not on the vehicle, to avoid potential initial production mismatches of engines and vehicles. For example, under current end-of-model-year production practices, some new 2027 MY heavy-duty vehicles may be equipped with 2026 MY diesel engines and thus the Step 2 warranty amendments would not apply to those engines.

The Step 2 warranty amendments would be applicable to heavy-duty engines that are fueled by diesel, gasoline, and alternative fuels. The Proposed Amendments would also apply to engine families used in hybrid vehicle applications. The Proposed Amendments would apply to engines in vehicles that use a California-certified hybrid powertrain, and the California-certified hybrid powertrain itself (see Section A.9 of this chapter, for further details on optionally certified hybrid powertrains).

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[40] MECA representatives noted that they cannot speak for engine and vehicle manufacturers. However, despite CARB staff's numerous requests, engine or vehicle manufacturers did not provide any specific suggestions for useful life or warranty length.

The Step 2 warranty amendments would not affect heavy-duty vehicles powered by pure electric powertrains (i.e., those without internal-combustion engines), fuel cells, or any other zero-emission technology. These types of technologies are still developing, and their commercial integration in heavy-duty vehicles is still evolving. Their current warranty period provisions are for 3 years or 50,000 miles as covered in CARB's February 2019 Zero-Emission Powertrain Certification Regulation (CARB, 2018i), and in CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (CARB, 2018a).

Lastly, the amendments include an operating hours provision in the warranty to allow for more appropriate warranty coverage for low-mileage vehicles, as discussed immediately below.

4.2. Re-introduction of the Engine Operational Hours Warranty Limit

One of the amendments under the June 2018 Step 1 warranty amendments was the removal of the 3,000-hour warranty limit for California heavy-duty diesel engines. This was done to align with the federal provisions which do not include any hourly limits on the warranty periods.

Historically, the original intent of limiting warranty periods on the basis of hours of operation was to acknowledge that some vocational vehicles, such as refuse haulers, have engines that typically idle for many hours and are driven many miles at low speeds, and hence do not accumulate mileage as quickly as other heavy-duty vehicles. With the much longer warranty mileages in the Step 2 warranty amendments, several stakeholders have commented, and CARB staff agrees, there is a need to reintroduce the hour provisions. Without an hour limit, manufacturers could be required to provide warranties for an unreasonable amount of operating hours. Consider, for example, a Class 8 vehicle that operates 16 hours a day, 5 days per week, mostly at idle or low speed. Such a vehicle would accumulate 4,160 hours per year and 41,600 operating hours within the 10-year warranty period. Without an hour limit, manufacturers would have to design for such a possibility, but the proposed 30,000-hour limit would provide an upper bound to operating hours for which manufacturers must plan. To ensure a reasonable design target for hours covered by warranty for such vocational vehicles, the Step 2 warranty amendments re-introduce an operational hour limit for the heavy-duty diesel warranty and include an operational hour limit for heavy-duty Otto-cycle engines as well.

4.3. Updated Maintenance Intervals

In addition to updating the maintenance intervals for heavy-duty diesel engines to include hybrid applications, as described above, staff proposes to also update the maintenance intervals applicable to heavy-duty Otto cycle engines, as discussed further below.

CARB staff is proposing to amend the minimum maintenance intervals for heavy-duty Otto-cycle engines beginning with the 2027 MY. The Proposed Amendments for the Otto-cycle engines are shown in Table III-12 below. The first column identifies the component or the system for which regulatory-specified minimum maintenance intervals are applicable. The second column shows the minimum maintenance interval periods that were derived by surveying owner's manuals for all 2018 California-certified on-road heavy-duty Otto-cycle engines. The current regulatory minimum maintenance intervals are the same for both California and U.S. EPA, and are shown in the third column, as specified in 40 CFR §86.004-25 (as updated by U.S. EPA, on October 25, 2016). Lastly, the fourth column is the proposed minimum repair/replacement intervals for the specified components and systems based on the rationale discussed below.

Table III-12. Heavy-Duty Otto-Cycle Engine Maintenance Schedule (GVWR >14,000 lbs.)

Component or System	Minimum Maintenance Interval from Survey of Owner's Manuals (miles or years/hours)	California & Federal Minimum Maintenance Interval specified in §86.004-25 (miles or hours)	Proposed Minimum Repair or Replacement Interval (miles or years/hours)
Exhaust Gas Recirculation (EGR) System (filter & cooler – not including hoses)	None	50k or 1,500 hr	110k [a]
Exhaust Gas Recirculation (EGR) System (valve & tubing)	None	100k or 3,000 hr	110k
Crankcase Ventilation System	100k or 10 years	50k or 1,500 hr	50k or 10 years
Fuel Injectors	None	100k or 3,000 hr	110k
Turbochargers	None	100k or 3,000 hr	110k [a]
ECU, Sensors, Actuators (excluding Oxygen Sensors)	None	100k or 3,000 hr	110k
Oxygen Sensor	None	80k or 2,400 hr	110k
Carburetors	None	100k or 3,000 hr	110k
Evaporative Emission Canisters	None	100k or 3,000 hr	110k
Air Injection System Components	None	100k or 3,000 hr	110k [a]
Emission-related Hoses and Tubes	None	50k or 1,500 hr	110k
Ignition Wires	100k or 4,000 hr	50k or 1,500 hr	100k or 4,000 hr
Catalytic Converter (bed only)	None	Not Replaceable [a]	Not Replaceable [a]
Catalytic Converter (other than catalyst bed)	None	100k or 3,000 hr	110k
Any other add-on or new technology emission related component or system whose primary purpose is to reduce emissions or whose failure will significantly degrade emissions control	None	NA	110k [c]

k – 1,000 miles; hr – hours

[a] Sensors and actuators are included only if they are integral to these assemblies and cannot be repaired without removing or replacing the assembly. Otherwise sensors and actuators would be subject to the maintenance intervals specified in the table for Electronic Control Units, Sensors, and Actuators.

[b] For components or systems designated in the table as "Not Replaceable," manufacturers would not be allowed to schedule any repair or replacement maintenance intervals throughout the applicable useful life of the heavy-duty Otto-cycle engine.

[c] Manufacturers would be given opportunity to request more frequent repair / replacement maintenance intervals for add-on or new technology emission-related components provided that the manufacturer demonstrates to the Executive Officer's satisfaction that such intervals are technologically necessary and appropriate.

To determine what maintenance intervals to propose, CARB staff examined the owner's manual survey results and looked for the shortest (i.e., most frequent) repair/replacement maintenance interval specified for emission-related parts, by any manufacturer. The proposed maintenance intervals reflect this methodology.

Manufacturers are required to disclose any maintenance requirements that would prevent the engine from complying with emission standards throughout the useful life of the engine in their certification applications. If no manufacturer indicated maintenance was required within the useful life for a particular emission-related component or system, then it is appropriate for the minimum maintenance interval to be set at the current useful life for that component or system. In most cases, the fourth column in Table III-12 reflects this rationale.

CARB staff believes the proposed maintenance intervals are appropriate for the following reasons:

- For the 2022 and 2023 MYs, the emission standards and useful life periods would remain unchanged.
- As described above in Section A.1 of this chapter, CARB staff expects manufacturers to be able to meet the MY 2024 to 2026 emission standards with minor refinements and calibration improvements to the technologies they are using today. Most manufacturers currently do not require any maintenance through the current useful life period for any components, and none of the proposed maintenance intervals go beyond the applicable current useful lives (for example, beyond 435,000 miles for HHDD engines).
- In the case when an existing component is redesigned or an entirely new technology is used in a component, the manufacturer would have the opportunity to petition CARB for more frequent maintenance intervals as needed, using the existing provision in §86.094-25 (b)(7)(ii) of the Heavy-Duty Diesel Test Procedures.
- Similarly, a manufacturer would also be able to request new scheduled maintenance intervals for an existing component if it may be influenced as a direct result of the implementation of any new technology. For example, the Crankcase Ventilation System currently has a scheduled maintenance repair/replacement interval at 50,000 miles for a LHDD engine. Under the current provisions, and continuing under the proposed Step 2 warranty amendments, a manufacturer would be able to request a more frequent interval for that existing system if there is some other new technology that could impact how the existing Crankcase Ventilation System performs.

The current maintenance interval provisions in the Heavy-Duty Diesel Test Procedures §86.004-25 (b)(4)(vi) list some components as "not replaceable." This means that manufacturers can only schedule repairs or replacements if they pay for them. The provisions were originally applicable for particulate trap elements, and catalytic converter beds, but under the June 2018 Step 1 warranty amendments EGR valves and coolers, and turbochargers were included for diesel engines. Under the proposed lengthened useful life provisions, CARB staff expects that manufacturers would improve the durability of their parts to last through the longer useful lives and thus would continue to be responsible for any scheduled repairs or replacements of these “not replaceable” components during this longer period.

Overall, if a manufacturer needs more frequent maintenance intervals due to using components with either existing or new technologies, as discussed above, to meet the proposed lengthened emission standards and warranty (and useful life) requirements, the existing provisions in the Heavy-Duty Diesel Test Procedures already offer a solution. Also, it is important to reiterate that the proposed changes to the maintenance intervals are only for the repair or replacement of parts, and not for cleaning (e.g., as in DPF ash removal, etc.) or other adjustments as may be necessary for the redesigned or new technologies to meet the more stringent emissions standards.

4.4. OBD Link to Warranty

OBD systems have been required on on-road heavy-duty vehicles since the 2013 MY. Because the HD OBD system is required to monitor all emission-related components and systems for proper operation, HD OBD provides a perfect tool for alerting the vehicle operator to emission-related failures and malfunctions that should be repaired during the warranty period. HD OBD even stores fault codes that specifically identify the malfunction, which can aid in vehicle repairs.

The June 2018 Step 1 warranty amendments formally clarified the link between HD OBD and the heavy-duty diesel warranty requirements by specifying that failures that cause the vehicle’s OBD MIL to illuminate are considered a warrantable condition. This was done in order to help ensure that the repairs of malfunctioning emission-related parts and systems and/or parts or systems used by OBD systems to monitor for faults that trigger the MIL on heavy-duty engines are performed in a timelier manner during the lengthened warranty periods. The Step 2 warranty amendments would similarly expand the linkage between heavy-duty warranty and OBD to all heavy-duty engines, not just diesel engines, beginning in MY 2027.

Overall, CARB staff expects that clearly linking warranty and OBD for all heavy-duty vehicles would incentivize vehicle owners to address the causes of MIL illumination more quickly, especially in cases where no loss of vehicle performance or fuel economy is apparent. This would result in emission reductions.

4.5. Special Consideration for Catalytic Converters Used in Heavy-Duty Otto-Cycle Engines

As described above in Subsection 4.3, some components are designated as “not replaceable” because of their relatively high price and severe emission impact under failure.

In the Proposed Amendments, CARB staff is proposing to designate catalytic converter beds as “not replaceable” for heavy-duty Otto-cycle engines because, like the diesel “not replaceable” components described above, Otto-cycle catalytic converters are high priced and cause severe emission increases when they fail as well. As Table III-13 shows, based on HD OBD certification durability demonstrations conducted for 2018 and 2019 MY heavy-duty Otto-cycle engines, if a catalytic converter fails, the emissions increase an average of 87 percent over baseline levels (CARB, 2020d), a severe impact. As Table III-13 also shows, catalytic converters are expensive, on average $2,500 for parts and labor to repair.

In the survey of owner's manuals for all 2018 California-certified on-road heavy-duty Otto-cycle engines described above in Subsection 4.3, CARB staff found that no manufacturer currently requires repairs or replacements for catalytic converter beds throughout the current useful life of the engines. Thus, these components are already deemed durable by manufacturers to last through the current useful life periods. Under the proposed lengthened useful life provisions, CARB staff expects that manufacturers would improve the durability of their parts to last through the longer useful lives and thus would continue to be responsible for any scheduled repairs or replacements of these "not replaceable" components during this longer period.

In addition, as previously mentioned, if an existing catalytic converter bed needs to be redesigned, or is based on an entirely new technology, or is impacted by another "upstream" technology, the manufacturer can petition CARB for more frequent maintenance intervals as needed, using the existing provision in §86.094-25 (b)(7)(ii) of the Heavy-Duty Diesel Test Procedures.

Table III-13. Repair Cost and Emissions Increase for Catalytic Converters Used on Heavy-Duty Otto-Cycle Engines

Component	Catalytic Converter
Repair Cost	$2,500
NOx Emissions Increase	87%

4.6. Prevent Current Maintenance Interval Provisions from Shortening Proposed Lengthened Warranty Periods

Prior to the June 2018 Step 1 warranty amendments, the heavy-duty maintenance regulations had provisions that could unintentionally supersede and shorten the proposed lengthened warranty periods. Specifically, 13 CCR 2036(d)(3)(A) states that warranty coverage ends after the first scheduled replacement of any emission-related component. Under the June 2018 Step 1 warranty amendments, this provision remained in effect, but a new subsection was added to require that any component replaced during the lengthened warranty period would continue to remain subject to the warranty requirements throughout the remainder of the proposed warranty period; however, the change was only applicable to heavy-duty diesel engines. The Step 2 warranty amendments make this same change applicable to all other heavy-duty engines (gasoline, etc.), which is needed to ensure that warranties stay effective for the intended duration and that warranty repairs and their associated emission reductions are achieved.

4.7. Removal of the California-registered Requirement for the Applicability of the Warranty Coverage

The current regulations in 13 CCR 2035(b)(1) limit California heavy-duty emissions warranty applicability only to California-certified vehicles that are registered in California. So, for example, if a vehicle owner purchases a heavy-duty vehicle in California in 2022 and registers it in California, but then moves it to Nevada in 2023 and registers it there, the California warranty provisions would cease to apply. That means that even though initially the vehicle would be covered by the Step 1 warranty amendments (e.g., an emissions warranty mileage of 350,000 miles for Class 8 vehicles), once the vehicle is no longer registered in California, the emissions warranty would end after 100,000 miles (the current federal warranty length).

Under the proposed Step 2 warranty amendments, California emissions warranty coverage would be expanded to California-certified vehicles with California-certified engines, even if they are registered outside California, beginning with the 2027 MY. The California warranty would remain with the vehicles even if they are subsequently sold or moved and registered outside of California.

The reasoning behind this proposed amendment is that heavy-duty vehicles originally sold in California can be subsequently resold and reregistered outside of California, and often either return to California or travel in and out of California during their normal course of doing business. CARB staff knows that out-of-state vehicles frequently travel to California; in fact, EMFAC predicts that out-of-state Class 8 vehicles account for 63 percent of the California VMT in 2027. It is reasonable to assume some of the out-of-state vehicles were originally sold in California. Having the warranty remain with the vehicle incentivizes timely repairs for faulty emission-related components so that when the vehicles eventually do operate in California, they will have lower emissions.

An additional benefit to the removal of the California-registered requirement is that the California-certified vehicles would likely retain a higher residual value compared to their less expensive counterparts that are not California certified. This higher residual value would provide some benefit, upon the vehicles' resale, for first, and subsequent, owners of the California-certified vehicles by retaining some of the value of the vehicles' lengthened warranty periods. In other words, vehicle owners that purchase vehicles in California and pay the incremental purchase price associated with the longer California warranties would retain the value of the longer warranties, even if they register the vehicles outside California.

4.8. Warranty Requirements for Optionally Certified Heavy-Duty Hybrid Powertrains

In conjunction with the Proposed Amendments involving the optional certification test procedures of heavy-duty hybrid powertrains (see Section A.9 of this chapter for more details), CARB staff is also proposing amendments to address the warranty requirements for these heavy-duty hybrid powertrains. In general, to ensure adequate durability for the vehicles in which they are used, the warranties for optionally certified hybrid powertrains will be the same as for a diesel engine that would typically be used in a comparable vehicle.

Specifically, for 2022 and subsequent MY diesel-cycle engine hybrid powertrains optionally certified to the provisions in 13 CCR 1956.8, the warranty periods would be as follows:

- For powertrains used in vehicles with a GVWR from 14,001 to 19,500 pounds, the warranty periods would be the same as for LHDD engines.
- For powertrains used in vehicles with a GVWR from 19,501 to 33,000 pounds, the warranty periods would be the same as for MHDD engines.
- For powertrains used in vehicles with a GVWR greater than 33,000 pounds, the warranty periods would be the same as for HHDD engines.
- For Otto-cycle engine hybrid powertrains optionally certified to the provisions in 13 CCR 1956.8 and used in vehicles with a GVWR greater than 14,000 pounds, the warranty periods and MY implementation schedule would be the same as for HDO engines.

4.8.1. Feasibility of Warranties for Optionally Certified Hybrid Powertrains

Engines are designed to meet performance criteria dictated by the work requirements of the vehicles in which the engines will be installed. As such, engine parameters such as horsepower and torque need to be correctly specified to ensure the vehicle will be able to perform its intended operational needs. In addition, the durability of the engine is also an important design consideration. For example, a Class 8 over-the-road tractor could accumulate a million miles over its service life so the engine in such vehicles is expected to be durable over that period. Generally, if an undersized engine is installed in a vehicle that typically requires a larger engine, the undersized engine will likely need to work harder than its design specifications. This may result in premature degradation of the smaller engine due to the increased stress that is placed on it. Practically, however, in a hybrid system where a downsized engine is used, the engine would not be designed or expected to provide sole power requirements for the vehicle but would share the load with the electric motor. Thus, it is feasible, if properly designed and integrated, for the durability of a downsized combustion engine in a hybrid powertrain to rival the expected durability of the larger engine that is used as the exclusive power source for similar vehicle applications.

The proposed warranty requirements would also apply to the electrified portion of a hybrid powertrain system, including, for example, the electric motor(s), battery pack, charge controllers and thermal management system, etc. Of these components, the battery is relatively more prone to performance degradation and usually is the most expensive component to replace. However, battery life and durability for heavy-duty vehicle applications are continuing to improve. For the transit bus sector, both BYD and Proterra are providing up to a 12-year warranty on their batteries (BYD, 2019; Metro, 2019). BYD batteries have been tested to over 7,000 cycles, which for transit application, translates to more than 30 years of normal service (Mass Transit, 2015). A 60-foot battery-electric articulated BYD bus has recently passed Altoona testing, completing the full 15,000-mile durability test (Metro, 2020). Both BYD and Proterra battery-electric buses have amassed over 130 million and 10 million miles, respectively, of revenue service miles (BYD, 2020; Proterra, 2020). Although the preceding discussion focuses on battery systems for dedicated battery-electric buses, identical or very similar battery systems could be used for heavy-duty hybrid vehicle applications, albeit likely with smaller battery pack(s) and different design and performance characteristics to accommodate different duty cycles expected for various heavy-duty vehicle vocations.

The proposed warranty and useful life requirements for hybrid powertrains match those for similar conventional engines, and are intended to be technology neutral while providing the consumers with similar protection for any power platforms they choose to purchase.

5. Useful Life Period Amendments

The Proposed Amendments for the heavy-duty useful life periods include the following elements, as discussed further in the subsections below:

1. Phase-in of longer useful life mileage periods to better match the longer service lives of modern heavy-duty vehicles.

2. Lengthening of the operational hour period for the heavy heavy-duty vehicles to account for vocational vehicles in this primary intended service class that do not accumulate a great number of miles because they are mostly used in low speed or idle operations.

3. Expand the useful life applicability to include heavy-duty hybrid vehicles which are equipped with California optionally certified heavy-duty hybrid powertrains.

5.1. Longer Useful Life Periods for Heavy-Duty Engines Used in Heavy-Duty Vehicles

California’s regulatory useful life provisions require heavy-duty engines to demonstrate their emissions compliance for specified periods of time or engine operation. The useful life is meant to ensure adequate durability of the engine and the vehicle’s emission control systems. The Proposed Amendments would phase in increased useful life mileage periods beginning with the 2027 MY, with the final phase-in occurring with the 2031 MY.

Subsection 5.1.1 describes the proposed phase-in of increased useful life periods. Subsection 5.1.2 describes why longer useful life periods are needed. Subsection 5.1.3 provides a discussion of feasibility of longer useful life periods. Subsection 5.1.4 provides further information regarding the applicability of the proposed increased useful life periods.

5.1.1. Proposed Increased Useful Life Mileage Periods

Table III-14 below shows the current useful life periods and the proposed phased-in lengthened useful life periods for the different heavy-duty engine categories that are used in heavy-duty vehicles weighing greater than 14,000 pounds GVWR.

Table III-14. Current and Proposed Heavy-Duty Useful Life Periods

Engine / Vehicle Category (GVWR)	Current Useful Life Periods (Miles)	Proposed Phase-in for Useful Life Effective MY 2027 (Miles)	Proposed Phase-in for Useful Life Effective MY 2031 (Miles)
HHDD / Class 8 >33,000 lbs.	435,000 10 years 22,000 hours	600,000 11 years 30,000 hours	800,000 12 years 40,000 hours
MHDD / Class 6-7 19,501 - 33,000 lbs.	185,000 10 years	270,000 11 years	350,000 12 years
LHDD / Class 4-5 14,001 - 19,500 lbs.	110,000 10 years	190,000 12 years	270,000 15 years
HDO >14,000 lbs.	110,000 10 years	155,000 12 years	200,000 15 years

As mentioned in Chapter I, Section B.5, the useful life mileage periods were chosen to roughly correspond to the mileage when engines get either rebuilt or get replaced. These proposed mileage values in Table III-14 were estimated using CARB staff's analysis of engine rebuild/replacement data, along with additional stakeholder input.

Based on stakeholder input, CARB staff's proposed useful life periods are for the most part roughly equivalent to 80 percent of heavy-duty engine/vehicles' service lives (MECA, 2019c). This approach is based on an analogy to light-duty vehicles where passenger cars subject to LEV III Regulations have a useful life period of 150,000 miles, while the average end-of-life mileage is considered to range from 165,000-190,000 miles, depending on the size and type of light-duty vehicle.

As previously shown in Table I-8, based on CARB staff's analysis, a typical MHDD engine gets rebuilt/replaced at 432,652 miles, of which 80 percent is approximately 350,000 miles, and which is thus the proposed 2031 MY useful life. This approach was used for both the MHDD and LHDD categories based on stakeholder input, but HHDD and the heavy-duty Otto-cycle engine categories' proposed useful life values were handled differently, as described below.

The proposed HHDD engine useful life value in 2031 is 800,000 miles, which corresponds to the useful life mileage currently used in EMFAC. The 800,000-mile value was also recommended by MECA and MEMA (MECA, 2019b; MEMA, 2019). Rather than representing 80 percent of the HHDD engine's service life (as is the case discussed earlier for the lower weight classes of engines), this value represents roughly 94 percent of the engine's service life. CARB staff considers this larger percentage to still be reasonable because it accounts for the prevalence of rebuilds common to the HHDD engine category which allows for accumulation of higher mileages.

For heavy-duty Otto-cycle engines, the proposed 200,000-mile useful life value for 2031 is based on current manufacturer product literature (Isuzu, 2019). This corresponds to 92 percent of the rebuild/replacement miles.

The 2027 MY phase-in mileages for all cases were obtained by using the approximate midpoint between the current useful life mileage and the proposed 2031 MY useful life mileage.

As previously explained in Chapter I, Section B.5.1.2, HHDD is the only category that has an hour provision that was used to account for vocational vehicles. The current hour provision was estimated using an average speed for an urban transit bus traveling at 13 mph. Using a similar approach, an average speed of 20 mph was used to determine the proposed hour provision for the useful life for the HHDD vocational vehicles. The 20-mph average speed was derived from a CARB research contract that collected activity study data for on-road heavy-duty diesel vehicles (CE-CERT, 2017). The different types of vehicles that were used in the study spanned several vocational areas such as shuttle buses, refuse haulers, utility repair vehicles, etc. Therefore, the average speed takes into account the different environmental factors and engine loads experienced by vocational vehicles.

5.1.2. Feasibility of Longer Useful Life Periods

The demonstrations described above in Section A.1 of this chapter establish technical feasibility of the proposed standards as long as necessary maintenance and replacements are conducted. The cost estimates in Chapter IX, Section B.1 take into account costs for the anticipated needed maintenance and replacements. The proposed useful life periods are deemed feasible because manufacturers may either design parts and systems that are durable and function for the full useful life periods, or specify appropriate maintenance intervals such that owners inspect, repair and replace parts as needed. The only restrictions on the manufacturer are that:

(1) the repair/replacement intervals must be longer than the regulatory minimum maintenance intervals, and

(2) the manufacturer must cover the replacement cost for any parts deemed not replaceable (i.e., for the EGR system, turbocharger, DPF, and catalytic converter bed).

Consider for example, a HHDD engine with a useful life of 800,000 miles/12 years/40,000 hours. The manufacturer of this engine could choose to make the engine and aftertreatment system durable to 800,000 miles/12 years/40,000 hours, if the manufacturer finds it technically feasible to do so. If, on the other hand, the manufacturer determines it is not feasible or cost-effective to do so, it could instead specify repair/replacement intervals at which time the owner's manual would direct the vehicle owner to repair or replace certain components.

Because under the Proposed Amendments, all minimum maintenance intervals are less than or equal to 435,000 miles in length, one option for the manufacturer in the above example would be to specify maintenance intervals of 435,000 miles for all components, with the manufacturer covering the cost of any needed replacement of the EGR system, turbocharger, DPF and catalytic converter bed. If the manufacturer finds it is necessary, the manufacturer could specify replacement of every component at the intervals shown in Table I-5 (for example, at 60,000 miles for the crankcase ventilation system, 125,000 miles for the DEF filter, etc.), as long as the manufacturer covered the cost of replacements of the EGR system, turbocharger, DPF and catalytic converter bed. If a manufacturer finds that even more frequent repair/replacement maintenance intervals are needed to meet the stricter standards in the Proposed Amendments, it can request maintenance intervals more frequent than those shown in Table I-5, as long as it demonstrates that such intervals are technologically necessary and appropriate. Each manufacturer will need to determine its preferred mix of improving durability and specifying needed maintenance, but the technical feasibility of doing so is not in question.

5.1.3. Applicability of the Proposed Lengthened Useful Life Amendments

The applicability of the Proposed Amendments for the useful life is the same as the applicability for the proposed warranty amendments, as described above in Subsection 4.1.3. The useful life amendments would first take effect with the 2027 MY and phase in further with the 2031 MY. The useful life amendments would be applicable to California-certified heavy-duty vehicles with a GVWR over 14,000 pounds and the engines used in such vehicles, regardless of whether they are registered in California. Federally certified heavy-duty vehicles operating in California would not be subject to the new useful life requirements.

Additionally, the Proposed Amendments would apply to heavy-duty engines that are fueled by diesel, gasoline, or alternative fuels, and engine families that are used concurrently in both dedicated internal-combustion engine vehicle applications and hybrid vehicle applications, certified engine families that are used exclusively in hybrid vehicle applications, vehicles that use an optionally California-certified hybrid powertrain, and the optionally California-certified hybrid powertrain used in such vehicles.

5.2. Lengthen the Operational Hour Useful Life Period for the Heavy Heavy-Duty Diesel Vehicles

The Proposed Amendments would lengthen the existing operational hour provision to define useful life for HHDD engines to allow for more appropriate coverage for vocational vehicles. These vocational vehicles are used mainly in start/stop operations, or they may simply be used for long periods of idle, resulting in a much greater accumulation of hours than of the odometer miles. To correspond to the longer mileages for the proposed useful life, the amendments would lengthen the useful life operational hours for the HHDD category as well.

The lower weight engine categories do not currently have an operational hour period for their useful lives, and the proposal does not seek to introduce one. CARB staff believes useful life hour periods are not needed for LHDD or MHDD engines because, even in 2031, their proposed useful life mileages would remain less than half the proposed HHDD useful life mileage (i.e., 270,000 miles and 350,000 miles for LHDD and MHDD versus 800,000 miles for HHDD). Hence, CARB staff believes LHDD or MHDD vehicles would be much less likely to accumulate unreasonably high activity hours before exceeding their useful life mileage.

5.3. Treatment of the Heavy-Duty Optionally Certified Hybrid Powertrains Regarding Useful Life

For hybrid powertrains that optionally certify using the optional hybrid vehicle powertrain testing procedures, to ensure adequate durability for the vehicles in which they are used, the useful life periods will be the same as for a diesel engine that would typically be used in a comparable vehicle. Specifically, for 2022 and subsequent MY diesel hybrid powertrains optionally certified to the provisions in 13 CCR 1956.8, the useful life periods would be as follows:

- For powertrains in vehicles with a GVWR from 14,001 to 19,500 pounds, the useful life period would be the same as for LHDD engines;
- For powertrains used in vehicles with a GVWR from 19,501 to 33,000 pounds, the useful life period would be the same as for MHDD engines;
- For powertrains used in vehicles with a GVWR greater than 33,000 pounds, the useful life period would be the same as for HHDD engines; and
- For Otto-cycle engine hybrid powertrains optionally certified to the provisions in 13 CCR 1956.8 and used in vehicles with a GVWR greater than 14,000 pounds, the useful life period would be the same as for HDO engines.

The rationale for staff’s proposed requirements for useful life for hybrid powertrains is similar to that as presented under Section A.4.8.1 of this chapter and is intended to be technology neutral while providing the consumers with similar protection for any power platforms they choose to purchase.

6. Emissions Warranty Information and Reporting and Corrective Action Procedure Amendments

The proposed EWIR and corrective action procedure amendments would improve the current program to ensure that it is more effective, and that corrective action is taken in a timely manner when failure rates exceed corrective action thresholds. Many elements of the current program would remain the same. The subsections below provide a summary of the proposed changes to the current program.

6.1. Warranty Reporting

6.1.1. EWIR Reporting Threshold and Duration of Reporting

The EWIR is the first level of reporting that manufacturers must submit to CARB in order to inform CARB of potentially defective emission-related components. The report requires manufacturers to submit warranty claim rate information on a quarterly basis. CARB staff has determined that several changes need to be made to the warranty reporting process in order to allow for an improved program that could more effectively track issues in the field and provide critical information for CARB to determine how the issues must be addressed.

The current EWIR program requires manufacturers to track the number of unscreened warranty claims for each emission control component by engine family. Unscreened warranty claims refer to the number of parts replaced during the warranty period for any reason, regardless of whether the replaced or repaired part actually experienced a failure. Once a component reaches an unscreened warranty claim rate of 1 percent or 25 claims, whichever is greater, manufacturers are required to submit an EWIR report quarterly, tracking the warranty claim rate. The Proposed Amendments would reduce the EWIR reporting threshold to an unscreened rate of 1 percent or 12 claims, whichever is greater, starting in the 2024 MY. This is to ensure that for engine families with a population of less than 2,500 engines, warranty claims are tracked and any issues are addressed quickly. Currently, if these low volume engine families wait until 25 claims are reached to report, then depending on the size of the engine family population, this can account for a large percentage of the engine family (much higher than 1 percent). This has resulted in CARB staff being unaware of emission control component issues until a high warranty rate is reached (e.g., 25 percent for an engine family with a population of 100 engines). The adjustment to the reporting threshold would result in a small increase in warranty reporting for the manufacturers. Manufacturers would be subject to corrective action triggers based on California or nationwide rates depending on whether they choose to report based on California or nationwide rates, respectively, or if CARB learns that California or nationwide rates exceed those specified in 13 CCR 2143.

Under current EWIR requirements manufacturers are required to submit warranty claim information throughout the warranty period, even if a recall is required and conducted. For example, under today’s 100,000 mile heavy-duty warranty period, if a manufacturer must recall and replace a component for a vehicle that has 80,000 miles on it, the manufacturer currently only has to provide data on the replacement part for another 20,000 miles, which may not be adequate to determine if the new part successfully resolved the defect. This can be problematic if a manufacturer introduces a new version of a component near the end of the warranty period because CARB staff is only able to track warranty data for that component for a limited period of time. Under the Proposed Amendments, manufacturers would be required to submit EWIR reports throughout the useful life period of the heavy-duty vehicle or engine for components that are recalled for exceeding the corrective action threshold, and, if an extended warranty was offered, throughout the extended warranty period. This would allow CARB staff to determine whether replacement parts adequately address the in-use issues that caused the original versions of the parts to fail at unacceptably high rates or if additional corrective action is necessary.

6.1.2. FIR Amendments

Currently, once the unscreened warranty claims rate reaches 4 percent or 50 claims (whichever is greater), a FIR must be submitted. The main purpose for this report is to determine the root cause of the failure and the true screened failure rate. This gives manufacturers the opportunity to screen out warranty claims for parts that were not defective and to assess the projected failure rate of a given emission control component to the end of the useful life period. The Proposed Amendments would reduce the reporting threshold so that FIRs would need to be submitted when the unscreened warranty claims rate reaches 4 percent or 25 claims, whichever is greater, for the 2024 through 2026 MYs. This proposed revision would, like the EWIR, address low volume engine families. For 2027 and subsequent MYs, staff proposes further revisions to account for the proposed lengthening of the warranty period. Because of this lengthening, it is appropriate to increase the reporting threshold and lengthen the reporting period as well as shown in Table III-15 below.

The Proposed Amendments would also add a process that manufacturers would need to follow in order to improve the failure rate analysis. If a manufacturer would like to modify the valid failure rate that was originally reported in the FIR, they would be required to reanalyze the failure rate within two years of submitting the FIR, based on an analysis of a new set of parts. Requiring manufacturers to analyze a new set of parts would ensure that the new analysis would be based on more recent information that would more accurately represent the performance and status of parts that are currently in-use. CARB would also reserve the right to require the manufacturer to provide the parts to CARB for further analysis. If a manufacturer is unable to provide the parts for further analysis, the parts would be considered to be valid failures when determining the failure rate. CARB would also reserve the right to request information regarding parts such as the associated vehicle identification number, associated engine serial number, failure mode for each component analyzed, mileage at the time of failure, and the methodology used to determine the failure mode. Overall, the proposed more rigorous failure rate analysis requirements are necessary to aid CARB staff in determining the accuracy of manufacturers' recalculations of failure rates, provide a tool for CARB staff to validate the information provided in FIRs, and help ensure that manufacturers' take needed corrective action.

6.1.3. EIR Amendments and Corrective Action Threshold

Currently, once an emission control component exceeds a true failure rate of 4 percent or 50 failures, whichever is greater, manufacturers are required to submit an EIR to assess the emissions impact of the failure and address the failure via corrective action.[41] As an alternative to conducting recalls, often times manufacturers have voluntarily proposed to extend warranty periods as an alternative to conducting recalls. CARB has approved such proposals if CARB determined that providing an extended warranty would be as effective as conducting a recall. Similar to the reduced FIR reporting threshold, the Proposed Amendments would reduce the reporting threshold as shown in Table III-15 below.

[41] The true failure rate is determined via the FIR analysis.

Table III-15. Proposed Reporting and Corrective Action Thresholds

MYs	EWIR Threshold	FIR Threshold	EIR Threshold	Corrective Action Threshold
Current	1% or 25 Unscreened Claims	4% or 50 Unscreened Claims	4% or 50 Failures	4% or 50 Failures
2024-2026	1% or 12 Unscreened Claims	4% or 25 Unscreened Claims	4% or 25 Failures	4% or 25 Failures
2027-2030	1% or 12 Unscreened Claims	Years 1-5 4% or 25 Unscreened Claims Years 6-7 5% or 30 Unscreened Claims Years 8-10 7% or 50 Unscreened Claims	Years 1-5 4% or 25 Failures Years 6-7 5% or 35 Failures	Years 1-5 4% or 25 Failures Years 6-7 5% or 35 Failures
2031 and subsequent	1% or 12 Unscreened Claims	Years 1-5 4% or 25 Unscreened Claims Years 6-7 5% or 35 Unscreened Claims Years 8-10 7% or 50 Unscreened Claims	Years 1-5 4% or 25 Failures Years 6-7 5% or 35 Failures Years 8-10 7% or 50 Failures	Years 1-5 4% or 25 Failures Years 6-7 5% or 35 Failures Years 8-10 7% or 50 Failures

Note: The threshold is the greater of the percentage of the population for which there is a warranty claim or failure, or the number of warranty claims or failures specified for each threshold.

The current EIR requirements are ambiguous regarding the EIR submission due date. The Proposed Amendments would clarify that EIRs are due within 90 days after an emission-related component exceeds the true failure rate percentages specified in Section 2143 or within 45 days if requested by CARB.

The Proposed Amendments would require manufacturers to submit a corrective action plan within 90 days of exceeding the corrective action threshold. The corrective action plan would need to include a description of the nonconformity, how the manufacturer's corrective action plan will fix the problem, and the implementation date. Initiating corrective action for components would be required within 30 days of the corrective action plan approval, unless the manufacturer has shown good cause for the deadline to be extended. This would provide an adequate amount of time for manufacturers to develop corrective action plans, while still addressing the in-use issues in a timely manner.

Manufacturers would also be required to perform a recall for any components that reach a failure rate of 25 percent over a five-year period. If a component reaches a 25 percent failure rate within five years, it is clear that the problem is systemic in nature and the component would very likely fail in the majority of vehicles. Hence, the Proposed Amendments would ensure a manufacturer conducts a recall to address the issue expeditiously.

6.2. Parts Storage

Currently, manufacturers analyze returned warranty parts to determine the various failure modes and failure rate. Failure mode information and the failure rate are reported in the FIR. Manufacturers are currently not required to store these parts or submit the parts to CARB for analysis making it impossible for CARB to verify the accuracy of the data and information presented in warranty reports. The Proposed Amendments would require manufacturers to store parts that are analyzed for a period of two years after the FIR is submitted, and upon request from CARB, subject them to further analysis. This would allow for further analysis and review of the parts if necessary and the ability for CARB staff to verify manufacturers' failure analysis conclusions, especially for parts deemed "no trouble found" by manufacturers.

6.3. Demonstration of Compliance with Emission Standards

The Proposed Amendments would remove the applicability of 13 CCR 2147 from 2024 and subsequent MY California-certified heavy-duty diesel and gasoline vehicles, and engines used in such vehicles, and specify that corrective action is required based solely on whether the failure rates of emission-related components meet or exceed the corrective action thresholds discussed above in Section A.6.1.3. It is appropriate for 13 CCR 2147 to no longer apply and to require corrective action based solely on failure rates meeting or exceeding corrective action thresholds rather than considering the emissions impact of the defective component as explained below.

In 2007, the Board adopted amendments to California's Emission Warranty Information Reporting and Recall Regulations and Emission Test Procedures for 2010 and subsequent MY on-road vehicles. One element of that rulemaking, like the current proposal, required manufacturers to recall vehicles that exceeded specified warranty claims rate without requiring CARB to consider the emissions impacts of failed emission control components (unless the manufacturer could demonstrate that the failure had no emissions impacts under any conceivable circumstance). CARB adopted that element because under the preexisting regulation (which remains in effect today), CARB had the burden to prove that a substantial number of vehicles or engines contained a failure in an emission-related component that resulted in the failure of the vehicles or engines to meet applicable emission standards over their useful lives. This burden is especially heavy for situations involving emission control components that gradually deteriorate (so emissions are still initially below applicable emission standards, but are nevertheless above the certified emission levels). In this scenario, it is clear that the vehicles or engines are emitting emissions above the levels they were certified to, and therefore require corrective action, despite the fact that those levels have not yet exceeded applicable certification emission standards. However, meeting this procedural burden required CARB to expend excessive resources and also unduly limited both the scope and timing of recalls.

CARB adopted the 2007 amendments based in part on its statutory authority to adopt emission standards and test procedures for new motor vehicles, and also based on its statutory authority to adopt in-use performance standards for motor vehicles.

In 2008, industry filed a legal challenge to the recall element of the 2007 rulemaking. A Los Angeles Superior Court held that element of the rulemaking action exceeded CARB's statutory authority, because the warranty claims rate was neither an emissions standard nor a test procedure for new motor vehicles, but that court did not rule whether that element of the rulemaking fell within CARB's authority to reduce emissions from in-use motor vehicles. CARB consequently acted to rescind the 2007 amendments.

CARB subsequently adopted, in a separate rulemaking, regulations that required heavy-duty engine manufacturers to procure in-use heavy-duty engines and test them to demonstrate compliance with HD OBD malfunction detection requirements. CARB adopted that regulation based on its authority to adopt emission standards and test procedures for new motor vehicles, and to adopt in-use performance standards for motor vehicles. Industry filed a legal challenge to that regulation, again asserting CARB lacked statutory authority to promulgate that regulation. In 2014, the Third District Court of Appeal held that CARB did not exceed its statutory authority in adopting in-use testing and recall provisions of the HD OBD Regulation. The court determined that the Legislature delegated to CARB broad and extensive implied authority to control in-use vehicle emissions. Because this element of the proposed rulemaking establishes an in-use performance standard for heavy-duty vehicles and heavy-duty engines, it also falls under CARB's broad and extensive implied authority to control in-use vehicle emissions and it is accordingly clear that CARB is authorized to adopt this element of the proposed rulemaking action.

This element of the rulemaking is necessary because, as explained above, the current regulations impair CARB's ability to timely require corrective actions, especially in scenarios involving emission control components that gradually deteriorate, so that emissions are still initially below applicable emission standards, but are nevertheless above certified levels. The proposed amendments would allow CARB to more expeditiously require needed corrective actions.

6.4. Corrective Action Procedures

The current regulations specify recall as a remedy if an emission-related component's failure rates exceed the corrective action threshold. However, manufacturers often voluntarily offer extended warranties in lieu of performing recalls; CARB has approved these requests if staff determines the extended warranty will be as effective as a recall in remedying the particular defect.

The Proposed Amendments would expressly prohibit the option of only offering extended warranty in lieu of recall for the following emissions-critical components: aftertreatment components, computers, EGR valves, EGR coolers, turbochargers, fuel injectors, DPF dosers, and urea dosers. Instead, manufacturers would have to recall and also provide extended warranties for the replacement parts that are used for the recall repair.

The Proposed Amendments would allow manufacturers to offer an extended warranty in lieu of recall for all other components, if they fail at the specified failure rates as identified above in Table III-15. For components that fail at a rate of 25 percent within 5 years, manufacturers would have to conduct a recall and provide an extended warranty for the replacement part that is used for the recall repair.

Manufacturers would be required to submit a corrective action plan to CARB within 90 days of exceeding the corrective action threshold, and would be required to take corrective action within 30 days of the corrective action plan being approved. The manufacturer can request the Executive Officer provide an extension for good cause.

6.5. Recall and Corrective Action Plan

The Proposed Amendments would revise the procedure manufacturers follow when conducting corrective action and require manufacturers to submit some additional information. Though the Proposed Amendments would significantly improve the corrective action process, many of the elements are the same as currently required. New elements include requiring manufacturers to provide a brief summary of the data and technical studies which support the manufacturer's decision regarding the specific corrections to be made. CARB staff would be able to require manufacturers to submit other information, reports, or data which may reasonably be necessary to evaluate the recall plan or corrective action. The Proposed Amendments would also add the requirement that repairs must be completed within a reasonable amount of time designated by CARB from the date the owner delivers the vehicle or engine for repair. This is critical to ensure that repairs are made in a timely manner, and that vehicle owners do not experience unnecessary downtime. If corrective action repairs are to be made by persons other than dealers or authorized warranty agents, manufacturers would have to explain why the technician qualifications identified would be adequate to complete the repair work properly. These new requirements are necessary to make a determination regarding whether the manufacturer's proposed solution to address the in-use issue is adequate.

6.6. Approval and Implementation of Corrective Action Plan

The Proposed Amendments would require a new approval process to facilitate the approval and implementation of a recall or corrective action plan. Under the proposed approval process, if the Executive Officer finds that the recall or corrective action plan is designed to correct the nonconformity and meets the requirements of the required recall plan, he or she will notify the manufacturer in writing. Once the approval letter has been received by the manufacturer, the manufacturer must implement the corrective action. The corrective action would be implemented within 30 days of approval of the corrective action plan, unless the manufacturer can show good cause for the Executive Officer to extend the deadline. This would ensure that corrective action is taken in a timely manner.

6.7. Notification of Owners

Under the Proposed Amendments, manufacturers would be required to notify vehicle or engine owners of a recall or other corrective action by first class mail or by such other means as approved by the Executive Officer. Such notification is already required for ordered recalls, but under the Proposed Amendments, would also be necessary for required recalls.[42] For good cause, the Executive Officer may require the use of certified mail to ensure an effective notification. Manufacturers would also be required to use all reasonable means necessary to locate vehicle or engine owners. For good cause, the Executive Officer may require the manufacturer to use motor vehicle registration lists available from commercial sources to obtain the names and addresses of vehicle or engine owners. These proposed requirements were developed to ensure that vehicle owners would be properly notified of nonconformities or defects with the emission control system. Without being properly informed, vehicle owners would not be aware of the need to have an issue addressed through recall or be informed of any extended warranty coverage. This could result in certain vehicles never getting repaired under a recall program, or vehicle owners paying out-of-pocket at independent dealerships for components that should have been repaired under an extended warranty program. If necessary, the Executive Officer would reserve the right to require

[42] CARB notifies manufacturers when it has determined, based on warranty reports, enforcement testing results, or any other information, that a substantial number of a class or category of vehicles or engines produced by the manufacturer, although properly maintained and used, contain a failure in an emission-related component which, if uncorrected, may result in the vehicles' or engines' failure to meet applicable standards over their useful lives. Under the Proposed Amendments, required recalls would be recalls that must automatically be performed by the manufacturer once the failure rate for a component exceeds the corrective action threshold.

subsequent notification by the manufacturer to vehicle or engine owners by first class mail or other reasonable means. Proper and effective notification is vital to implementing a recall successfully and achieving a high capture rate.

6.8. Owner Notification Letter

Manufacturers are currently required to notify vehicle and engine owners of a recall, extended warranty, or other corrective action through an owner notification letter. It is proposed that this requirement remain intact, but some of the requirements regarding the content of the letters would be modified. The new requirements would make owner notification letters more informative and more effective by encouraging owners to have corrective action performed on their vehicles or engines. The proposed new information that would be required to be included in owner notification letters is as follows:

1. The statement: "The California Air Resources Board has determined that your (vehicle or engine) has an emission control component problem that requires corrective action." This statement is necessary to ensure that vehicle or engine owners are aware that there is an issue with the emission control system of their vehicle or engine that must be corrected.
2. A statement that explains that vehicle or engine owners will be reimbursed if they paid out-of-pocket to have the nonconformity remedied. This would allow for vehicle owners to be reimbursed in a timely manner for the repair of defects that would have been covered under the corrective action program.
3. A statement that explains that a manufacturer cannot deny eligibility for a vehicle or engine owner to participate in a recall or other corrective action solely on the basis of the owner using parts not manufactured by the OEM, or had repairs performed by outlets other than the vehicle or engine manufacturer's franchised dealers. Many vehicle and engine owners use aftermarket parts, or have their vehicles serviced or repaired at independent repair shops. This should not affect their ability to participate in recall or corrective action programs.
4. A clear description of the components that will be affected by the recall or other corrective action and a general statement of the measures to be taken to correct the nonconformity. This statement is necessary so that vehicle and engine owners would be informed of the problem and the corrective action that would be taken to remedy the issue.
5. A description of the procedure which the vehicle or engine owner should follow to have the nonconformity corrected, the date the corrective action program begins, the amount of time needed to correct the nonconformity, and a designation of the facilities at which the nonconformity can be remedied. This information would ensure that owners are aware of how to get their vehicles or engines repaired and completed in a timely manner. This would also be beneficial for manufacturers as it would help answer many basic questions that owners would otherwise have regarding the corrective action process.
6. A statement that indicates that in order to ensure the full protection under the emissions warranty and the ability to participate in future recalls, it is recommended that the vehicle or engine owner complete recall repair work as soon as possible. Failure to do so could be determined as a lack of proper

maintenance of the vehicle or engine. It is critical that vehicle and engine owners have known in-use issues addressed in a timely manner when a solution is available through recall. It is reasonable to consider not having recall repair work performed on a vehicle to be a lack of proper maintenance.

7. A telephone number must be provided for owners to call in order to report difficulty in obtaining recall repairs. This would be beneficial for both manufacturers and owners. It would aid owners in obtaining recall repairs and inform manufacturers about any deficiencies in the implementation of the recall plan.

6.9. Preliminary Tests

Currently, under an ordered recall, the Executive Officer reserves the right to require manufacturers to conduct tests on components and vehicles or engines to demonstrate the effectiveness and adequacy of the corrective action. Under the Proposed Amendments, this would also apply for corrective action that would be required due to failure rates. The requirement is critical as it would aid the Executive Officer in determining whether a proposed recall repair is effective and provides an adequate solution to resolve problems with the component failures in the field while ensuring that affected vehicles or engines comply with emission standards.

6.10. Communication with Repair Personnel

Currently, under an ordered recall, manufacturers are required to provide a copy of all communications which relate to the recall plan directed to dealers and other persons who are to perform the repair contemporaneously to CARB staff. Under the Proposed Amendments, this would also apply to corrective action that would be required due to failure rates. It is important that CARB staff be aware of any updates or changes made to the recall plan or corrective action procedures to ensure that the modification would not reduce the effectiveness of the recall.

6.11. Carryover and Carry Across Applications

Warranty data indicate that, in the past, manufacturers have continued to use components with high failure rates for multiple MYs without making improvements (CARB, 2020e). Currently, manufacturers can use certification emissions data generated from a previous year or a similar engine family in lieu of performing new certification emissions testing via procedures called “carryover and carry across.” As an added mechanism to encourage manufacturers to expeditiously address problems, the Proposed Amendments would prevent manufacturers from using carryover and carry across data for engine families or test groups in any of the following situations:

- Noncompliance with in-use testing requirements specified in 13 CCR 2111-2140 and Part II, Subpart T of the Heavy-Duty Diesel Test Procedures;
- Noncompliance with warranty reporting requirements specified in 13 CCR 2141-2149; and/or
- Equipped with components with failure rates exceeding the thresholds specified in 13 CCR 2143 for past MYs if the component has not been improved.

6.12. Summary of EWIR Amendments

Table III-16 below provides a summary of the major differences between the current EWIR requirements and the proposed EWIR requirements.

Table III-16. Current and Proposed EWIR Requirements

	Current Requirements	Proposed Requirements
6.2 Parts Storage	• No storage requirement.	• Parts must be stored for 2 years.
6.3 Demonstration of Compliance with Emission Standards	• Manufacturers may demonstrate compliance with emission standards to overcome the presumption of noncompliance in order to avoid taking corrective action.	• No longer applicable. The need for corrective action will be based solely on failure rates.
6.4 Corrective Action Procedures	• Components are not identified for specific types of corrective action. • Extended Warranty coverage is not required for replacement parts. • Corrective action plans must be submitted within 45 days of being informed of a nonconformity.	• Certain components are identified as being subject to recall and extended warranties, while some are only subject to extended warranties. (Any component is subject to recall if it reaches a 25% failure rate within 5 years.) • Extended warranty coverage is required for replacement parts. • Corrective Action Plans must be submitted within 90 days of exceeding the corrective action threshold.
6.5 Recall and Corrective Action Plan	• Manufacturers are required to submit corrective action plans for approval prior to implementation. The plans are reviewed to ensure that they will adequately address the problem that is occurring in the field.	• Manufacturers would be required to submit much of the same information, but include additional information so that CARB staff would be able to make more informed decisions when evaluating and approving recall and corrective action plans.
6.6 Approval and Implementation of Corrective Action Plan	• Manufacturers are required to implement corrective action plans within 45 days of receiving approval.	• Manufacturers would be required to implement the corrective action plan within 30 days of receiving approval, unless there is good cause to extend the deadline
6.7 Notification of Owners	• Manufacturers are required to notify vehicle and engine owners of corrective action.	• Manufacturers may have to take additional action to ensure that vehicle and engine owners are notified, such as using certified mail.
6.8 Owner Notification Letter	• Manufacturers must submit owner notification letters for approval as part of the corrective action plan.	• Manufacturers would follow the same approval process, but include additional information specified in Subsection 6.8.
6.9 Preliminary Tests	• Under an ordered recall, Executive Officer can request test data to demonstrate the effectiveness of corrective action repairs.	• No change to current requirements.
6.10 Communication with Repair Personnel	• Manufacturers must submit repair instructions and technical service bulletins related to corrective action repairs as part of the corrective action plan.	• In addition to submitting repair instructions and technical service bulletins, manufacturers would also submit any updates to repair instructions or technical service bulletins.
6.11 Carryover and Carry Across Applications	• Though warranty and failure rate information may have been used when evaluating if it is appropriate to use carryover or carry across data, it was not explicitly stated how it would be used.	• Heavy-duty diesel and heavy-duty Otto-cycle test procedures would explicitly state that carryover or carry across data cannot be used if past MYs have exhibited that they are equipped with components that have failure rates greater than the corrective action thresholds and if an improved version of the component is not being used.

7. Emissions Averaging, Banking, and Trading Program Amendments

In order to resolve the ABT accounting discrepancies between CARB and U.S. EPA for 2022 and subsequent MYs, CARB proposes the establishment of a California-only credit pool (CA-ABT) starting with the 2022 MY.

Under the Proposed Amendments, on-road heavy-duty engine and hybrid powertrain manufacturers would be able to initiate their CA-ABT program by transferring a portion of their national credits balance into the CA-ABT account during the 2022 MY. Credits that were generated prior to the 2010 MY would not be transferrable to the CA-ABT account. Key characteristics of the CA-ABT program are described in the following subsections.

7.1. Transferrable Federal-ABT Credits

Under the Proposed Amendments, federal-ABT credits that were generated prior to the 2010 MY would not be allowed to be transferred into the CA-ABT program. Thus, only credits generated from 2010 through 2021 MY engines could be transferred from the federal-ABT program to the CA-ABT program.

CARB staff's rationale for this amendment is based on action previously taken by U.S. EPA. As noted earlier in Chapter I, Section B.7, federal-ABT credits generated prior to the 2004 MY were subject to a three-year credit life limit (U.S. EPA, 1997b). Starting with the 2004 MY, U.S. EPA removed these credit life provisions altogether from the federal regulations. U.S. EPA rationalized that even with an unlimited lifetime, all existing credits generated after the 2004 MY were expected to be used anyway by the 2010 MY (U.S. EPA, 1997b). In other words, U.S. EPA assumed the credits should be used within 6 years or less. CARB staff agrees, and thus used this rationale for the basis for staff's proposal. CARB staff believes that the absence of a credit life requirement would lead to undermining the benefits of emission standards as manufacturers will continue to use the credits to certify engine families to FELs above the applicable standards.

7.2. Limitations on Credit Transfers from Federal-ABT to CA-ABT

In order to ensure that the amount of credit a manufacturer transfers from its federal-ABT account into its new CA-ABT account is reasonable and related to the volume of sales a manufacturer has in California, the maximum amount of credit transfer into the CA-ABT account would be limited. Manufacturers would need to examine their California and 50-state sales volume for engines within each ABT averaging set during the preceding three MYs (2019-2021). The percentage of California engine sales to national sales for each averaging set over this three-year period would define a percentage cap for the transfer of federal credits generated from the 2010 through 2021 MYs. The following equation describes how the amount of credit transfer into the CA-ABT account is determined:

$$\begin{pmatrix} \textit{Maximum allowable credit} \\ \textit{transfer to } CA - ABT \textit{ bank} \\ \textit{in 2022 model year for} \\ \textit{each heavy} - \textit{duty averaging set} \end{pmatrix} = CR \times \left(\sum_{i=t_1}^{t_2} (CA)_i \right) \div \left(\sum_{i=t_1}^{t_2} (National)_i \right) \quad \text{(Equation III-3)}$$

where:

t_1 = 2019 MY,

t_2 = 2021 MY,

CA_i = California sales volume of engines for the corresponding averaging set in MY i,

$National_i$ = the number of engines produced for U.S. sales within the corresponding averaging set in MY i,

CR = banked federal credits for the corresponding averaging set generated in the 2010 to 2021 MY period.

Equation III-3 above would ensure that a manufacturer could not fill its CA-ABT account with credits unrelated to operation in California and thereby avoid the need to reduce emissions in California.

Consider, for example, a manufacturer that produces 1,000 LHDD engines in the 2019-2021 MY period for distribution in the United States. After examining its records, the manufacturer determines that a total of 200 of those engines were sold in the California market. In this case, the California percentage of sales in the LHDD averaging set would be 20 percent.

During the 2022 MY period, the manufacturer would be allowed to transfer 20 percent of their federal-ABT account balance to the CA-ABT account in the LHDD averaging set. The remaining 80 percent of the LHDD credits would continue to be available for use in the federal-ABT account.

In addition, the transfer of credits into a CA-ABT account would be treated similarly to any other credit transfer transaction. Manufacturers participating in this program would have to submit credit transfer letters to both U.S. EPA and CARB informing the agencies of the intent to transfer credits into the CA-ABT program from the federal-ABT account.

7.3. Hybrid Powertrain Families

The Proposed Amendments include new provisions for certification of hybrid powertrain families for criteria pollutants. As such, hybrid powertrain families would also be eligible for participation in the CA-ABT program.

Hybrid powertrain families would be grouped together with the engine families from the same primary intended service class. Once the primary intended service class for each hybrid powertrain family is determined, manufacturers would be able to choose an FEL for the hybrid powertrain family and perform the necessary ABT calculations within the applicable averaging set. The following averaging sets define the grouping of hybrid powertrain families within the CA-ABT program:

- HDO averaging set includes medium-duty Otto-cycle engines (MDOE), heavy-duty Otto-cycle engines, and hybrid powertrain families used in Class 4-8 vehicles using Otto-cycle engines,
- LHDD averaging set includes medium-duty diesel engines (MDDE), light heavy-duty diesel engines, and hybrid powertrain families used in Class 4 and 5 vehicles using diesel engines,
- MHDD averaging set includes medium heavy-duty diesel engines, and hybrid powertrain families used in Class 6 and 7 vehicles using diesel engines, and
- HHDD averaging set includes heavy heavy-duty diesel engines, and hybrid powertrain families used in Class 8 vehicles using diesel engines.

7.4. Credit Life in CA-ABT

As indicated earlier in Chapter I, Section B.7, credits in the federal-ABT program were subject to a three-year credit life requirement prior to the 2004 MY. For the reasons previously discussed above in Subsection 7.1, these provisions were removed starting with the 2004 MY. As discussed, U.S. EPA believed that all existing credits generated after 2004 MY would be used by the 2010 MY (U.S. EPA, 1997b).

However, a review of the federal-ABT accounts for heavy-duty Otto-cycle and diesel engine manufacturers revealed that U.S. EPA's analysis was based on incorrect assumptions. As of the 2020 MY, there are still several heavy-duty manufacturers that have large quantities of NOx credits left over from pre-2010 MY activity. Thus, these findings support CARB staff's proposal to disallow credits generated prior to 2010 being transferred into the CA-ABT program and to reinstitute credit life requirements into the CA-ABT program.

The Proposed Amendments would reinstitute credit life requirements for all credits generated in the CA-ABT program. The credit life requirements of criteria credits in the CA-ABT program have been structured similarly to the requirements in the federal Phase 2 GHG Regulations in 40 CFR §1036.740(d), last amended October 25, 2016. Credits in the CA-ABT bank may be used only for five MYs after the year in which they are generated. For example, credits generated in MY 2022 may be used to demonstrate compliance with emission standards only through MY 2027.

7.5. Heavy-Duty Zero-Emission Averaging Set

In order to help incentivize production of heavy-duty ZEVs and associated criteria and greenhouse gas emission benefits, especially in the years before they are required by the ACT Regulation, the proposed CA-ABT program would also include amendments to establish a new heavy-duty zero-emission averaging set. Under these provisions, Class 4-8 ZEV families certified under 17 CCR 95663 would be eligible to generate NOx credits in the CA-ABT program, starting with the 2022 MY. The amount of NOx credits in this averaging set would be calculated using the following equation:

$$Zero\ emission\ NOx\ credits = Std \times ECF \times UL \times Sales \times 10^{-6} \quad \text{(Equation III-4)}$$

where:

Heavy-Duty Zero-emission NOx credits are calculated for each certified ZEV model within the vehicle family in Megagrams,

Std = the applicable FTP duty cycle NO_X emission standard in grams per brake horsepower hour for the corresponding MY as specified in the Heavy-Duty Diesel Test Procedures §86.xxx-11 (for 2022 and 2023 MY vehicle families, manufacturers must use the applicable 2024 MY FTP duty cycle NOx emission standard for calculating credits). For Class 4 and 5 vehicle families, use the FTP duty cycle NOx emission standard applicable to light heavy-duty engines. For Class 6 and 7 vehicle families, use the FTP duty cycle NOx emission standard applicable to medium heavy-duty engines. For Class 8 vehicle families, use the FTP duty cycle NOx emission standard applicable to heavy heavy-duty engines,

ECF = the transient cycle conversion factor (in bhp-hr/mile) is the total (integrated) cycle brake horsepower-hour for the applicable ZEV family model during the Vehicle-FTP cycle (as defined in 40 CFR Appendix II to part §1036 (c)) divided by 6.8 miles for diesel engines,

UL = applicable useful life for the vehicle family in miles as defined in 40 CFR §1037.105 and 40 CFR §1037.106 last amended on October 25, 2016,

Sales = California sales volume for Class 4-8 ZEV models sold within the given vehicle family during the MY. Projected MY sales are used for initial certification. Actual sales numbers are used for end-of-year compliance determination.

One key feature of the proposed heavy-duty zero-emission credits is that they could be transferred into any other averaging set for CA-ABT calculations, which would enable a manufacturer to make more heavy-duty ZEVs in lieu of certifying other engine families to more stringent standards. For example, credits generated in the zero-emission averaging set may be used in the heavy-duty Otto-cycle averaging set or any of the heavy-duty diesel averaging sets. The five-year credit life period is also applicable to the credits generated in this averaging set.

The Proposed Amendments terminate the heavy-duty zero-emission averaging set and all banked credits in this averaging set at the end of the 2030 MY. CARB staff believes that after 9 years of development, production, and distribution of heavy-duty ZEVs, the technology would reach the point of maturity, and therefore, an incentive mechanism would no longer be needed to support heavy-duty ZEV production. The elimination of credits in this averaging set would ensure that combustion engine technologies meeting the stringent 2031 and subsequent MY standards would be introduced.

7.6. Early Compliance Credit Multipliers

The Proposed Amendments would include provisions to provide compliance credit multipliers to manufacturers that elect to earlier certify 2022 through 2030 engine families or hybrid powertrain families to applicable emission standards. This would incentivize early emission reductions and would be especially helpful in regions like the South Coast Air Basin where short-term emission reductions are critical for SIP attainment. Credits generated from heavy-duty ZEV families are not eligible for early compliance credit multipliers.

If a manufacturer chooses to participate in this program, it would need to meet all applicable future MY regulatory requirements such as the certification emission standards, in-use compliance program requirements, durability demonstration program requirements, warranty and useful life requirements, OBD requirements, etc., as set forth in, without limitation, 13 CCR 1956.8, 1971.1, 1971.5, 2035, 2036, 2112, and 2139 for the specified MYs. For example, an eligible 2025 MY engine family would need to demonstrate compliance with the 2027 MY emission standards, durability, warranty and useful life, in-use testing, and OBD requirements, etc., in order to participate in the program.

Credits for engine families and hybrid powertrains that are eligible for early compliance credit multipliers would be calculated, adjusted, and banked using the following equation:

$$adjusted\ credits = emission\ credits\ \times ECCM \qquad \text{(Equation III-5)}$$

where:

adjusted credits = Amount of credits that can be banked in the CA-ABT program (in Megagrams),

emission credits = Amount of credits calculated for each eligible engine family or hybrid powertrain as shown in Equation I-1 (in Megagrams),

ECCM = Early compliance credit multiplier as described in Table III-17.

Table III-17. Early Compliance Credit Multipliers

Engine (hybrid powertrain) Family MY	Complying with the Regulations for MYs[a]	Early Compliance Credit Multiplier
2022-2023	2024 – 2026	1.5
	2027 – 2030	2.0
	2031 and subsequent	2.5
2024-2026	2027 – 2030	1.5
	2031 and subsequent	2.0
2027-2030	2031 and subsequent	1.5

[a] Compliance with MY regulations means compliance with the requirements of 13 CCR 1956.8, 1971.1, 1971.5, 2035, 2036, 2112, and 2139 for the specified MYs.

In proposing the numerical values for early compliance credit multipliers, CARB staff considered the overall emission benefits from introducing new emission control technologies. Large multipliers were not considered because they would effectively dilute the effectiveness of future emission standards.

8. Heavy-Duty Engine Durability Demonstration Program and In-Use Emissions Data Reporting Amendments

Currently, on-road heavy-duty engine manufacturers are required to conduct a DDP as part of the certification process. The purpose of the DDP is twofold. First, manufacturers demonstrate that emission-related components are durable throughout the full useful life of the engine subject to the manufacturer-specified maintenance intervals. Second, manufacturers use the DDP data to calculate deterioration factors for various pollutants. Manufacturers must demonstrate that the full useful life exhaust emissions test results are at or below the applicable emission standards before CARB will issue an Executive Order for that engine, which then legally allows the manufacturer to sell that engine in California.

For heavy-duty Otto-cycle engines, CARB staff's review of certification data did not identify any issues relating to the DDP data from the laboratory aging procedures compared to information from in-use operations. Therefore, CARB staff is not proposing any changes to the DDP for on-road heavy-duty Otto-cycle engines. However, as the useful life period for Otto-cycle engines would be lengthened beginning in the 2027 MY, manufacturers would need to account for the lengthened useful life in the existing procedures for bench aging of TWCs for the durability demonstration.

As discussed above in Chapter II, Section C.8, the current DDP is not indicating the same type or frequency of emission-related component failure rates that is observed in real-life operations of heavy-duty diesel engines (U.S. EPA, 2019). Therefore, for heavy-duty diesel engines, the Proposed Amendments include a new standardized methodology for demonstrating durability. The standardized methodology in the Proposed Amendments would include the following elements for the heavy-duty diesel DDP.

8.1. Increased Break-in Period for Medium-Duty and Heavy-Duty Diesel Engines

Prior to conducting an official emissions test on a new engine, manufacturers typically accumulate 125 hours of service on the engine in order to ensure that the emission levels have stabilized. This period is commonly referred to as the break-in period. It should be noted that the default 125-hour break-in requirement for on-road heavy-duty engines was originally established in 40 CFR §86.090-26 (c)(4) on April 11, 1989. At that time, manufacturers did not use any type of aftertreatment system (in particular, an SCR system) in their designs. However, currently the industry-wide engine and aftertreatment system architecture for on-road heavy-duty diesel engine relies heavily on a DOC, DPF, and SCR architecture in order to comply with the emission standards. CARB staff believes that the introduction of such aftertreatment systems, especially the SCR system, requires a longer break-in period to ensure aftertreatment systems have stabilized in their ability to control exhaust emissions.

In order to evaluate the validity of the 125-hour break-in period, CARB staff compared the break-in requirements for Tier III off-road compression-ignition (CI or diesel) engines (40 CFR §89.118 (a)(2), last amended October 23, 1998) versus the Tier IV requirements (40 CFR §1039.801, last amended October 25, 2016). The Tier III break-in requirements were set at 125 hours for off-road diesel engines that did not use a complex aftertreatment system (no products used SCR technology). On the other hand, many of the Tier IV products in the 130-560 kW category use the same DOC, DPF, SCR aftertreatment architecture as used with on-road heavy-duty diesel engines. The applicable regulations increased the break-in requirements for Tier IV products to 300 hours unless the manufacturer can demonstrate a shorter break-in period.

Since the break-in requirements for Tier IV off-road diesel engines take into account the addition of the aftertreatment system, CARB staff is proposing a similar approach for 2024 and subsequent MY on-road heavy-duty diesel engines by increasing the default break-in period to 300 hours. Manufacturers will still be allowed to use a shorter break-in period if they can show stabilized emissions in a shorter break-in period via periodic emissions testing using the applicable certification emissions test cycles.

8.2. Standardized Aging Cycles

Currently, on-road heavy-duty diesel engine manufacturers propose and use a customized aging cycle that is intended to be representative of their typical in-use vehicle operations.

Under the proposed DDP, manufacturers would be limited to only two aging cycle options to demonstrate durability. The use of standardized cycles creates a level playing field amongst different engine manufacturers so that all certified products would go through the same aging process in order to validate component durability and determine the deterioration factors. Also, the aging cycles are comprised of certification test cycles that are largely developed from data generated from actual in-use heavy-duty vehicles, so the cycles reflect how engines are operated in the field, rather than reflect cycles that are designed to complete the aging process as quickly as possible.

The two standardized aging cycles (Cycle-1 and Cycle-2) are further described in Figure III-16 and III-17.

Figure III-16. Cycle-1 Service Accumulation Cycle

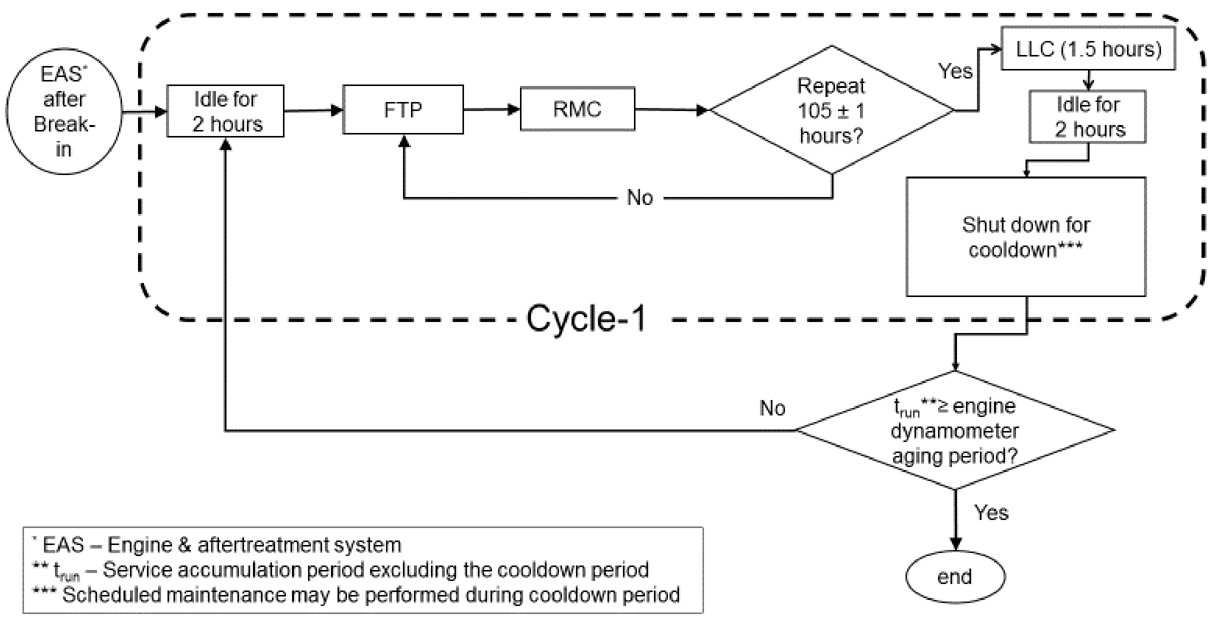
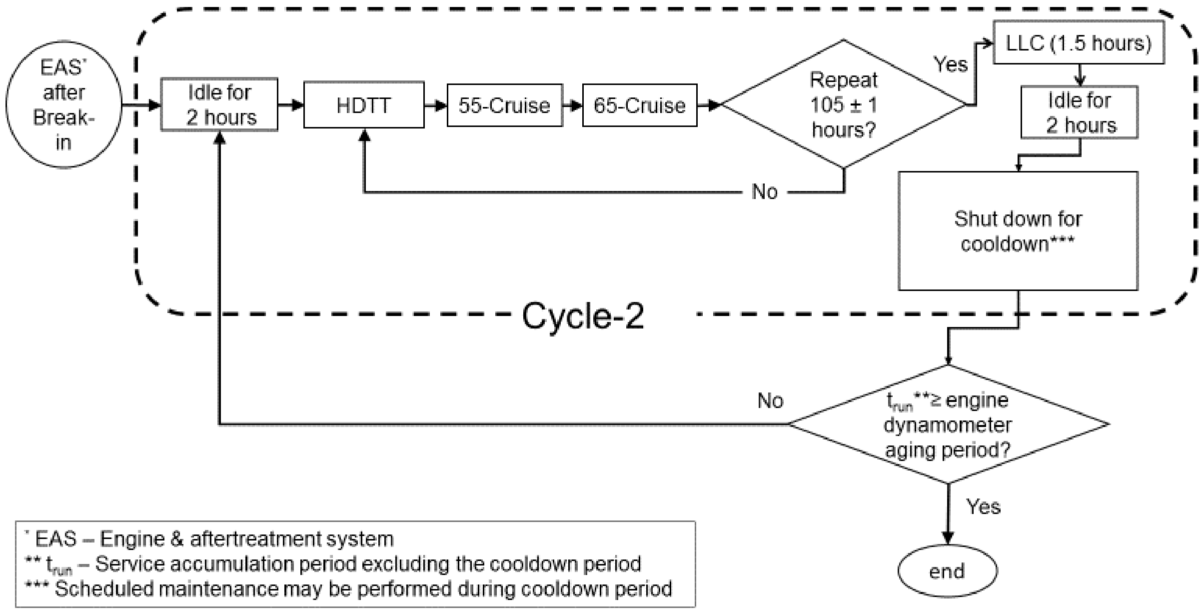


Figure III-17. Cycle-2 Service Accumulation Cycle



As shown in the figures, Cycle-1 uses the standard engine certification cycles (FTP, RMC-SET, and LLC) for aging the engine and aftertreatment system. Cycle-2 uses the standard chassis certification cycles for the Phase 2 GEM (CARB, 2018h). These include the Heavy-Duty Transient Test Cycle (HDTT) as described in Appendix I to 40 CFR Part 1037 and 40 CFR §1037.510(a)(3), the 55 mph highway cruise cycle (55-cruise) and 65 mph highway cruise cycle (65-cruise) as described in 40 CFR §1037.510(a)(3), last amended October 25, 2016.

The applicability of the Cycle-1 and Cycle-2 service accumulation cycles is dependent on the vehicle configuration in which the engine would be used and is described below.

8.3. Impact of Vehicle Size, Configuration, and Application on Aging Cycle Selection

In order to quantify the impacts of vehicle size, configuration, and application on engine and aftertreatment system deterioration, the revised DDP would include provisions for engine manufacturers to examine these vehicle variables for each engine family while generating the applicable aging cycles.

The Proposed Amendments would require manufacturers to use the Phase 2 GEM to generate applicable engine dynamometer cycles for HDTT, 55-cruise, and 65-cruise cycles and compare those cycles to the standard engine dynamometer certification cycles (FTP, RMC-SET). Manufacturers would be required to use the cycle with the highest load factor in the DDP.

Load factor is defined as:

$$Load\ Factor = \frac{\int_0^T P_i \cdot dt}{P_{max} \cdot D} \qquad \text{(Equation III-6)}$$

where:

P_i = Instantaneous engine power (hp)

D = Total duration of the cycle (seconds)

P_{max} = Maximum engine power rating (hp)

t = time (seconds)

For example, if the load factor for the Cycle-2 (combination of HDTT/55-cruise/65-cruise cycles) is 44 percent and the load factor for Cycle-1 (combination of FTP/RMC-SET cycles) is 41 percent, then Cycle-2 would be required for the DDP.

CARB staff has reviewed the 2018 MY Executive Orders[43] issued for on-road heavy-duty diesel engines. Only one engine manufacturer (Cummins, Inc.) does not certify any GHG vehicle families with CARB. All other engine manufacturers also certify GHG vehicle families, and therefore have access to the vehicle configuration information that is necessary for running the GEM model.

In the case of Cummins Inc., CARB staff recommends that, at a minimum, it identify the applicable regulatory vehicle subcategories as defined in 40 CFR §1037.230, last amended October 25, 2016, for each certified engine family. Cummins could then use typical vehicle configuration parameters that were used in previous MY vehicles to determine which service accumulation cycle it must use for the DDP.

8.4. Increasing the Required Laboratory Aging Hours to Full Useful Life

Currently, on-road heavy-duty diesel engine manufacturers use aging cycles that are intended to represent aging of the engine and aftertreatment system to approximately 35 to 50 percent of useful life. Upon completion of the aging program, the durability emissions data are extrapolated to full useful life of the engine and aftertreatment system to calculate the numerical value of the applicable deterioration factor for each durability data engine.

Based on the information from vehicle and engine compliance activities (U.S. EPA, 2019), it is clear that the current laboratory aging process does not accurately reflect the ability of actual in-use engines to control emissions over their

[43] The California Executive Orders can be viewed on CARB's website at https://ww3.arb.ca.gov/msprog/onroad/cert/cert.php#6.

useful lives. CARB staff is therefore proposing to extend the length of the DDP to the full useful life of the engine and aftertreatment system. However, for 2024 through 2026 MY heavy heavy-duty engines and for all other engines starting with the 2027 MY, CARB staff is proposing provisions that would allow the use of accelerated aftertreatment aging for a portion of useful life in order to reduce the overall aging period. The minimum required aging hours for different primary intended service classes of heavy-duty diesel engines are described below in Subsections 8.7 through 8.9 of this chapter.

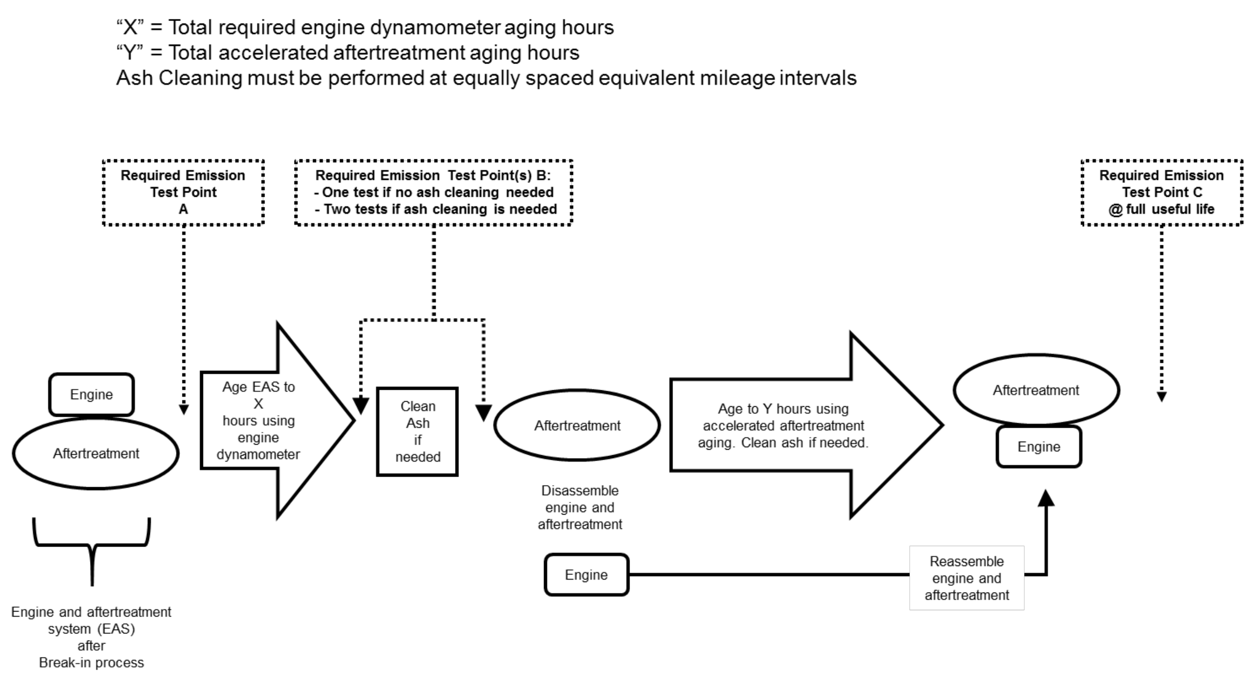
8.5. Diesel Aftertreatment Accelerated Aging Cycle

The Diesel Aftertreatment Accelerated Aging Cycle (DAAAC) (Bartley, 2012) protocol is a process developed by SwRI that focuses strictly on aging the aftertreatment system by accelerating two mechanisms that degrade the overall efficiency of the aftertreatment system:

- Thermal degradation, and
- Chemical degradation.

Although the main objective of the DAAAC is to accelerate the aging process, it does not account for the impacts of aging on all engine emission-related components. Figure III-18 shows a schematic of the sequence of events using the DAAAC process.

Figure III-18. Sequence of Events for Combined Engine Dynamometer and Accelerated Aftertreatment Aging



Although CARB staff is proposing the use of the DAAAC protocol to simulate the accelerated aging of the aftertreatment system, it is also proposing to allow manufacturers to also propose other accelerated aging protocols that simulate thermal and chemical degradation of the aftertreatment system. Use of such manufacturer proposals would be subject to advance approval by CARB, based on information provided and the exercise of good engineering judgment.

Manufacturers that opt to use the accelerated aftertreatment aging option would also be required to periodically submit emissions data from in-use on-road heavy-duty diesel engines. The data to be submitted would be collected and stored on the on-board computer, and would help validate how accurately the accelerated aging data represents true in-use deterioration. Additional details regarding in-use emissions data reporting is described below.

8.6. In-Use Vehicle Emissions Data Reporting

Manufacturers that opted to use the accelerated aftertreatment aging would be required to submit periodic in-use vehicle emissions reports to CARB. The Proposed Amendments would require periodic reporting of vehicle engine control module data (including REAL parameters) to CARB as follows:

(a) Manufacturers must submit a separate report for each heavy-duty diesel engine family (with SCR system) that was certified for sale in California.

(b) The initial report must be electronically submitted to CARB by December 31 of the applicable engine family MY. For example, the initial report for a 2024 MY engine family must be submitted by December 31, 2024.

(c) Subsequent annual reports must be electronically submitted to CARB by December 31 of the subsequent MYs. For example, the subsequent reports for a 2024 MY engine family must be submitted by December 31, 2025, 2026, and so forth.

(d) For each vehicle/engine, data must be recorded at least once per calendar year. Also, for each annual vehicle/engine data recording throughout its useful life, the interval between valid annual data recordings must be at least six months. For example, a vehicle sampled at August 1, 2025 should not be sampled again until at least February 1, 2026.

(e) In-use emission reports for each vehicle/engine must provide the following information:

(1) Engine family name
(2) Vehicle family name
(3) California sales volume of vehicles for each engine family
(4) Engine model name
(5) Rated engine model power (hp)

(6) Vehicle identification number (VIN)
(7) Engine serial number
(8) Odometer reading (miles)
(9) Engine run time/hour-meter reading (hours)
(10) Date when all data was recorded
(11) All tracking parameters identified in 13 CCR 1971.1(h)(5)
(12) In lieu of tracking parameters in subsection (11) above, manufacturers may submit another set of parameters that identify the in-use emissions characteristics of each vehicle. The format and content of these parameters must be determined based on good engineering judgment and is subject to CARB approval.

(f) CARB staff recognizes it may not be feasible to collect data from all vehicles/engines that have been originally sold in the California market. As such, for each engine family, manufacturers must submit all in-use vehicle emissions data collected by the manufacturer in that reporting year, and at a minimum collect data on 20 percent of vehicles that were originally sold in the California market.

(g) Manufacturers who collect data on more than 50 percent of their California sales for three consecutive MYs in 2024 through 2030 MYs, will be eligible for a longer accelerated aftertreatment aging period (with commensurate shorter engine dynamometer aging periods). For 2031 and subsequent MYs, manufacturers must collect data on more than 50 percent of their California sales for five consecutive MYs in order to be eligible for longer accelerated aftertreatment aging periods.

(h) The in-use emissions data requirements specified in sections (a)-(g) above are not required for engines that have passed their applicable useful life.

(i) In-use emission reports must include data from vocational, and if applicable, tractor vehicles as defined in 40 CFR §1037.801, last amended October 25, 2016.

(j) Staff will use this information to screen for engine families that may show high emission deterioration rates that do not match the results observed through laboratory aging.

8.7. DDP – 2024 to 2026 MYs

The program proposed for the 2024 through 2026 MYs takes into account the fact that the useful life periods would remain at today's current values.

Under the Proposed Amendments, Table III-18 specifies the applicable service accumulation schedules for on-road medium-duty and heavy-duty diesel engines for the 2024 through 2026 MY period. Note that for these MYs, the DAAAC protocol would only be an option for HHDD engines. The required durability hours were selected so that the proposed DDP can be completed within one calendar year, therefore, the program would not adversely impact the product development cycle. As such, only the HHDD service class would have the option to use the DAAAC process.

Table III-18. 2024 to 2026 MY DDP Service Accumulation Schedules

<table>
<tr><th>Primary Intended Service Class</th><th>Useful Life (miles)</th><th colspan="2">Engine Dynamometer hours (% of Useful Life)</th><th>DAAAC hours (% of Useful Life)</th></tr>
<tr><td>Medium-Duty</td><td>150,000</td><td colspan="2">3,400 hours
(100% UL)</td><td>0</td></tr>
<tr><td>LHDD</td><td>110,000</td><td colspan="2">2,500 hours
(100% UL)</td><td>0</td></tr>
<tr><td>MHDD</td><td>185,000</td><td colspan="2">4,200 hours
(100% UL)</td><td>0</td></tr>
<tr><td rowspan="2">HHDD</td><td rowspan="2">435,000</td><td>Option 1[a]</td><td>4,900 hours
(50% UL)</td><td>505 hours
(50% UL)</td></tr>
<tr><td>Option 2</td><td>9,800 hours
(100% UL)</td><td>0</td></tr>
</table>

[a] Option 1: This option would require the submittal of in-use vehicle emissions data, as described in Subsection 8.6 of this chapter.

The number of hours of dynamometer aging were based on the average vehicle speed for the GEM model cycles (HDTT, 55-cruise, 65-cruise). The required DAAAC hours were based on information from the SwRI Low NOx Stage 1 testing program final report (Sharp et al., 2017b). Based on the SwRI analysis, 1,000 hours of DAAAC corresponds to 435,000 miles of service accumulation.

CARB staff anticipates that all HHDD engine manufacturers would use the DAAAC process (option 1 in Table III-18) in the 2024-2026 MY period because this process would reduce certification costs and shortens the overall DDP period, thereby providing more time to complete their certification application. Therefore, it is expected that all HHDD manufacturers would be submitting in-use vehicle emissions data (as described above in Subsection 8.6) to CARB starting with 2024 MY HHDD engines.

8.8. DDP – 2027 to 2030 MYs

As indicated above in Section A.5 of this chapter, the Proposed Amendments include provisions that would extend the useful life periods for all on-road heavy-duty service classes in two phases. The first phase would begin with the 2027 MY. The second phase would go into effect with the 2031 MY. The anticipated DDP for the 2027 through 2030 MYs would rely on the same elements used in the optional aging protocol for 2024 through 2026 MY on-road HHDD engines:

- Engine dynamometer aging for a portion of useful life,
- DAAAC for a portion of useful life, and
- Periodic submittal of emissions data from in-use engines covering the full useful life period.

However, because the Proposed Amendments would extend the applicable useful life values starting with the 2027 MY, the proposed service accumulation schedules, as shown in Table III-19, would be applicable.

Table III-19. 2027 to 2030 MY DDP Service Accumulation Schedules

Primary Intended Service Class	Proposed Useful Life (miles)	Engine Dynamometer hours (% of Useful Life)	DAAAC hours (% of Useful Life)
Medium-Duty	50,000	3,400 hours (100% UL)	0
LHDD[a]	190,000	3,000 hours (69% UL)	135 hours (31% UL)
MHDD[a]	270,000	4,200 hours (69% UL)	195 hours (31% UL)
HHDD[a]	600,000	4,900 hours (36% UL)	885 hours (64% UL)

[a] The engines in this service class would be required to submit in-use emissions data, as described in Subsection 8.6 of this chapter.

The service accumulation hours were selected in a manner so that significant aging hours on the dynamometer were achieved for all service classes (3,000 to 4,900-hour range). CARB staff is concerned with component failure rates as observed in the U.S. EPA study (U.S. EPA, 2019), therefore, CARB staff does not believe engine dynamometer hours shorter than shown in Table III-19 would be adequate. CARB staff also anticipates the introduction of new technologies on the engine side such as cylinder deactivation in 2027 and subsequent MYs. These new technologies would require some level of service accumulation on the engine dynamometer to verify durability before introduction into commerce.

However, manufacturers that submit in-use emissions reports for more than 50 percent of their California sales volume for three consecutive MYs would be able to use longer periods of accelerated aftertreatment aging as shown in Table III-20 below. The schedule below reduces the total engine dynamometer run time by approximately 14 to 18 percent for various service classes, thereby reducing the total aging time for the DDP.

Table III-20. 2027 to 2030 MY DDP Service Accumulation Schedules for Engine Manufacturers that Submit In-Use Emissions Reports for More Than 50 Percent of Their California Sales Volume for Three Consecutive MYs

Primary Intended Service Class	Proposed Useful Life (miles)	Engine Dynamometer hours (% of Useful Life)	DAAAC hours (% of Useful Life)
Medium-Duty	150,000	3,400 hours (100% UL)	0
LHDD[a]	190,000	2,500 hours (58% UL)	185 hours (42% UL)
MHDD[a]	270,000	3,500 hours (57% UL)	265 hours (43% UL)
HHDD[a]	600,000	3,750 hours (28% UL)	1,000 hours (72% UL)

[a] The engines in this service class would be required to submit in-use emissions data, as described in Subsection 8.6 of this chapter.

8.9. DDP – 2031 and Subsequent MYs

The proposed DDP for 2031 and subsequent MYs is very similar to the proposed DDP program for 2027 through 2030 MYs. The key difference is the proposed increase in useful life periods for 2031 and subsequent MYs which requires a longer service accumulation schedule. The program relies on the same elements used in the 2027 through 2030 MY program for on-road heavy-duty diesel engines:

- Engine dynamometer aging for a portion of useful life,
- DAAAC for a portion of useful life, and
- Periodic submittal of emissions data from in-use engines covering the full useful life period.

The service accumulation schedules proposed for the 2031 and subsequent MYs are shown in Table III-21.

Table III-21. 2031 and Subsequent MY DDP Service Accumulation Schedules

Primary Intended Service Class	Proposed Useful Life (miles)	Engine Dynamometer hours (% of Useful Life)	DAAAC hours (% of Useful Life)
Medium-Duty	150,000	3,400 hours (100% UL)	0
LHDD[a]	270,000	3,180 hours (52% UL)	300 hours (48% UL)
MHDD[a]	350,000	4,200 hours (53% UL)	380 hours (47% UL)
HHDD[a]	800,000	4,900 hours (27% UL)	1,345 hours (73% UL)

[a] The engines in this service class would be required to submit in-use emissions data, as described in Subsection 8.6 of this chapter.

Once again, the service accumulation hours were selected in the same manner described in Subsection 8.8 of this chapter. The minimum engine dynamometer aging requirement varied from 3,200 to 4,900 hours depending on the intended service class. This methodology is expected to verify the durability of new technologies on the next generation diesel engines.

Additionally, manufacturers that submit in-use emissions reports for more than 50 percent of their California sales volume for five consecutive MYs would be able to use longer periods of accelerated aftertreatment aging as shown in Table III-22 below. The schedule below reduces the total engine dynamometer run time by approximately 14 to 18 percent for all service classes, thereby reducing the total aging time for the DDP.

Table III-22. 2031 and Subsequent MY DDP Service Accumulation Schedules for Engine Manufacturers that Submit In-Use Emissions Reports for More Than 50 Percent of Their California Sales Volume for Five Consecutive MYs

Primary Intended Service Class	Proposed Useful Life (miles)	Engine Dynamometer hours (% of Useful Life)	DAAAC hours (% of Useful Life)
Medium-Duty	150,000	3,400 hours (100% UL)	0
LHDD[a]	270,000	2,500 hours (41% UL)	370 hours (59% UL)
MHDD[a]	350,000	3,500 hours (44% UL)	450 hours (56% UL)
HHDD[a]	800,000	3,750 hours (21% UL)	1,460 hours (79% UL)

[a] The engines in this service class would be required to submit in-use emissions data, as described in Subsection 8.6 of this chapter.

9. Powertrain Certification Test Procedures for Heavy-Duty Hybrid Vehicles Amendments

The Proposed Amendments would provide a voluntary option for certifying hybrid powertrains to criteria pollutant emission standards using powertrain testing procedures. The Proposed Amendments would allow heavy-duty hybrid vehicle manufacturers to seek voluntary powertrain-based (as opposed to engine-based, or chassis dynamometer-based) certification. The powertrain testing procedures would align with corresponding federal procedures for powertrain testing and would be based on the U.S. EPA Phase 2 GHG technical amendments for powertrain testing. The Proposed Amendments would amend the existing California powertrain testing procedures for certifying hybrid powertrains to GHG emission standards to allow them to also be used as an optional procedure to certify to criteria pollutant emission standards.

As described above, currently three separate entities are involved in the manufacture and certification of a heavy-duty hybrid vehicle: manufacturers of the conventional engine, the hybrid system, and the vehicle. CARB staff believes that the proposed hybrid powertrain certification procedures could potentially reduce the number of entities typically involved in the manufacturing and certification of hybrid vehicles. This would result in hybrid vehicles that have the potential to emit lower emissions and achieve improved fuel economy, as well as improved durability, through the increased level of vehicle integration.

The Proposed Amendments would expand on U.S. EPA's powertrain certification testing for GHG emission standards and allow manufacturers the option to use the amended procedures to certify heavy-duty hybrid powertrains to criteria pollutant emission standards for 2022 and subsequent MYs. The Proposed Amendments to the existing Phase 2 GHG hybrid powertrain procedures would provide manufacturers with flexibility in selecting the conventional engines that are used in the hybrid powertrains. Under the Proposed Amendments, the complete hybrid powertrain, including the combustion engine, the hybrid system, and exhaust aftertreatment systems, would be required to be tested as a unit on a powertrain dynamometer. The CARB certification value for a heavy-duty hybrid powertrain would be determined through emissions measurements and calculations using powertrain dynamometer test results. Once certification requirements are satisfied, an Executive Order would be issued to the entity that applied for certification. All hybrid powertrains intended for use in heavy-duty hybrid vehicles certified using the proposed powertrain testing procedures would need to comply with all certification requirements for heavy-duty engines and vehicles, as applicable, including, but not limited to, useful life, emissions warranty, durability demonstration, and OBD requirements.

10. Heavy-Duty Vehicle GHG Tractor APU Certification Amendments

The Proposed Amendments would ensure that California's certification requirements and emission standards for diesel APUs used in new California-certified on-road tractors are as stringent as existing federal requirements, while enhancing California's ability to verify APU compliance in-use and to administer corrective action in a timely manner when needed. This is necessary to ensure that the emission benefits attributed to the APU portion of the Phase GHG requirements will be fully realized and protected in California. Specifically, the Proposed Amendments would modify §1037.106(g)(2) of the California Phase 2 GHG test procedures by referencing the California off-road diesel engine test procedures[44] instead of referencing the federal nonroad diesel engine test procedures as is currently the case. The federal test procedures are referenced because the California test procedures do not yet require APUs to certify to a 0.02 g/kW-hr PM emission standard. As proposed in this rulemaking, the federal certification requirements for APUs in 40 CFR §1039.699 would be incorporated into California's off-road diesel engine test procedures, henceforth requiring compliance with a 0.02 g/kW-hr PM emission standard for all California-certified APUs. This would maintain harmonized certification requirements for tractor APUs between California and U.S. EPA. Table III-23 shows the current and proposed requirements for California's PM certification requirements for an APU that would be used in a new 2024 and subsequent MY tractor.

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[44] California Exhaust Emission Standards and Test Procedures for New 2011 and Later Tier 4 Off-Road Compression-Ignition Engines, PART I-D

Table III-23. California's PM Certification Requirements for a Diesel APU Used in a New 2024 and Subsequent MY Tractor

Requirements	Current	Proposed
Regulatory Pathway	40 CFR §1039.699	California 2011 and Later Off-Road Compression-Ignition Engine Test Procedures that is proposed to be amended to include 40 CFR §1039.699
PM Emission Standard	0.02 g/kW-hr	Same
PM Test Procedures	Steady-state tests in 40 CFR §1039.505	Same
California Enforcement	None for the 0.02 g/kW-hr standard	Yes

Additionally, the Proposed Amendments would modify the idling ATCM requirements pertaining to diesel APUs that may be used as an alternative idle reduction technology. The Proposed Amendments would add an APU certified to 40 CFR §1039.699 (0.02 g/kW-hr PM standard) incorporated in the California off-road engine test procedures to the approved provisions for diesel APUs, in addition to the current approved provisions of routing the APU's exhaust to the vehicle exhaust and to retrofitting the APU with a verified Level 3 PM control device. The Proposed Amendments would also allow an APU certified to 40 CFR §1039.699 to comply with the requirements of the idling ATCM.

11. California Phase 2 GHG Regulation Clean-up Items

Since CARB adopted the California Phase 2 GHG standards and began implementing them, CARB staff has become aware that several minor clarifications and corrections are needed. The Proposed Amendments would make some minor changes to the California Phase 2 GHG Regulation, which are summarized below.

Definition of Medium-Duty Vehicle

The Proposed Amendments would clarify the definition of medium-duty vehicle to include 2018 and subsequent MY ZEVs with GVWR between 8,501 and 14,000 pounds because these vehicles were inadvertently omitted in the previous rulemaking. The Proposed Amendments are necessary to clarify that 2018 and subsequent ZEVs can be certified as medium-duty vehicles.

End-of-Year Report Requirements

Currently, manufacturers are required to submit an end-of-the-year report on vehicles sold after the end of the MY. Currently, only total U.S.-directed production volumes are required in the end-of-year reporting requirements. The Proposed Amendments would require manufacturers to specify which vehicles certified to the Phase 2 GHG standards were sold in California. This proposed modification is necessary to ensure manufacturer compliance in California and to enable CARB staff to collect California specific data to more effectively develop CARB's heavy-duty vehicle emission inventory model.

Recall Provisions

The Proposed Amendments would correct regulatory text which inadvertently references federal recall provisions instead of California-specific recall provisions.

Environmental Performance Label Amendments

As part of the California Phase 2 GHG Regulation, CARB is requiring environmental performance consumer labels for new chassis-certified medium-duty vehicles, and pick-up trucks and vans, with GVWR of 8,501 to 14,000 pounds, except medium-duty passenger vehicles, manufactured on or after January 1, 2021.

The Proposed Amendments would make minor clean-up modifications to these labels. Proposed modifications include changing the font size of "California Air Resources Board" from 18 point to 16 point to fit in the space provided, and fixing some width specifications, formatting requirements, and typographical errors from the original regulatory text. These minor modifications are needed for clarity and consistency purposes.

Trailer-Specific Amendments

The Proposed Amendments would specifically add the word "trailer" to the emissions warranty, in-use compliance, and emissions warranty reporting regulations to clarify that such regulatory provisions in title 13, CCR apply to trailers. As mentioned earlier, the Phase 2 GHG standards included trailers as a newly defined class of heavy-duty vehicles and added trailer warranty and useful life periods to the applicable CCR sections. Thus, it was apparent heavy-duty vehicles encompassed trailers. CARB staff is accordingly proposing to clarify this definition of vehicle by expressly adding the term "trailer" to the term "vehicle" throughout the text of the emissions warranty, in-use compliance, and emissions warranty information and reporting regulations to clarify what was already adopted in the Phase 2 GHG standards. While it is clear that heavy-duty vehicles include trailers in its definition in the Phase 2 standards, the Proposed Amendments eliminate any ambiguity in its application to trailers.

In addition, the Proposed Amendments would correct typographical errors in the regulation such as updating the California effective date of the regulation, requiring submission of aerodynamic device testing data to CARB rather than to U.S. EPA, and correcting a "greater than" symbol to a "greater than or equal" symbol. The Proposed Amendments would also amend the definition of "vehicle" in the California Phase 2 GHG Regulation.

Additionally, the Proposed Amendments include a provision where the Executive Officer has the ability to exempt specific trailer configurations from meeting the required emission standards when it is determined that the technology is not available to meet the standard. Although the trailer emission standards are readily attainable, CARB staff has become aware of a few very specific specialty trailer types that have unique design specifications that may make it difficult to meet the emission standards they are subject to in the very early years of the program. CARB staff believes that these barriers will be readily overcome with time. Although CARB staff expects this exemption provision would rarely be used, staff anticipates that it may encounter a few of these very special cases and does not want to hinder the market for these rare specialty trailers that have become subject to the Phase 2 trailer standards.

Warranty, In-Use Compliance and Recall

The Proposed Amendments would add the warranty requirements of 13 CCR 2035, et seq. to the list of documents designed to be used in conjunction with the California GHG Exhaust Standards and Test Procedures for 2014 and Subsequent MY Heavy-Duty Vehicles.

12. Medium-Duty Engine Clarifications and Amendments

To clarify the useful life of LEV III engines used in medium-duty vehicles from 10,001 to 14,000 pounds GVWR, the Proposed Amendments would align the useful life of medium-duty engines with medium-duty vehicles at 150,000 miles. The current engine useful life of 120,000 miles will sunset in the 2022 MY, and the LEV III useful life regulatory language of 150,000 miles would be modified to include engines used in medium-duty vehicles beginning in the 2023 MY. This clarification would ensure that the useful life of an engine used in a medium-duty vehicle would match the required 150,000 miles useful life of the vehicle.

Another proposed amendment that would apply to medium-duty engines would be clarifying the existing prohibition of using a medium-duty engine in a heavy-duty vehicle greater than 14,000 pounds GVWR. Although existing regulations prohibit installing a medium-duty engine into a heavy-duty vehicle over 14,000 pounds GVWR, CARB staff believes that more clearly expressing this prohibition in the Proposed Amendments will reinforce this prohibition to the regulated industry, to ensure that medium-duty engines, which would have a significantly shorter useful life and warranty requirements, would not be installed in heavy-duty vehicles greater than 14,000 pounds GVWR.

In addition, the Proposed Amendments to the LEV III provision that allows heavy-duty vehicles greater than 14,000 pounds GVWR, and engines used in such vehicles, to be grouped with a medium-duty vehicle certification group, would be limited to 2023 and earlier MYs. Limiting the usage of this provision to 2023 and earlier MYs would ensure that all 2024 and subsequent MY heavy-duty vehicles greater than 14,000 pounds GVWR and engines used in such vehicles would be certified to the proposed low NOx emission standards, which would be more stringent than the current medium-duty vehicle chassis emission standards, and hence would prevent excess emissions.

B. Future Rulemaking Plans

U.S. EPA is funding the following work relevant to the Proposed Amendments:

- Developing a diesel aftertreatment rapid-aging protocol;
- Assessing feasibility and cost of open crankcase systems on heavy-duty diesel engines;
- Testing heavy-duty gasoline engines and technologies on Class 3 to 7 trucks;
- Evaluation of new weighting factors for the FTP and RMC-SET test cycles; and
- Developing new requirements for engine rebuild practices.

Although U.S. EPA's work in these areas will not be complete in time to inform CARB's Proposed Amendments outlined in this Staff Report, given the urgency with which California must act on its air quality challenges, CARB staff believes the work to be valuable and anticipates relying on this work in future rulemakings.

IV. THE SPECIFIC PURPOSE AND RATIONALE OF EACH ADOPTION, AMENDMENT, OR REPEAL

California Government Code section 11346.2(b)(1) requires a description of the specific purpose for each proposed amendment, as well as a description of the rationale for determining that each proposed amendment is reasonably necessary to both carry out the purposes of CARB staff's proposal and to address the problems described in Chapter II. Accordingly, Appendix F: Purpose and Rationale presents the summary of each proposed amendment and describes its purpose and rationale.

V. BENEFITS ANTICIPATED FROM THE REGULATORY ACTION, INCLUDING THE BENEFITS OR GOALS PROVIDED IN THE AUTHORIZING STATUTE

A. Baseline Assumptions

On-road mobile source emissions in California are currently estimated using the EMFAC2017 model.[45] The baseline vehicle inventory includes the vehicle sales and population growth assumptions currently reflected in CARB's EMFAC emissions inventory model for combustion engines that are certified and intended for use in vehicles greater than 10,000 pounds GVWR. The current EMFAC model also reflects implementation of currently existing state and federal laws and regulations including the Truck and Bus Regulation, Drayage Truck Regulation, idling restrictions and the Certified Clean Idle Regulation, Phase 1 and 2 GHG Regulations, ICT Regulation, and the Optional Low NOx Program. This is the "legal baseline" for the Proposed Amendments.

CARB staff used the legal baseline to calculate the emission benefits from the Proposed Amendments because the California Department of Finance requires the main impact analysis to be calculated relative to the legal baseline, which only accounts for existing regulations. However, CARB staff recognizes that recently proposed regulations that are not approved by the Office of Administrative Law may affect the baseline calculations. As noted earlier, both the proposed ACT Regulation and the Proposed Amendments impact the same class of vehicles and engines during the same timeframe, although the regulations intend to achieve distinct purposes and therefore have independent utility. The implementation of the proposed ACT Regulation would result in fewer heavy-duty engines and vehicles being subject to the Proposed Amendments because a percentage of vehicles would be required to be zero-emission by the proposed ACT Regulation. To determine the potential impact of the proposed ACT Regulation on the Proposed Amendments, CARB staff examined the baseline as if the proposed ACT Regulation were included with existing regulations. Figure V-1 below shows how the ACT Regulation could affect the baseline emissions and projected benefits of the Proposed Amendments, based on the proposal for the ACT Regulation proposed to the Board in December 2019. As Figure V-1 shows, the ACT Regulation would reduce both the baseline emissions and the benefits expected from the Proposed Amendments. Based on the December 2019 ACT Regulation Proposal, staff estimated that in 2031 the benefits of the Proposed Amendments versus an ACT-Adjusted baseline would be approximately 20 percent less than the benefits estimated versus the Legal baseline.

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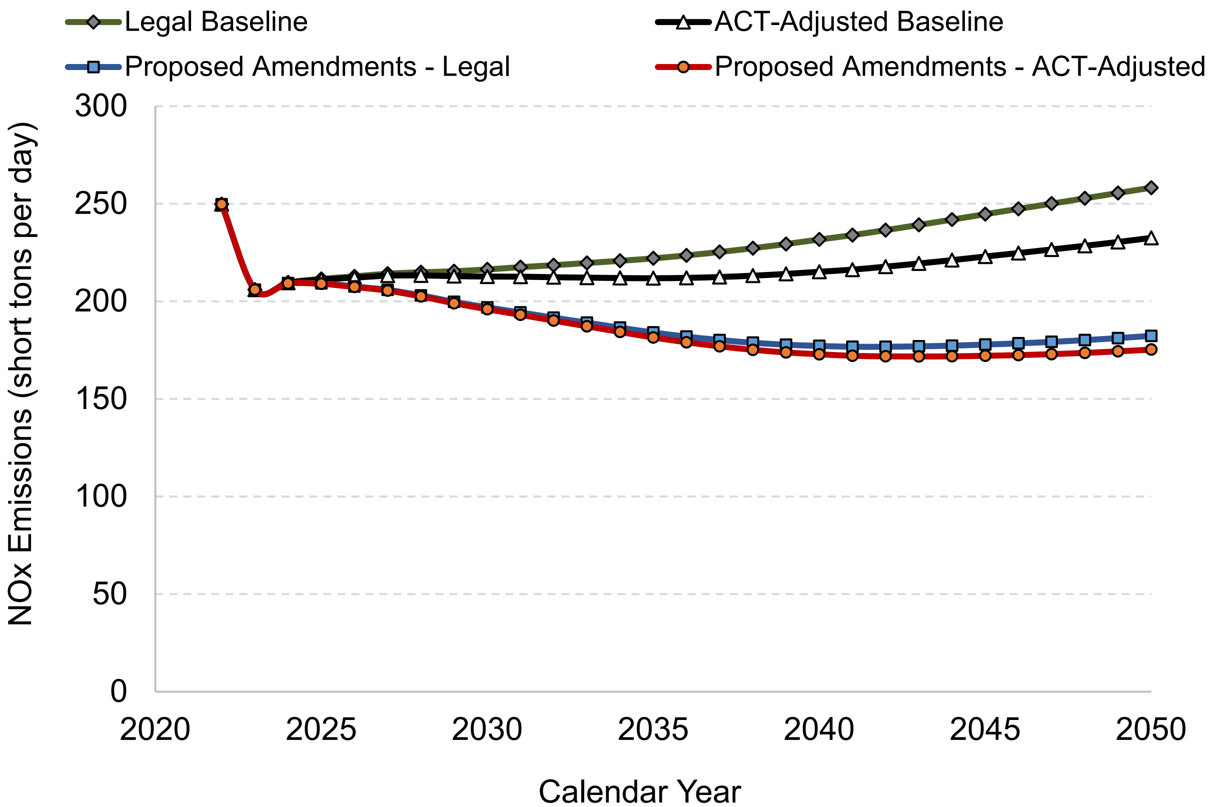
[45] The EMFAC2017 model is developed and used by CARB to assess emissions from on-road vehicles including cars, trucks and buses in California, and to support CARB's regulatory and air quality planning efforts to meet Federal Highway Administration's transportation and planning requirements. U.S. EPA approves EMFAC for use in SIP and transportation conformity analyses.

Figure V-1. Impact of ACT-Adjusted vs Legal Baseline[46]



Once the legal baseline is established, the legal baseline is then modified to reflect the requirements in the Proposed Amendments to establish the emissions inventory with the Proposed Amendments. The emission benefits are estimated as the difference between the legal baseline and the Proposed Amendments inventories. For simplicity, the remaining discussions in the Staff Report will use the term "baseline" to mean the "legal baseline."

Because the Proposed Amendments would increase new vehicle purchase prices, it is possible it could encourage California fleets to retain their existing vehicles slightly longer or to consider purchasing used vehicles in lieu of new vehicles in California. However, as described further in Chapter IX below, the expected percent increases in vehicle cost are relatively modest (about 0.5 to 10.4 percent depending on vehicle class, application, and year purchased). In addition, each fleet is expected to make such purchase decisions based on their own business practices, future fleet needs, economic conditions, fuel prices, and numerous other factors, and it is beyond the scope of this analysis to quantify the results of each such fleet decision. Hence, in

[46] This figure is intended to illustrate the impact of the ACT Regulation on baseline emissions and expected benefits of the Proposed Amendments. This figure is based on the ACT Regulation as proposed to the Board in December 2019, but note that the ACT proposal is being revised and may differ from what is eventually adopted.

estimating the emission benefits for this Staff Report, CARB staff did not attempt to quantify any such changes in fleet purchase behavior.

B. Emission Benefits

1. Criteria Pollutant Emission Benefits

The Proposed Amendments are designed to reduce NOx emissions from engines in heavy-duty vehicles with GVWR greater than 14,000 pounds (Class 4 and above) and engines used in medium-duty vehicles with GVWR 10,001 to 14,000 pounds (Class 3 vehicles). The proposed FTP, RMC-SET, LLC, and idling NOx certification standards and the in-use requirements would significantly reduce tailpipe NOx emissions during most vehicle operating modes such as high-speed steady-state, transient, low load urban driving, and idling modes of operation. The effect of the proposed revisions to the warranty, useful life, emissions warranty reporting information, and durability demonstration procedures would also provide emission benefits by encouraging more timely repairs to emission-related malfunctions and encouraging manufacturers to produce more durable emission control components thereby reducing the rate at which emissions deteriorate.

Table V-1 shows the projected NOx emission benefits for the proposed primary requirements (which are shown in Tables III-1 and III-4), for key milestone years in California, statewide, and in the South Coast and San Joaquin Valley air basins. In 2031, the target SIP date to meet the 2008 ozone ambient air quality standards, NOx emission benefits relative to the baseline are estimated to be approximately 23.2 tpd statewide, 7.0 tpd in the South Coast Air Basin and 5.7 tpd in the San Joaquin Valley Air Basin. The Proposed Amendments are projected to reduce NOx emissions by approximately 352,795 tons statewide between the years 2022 through 2050.
Table V-2 shows the projected statewide NOx emission benefits from the Proposed Amendments for calendar years 2022 through 2050.

Table V-1. Projected NOx Emission Benefits from the Proposed Amendments Statewide and for the South Coast and San Joaquin Valley Air Basins (tpd)

Calendar Year	Statewide	South Coast	San Joaquin Valley
2024	0.4	0.1	0.1
2031	23.2	7.0	5.7
2040	54.5	16.3	13.6
2050	75.9	23.0	19.0

Table V-2. Projected Statewide NOx Emission Benefits from the Proposed Amendments for 2022 to 2050

Calendar Year	NOx Tons Per Year Benefits
2022	0
2023	0
2024	114
2025	722
2026	1,608
2027	2,584
2028	3,694
2029	4,891
2030	6,070
2031	7,246
2032	8,387
2033	9,532
2034	10,693
2035	11,847
2036	12,982
2037	14,073
2038	15,118
2039	16,101
2040	17,010
2041	17,852
2042	18,646
2043	19,411
2044	20,154
2045	20,852
2046	21,505
2047	22,110
2048	22,679
2049	23,212
2050	23,702
2022-2050 (tons)	**352,795**

As discussed earlier, the proposed PM standard of 0.005 g/bhp-hr is intended to prevent backsliding by encouraging manufacturers to continue using DPFs capable of reducing PM tailpipe emissions down to 0.001 g/bhp-hr levels. Manufacturers would likely continue to use the same DPFs that they are currently using and thus no additional PM benefits are expected from this requirement. However, since NOx is also a precursor to secondary PM2.5 formation, NOx emission reductions would also provide ambient PM2.5 emission benefits. The reductions in secondary PM formation would provide significant health benefits as discussed below in Section E of this chapter.

2. Greenhouse Gas Emission Benefits

The Proposed Amendments are not expected to have any significant impacts on GHG emissions. CARB staff believes regardless of the Proposed Amendments, manufacturers will continue to comply with the Phase 2 GHG vehicle and engine standards, which will dictate their GHG emissions. As discussed earlier, many 2019 MY certified heavy-duty engines currently meet the Phase 2 GHG standards and their NOx emissions certification level is less than 0.1 g/bhp-hr on the FTP. These engines would need some engine calibration optimization and likely improved catalyst substrates to meet both the proposed 2024 NOx standard of 0.05 g/bhp-hr and the Phase 2 GHG standards.

The proposed 2027 NOx standard of 0.020 g/bhp-hr is also not expected to have impacts on GHG emissions. Engine technologies identified to meet the proposed 2027 NOx standard such as cylinder deactivation would enable compliance with the proposed NOx standards without an increase in GHG emissions. The dual SCR system with dual dosing would also provide significant NOx reductions during cold start and low load operations with no impacts on GHG emissions. Therefore, CARB staff expects that manufacturers' compliance with the Phase 2 GHG engine standards will not result in increases of GHG emissions.

As discussed above, the proposed associated amendments are not expected to have additional GHG emission benefits beyond those claimed in the Phase 2 GHG Regulation. However, they would improve implementation as well as effectiveness of the Phase 2 GHG Regulations and help realize the expected GHG emission benefits of the regulation.

C. Benefits to Typical Businesses

Typical businesses that may benefit from the Proposed Amendments include OEM component suppliers, innovative technology suppliers, and individual truck and bus owners, including fleets (trucking or bus operations). No OEM component suppliers are located in California, but truck and bus owners and some innovative technology suppliers are. Subsection 1 below discusses benefits for OEM component suppliers. Subsection 2 below discusses benefits for truck and bus owners. Finally, Subsection 3 discusses benefits to innovative technology manufacturers.

1. Original Equipment Manufacturer Component Suppliers

OEM component suppliers include engine component (e.g., cylinder deactivation, telematics, engine management software, etc.) and emission control system manufacturers. These businesses would benefit from increased business opportunities created by the need to develop, sell, and support new technology solutions to further reduce NOx emissions.

2. Truck and Bus Owners

As discussed further in Chapter IX, although overall the Proposed Amendments would increase truck prices and DEF consumption and thereby impose costs on truck and bus owners, the Proposed Amendments would also provide benefits and savings to truck and bus owners as well. Three elements of the Proposed Amendments would provide savings to truck and bus owners: the lengthened emissions warranty provisions, the lengthened useful life provisions, and the EWIR and corrective action procedure amendments. Under the Proposed Amendments, the manufacturer's emissions warranty period would be significantly lengthened, and owners would benefit by not having to pay out-of-pocket for vehicle repairs during that time. In addition, the proposed longer useful life and proposed durability demonstration protocol for the longer useful life would encourage manufacturers to produce more durable components, resulting in fewer failures and less downtime for truck and bus owners. Finally, the EWIR and corrective action procedure amendments would result in more extended warranties and recalls, which would result in a cost savings for vehicle purchasers because components that they previously would have had to pay for out-of-pocket would now be repaired or replaced under an extended warranty or recall.

3. Innovative Technology Manufacturers

Manufacturers of innovative technologies have the opportunity for increased business as a result of the Proposed Amendments. For example, one opposed piston manufacturer headquartered in San Diego, California, Achates Power, is currently developing an engine potentially capable of achieving the proposed low NOx standards. The Achates opposed piston technology is one strategy that manufacturers could consider using to meet the 2027 and subsequent MY proposed emission standards.

In addition, as shown in Figure V-2, there are several heavy-duty ZEV manufacturers located within California that may benefit from the Proposed Amendments. Since the proposed amendments would create a new heavy-duty zero-emission averaging set as a way to incentivize heavy-duty ZEVs, the market share of these technologies may increase.

Figure V-2. MHDD and HHDD ZEV Manufacturers Located in California

D. Benefits to Small Businesses

Small businesses that may be affected by the Proposed Amendments include small fleets and engine repair facilities. As mentioned above, small fleets[47] would benefit financially in having to pay less for engine repairs and less downtime. This is because under the Proposed Amendments, the manufacturer's warranty period would be significantly lengthened, and owners would not have to pay out-of-pocket for vehicle repairs. In addition, engine repair facilities may also benefit from increased business opportunities due to the lengthened warranty, which would encourage vehicle owners to pursue more timely repairs.

E. Health Benefits to Californians

NOx is a precursor to ozone and secondary PM formation. Exposure to ozone and PM2.5 is associated with increases in premature death, hospitalizations, visits to doctors, use of medication, and emergency room visits due to exacerbation of chronic heart and lung diseases and other adverse health conditions. The South Coast Air Basin has the highest ozone levels in the nation while the San Joaquin Valley has the greatest PM2.5 challenge. Thus, reductions in NOx emissions from heavy-duty vehicles would provide significant regional health benefits to California residents by reducing exposure to ozone and PM2.5. Californians would benefit from reduced emergency

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[47] Small fleets are defined here to be California fleets within the trucking industry with three or fewer heavy-duty vehicles.

room and doctor's office visits for asthma, reduced hospitalizations for worsened heart diseases, and reduced premature death. This in turn would result in reduced asthma-related school absences, reduced sick days off from work, reduced health care costs, and increased economic productivity.

The Proposed Amendments also include associated amendments that impact the Phase 2 GHG Regulations and powertrain test procedures. These associated amendments would provide clarifications and corrections to affected manufacturers in complying with the Phase 2 GHG Regulation, in addition to providing an optional certification procedure for manufacturers of heavy-duty hybrid vehicles to certify to criteria pollutant emission standards using the amended powertrain test procedure. There are no additional GHG benefits resulting from the Proposed Amendments beyond those claimed by the Phase 2 GHG Regulation. However, the Proposed Amendments would make implementation of the Phase 2 GHG Regulation more effective and help realize the expected emission benefits from the regulation. As there are no additional expected benefits due to these associated amendments, the following benefits analyses will focus on the remaining Proposed Amendments.

As part of setting the NAAQS for ozone, U.S. EPA quantifies the health risk from exposure to PM2.5 (U.S. EPA, 2010), and CARB relies on the same health studies for this evaluation. The evaluation method used in this analysis is the same as the one used for CARB's Low Carbon Fuel Standard 2018 Amendments (CARB, 2018b), the HDVIP and PSIP (CARB, 2018d), and the proposed ACT Regulation (CARB, 2019l).

CARB staff analyzed the value associated with five health outcomes in the baseline, Proposed Amendments, and alternatives: cardiopulmonary mortality, hospitalizations for cardiovascular illness, hospitalizations for respiratory illness, emergency room visits for respiratory illness, and emergency room visits for asthma. These health outcomes were selected because U.S. EPA has identified these as having a causal or likely causal relationship with exposure to PM2.5.[48] U.S. EPA examined other health endpoints such as cancer, as well as reproductive and developmental effects, but determined there was only suggestive evidence for a relationship between these outcomes and PM2.5 exposure, and insufficient data to include these endpoints in the national health assessment analysis routinely performed by U.S. EPA.

[48] In this Staff Report, we have quantified health benefits due to the reduction in secondary PM2.5 expected from the Proposed Amendments. We expect the Proposed Amendments would also lead to additional, smaller health benefits due to ambient ozone reductions, but they are not quantified here.

U.S. EPA has also determined a causal relationship between non-mortality cardiovascular effects and short and long-term exposure to PM2.5, and a likely causal relationship between non-mortality respiratory effects (including worsening asthma) and short and long-term PM2.5 exposure. These outcomes lead to hospitalizations and emergency room visits and are included in this analysis.

In general, health studies have shown that populations with low socioeconomic standings are more susceptible to health problems from exposure to air pollution. However, the models currently used by U.S. EPA and CARB do not have the granularity to account for this impact. The location and magnitude of projected emission reductions resulting from many proposed regulations are not known with sufficient accuracy to account for the socioeconomic impacts, and an attempt to do so would produce uncertainty ranges so large as to make conclusions difficult. CARB acknowledges this limitation.

Table V-3 shows the annually estimated statewide-avoided premature mortality, hospitalization, and emergency room visits. The Proposed Amendments are expected to prevent nearly 3,900 deaths.

The Proposed Amendments may also decrease the occupational exposure to air pollution of California truck operators and other employees who work around truck traffic. CARB staff cannot quantify the potential effect on occupational exposure due to lack of data on typical occupational exposure for these types of workers.

Table V-3. Annual Statewide Avoided Mortality and Morbidity Incidents Under the Proposed Amendments[49]

Calendar Year	Cardiopulmonary Mortality	Hospitalizations for Cardiovascular Illness	Hospitalizations for Respiratory Illness	Emergency Room Visits	Total
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	1	0	0	1	2
2025	7	1	1	3	12
2026	15	2	2	7	26
2027	25	3	4	12	44
2028	36	5	6	17	64
2029	48	7	8	23	86
2030	61	9	10	29	109
2031	73	11	13	35	132
2032	86	13	15	41	155
2033	98	15	18	47	178
2034	111	17	20	53	201
2035	124	19	23	59	225
2036	138	21	26	65	250
2037	151	24	28	70	273
2038	163	26	31	76	296
2039	175	28	33	81	317
2040	186	30	35	86	337
2041	197	31	37	91	356
2042	208	33	39	96	376
2043	218	35	41	100	394
2044	227	36	44	104	411
2045	237	38	46	108	429
2046	246	40	47	112	445
2047	254	41	49	116	460
2048	262	43	51	119	475
2049	270	44	53	123	490
2050	277	45	54	126	502
Total	**3894**	**616**	**735**	**1801**	**7046**

Note: Rounded to whole numbers

[49] Refer to footnote 48.

Statewide valuation of health benefits was calculated by multiplying the statewide total number of incidents for 2022 through 2050 as shown in Table V-3 by the value per incident, as shown in Table V-4. The estimated total statewide health benefit derived from the Proposed Amendments is estimated to be $36.8 billion.

Table V-4. Statewide Valuation from Avoided Health Outcomes Under the Proposed Amendments[50]

Outcome	Value Per Incident	Avoided Incidents	Total Valuation
Avoided Premature Mortality	$9,419,320	3894	$36.7 billion
Avoided Cardiovascular Hospitalizations	$56,588	616	$34.9 million
Avoided Acute Respiratory Hospitalizations	$49,359	735	$36.3 million
Avoided Emergency Room Visits	$810	1,801	$1.46 million
Total		**7046**	**$36.8 billion**

Note: Total valuation has been rounded.

F. Statewide Monetary Benefits

As discussed below, three elements of the Proposed Amendments would provide savings to truck and bus owners: the lengthened warranty, lengthened useful life, and the EWIR and corrective action procedure amendments. Additionally, all Californians would benefit from the Proposed Amendments' health benefits, which can be monetized as discussed above in Section E of this chapter. Chapter IX below provides detailed information regarding cost and economic impact of the Proposed Amendments.

1. Savings Benefits from Proposed Lengthened Warranty

Truck and bus purchasers would experience savings resulting from the additional repairs that are covered under a longer warranty period. Although CARB staff expects that the added costs associated with the longer warranty periods would ultimately be passed on to consumers in the form of an increased purchase price for the trucks, on average, vehicle buyers would gradually recoup the initial increase in purchase price as they save money on repairs. For these vehicle buyers, the increased purchase price of the vehicle would be offset by savings benefits over time.

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[50] Refer to footnote 48.

Additionally, some vehicle buyers commonly finance their vehicle purchase, and for the increased purchase price they would incur a corresponding increase in the transaction costs associated with financing. For these vehicle buyers, the increased transaction costs are not expected to be completely offset by the savings benefits.

The projected statewide savings benefits from the lengthened warranty are shown in Table V-5. For simplicity, CARB staff assumes that the vehicle purchaser receives repair savings beginning in the sixth year of vehicle ownership. The savings are expected to occur in the sixth year because the current heavy-duty Step 1 Warranty Regulation covers vehicles through the fifth year of ownership. Therefore, as shown in detail below in Table V-5, when the proposed Step 2 warranty amendments are implemented in MY 2027, which would correspond to calendar year 2028 for the heavy-duty vehicles with diesel engines, the first year that the savings are realized is in calendar year 2033. Whereas, for the heavy-duty vehicles with Otto-cycle engines, the MY 2027 corresponds to that same calendar year, and so the savings for the 2027 calendar year would be realized six years later in 2032.

Table V-5. Statewide Savings Benefits from Lengthened Warranty

Calendar Year	Year Savings Occurs	HHDD	MHDD	LHDD	HDO	Total
2027	2032	$0	$0	$0	$900,776	$900,776
2028	2033	$1,195,852	$6,990,817	$2,361,620	$918,834	$11,467,123
2029	2034	$1,223,267	$7,164,144	$2,405,233	$921,511	$11,714,155
2030	2035	$1,247,721	$7,243,949	$2,446,075	$914,997	$11,852,742
2031	2036	$1,266,523	$7,339,707	$2,478,138	$1,690,689	$12,775,056
2032	2037	$7,603,903	$18,813,415	$6,806,212	$1,695,886	$34,919,416
2033	2038	$7,811,766	$19,100,187	$6,952,137	$1,712,171	$35,576,261
2034	2039	$8,084,630	$19,726,513	$7,172,608	$1,728,710	$36,712,461
2035	2040	$8,232,277	$20,086,648	$7,320,115	$1,744,823	$37,383,863
2036	2041	$8,289,588	$20,177,301	$7,365,754	$1,773,682	$37,606,326
2037	2042	$8,344,570	$20,365,667	$7,417,033	$1,788,739	$37,916,009
2038	2043	$8,421,590	$20,417,890	$7,473,924	$1,804,120	$38,117,524
2039	2044	$8,498,661	$20,566,571	$7,528,858	$1,818,631	$38,412,722
2040	2045	$8,595,723	$20,639,071	$7,586,674	$1,832,882	$38,654,350
2041	2046	$8,655,223	$20,724,322	$7,644,716	$1,846,972	$38,871,233
2042	2047	$8,729,630	$20,881,832	$7,707,353	$1,860,753	$39,179,568
2043	2048	$8,808,035	$20,994,606	$7,767,379	$1,874,190	$39,444,210
2044	2049	$8,901,851	$21,163,328	$7,832,117	$1,887,244	$39,784,539
2045	2050	$8,983,662	$21,327,830	$7,894,576	$1,900,009	$40,106,077

2. Savings Benefits from Proposed Lengthened Useful Life

CARB staff expects that the longer useful life would encourage development of more durable components and thus result in the need for fewer repairs. However, because it is not possible to determine how many fewer repairs would result from the improved durability, direct savings from longer useful life are not quantified.

3. Savings Benefits from Proposed EWIR and Corrective Action Amendments

The proposed EWIR amendments would require manufacturers to more expeditiously repair or replace parts that are identified as having systemic issues through the EWIR program. This would result in savings for vehicle purchasers because components for which they previously had to pay for out-of-pocket would now be repaired or replaced under an extended warranty or recall. Savings from repairs of failures that would be covered under the requirements of Step 1 and Step 2 emissions warranty lengthening amendments were not included as savings in the EWIR amendments because they were attributed to the Step 1 and Step 2 warranty amendments, as discussed above. Therefore, savings attributed to the EWIR amendments do not occur until the new lengthened warranty periods have ended. For the 2024 through 2026 MYs, for example, the warranty period is 5 years, so savings related to the EWIR amendments would start after the warranty period has ended. For MYs 2027-2030, the proposed new warranty period would be 7 years, so savings related to the EWIR amendments would be realized starting in the 8th year. For MYs 2031 and subsequent, the proposed new warranty period would be 10 years, so savings related to the EWIR amendments would be realized starting in the 11th year.

The projected statewide savings benefits from the EWIR amendments are shown in Table V-6.

Table V-6. Statewide Savings Benefits from EWIR Amendments

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2022	$0	$0	$0	$0	$0
2023	$0	$0	$0	$0	$0
2024	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0
2026	$0	$0	$0	$0	$0
2027	$0	$0	$0	$0	$0
2028	$0	$0	$0	$0	$0
2029	$0	$0	$0	$501,295	$501,295
2030	$425,279	$0	$0	$502,875	$928,154
2031	$434,671	$0	$0	$509,144	$943,815
2032	$444,032	$0	$0	$0	$444,032
2033	$0	$0	$0	$0	$0
2034	$0	$0	$0	$398,037	$398,037
2035	$4,732,926	$6,113,069	$1,177	$406,016	$11,253,189
2036	$4,841,431	$6,264,633	$1,199	$407,199	$11,514,463
2037	$4,938,215	$6,334,418	$1,219	$404,321	$11,678,173
2038	$5,012,627	$6,418,153	$1,235	$0	$11,432,016
2039	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0
2041	$0	$0	$0	$418,470	$418,470
2042	$0	$0	$1,631,803	$419,756	$2,051,559
2043	$0	$0	$1,666,789	$423,787	$2,090,576
2044	$0	$0	$1,719,647	$427,881	$2,147,528
2045	$0	$0	$1,755,012	$431,869	$2,186,881
2046	$0	$0	$1,765,954	$439,012	$2,204,966
2047	$0	$0	$1,778,249	$442,738	$2,220,987
2048	$0	$0	$1,791,888	$446,546	$2,238,434
2049	$0	$0	$1,805,059	$450,137	$2,255,196
2050	$0	$0	$1,818,920	$453,665	$2,272,585

4. Overall Statewide Savings Benefits from the Proposed Amendments

Table V-7 below shows the total statewide savings of $651 million from the lengthened warranty and EWIR amendments for the analysis period of 2022 through 2050 based on the cost analysis in Chapter IX. The total savings benefit of the Proposed Amendments is approximately $37.4 billion dollars over the regulatory period, with nearly all that due to monetized health benefits.

Table V-7. Total Statewide Savings Benefits of the Proposed Lengthened Warranty and EWIR Amendments

Calendar Year	Warranty	EWIR	Total Savings
2022	$0	$0	$0
2023	$0	$0	$0
2024	$0	$0	$0
2025	$0	$0	$0
2026	$0	$0	$0
2027	$0	$0	$0
2028	$0	$0	$0
2029	$0	$501,295	$501,295
2030	$0	$928,154	$928,154
2031	$0	$943,815	$943,815
2032	$900,776	$444,032	$1,344,809
2033	$11,467,123	$0	$11,467,123
2034	$11,714,155	$398,037	$12,112,192
2035	$11,852,742	$11,253,189	$23,105,931
2036	$12,775,056	$11,514,463	$24,289,519
2037	$34,919,416	$11,678,173	$46,597,589
2038	$35,576,261	$11,432,016	$47,008,277
2039	$36,712,461	$0	$36,712,461
2040	$37,383,863	$0	$37,383,863
2041	$37,606,326	$418,470	$38,024,795
2042	$37,916,009	$2,051,559	$39,967,568
2043	$38,117,524	$2,090,576	$40,208,100
2044	$38,412,722	$2,147,528	$40,560,249
2045	$38,654,350	$2,186,881	$40,841,231
2046	$38,871,233	$2,204,966	$41,076,199
2047	$39,179,568	$2,220,987	$41,400,555
2048	$39,444,210	$2,238,434	$41,682,644
2049	$39,784,539	$2,255,196	$42,039,736
2050	$40,106,077	$2,272,585	$42,378,662
Total	**$581,394,412**	**$69,180,356**	**$650,574,767**

VI. AIR QUALITY

This chapter summarizes the potential air quality impacts in California resulting from CARB staff's Proposed Amendments. The Proposed Amendments are intended to improve the health and welfare of California's residents by reducing NOx emissions from all new heavy-duty engines used in heavy-duty vehicles with GVWR greater than 10,000 pounds. Although the Proposed Amendments also reduce the PM emission standards by 50 percent, this change is not expected to further reduce PM emissions but it is intended to prevent PM increases by ensuring that the highly effective filter technologies used to control PM emissions today will continue to be used in the future.

Section A of this chapter describes the baseline used to estimate emission benefits of the Proposed Amendments. Section B includes an overview of the emission inventory methods, and Section C describes the resulting changes in NOx emissions. This chapter also discusses the expected reduction in secondary PM formation as a direct result of lowering ambient NOx emissions. Further details concerning the emission inventory development is provided in Appendix D.

A. Baseline Information

NOx emission benefits resulting from the Proposed Amendments are compared against a legal baseline that reflects the current situation and includes the effects of existing state and federal regulations. A more detailed discussion of the baseline is provided above in Chapter V, Section A.

B. Emission Inventory Methods

As described further in Appendix D, CARB staff used CARB's mobile source emissions inventory model EMFAC2017 (CARB, 2019f) to estimate the baseline emissions and assess the impact of the Proposed Amendments on NOx emissions. This model incorporates the latest available information on vehicle emission rates, population, and VMT.

CARB staff created scenarios for the baseline, and for conditions under the Proposed Amendments. CARB staff then produced emissions inventories for both scenarios by calculating the product of a pollutant emission rate (e.g., grams of pollutant per mile) per some unit of activity (e.g., miles driven) multiplied by that activity and population.

The technologies expected to be deployed to meet the Proposed Amendments (cylinder deactivation, improved SCR systems, etc.) are expected to have minimal direct impact on PM and GHG emissions. However, the reduction in NOx emissions would reduce secondary PM formation (or PM2.5). Therefore, only NOx and secondary PM2.5 emission benefits were quantified for this rulemaking.

Although the Proposed Amendments would cut the PM standard in half, no additional PM benefits are projected because the current DPFs that manufacturers are currently using control PM emissions to almost 90 percent below today's current PM emission standard. As mentioned previously, the Proposed Amendments to lower the PM standard are intended to avoid PM increases by preventing backsliding (i.e., prevent manufacturers from using less robust DPFs).

CARB staff used a spatial interpolation method known as inverse distance-squared weighting to estimate exposure to PM2.5 emitted directly from diesel sources (primary PM2.5) and from PM2.5 formed from precursor gases (secondary PM2.5). In this analysis primary PM2.5 remain the same (i.e. no reduction), thus only secondary PM2.5 reductions were calculated from NOx emission reductions, as described further in Appendix E.

C. Emission Inventory Results

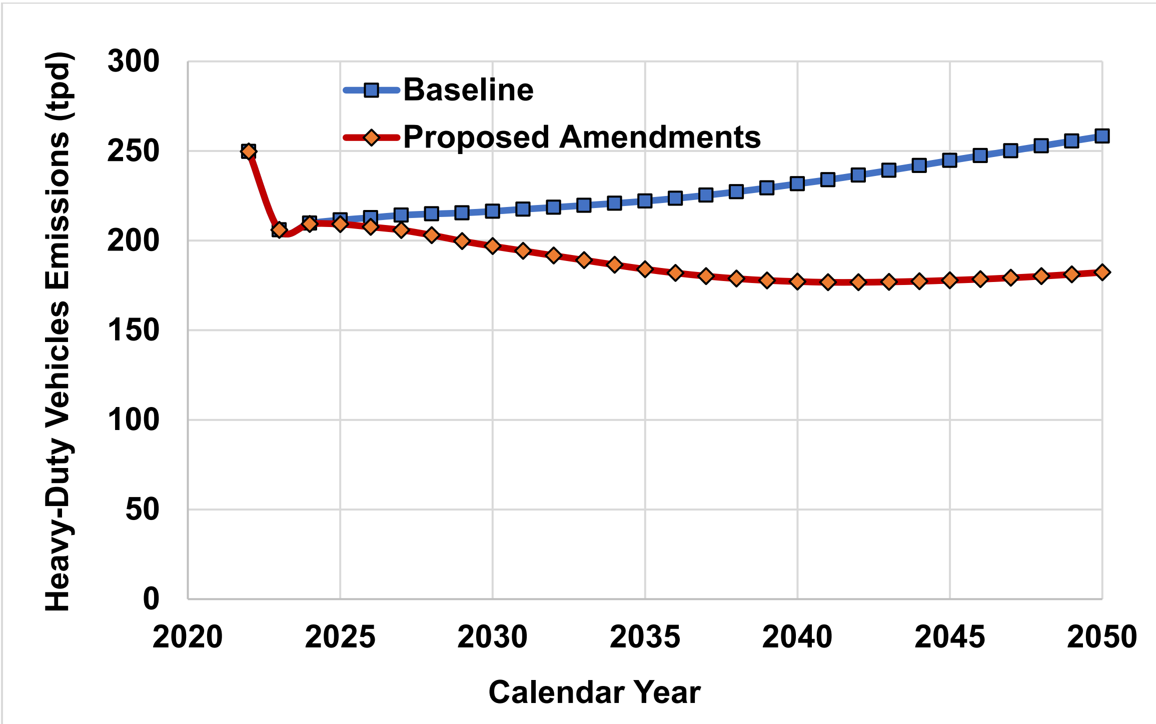
The Proposed Amendments are expected to result in significant NOx emission reductions due to reducing the tailpipe NOx standard for new heavy-duty engines by up to 90 percent below the current NOx standard, by introducing a new certification test cycle that would further reduce NOx emissions when engines are operated at sustained lower loads, and improving the in-use emission testing requirements to ensure NOx reductions are occurring under real-world operations. Table VI-1 summarizes the expected statewide NOx emissions for the proposed primary requirements (as shown in Tables III-1 and III-4), for key milestone calendar years. The resulting emission reductions contribute to California's SIP Strategy and Climate Change Scoping Plan.

Table VI-1. Statewide NOx Emissions and Benefits: Legal Baseline Versus Proposed Amendments (tpd)

Calendar Year	Baseline	Proposed Rule	Benefits
2024	209.67	209.31	0.36
2031	217.52	194.30	23.22
2040	231.68	177.17	54.51
2050	258.23	182.31	75.92

Figure VI-1, below, illustrates NOx emissions of the Proposed Amendments relative to the legal baseline for calendar years 2022-2050. Projected NOx emissions decrease sharply until 2025. This is mainly due to the Truck and Bus Regulation which requires most diesel vehicles with a GVWR above 14,000 pounds to upgrade to 2010 MY and newer engines sooner than what would occur under normal vehicle turnover. The NOx emissions gradually increase over time because of increases in vehicle population and VMT. The shift between emission reductions in earlier years and then increasing emissions is due to increasing fleet penetration of low NOx vehicles (decreasing emissions) and increasing vehicle population and VMT (increasing emissions). The delta (or benefit) versus the legal baseline is 76 tpd NOx emissions in 2050.

Figure VI-1. California NOx Emissions for all Heavy-Duty Vehicles (Proposed Amendments vs. Legal Baseline)



D. Greenhouse Gas Emission Impacts

As discussed in Section B.2 of Chapter V, the Proposed Amendments are not expected to have any significant impacts on GHG emissions. CARB staff believes regardless of the Proposed Amendments, manufacturers will continue to comply with the Phase 2 GHG vehicle and engine standards, which will dictate their GHG emissions.

However, as discussed in Chapter IX, Section B.1.2, since the proposed standards are designed to control NOx emissions under the majority of the vehicle operations including those operations currently not controlled using SCR, such as low load urban driving and idling, it is expected that more DEF and thus ammonia will be consumed to meet the proposed requirements compared to existing conditions. The increased DEF consumption may also result in increases in upstream CO2 emissions associated with the manufacturing of the additional DEF. CARB staff estimates additional urea production due to implementing the Proposed Amendments would cause a total increase of 0.50 million metric tons of CO2 emissions from 2024 to 2050, averaging around 18,260 metric tons of CO2 emissions per year statewide.[51] Compared to the

[51] CARB staff assumed a life cycle emission factor of 2.53 tons CO2 per metric ton of urea produced (Alfian & Purwanto, 2019). The emission factor assumes that in the process of making urea, hydrogen is produced using the steam methane reforming process. The additional urea consumed due to the proposed amendments is estimated from Table IX-8 assuming DEF costs $2.91 per gallon.

billions of metric tons of GHG emissions emitted from on-road vehicles from 2024 to 2050 statewide, the contribution of upstream CO_2 emissions from the additional urea production to the overall inventory is minor. Notably, any increase in CO_2 emissions due to this particular measure would be far less than the overall CO_2 reductions expected from implementation of the 2016 State SIP Strategy. The 2016 State SIP Strategy is projected to reduce mobile source GHG emissions statewide by 20 million metric tons of CO_2 equivalency in 2030 (CARB, 2017b)

VII. ENVIRONMENTAL ANALYSIS

A. Introduction

This chapter provides the basis for CARB's determination that no subsequent or supplemental environmental analysis is required for the Proposed Amendments. A brief explanation of this determination is provided below in Section D of this chapter.

CARB's regulatory program, which involves the adoption, approval, amendment, or repeal of standards, rules, regulations, or plans for the protection and enhancement of the State's ambient air quality, has been certified by the California Secretary for Natural Resources under Public Resources Code section 21080.5 of the California Environmental Quality Act (CEQA) (14 CCR 15251(d)). Public agencies with certified regulatory programs are exempt from certain CEQA requirements, including but not limited to, preparing environmental impact reports, negative declarations, and initial studies. Instead, CARB, as a lead agency, prepares a substitute environmental document (referred to as an "Environmental Analysis" or "EA") as part of the Staff Report to comply with CEQA (17 CCR 60000-60008). This chapter constitutes that EA.

CARB's regulatory program provides that CARB may rely upon (i.e., tier from) a prior EA if CARB determines a previous analysis remains applicable to and adequate for the project (17 CCR 60004(b)(1)(B)). Because the Proposed Amendments implement two measures previously included within CARB's Revised Proposed 2016 State Strategy for the State Implementation Plan (2016 State SIP Strategy), "Low-NOx Engine Standard" and "Lower In-Use Emission Performance Level," the environmental impact of the Proposed Amendments was already examined as part of the EA for that Plan. Hence, the Proposed Amendments are considered within the scope of that prior EA, entitled *Final Environmental Analysis for the Revised Proposed 2016 State Strategy for the State Implementation Plan,* (CARB, 2017c) or Final EA.

Section B below discusses the prior Final EA and its conclusions with respect to the "Low-NOx Engine Standard" and "Lower In-Use Emission Performance Level" measures. Section C briefly summarizes the Proposed Amendments and how they fit within the two 2016 SIP measures.

B. Prior Environmental Analysis

In March 2017, the Board adopted the 2016 State SIP Strategy. The SIP is designed to reduce emissions of ozone-forming pollutants and PM2.5 and describes the programmatic and regulatory mechanisms of the federal Clean Air Act requirements to meet federal air quality standards. CARB's 2016 State SIP Strategy describes twenty-seven specific measures and CARB's commitment to achieve the mobile source and consumer products reductions needed to meet federal air quality standards. The measures included in the 2016 State SIP Strategy would:

- Establish more stringent engine performance standards for cleaner combustion technologies (Low-NOx Engine Standard);

- Ensure that emissions control systems remain durable over the lifetime of the vehicle (Lower In-Use Emission Performance Level);
- Increase the penetration of near-zero and ZEV technology across a range of applications;
- Expand the requirements for cleaner Low-Emission Diesel fuels;
- Conduct pilot studies to demonstrate new technologies;
- Incentivize the turnover of equipment and fleets to the cleanest technologies;
- Increase system efficiencies; and
- Reduce emissions from consumer products.

When the 2016 State SIP Strategy was proposed for the Board's consideration in March 2017, it included as an appendix an EA prepared under CARB's certified regulatory program, referred to here as the Final EA (as mentioned above in Section A). The Final EA provided a programmatic analysis of the potentially significant adverse and beneficial environmental impacts resulting from implementation of the twenty-seven measures in the 2016 State SIP Strategy, and their associated reasonably foreseeable compliance responses.

The Final EA was based on the reasonably foreseeable compliance responses of the regulated entities that would be impacted by the aforementioned SIP measures. The Final EA concluded that implementation of the SIP measures could result in short-term and long-term beneficial impacts to air quality, energy demand, and greenhouse gases. It further concluded that the proposed measures would result in less-than-significant impacts to: energy demand, hazards and hazardous materials, land use and planning, mineral resources, population and housing, public services, and recreational services.

The Final EA also concluded that, taking the twenty-seven proposed measures together, there could be potentially significant and unavoidable adverse impacts to aesthetics, agriculture and forest resources, air quality, biological resources, cultural resources, geology and soils, hazards and hazardous materials, hydrology and water quality, noise, transportation/traffic, and utilities and service systems.

The potentially significant and unavoidable adverse impacts identified in the Final EA are primarily related to short-term, construction-related activities. While many of the identified potentially significant adverse impacts could be reduced to a less-than-significant level by mitigation that can and should be implemented by local lead agencies, authority to do so is beyond the purview of CARB. The authority to determine project-level impacts and require project-level mitigation lies with land use and/or permitting agencies for individual projects, causing inherent uncertainty in the degree of mitigation that may ultimately be implemented to reduce potentially significant impacts. Consequently, the Final EA took the conservative approach in its post-mitigation significance conclusion and disclosures of potentially significant and unavoidable adverse impacts, for CEQA compliance purposes. While the Final EA indicated that there may be potential adverse environmental impacts from the twenty-seven SIP measures as a whole, it concluded that these impacts are speculative and cannot be precisely quantified until the scope of the measures is defined by actual proposed regulations. As discussed below, the Proposed Amendments, which implement the two measures: “Low-NOx Engine Standard” and “Lower In-Use Emission Performance Level,” would not constitute a substantial change or new information resulting in any new significant effects or a substantial increase in the severity of previously-identified significant effects.

The Final EA addresses the potential compliance responses for those two measures as follows:

(1) Low-NOx Engine Standard

The goal of this measure is to introduce low emission engine technologies that will substantially lower NOx emissions from on-road heavy-duty vehicles. California would adopt its own low NOx standard which would apply to all vehicles with new heavy-duty engines sold in California. Because of the significant emissions impacts of interstate trucking in California, the SIP assigns the federal government the responsibility to implement a national low-NOx engine standard as well.

The Final EA determined that reasonably foreseeable compliance responses under the California-only Low-NOx measure would include changes in heavy-duty vehicle engine manufacturing and near-zero emission technology that substantially lowers NOx emissions in new heavy-duty vehicle models sold starting in 2023.[52] New models meeting the new standard would be introduced through natural fleet turnover (i.e., replacement of existing models with new models). The Final EA concluded that no new manufacturing facilities would be anticipated to be required.

Note that, with regard to potential future federal (i.e., U.S. EPA) rulemaking activities, the Final EA concluded that such actions are beyond CARB’s control, since CARB lacks the authority to develop or implement the federal low-NOx standard. It would therefore be speculative for the Final EA to attempt to analyze the impacts of potential compliance responses associated with the federal measure. If U.S. EPA undertakes these federal rulemaking actions, U.S. EPA would complete the appropriate environmental analysis at the federal level.

(2) Lower In-Use Emission Performance Level

This measure is aimed at ensuring that in-use heavy-duty vehicles continue to control emissions throughout their useful lives. The measure assumes CARB staff would develop and propose regulatory amendments and new regulations to address in-use emission compliance and to decrease engine deterioration and improve emission control efficiency. This suite of actions would include: amendments to CARB’s existing PSIP and HDVIP; amendments to warranty and useful life provisions; amendments to

[52] The 2016 State SIP Strategy calls for compliance with the Low NOx Standard measure beginning with the 2023 MY engines. However, the Proposed Amendments would require implementation to begin with the 2024 MY engines. This proposed implementation date for the low NOx standard is designed to coincide with changes in stringency of the Phase 2 GHG standards. This would provide manufacturers the opportunity to implement NOx optimization strategies together with the changes to Phase 2 GHG stringency in 2024 MY and 2027 and subsequent MY Phase 2 GHG standards.

the durability demonstration provisions within the certification requirements for heavy-duty engines; amendments to the NTE supplemental test procedures for heavy-duty diesel engines; and a comprehensive HD I/M program.

The Final EA determined that reasonably foreseeable compliance responses under this measure could include the need to either modify existing light-duty testing centers or construct new testing centers, in order to facilitate a new “smog check” program for heavy-duty trucks.

Collectively, taking into account all components of the SIP across all categories, the Final EA concluded that the potential adverse environmental impacts of the SIP are outweighed by the substantial air quality benefits that will result from its adoption and implementation. At its hearing on March 23, 2017, the Board adopted Resolution 17-7 certifying the Final EA, approving the written responses to comments on the Final EA, and adopting the findings and statement of overriding considerations. A Notice of Decision was filed with the Office of the Secretary of the Natural Resources Agency for public inspection.

C. The Proposed Amendments

The Proposed Amendments are discussed in detail in Chapter III of this Staff Report. They include the following elements that implement the Low-NOx Engine Standard measure:

- Significantly more stringent NOx emission standards on existing certification cycles such as the FTP, RMC-SET, and idling test procedures that would take effect in two steps: first for MYs 2024-2026 and then a more stringent standard for MYs 2027 and subsequent;
- New NOx emission standards on a new low load certification cycle designed to control emissions that occur during cold start warm-up, idling, sustained low load driving, and transient operations, which constitutes a large fraction of how trucks actually operate in urban areas;
- Modifications to the emissions ABT program;
- New powertrain test procedures for certification of heavy-duty hybrid vehicles;
- Adoption of APU certification requirements in the California Phase 2 GHG tractor requirements; and
- Other minor amendments to the California Phase 2 GHG programs.

The Proposed Amendments also include the following elements that implement parts of the Lower In-Use Emission Performance Level measure:

- Strengthened heavy-duty in-use testing procedures including revised test procedures and in-use data analysis techniques so that emissions over a broader range of the vehicle’s operation are covered;
- Longer regulatory useful life to more accurately reflect the actual service lives that heavy-duty vehicles are operating on the road today;

- Longer emissions warranty periods to help ensure that emission control systems are well-designed and built properly and make it more likely that emission-related repairs are completed promptly;
- Revised durability demonstration procedures to more accurately assess engine and exhaust aftertreatment system durability during certification to better reflect real-world emission control deterioration; and
- Revised warranty corrective action provisions.

The scope of the proposed actions in the Proposed Amendments falls within the broad suite of actions called for in the two 2016 State SIP Strategy measures described above in Section B. Note that two actions included in the "Lower In-Use Emission Performance Level" measure of the 2016 State SIP Strategy are not part of this proposal. Specifically, these two actions include: (1) amendments to the PSIP and HDVIP and (2) development of a new HD I/M program. Amendments to the PSIP and HDVIP were already adopted by the Board in July 2018, and the HD I/M program is currently under development in a separate rulemaking. The PSIP and HDVIP were developed for the Board's consideration earlier than the other companion elements in the "Lower In-Use Emission Performance Level," because (1) the objective of these elements was to reduce PM emissions from in-use heavy-duty vehicles; (2) amendments to the regulatory elements did not require significant development time to bring them to the Board compared to the other companion elements which targeted new engines and vehicles with the main focus on NOx emission reductions that required significant development time to demonstrate technical feasibility, and (3) they are near-term measures designed to provide PM reductions to meet ambient air quality standards for PM as well as reduce exposure to diesel PM, and protect Californians from the adverse health effects of ultrafine diesel PM. The HD I/M program, on the other hand, requires more time to develop it from concept to a full-fledged program, requiring extensive consultation with sister State agencies, truck and fleet owners, trucking industry representatives, non-governmental organization representatives, and other interested and knowledgeable stakeholders to identify, discuss, and evaluate key technical and programmatic components of a comprehensive HD I/M program within the parameters set forth in Senate Bill 210 (CLI, 2019a). The goal is to develop a more comprehensive HD I/M program which would help ensure all vehicle emissions control systems are adequately maintained throughout the vehicles' operating lives. As a result, the compliance responses in the Final EA from these two aspects of the "Lower In-Use Emission Performance Level" 2016 State SIP Strategy measure would not be applicable to the Proposed Amendments.

D. Analysis

1. Legal Standards

When considering later activities which were included within a programmatic project for which a substitute document equivalent to a Program Environmental Impact Report (abbreviated as EIR in the CEQA Guidelines below) or negative declaration had previously been prepared, CARB looks to Public Resources Code section 21166 and

CEQA Guidelines section 15162 for guidance on the requirements for subsequent or supplemental environmental review.

CEQA Guidelines section 15162 states:

(a) When an EIR has been certified or a negative declaration adopted for a project, no subsequent EIR shall be prepared for that project unless the lead agency determines, on the basis of substantial evidence in the light of the whole record, one or more of the following:

(1) Substantial changes are proposed in the project which will require major revisions of the previous EIR or negative declaration due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects;

(2) Substantial changes occur with respect to the circumstances under which the project is undertaken which will require major revisions of the previous EIR or negative declaration due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects; or

(3) New information of substantial importance, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous EIR was certified as complete or the negative declaration was adopted, shows any of the following:

(A) The project will have one or more significant effects not discussed in the previous EIR or negative declaration;

(B) Significant effects previously examined will be substantially more severe than shown in the previous EIR;

(C) Mitigation measures or alternatives previously found not to be feasible would in fact be feasible and would substantially reduce one or more significant effects of the project, but the project proponents decline to adopt the mitigation measure or alternative; or

(D) Mitigation measures or alternatives which are considerably different from those analyzed in the previous EIR would substantially reduce one or more significant effects on the environment, but the project proponents decline to adopt the mitigation measure or alternative.

If a subsequent or supplemental Environmental Impact Report or negative declaration is not required, the lead agency may determine that the activity is within the scope of the project covered by the programmatic environmental analysis (14 CCR 15168(c)(2); 17 CCR 60004(b)(1)(B)).

2. Basis for Determination

CARB staff has determined that the Proposed Amendments do not involve any changes that result in any new significant adverse environmental impacts or a substantial increase in the severity of the significant adverse impacts previously disclosed in the prior Final EA. Further, there are no changes in circumstances or new information that would otherwise warrant any subsequent or supplemental environmental review. The prior EA adequately addresses the implementation of the 2016 State SIP Strategy as modified by the Proposed Amendments and no additional environmental analysis is required. The basis for CARB staff's determination that none of the conditions requiring further environmental review are triggered by the Proposed Amendments is based on the following analysis.

> *(1) There are no substantial changes to the measures previously analyzed in the Environmental Analysis which require major revisions to the Environmental Analysis involving new significant environmental effects or a substantial increase in the severity of previously identified effects.*

The Proposed Amendments fall within the scope of the 2016 State SIP Strategy measures. For on-road heavy-duty vehicles, the 2016 State SIP Strategy calls for low-NOx engines that are 90 percent cleaner than today's, while ensuring that the in-use fleet continues to operate as cleanly as possible. As described in Chapter III, the Proposed Amendments would significantly reduce NOx and secondary PM emissions by requiring new engines to certify to lower NOx emission standards over current certification cycles as well as over a new low load certification cycle. In addition, the Proposed Amendments would also revise the heavy-duty in-use testing program to make it more effective in controlling in-use emissions during the majority of the vehicle's operations including idling, low load urban driving, and highway operations. Furthermore, the Proposed Amendments would further lengthen the useful life and warranty periods and revise the emissions warranty information reporting requirements and corrective action procedures resulting in improved engine and aftertreatment system durability, and reduced deterioration rates. Thus, the emissions reductions from the Proposed Amendments are expected to result in much needed improved air quality and public health for Californians and reduced exposure to toxic air contaminants in disadvantaged communities.

As described in Chapter I, since 2010 manufacturers have met the current standards for heavy-duty diesel engines using DPFs for PM, urea-based SCR aftertreatment systems for NOx, and DOCs for NMHC. For Otto-cycle heavy-duty engines, TWCs are used to meet these standards. For both Otto-cycle and diesel engines, it is expected that manufacturers will continue to use similar aftertreatment technologies to meet the proposed standards. However, the systems could differ in terms of placement of exhaust aftertreatment components closer to the engine and packaging of exhaust aftertreatment components for improved thermal control, new substrate formulations for improved NOx conversion efficiency, use of cylinder deactivation, and increasing the volume of the catalysts. In addition to advanced aftertreatment systems, manufacturers may also use engine calibration strategies to meet the proposed 2024 and 2027 MY

NOx standards and technologies such as cylinder deactivation and variable valve actuation to meet the more stringent 2027 MY NOx standards.

Since the proposed standards are designed to control NOx emissions under the majority of the vehicle operations including those operations currently not controlled using SCR, such as low load urban driving and idling, it is expected that more DEF and thus ammonia will be consumed to meet the Proposed Amendments compared to existing conditions. DEF is a non-toxic, nonhazardous, and non-flammable substance that is safe to handle and store and poses no serious risk to humans, animals, equipment or the environment when handled properly. It is stored on board the vehicle in a separate tank, which is replenished periodically. As discussed in Chapter I, DEF when injected to the hot exhaust decomposes to form ammonia and CO2. The ammonia then reacts with NOx in the exhaust over the SCR catalyst to form harmless nitrogen and water. Since DEF is produced from gaseous ammonia and gaseous CO2 captured from the atmosphere, the decomposition of DEF into ammonia and CO2 does not result in any net additional CO2 to the environment. The amount of DEF or ammonia injected to the SCR catalysts needs to be precisely controlled to prevent ammonia slip at the tailpipe as well as achieve maximum NOx conversions. A lower ammonia to NOx ratio results in lower NOx conversions, and a higher ammonia to NOx ratio results in ammonia slip. Thus, model-based control strategies together with better DEF atomization and mixing path reduction can be used to improve NOx conversion efficiency and reduce ammonia slip. Any ammonia slip at the tailpipe can be controlled, as currently practiced, using a clean-up ASC installed downstream of the SCR catalyst.

The increased DEF consumption may also result in increases in upstream CO2 emissions associated with the manufacturing of the additional DEF. Most of the DEF manufacturing plants are located outside of California. CARB staff estimates additional urea production due to implementing the Proposed Amendments would cause a total increase of 0.50 million metric tons of CO2 emissions from 2024 to 2050, averaging around 18,260 metric tons of CO2 emissions per year statewide.[53] Compared to the billions of metric tons of GHG emissions emitted from on-road vehicles from 2024 to 2050 statewide (CARB, 2016a), the contribution of upstream CO2 emissions from the additional urea production to the overall inventory is minor. Notably, any increase in CO2 emissions due to this particular measure would be far less than the overall CO2 reductions expected from implementation of the 2016 State SIP Strategy, which is the overall “project” analyzed in the prior Final EA. The 2016 State SIP Strategy is projected to reduce mobile source GHG emissions statewide by 20 million metric tons of CO2 equivalency in 2030 (CARB, 2017b). The Proposed Amendments, as noted above, are part of the 2016 State SIP Strategy. Furthermore, as noted in the paragraphs below, other foreseeable aspects of the Proposed Amendments are

[53] CARB staff assumed a life cycle emission factor of 2.53 tons CO2 per metric ton of urea produced (Alfian & Purwanto, 2019). The emission factor assumes that in the process of making urea, hydrogen is produced using the steam methane reforming process. The additional urea consumed due to the proposed amendments is estimated from Table IX-8 assuming DEF costs $2.91 per gallon.

expected to more than compensate for the increase in GHG emissions due to increased DEF use.

Even with an increase in DEF use, the Proposed Amendments would not have any significant GHG impacts. Regardless of the Proposed Amendments, manufacturers will continue to comply with the Phase 2 GHG vehicle and engine standards, which will largely dictate their GHG emissions.

Engine technologies identified to meet the proposed 2027 NOx standard such as cylinder deactivation provide both NOx and GHG benefits. CARB staff expects the existence of the HD Omnibus Regulation may provide a more cost-effective way to achieve needed GHG reductions to meet the 2027 Phase 2 GHG standards. This would be achieved by selecting NOx reduction technologies that also reduce GHG emissions, or allow the GHG standards to be met more cheaply by encouraging manufacturers to use such engine technologies.

It is possible that for some individual engine families in MYs 2024 to 2026, a manufacturer that otherwise planned to over-comply with the MY 2024 to 2026 GHG standards (i.e., to have CO2 lower than required by the standards) could over-comply less than they otherwise would if they choose to comply with the MY 2024 to 2026 NOx standards via a strategy that increases CO2 and fuel consumption. However, because manufacturers have a strong incentive to supply fuel efficient vehicles to their customers and because most manufacturers have stated it will be difficult for them to meet the 2024 GHG standards and hence are unlikely to be planning to over-comply by any significant amount, CARB staff expects such a scenario to be unlikely. If a manufacturer finds it more difficult to comply with the 2024 GHG standards because of the Proposed Amendments, the manufacturer may need to add additional GHG technologies to bring its engine families into compliance with the 2024 Phase 2 GHG standards. As described more fully in Chapter IX, CARB staff has considered costs for the additional technology incurred by a manufacturer to mitigate any GHG penalties for MYs 2024 to 2026.

Overall, the Phase 2 GHG vehicle and engine standards will dictate lower GHG emissions, because the proposed 2027 and subsequent NOx standards are likely to encourage use of technologies that reduce both NOx and CO2. Additionally, the CO2 increases associated with additional DEF production are minor in comparison with the GHG benefits of both the Proposed Amendments and the overall 2016 State SIP Strategy. Therefore, the total CO2 emissions overall would be the same or lower with the Proposed Amendments than without them.

The Proposed Amendments contain provisions establishing a heavy-duty zero-emission averaging set intended to incentivize manufacturers to make heavy-duty ZEVs, both to encourage them to comply with the proposed ACT Regulation and to encourage them to make heavy-duty ZEVs in advance of or in addition to the heavy-duty ZEV mandates contained in the proposed ACT Regulation. To the extent that the Proposed Amendments cause additional production of heavy-duty ZEVs, they could lead to the same sort of impacts that the ACT Regulation is anticipated to cause (Short-Term

Construction-Related Air Quality Impacts, etc.), as documented in the Environmental Analysis in Chapter VII of the ISOR for the ACT Regulation (CARB, 2019l). However, because the Proposed Amendments are expected to have a small impact on the number of heavy-duty ZEVs constructed, i.e., many fewer than those needed to satisfy the ACT Regulation mandates, all impacts are expected to be less than significant. In addition, the emission benefits of the Proposed Amendments are expected to offset far more than any temporary increases in emissions.

Thus, the Proposed Amendments do not include changes that would alter the findings in the Final EA of the 2016 SIP. As indicated in the Final EA, the Proposed Amendments would result in changes to heavy-duty engine manufacturing to include near-zero emission technology that significantly lowers NOx emissions in new heavy-duty engine models sold beginning in 2024. The technologies needed to build low NOx heavy-duty engines are incremental improvements to existing technologies, and it remains true that no new manufacturing facilities would be anticipated to be required.

Except for the HD I/M program element, all the other elements included in the Lower In-Use Emission Performance Level measure are currently existing requirements that are applicable to heavy-duty vehicles. The Proposed Amendments would simply amend these regulations to make them more effective in ensuring emissions are controlled in-use. For example, the HDIUT program requires manufacturers to test in-use heavy-duty vehicles using PEMS and evaluate the emissions data collected for compliance using the NTE protocol. As discussed extensively in Chapter II, there are severe shortcomings associated with today's NTE-based HDIUT program. Many manufacturers currently comply without submitting any valid data, and, on average, the NTE-based protocol captures less than six percent of actual real-world operation. The Proposed Amendments would not change how manufacturers would collect emissions data but would revise the methodology used to evaluate emissions data collected using PEMS to ensure emissions are controlled during real-world operation. Similarly, the Proposed Amendments to revise the durability demonstration procedures, warranty period, and useful life period requirements would improve deterioration of engine and aftertreatment systems by encouraging manufacturers to design more durable components.

As mentioned above, the Final EA determined that reasonably foreseeable compliance responses under this measure could include the need to either modify existing light-duty testing centers or construct new testing centers, in order to facilitate a new "smog check" program for heavy-duty trucks. The determination for the need for new test centers was associated with the implementation of a new HD I/M program which is currently under development but which is not part of this rulemaking. As a result, this compliance response does not apply to the Proposed Amendments. The Proposed Amendments would regulate new engine and vehicle manufacturers.

Because there is no substantive change to the way engine manufacturers would comply with the Proposed Amendments, the Proposed Amendments would not result in additional physical changes to the environment beyond what has already been identified in the Final EA. CARB staff does not expect the regulated entities' compliance responses to change from that identified in the Final EA of the 2016 State SIP Strategy, mainly because the Proposed Amendments simply implement the measures included in the 2016 SIP. Therefore, CARB staff does not anticipate that the Proposed Amendments would cause new significant environmental effects or a substantial increase in the severity of previously identified effects in the Final EA.

(2) There are no substantial changes with respect to the circumstances under which the Proposed Amendments are being undertaken which require major revisions to the previous Environmental Analysis involving new significant environmental effects or a substantial increase in the severity of previously identified effects.

There are no substantial changes to the environmental setting or circumstances in which the Proposed Amendments are being implemented compared to that analyzed in the Final EA of the SIP. As explained above, the new measures do not substantially alter the types of compliance responses of the regulated entities or result in any changes that significantly affect the physical environment.

(3) There is no new information of substantial importance, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous Environmental Analysis was certified as complete, that changes the conclusions of the Environmental Analysis with regard to impacts, mitigation measures, or alternatives.

No new information of substantial importance that changes the conclusions of the Final EA has become available to CARB staff since the Final EA was certified. The project will not have any significant effects that are not discussed in the Final EA. Significant effects previously examined will not be substantially more severe than previously analyzed in the Final EA. No newly feasible or different mitigation measures are known which could substantially reduce one or more of the previously-identified significant effects of the project. Therefore, there is no new information of substantial importance that changes the conclusions in the Final EA about the potential environmental impacts to any resource areas, mitigation measures for those impacts or alternatives.

In sum, no supplemental or subsequent EA is required for the Proposed Amendments because, as described above, the Proposed Amendments do not result in any new environmental impacts or in a substantial increase in severity to the impacts previously disclosed in the Final EA. Further, there are no changes in circumstances or new information that would otherwise warrant an additional environmental review.

VIII. ENVIRONMENTAL JUSTICE

State law defines environmental justice as the fair treatment and meaningful involvement of people of all races, cultures, incomes, and national origins, with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Gov. Code, § 65040.12, subd. (e)(1)). Environmental justice includes, but is not limited to, all of the following: (A) The availability of a healthy environment for all people. (B) The deterrence, reduction, and elimination of pollution burdens for populations and communities experiencing the adverse effects of that pollution, so that the effects of the pollution are not disproportionately borne by those populations and communities. (C) Governmental entities engaging and providing technical assistance to populations and communities most impacted by pollution to promote their meaningful participation in all phases of the environmental and land use decision making process. (D) At a minimum, the meaningful consideration of recommendations from populations and communities most impacted by pollution into environmental and land use decisions (Gov. Code, § 65040.12, subd. (e)(2)). The Board approved its Environmental Justice Policies and Actions (Policies) on December 13, 2001, to establish a framework for incorporating environmental justice into CARB's programs consistent with the directives of State law (CARB 2001). These policies apply to all communities in California, but are intended to address the disproportionate environmental exposure burden borne by low-income communities and communities of color. Environmental justice is one of CARB's core values and fundamental to achieving its mission.

Over the past thirty years, CARB, local air districts, and federal air pollution control programs have made substantial progress towards improving air quality in California and are on track to meet the statutory goals of reducing GHG emissions to 1990 levels by 2020. Despite this progress, some areas in California still exceed health-based air quality standards for ozone and PM. One of the most important factors for identifying disadvantaged communities are disproportionate effects of environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation.

Heavy-duty vehicles are significant contributors to California's air pollution problems. As described further above in Chapter II, Section A.2, they are an important source of toxic diesel PM emissions and emit significant quantities of NOx and PM, which result in the formation of ambient ozone and PM2.5 in California. Heavy-duty vehicles are the predominant means of distributing good and services. Their prevalence can be seen at distribution centers, ports, warehouses, and along major roadways, all of which are commonly located around more densely populated urban areas, including in low-income and disadvantaged communities.

The Proposed Amendments are therefore consistent with CARB's environmental justice policy reducing exposure to harmful pollutants. The Proposed Amendments would significantly reduce NOx emissions from heavy-duty vehicles and would prevent PM emission increases. They would result in significant emission reductions contributing to the overall reduction of public exposure to criteria air pollutants from heavy-duty vehicles operating throughout the state. In particular, they would provide significant air quality benefits to communities located in proximity to major freight corridors such as ports and railyards, distribution centers, truck stops, and other places where a high density of trucks operate. Many such these communities are environmental justice areas that are already affected by the cumulative impact of air pollution from multiple mobile, commercial, industrial, area-wide, and other sources. As a result, the adoption of these amendments is expected to benefit residents of such communities, affirming the Board's commitment to the fair treatment of all people throughout California.

IX. ECONOMIC IMPACTS ASSESSMENT OR STANDARDIZED REGULATORY IMPACT ANALYSIS

This chapter summarizes CARB staff's estimated cost and benefit impacts of the Proposed Amendments. Section A describes the changes to the cost analysis since the release of the Standardized Regulatory Impact Assessment (SRIA). Section B includes the cost methodology and analysis for each element of the Proposed Amendments. Section C discusses the direct cost impacts on businesses and individuals. Section D describes the fiscal impacts to local and state government. Section E contains the macroeconomic impacts. Finally, Section F presents a sensitivity analysis of indirect incremental warranty costs using the NREL survey warranty responses. For more detail regarding CARB staff's methodology, refer to Appendix C-3: Further Detail on Costs and Economic Analysis.

Similar to the emissions impact analysis in Chapter V, the economic impacts of the Proposed Amendments are evaluated against the baseline scenario for the analysis period from 2022 through 2050. As previously stated in Chapter V, the baseline vehicle inventory includes the vehicle sales and population growth assumptions currently reflected in CARB's EMFAC2017 (CARB, 2019f) emissions inventory model for combustion engines, certified and intended for use in vehicles greater than 10,000 pounds GVWR. The current EMFAC model reflects implementation of currently existing state and federal laws and regulations including the Truck and Bus Regulation, Drayage Truck Regulation, idling restrictions and the Certified Clean Idle Regulation, Phase 1 and 2 GHG Regulations, ICT Regulation, and the Optional Low NOx Program.

A. Changes Since the Release of the SRIA

CARB staff's proposal and economic impact analysis has evolved in a number of ways since the SRIA was posted on January 24, 2020, as described further below. (The SRIA is attached as Appendix C-1 and also is available on the California Department of Finance's website.[54])

First, CARB's contractor, NREL, submitted its report on costs associated with developing and integrating emission control technologies to achieve a 0.02 g/bhp-hr NOx standard. NREL surveyed OEMs and used the survey results to estimate costs associated with the engine system, increasing durability and meeting the lengthened useful life requirements, additional OBD hardware, and aftertreatment technology packages. CARB staff updated the hardware and technology costs that were presented in the SRIA based on results from NREL's estimates. In the SRIA, CARB staff had to explicitly account for the cost of lengthening useful life, but NREL's results included lengthened useful life in the research and development and hardware costs associated with meeting a 0.02 g/bhp-hr NOx standard. Hence, CARB staff was able to rely on the NREL results rather than separately adding a cost for lengthened useful life. In addition, to account for the possibility that it may be more costly for manufacturers to

[54] Department of Finance's website for Major Regulations SRIAs and Calendar, http://www.dof.ca.gov/Forecasting/Economics/Major_Regulations/Major_Regulations_Table/

meet the 2024 Phase 2 GHG standards due to having to simultaneously meet the proposed NOx standards for 2024-2026 MY diesel engines, staff conservatively updated the technology cost for 2024-2026 MY diesel engines by adding an additional one percent to the cost of GHG technology needed to reduce GHG emissions. CARB staff also updated the DDP cost to include the cost for additional test points at 435,000 miles and full useful life for 2027 and subsequent MY engines.

Second, based on stakeholder feedback and an assessment of the proposed lengthened warranty and useful life's expected cost and emission benefits, CARB staff revised the lengthened warranty and useful life proposals since preparing the SRIA. As shown in Tables IX-1 and IX-2, CARB staff scaled back the final lengthened warranty and useful life proposals. CARB staff is now also proposing a phase-in between 2027 and 2031 rather than implementing the lengthened useful life and warranty all in one step in 2027. Costs for useful life, warranty, EWIR, and durability demonstration were recalculated to account for the revised warranty and useful life proposals. For example, costs were added for manufacturers to conduct three separate durability programs, one for 2024 to 2026 products, one for 2027 to 2030 products and one for 2031 and subsequent MY products.

Table IX-1. Updates to Warranty Proposal Since SRIA

Engine / Vehicle Category (GVWR)	SRIA Proposal for Step 2 Warranty Effective MY 2027 and subsequent (Miles)	New Proposal for Step 2 Warranty Effective MY 2027 - 2030 (Miles)	New Proposal for Step 2 Warranty Effective MY 2031 and subsequent (Miles)
HHDD / Class 8 >33,000 lbs.	800,000 14 years	450,000 7 years/ 22,000 hours	600,000 10 years/ 30,000 hours
MHDD / Class 6-7 19,501 - 33,000 lbs.	360,000 14 years	220,000 7 years / 11,000 hours	280,000 10 years/ 14,000 hours
LHDD / Class 4-5 14,001 - 19,500 lbs.	280,000 14 years	150,000 7 years/ 7,000 hours	210,000 10 years/ 10,000 hours
HDO >14,000 lbs.	200,000 14 years	110,000 7 years/ 6,000 hours	160,000 10 years/ 8,000 hours
Medium-Duty Diesel Engine Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs.	280,000 14 years	100,000 5 years/ 3,000 hours*	100,000 5 years/ 3,000 hours*
Medium-Duty Otto Engine Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs.	200,000 14 years	50,000 5 years*	50,000 5 years*

* These are the current warranty requirements. The Proposed Amendments would not change warranty lengths for these vehicle/engine categories.

Table IX-2. Updates to Useful Life Proposal Since SRIA

Engine / Vehicle Category (GVWR)	SRIA Proposal for Step 2 Useful Life Effective MY 2027 and subsequent (Miles)	New Proposal for Useful Life Phase-in Effective MY 2027 - 2030 (Miles)	New Proposal for Useful Life Phase-in Effective MY 2031 and subsequent (Miles)
HHDD / Class 8 >33,000 lbs.	850,000 18 years/ 22,000 hours	600,000 11 years/ 30,000 hours	800,000 12 years/ 40,000 hours
MHDD / Class 6-7 19,501 - 33,000 lbs.	450,000 18 years	270,000 11 years	350,000 12 years
LHDD / Class 4-5 14,001 - 19,500 lbs.	350,000 18 years	190,000 12 Years	270,000 15 years
HDO >14,000 lbs.	250,000 18 years	155,000 12 Years	200,000 15 years
Medium-Duty Diesel Engine Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs.	350,000 18 years	110,000 10 years*	110,000 10 years*
Medium-Duty Otto Engine Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs.	250,000 18 years	110,000 10 years*	110,000 10 years*

* These are the current useful life requirements. The Proposed Amendments would not change useful life lengths for these vehicle/engine categories.

Third, based on emission test results from the Low NOx demonstration at SwRI as well as comments from industry and U.S. EPA staff, CARB staff revised the values for FTP, RMC-SET, LLC, and idle certification standards from the previous proposal. For 2024 to 2026 MY engines, the FTP/RMC-SET standards were kept at 0.050 g/bhp-hr NOx, but the LLC standard was relaxed from 0.05 to 0.20 g/bhp-hr NOx. For 2027 and newer MY engines, the FTP/RMC-SET standards were kept at 0.020 g/bhp-hr NOx, the LLC standard was relaxed from 0.020 to 0.040 g/bhp-hr NOx, and the idle standard was relaxed from 1 to 5 g/hr NOx.

Fourth, CARB staff made changes to the in-use test procedures proposal. CARB staff coordinated with U.S. EPA staff, ICCT staff, EMA, the Joint Research Council, and individual manufacturers in developing the new in-use method known as the 3B-MAW method. Although the method does take some cues from Europe's Euro VI MAW program, the data coverage, windows, evaluation, and applicable standards are different and, in CARB staff's view, stricter and superior to the Euro VI MAW program. Similar to the proposal in the SRIA, the 3B-MAW in-use method would start for 2024 MY engines and cover cold start emissions for 2027 and subsequent MY engines. CARB staff added the requirement of collecting OBD data, ammonia storage, and REAL data during HDIUT to provide staff sufficient data for evaluating in-use testing results. CARB staff has updated in-use testing costs to reflect these changes.

Fifth, CARB staff made changes to the proposed EWIR provision since the SRIA submission. In the SRIA, CARB staff had proposed the modified EWIR provision would phase in starting with 2022 MY engines. CARB staff now proposes the modified EWIR provision would phase in starting with 2024 MY engines to align with the proposed phase-in of more stringent NOx standards for 2024 and subsequent MY engines.

Table IX-3 summarizes the updated test certification cycles, in-use testing, durability demonstration, useful life, warranty, and EWIR requirements of the Proposed Amendments. The current baseline of each of the elements and the changes proposed in 2024, 2027, and 2031 are presented in Table IX-3.

Table IX-3. Updated Test Certification Cycles and Timeline for the Proposed Amendments

Standards, Test Procedures, and Elements	Units	Baseline (B)	2024	2027	2031
1) FTP/RMC-SET	g/bhp-hr NOx	0.2	0.050	0.020	0.020
2) LLC	g/bhp-hr NOx	---	0.2	0.040	0.040
3) Idling	g/hr NOx	30	10	5	5
4) HDIUT					
Method		Current NTE	Binned MAW	Binned MAW w/ Cold Start	Binned MAW w/ Cold Start
In-Use Threshold	g/bhp-hr NOx	0.45	1.5x Standards	1.5x Standards	1.5x Standards
5) Durability Demonstration Program (DDP)		(35-50)% × UL	100% UL aging	100% UL aging	100% UL aging
6) UL (HHD/MHD/LHD/HDO)	10^3×miles	435/185/110/110	Baseline	600/270/190/155	800/350/270/200
7) Warranty (HHD/MHD/LHD/HDO)	10^3×miles	350/150/110/50	Baseline	450/220/150/110	600/280/210/160
8) Emissions Warranty Information Reporting (EWIR)	---	EWIR	Mod EWIR	Mod EWIR	Mod EWIR

FTP/RMC-SET = Current and proposed NOx standards certified under the heavy-duty transient Federal Test Procedure and the Ramped Modal Cycle of the supplemental emissions test.
LLC = Proposed NOx standards certified under the Low Load Cycle.
Idling = Current and proposed NOx standards certified under the supplemental idling test procedure.
HDIUT Method = Current and proposed Heavy-Duty In-Use Test Methods.
HDIUT In-Use Threshold = Current and proposed NOx standards using the HDIUT Methods.
DDP = Current and proposed modifications to the Durability Demonstration Program.
UL = Current and proposed useful life periods for heavy-duty diesel- and Otto-cycle engines/vehicles.
Warranty = Current and proposed warranty period for heavy-duty diesel- and Otto-cycle engines/vehicles.
EWIR = Current and proposed modifications to the Emissions Warranty Information and Reporting Program.

Sixth, CARB staff modified the Proposed Amendments by including Class 4 to 8 ZEVs in the CA-ABT program. Total incremental costs for the industry were estimated based on all 14 heavy-duty engine manufacturers and 17 Class 4 to 8 heavy-duty ZEV manufacturers participating in the program.

Seventh, CARB staff also modified the proposal to use information from the in-use emissions data reporting program as a tool to validate the results from the durability demonstration program. As such, for the cost analysis, CARB staff has combined the costs for the laboratory service accumulation and in-use emissions reporting into one aggregate cost for the DDP. For the in-use emissions reporting program, CARB staff has modified the regulatory language so that:

- Heavy heavy-duty diesel-fueled engine families that use the optional DDP with accelerated aftertreatment aging would be required to submit reports for 2024 through 2026 MYs, and would be required to submit reports for 2027 and subsequent MYs.

- Medium heavy-duty and light heavy-duty diesel-fueled engine families that use accelerated aftertreatment aging would be required to submit reports for 2027 and subsequent MYs.

Eighth, CARB staff has updated the projected sales volume of medium- and heavy-duty combustion engines to be based on the legal baseline. In addition, CARB staff has also updated the projected engine sales volume to reflect the recently adopted Zero-Emission Airport Shuttle Bus Regulation and Assembly Bill 739 (CLI, 2017). In the SRIA, CARB staff performed the cost analysis based on the modeled baseline to account for the proposed ACT Regulation as both the proposed ACT Regulation and the Proposed Amendments would impact the same class of vehicles and engines during the same timeframe (see Chapter V for further details). However, the California Department of Finance requires the main cost analysis to be based on the legal baseline in their comments on CARB's submitted SRIA.

Ninth, CARB staff has added optional 50-state-directed engine standards to provide manufacturers the flexibility to certify their 2024 through 2026 MY engines to a less stringent NOx standard, if they meet that standard nationwide.

Tenth, CARB staff has added proposed revisions to the current optional low NOx standards so that manufacturers would continue to have an incentive to develop and certify engines even cleaner than those that would be required by the Proposed Amendments.

State and local tax revenue projections were adjusted to reflect the final allocations per the State of California Guidelines. The figures for final allocation were used in this analysis.

B. Direct Costs

This rulemaking action includes the proposed Heavy-Duty Omnibus Regulation as well as minor amendments to other associated regulations. The minor amendments to other associated regulations are not projected to increase costs. Therefore, the following cost analysis discussion focuses on the elements of the Proposed Amendments that are expected to affect costs. The Proposed Amendments would regulate vehicle and engine (GVWR >10,000 pounds) manufacturers; hence, those manufacturers are anticipated to incur the majority of the estimated direct costs. Since the affected manufacturers are located outside of California, CARB staff assumes all of the direct costs would be passed on to California vehicle fleets who purchase the California-certified vehicles that would be required to comply with the Proposed Amendments.[55] The direct cost inputs for the various parts of the Proposed Amendments package are described in the sections below as follows:

1. New Low NOx Standards Costs

1.1. Technology Costs

The incremental low NOx technology costs include the cost of: 1) new and/or improved engine and aftertreatment technologies to meet the more stringent NOx standards, and 2) research and development investment for the new technologies.

CARB staff contracted with NREL to conduct a cost analysis to estimate costs associated with new engine technologies and hardware upgrades, aftertreatment system upgrades, as well as research and development as compared to the 2018 technology baseline. NREL conducted a survey in 2019 of the engine, aftertreatment, and other suppliers on the cost to make technology packages to fulfill the proposed low NOx emission standards including California-only sales volume and extension of useful life. NREL published their cost survey and analysis results in March 2020 (NREL, 2020). The technology package associated with meeting the 2024 proposed amendments for diesel engines included EGR cooler bypass, changes and upgrades to current aftertreatment technologies (DOC, DPF, ASC, DEF dosing, OBD sensors and controllers), and others. The technology package associated with meeting the 2027 proposed amendments for diesel engines included cylinder deactivation, light-off SCR, changes and upgrades to current aftertreatment technologies (DOC, DPF, ASC, DEF dosing, OBD sensors and controllers), and others. The technology package for Otto-cycle (gasoline) engines to meet the more stringent NOx standards included upgrades to current TWC technology.

[55] All the affected engine manufacturers are located outside California. However, as described above in Chapter V and shown in Figure V-1, a number of heavy-duty ZEV manufacturers who could generate credits under the Proposed Amendments are located in California.

For the Proposed Amendments' low NOx technology cost assessment, CARB staff adjusted NREL's technology cost values to reflect the different useful life and warranty periods from the NREL surveys and the Proposed Amendments.

Comments from industry have suggested there would be a GHG emission penalty to meet the more stringent NOx standards. However, the SwRI Low NOx testing program results have shown no GHG emission penalty to meet the proposed 0.020 g/bhp-hr NOx standard for 2027 and subsequent MY engines. Although staff also does not expect there would be any GHG emission penalty to meet the proposed 0.05 g/bhp-hr NOx standards for 2024-2026 MY engines, meeting the 0.05 g/bhp-hr NOx standard may make it more difficult to simultaneously meet the 2024 Phase 2 GHG standards. Thus, staff has conservatively added an additional one percent to the cost of GHG technology needed to reduce GHG emissions. Staff used U.S EPA's technology cost estimates in the federal Phase 2 GHG Regulation to estimate incremental costs per vehicle for every one percent of GHG emission reductions (U.S. EPA, 2016c). The resulting additional GHG technology costs for 2024-2026 MY engines are $501 for HHDD engines and $100 for MD, LHDD, and MHDD engines.

Table IX-4 below presents a summary of technologies and their adjusted incremental cost (in 2018$) for a 6/7-liter diesel and 12/13-liter diesel engine to meet the 2024, 2027, and 2031 amendments based on NREL's March 2020 findings. The total integrated cost for both the hardware and research and development for heavy-duty Otto-cycle engines based on the NREL report is an estimated average value of $411.

Table IX-4. Summary of Technologies and Adjusted Incremental Costs (2018$) for Meeting the 2024 and 2027 Low NOx Standards Based on NREL Survey

		6/7-Liter Diesel			12/13-Liter Diesel		
Applicable MYs		**2024-2026**	**2027-2030**	**2031+**	**2024-2026**	**2027-2031**	**2031+**
Engine Technology[a]	EGR Cooler Bypass	$243	na	na	$302	na	na
	Cylinder Deactivation	na	$811	$831	na	$1,017	$1,097
	Other	na	$588	$665	na	$764	$932
Aftertreatment Technology[a]	Light-off SCR	na	$988	$1,030	na	$1,181	$1,256
	DOC (subtotal)	$10	$31	$50	$89	$105	$125
	DPF (2018 baseline system only)[b]	($17)	$9	$34	($44)	($7)	$38
	SCR + ASC + DEF Dosing (subtotal)	$621	$747	$865	$784	$917	$1,079
	OBD sensors and controllers (NOx, Ammonia, temp sensors)	$333	$452	$564	$330	$457	$611
	Other*	$175	$204	$232	$150	$384	$667
Total Incremental Hardware Cost to Manufacturer		**$1,365**	**$3,830**	**$4,271**	**$1,611**	**$4,818**	**$5,803**
Incremental Research and Development Costs to Manufacturer[c]		**$85**	**$82**	**$78**	**$354**	**$355**	**$356**
Incremental Cost to Simultaneously Meet Phase 2 GHG Standards[d]		**$100**	**na**	**na**	**$501**	**na**	**na**
Total Incremental Cost		**$1,550**	**$3,912**	**$4,350**	**$2,466**	**$5,173**	**$6,159**

[a] Values are only shown for technologies applicable to that application.
[b] Values in parentheses represent savings compared to the baseline 2018 technology and costs.
[c] Note that the research and development costs in Table IX-4 were estimated by NREL based on original equipment manufacturer shareholder reports and adjusted by CARB staff to fit the Proposed Amendments. They are intended to represent fixed research and development costs distributed on a per engine basis, based on the population of engines expected to be subject to the Proposed Amendments in the legal baseline.
[d] Incremental cost to meet Phase 2 GHG emission standards was derived using U.S. EPA's cost estimate for the federal Phase 2 GHG Regulation.

In addition to the useful life and warranty adjustments, CARB staff applied a steep learning curve (U.S. EPA, 2016a), as used in previous U.S. EPA analyses, to the costs associated with the new engine and aftertreatment system technologies needed to comply with the Proposed Amendments to reflect improvements and cost reductions in the manufacturing processes over time. The steep-portion learning algorithm was applied for those technologies considered to be newer technologies that would likely have rapid cost reductions through manufacturer learning. The steep portion learning algorithm results in 20 percent lower costs after two full years of implementation. Once the steep-portion learning steps have occurred, flat portion learning at 3 percent per year is applied for 5 years, then 2 percent per year is applied for the next 5 years, and lastly 1 percent per year is applied for the next 5 years. The cost would remain the same beyond the 17-year span of the steep learning curve. Table IX-5 summarizes the total incremental cost of engine and aftertreatment system technologies as well as research and development, for each engine type once the learning curve effects were applied, from 2022 to 2050 MY engines.

Table IX-5. Total Incremental Costs of Engine Technologies, Aftertreatment System Technologies, and Research and Development Based on Engine Size and Fuel Type to Meet the Proposed Heavy-Duty Low NOx FTP, RMC-SET, LLC, and Idle Standards for MY 2022 to 2050 Engines (2018$ per engine)

MY Engine	6/7-liter Diesel	12/13-liter Diesel	6/7-liter Gasoline
2022	$0	$0	$0
2023	$0	$0	$0
2024	$1,550	$2,466	$411
2025	$1,550	$2,466	$411
2026	$1,309	$2,165	$411
2027	$3,912	$5,173	$411
2028	$3,912	$5,173	$411
2029	$3,306	$4,438	$411
2030	$3,233	$4,349	$411
2031	$4,350	$6,159	$411
2032	$4,350	$6,159	$411
2033	$3,681	$5,326	$411
2034	$3,601	$5,226	$411
2035	$3,524	$5,129	$411
2036	$3,448	$5,035	$411
2037	$3,375	$4,944	$411
2038	$3,304	$4,855	$411
2039	$3,258	$4,798	$411
2040	$3,213	$4,742	$411
2041	$3,169	$4,687	$411
2042	$3,126	$4,633	$411
2043	$3,083	$4,580	$411
2044	$3,063	$4,554	$411
2045	$3,042	$4,528	$411
2046	$3,022	$4,503	$411
2047	$3,002	$4,478	$411
2048	$2,982	$4,453	$411
2049	$2,982	$4,453	$411
2050	$2,982	$4,453	$411

CARB staff used the incremental costs on a per vehicle basis listed in Table IX-5 and the EMFAC future vehicle sales projections to estimate the statewide annual incremental costs associated with the low NOx technology, as shown in Table IX-6 below.

Table IX-6. Statewide Incremental Increase in Costs Associated with Low NOx Technology Including Hardware and Research and Development

Calendar Year	Technology Cost
2022	$0
2023	$0
2024	$1,825,884
2025	$45,200,392
2026	$45,745,702
2027	$40,982,758
2028	$109,539,586
2029	$111,797,840
2030	$96,736,169
2031	$96,282,989
2032	$134,783,615
2033	$137,481,896
2034	$121,521,857
2035	$121,265,142
2036	$119,537,729
2037	$118,057,423
2038	$116,470,502
2039	$115,117,319
2040	$114,501,103
2041	$113,726,998
2042	$113,194,894
2043	$112,594,172
2044	$112,202,975
2045	$112,437,873
2046	$112,674,805
2047	$112,834,056
2048	$113,036,856
2049	$113,193,816
2050	$113,193,816
Total	**$2,775,938,169**

1.2. DEF Consumption Costs

Because the Proposed Amendments would require SCR systems to operate during more of vehicles' actual operating hours, for example, even during low load conditions, the Proposed Amendments would likely require the consumption of more DEF. The annual total incremental change in operational costs due to DEF consumption for 2024-2026 and 2027+ MY engines are summarized by year in Table IX-7.

Table IX-7. Incremental Annual DEF Consumption Costs by Engine Class (2018$ per engine)

Engine Class	MY 2024-2026	MY 2027+
HHDD	$89.84	$107.81
MHDD	$36.97	$44.37
LHDD	$36.63	$43.96
MDDE-3	$19.61	$23.53
MDOE-3	$0.00	$0.00
HDO	$0.00	$0.00

CARB staff used the incremental DEF consumption cost on a per vehicle basis listed in Table IX-7 and the EMFAC future vehicle sales projections to estimate the statewide annual incremental costs associated with the anticipated increased DEF consumption, as shown in Table IX-8.

Table IX-8. Statewide Incremental Increase in Costs Associated with Increased DEF Consumption to Meet the Proposed Amendments

Calendar Year	Annual DEF Consumption
2022	$0
2023	$0
2024	$4,635
2025	$1,260,430
2026	$2,535,391
2027	$3,841,377
2028	$5,427,646
2029	$7,049,592
2030	$8,698,381
2031	$10,370,476
2032	$12,090,101
2033	$13,848,578
2034	$15,661,540
2035	$16,257,271
2036	$16,845,154
2037	$17,415,968
2038	$19,300,350
2039	$19,920,738
2040	$20,226,153
2041	$20,516,054
2042	$20,797,440
2043	$22,756,630
2044	$23,028,468
2045	$23,601,250
2046	$24,142,753
2047	$24,348,447
2048	$24,554,099
2049	$24,753,806
2050	$24,936,098
Total	**$424,188,827**

2. Lower PM Standards Compliance Costs

CARB staff's analysis of 2018 MY heavy-duty diesel engine PM certification levels show that 93 percent of the engines have emission certification levels below the proposed PM standard of 0.005 g/bhp-hr. These engines can continue to use their existing filters to meet the proposed standard and thus no additional cost would be imposed to meet this standard. The remaining 7 percent of the certified engines have PM certification levels above the 0.005 g/bhp-hr but below the current 0.01 g/bhp-hr. These engines would need some additional calibration work to reduce PM emissions and meet the proposed PM standard.

NOx and PM emissions in diesel engines are closely tied together, and calibration to optimize NOx emissions would also involve calibration to optimize PM emissions. CARB staff therefore assumes that the cost for reducing PM emissions would be absorbed by the engineering cost required to optimize NOx emissions (included in Table IX-4) and that there would be no additional cost to meet the proposed PM standard.

3. Amended Heavy-Duty In-Use Test Procedure Costs

CARB staff estimated administrative costs for manufacturers to implement the HDIUT amendments, including the new 3B-MAW method. CARB staff does not assume any additional hardware or DEF costs would be needed to comply with the HDIUT amendments, because the costs discussed in Section A.1 of this chapter include design and calibration costs to meet HDIUT. Costs attributed to the Proposed Amendments include cost for initial learning to be able to analyze the in-use testing with the proposed 3B-MAW test procedure and OBD data collection capability, cost for testing California-certified engine families, and cost for coordinating test plan pre-approval and OBD data reporting. Further details for each cost component are as follows:

- Initial implementation of the 3B-MAW and the OBD data reporting amendments – It was estimated that 160 hours and 40 hours would be necessary for a junior engineer at a salary of $70 per hour (U.S. BLS, 2019) to set up the 3B-MAW and the OBD data reporting requirements, respectively. An additional hardware cost of $2,509 was attributed to a HEM data logger or similar device to record OBD parameters. The labor and hardware costs were attributed to the eight heavy-duty engine manufacturers subject to the HDIUT program. In total, an initial cost of $132,072 was estimated in the first year of implementing the amendments.

- In-use testing of the California-only certified engine families outside of the federal HDIUT program – The number of engine families required for testing by a manufacturer for any year is 25 percent of qualifying engine families per year as described in 40 CFR 86.1905. Qualifying engine families are those that sell a minimum of 1,500 units in a calendar year. The number of engine families required for testing was therefore estimated to be 25 percent of the total number of diesel engines divided by 1,500 units. An engine family test would require between 5 to 10 vehicles. Staff assumed manufacturers would test 10 percent of their qualifying engine families with 10 vehicles and 90 percent of their qualifying engine families with 5 vehicles. It would cost manufacturers approximately $1,680 per tested vehicle; hence the weighted average testing cost per each qualifying engine family would be $9,240. The total cost to manufacturers in a given year is the testing cost per qualifying engine family multiplied by the number of qualifying engine families produced in a year.

- Coordination for test plan pre-approval and OBD reporting – CARB staff estimated 80 hours for a junior engineer would be required for both the test plan approval coordination and OBD reporting amendments for each tested engine family. The additional labor cost is the labor cost for each tested engine family multiplied by the estimated number of engine families to be tested each year.

A summary of the HDIUT procedure amendment costs is presented in Table IX-9.

Table IX-9. Summary of Heavy-Duty In-Use Test Procedure Amendment Costs

Calendar Year	Initial Costs	CA Engine Family Testing	Test Plan Coordination and OBD Data	Total HDIUT Costs
2024	$132,072	$364	$221	$132,657
2025	$0	$37,035	$22,446	$59,481
2026	$0	$37,482	$22,716	$60,198
2027	$0	$38,403	$23,275	$61,678
2028	$0	$38,813	$23,523	$62,336
2029	$0	$39,671	$24,043	$63,714
2030	$0	$40,258	$24,399	$64,657
2031	$0	$40,811	$24,734	$65,544
2032	$0	$41,952	$25,426	$67,378
2033	$0	$42,812	$25,947	$68,759
2034	$0	$44,223	$26,802	$71,025
2035	$0	$45,055	$27,306	$72,362
2036	$0	$45,315	$27,463	$72,778
2037	$0	$45,671	$27,680	$73,351
2038	$0	$45,946	$27,846	$73,792
2039	$0	$46,308	$28,065	$74,373
2040	$0	$46,636	$28,264	$74,900
2041	$0	$46,914	$28,433	$75,347
2042	$0	$47,292	$28,662	$75,954
2043	$0	$47,631	$28,867	$76,498
2044	$0	$48,055	$29,124	$77,180
2045	$0	$48,452	$29,365	$77,817
2046	$0	$48,847	$29,604	$78,451
2047	$0	$49,219	$29,829	$79,048
2048	$0	$49,617	$30,071	$79,688
2049	$0	$49,978	$30,290	$80,268
2050	$0	$49,978	$30,290	$80,268
Total	**$132,072**	**$1,162,739**	**$704,690**	**$1,999,501**

4. Lengthened Warranty Costs

In order to estimate the incremental costs due to staff's proposed lengthened warranty, CARB staff first examined current warranty practices and coverages. CARB staff first established the warranty purchasing practices for the heavy-duty market, and then determined the average miles driven and associated costs while under warranty. From there, CARB staff estimated the projected costs and the overall incremental costs for Step 2 warranty.

4.1. Baseline Warranty Purchasing Business Practices

Once the June 2018 Step 1 warranty amendments are implemented beginning with the 2022 MY, the warranty coverage market for heavy-duty vehicles is expected to be comprised of CARB-required emission control system warranties, manufacturer-provided warranties, and customer-purchased extended warranties. The projection for warranty coverages beginning in MY 2022 is expected to have a profile as shown in Table IX-10 for heavy-duty diesel vehicles. These values come from estimates based on a survey conducted by the Sacramento ISR, and discussions with manufacturers and third-party warranty providers, all accomplished as part of CARB's June 2018 Step 1 warranty amendment rulemaking effort (CARB, 2018e). The baseline used in this analysis accounts for real-world purchasing behavior and focuses on the out-of-pocket expenses that would be covered under the Proposed Amendments. Table IX-10 also shows the expected baseline for the HDO vehicles. Because heavy-duty vehicles with Otto-cycle engines were not included in the June 2018 Step 1 warranty amendments, a similar breakdown based on the Sacramento ISR survey was not developed for that category.

As Table IX-10 shows, for the HHDD and MHDD vehicle categories, CARB staff expects 40 percent of vehicles to have warranty beyond the minimum required emissions warranty, and 60 percent of vehicles to have just the minimum warranty coverage required by the June 2018 Step 1 warranty amendments. One hundred percent of the LHDD vehicle category is estimated to have a warranty coverage of 110,000 miles, the minimum required by the June 2018 Step 1 warranty amendments. Similarly, for the HDO vehicles, as a conservative approach (which will overestimate cost), CARB staff assumed that 100 percent of these engines rely on the CARB-regulatory specified warranty periods and do not currently purchase extended warranties.

Table IX-10. Projected Baseline Warranty Purchasing Business Practices Due to the June 2018 Heavy-Duty Warranty Amendments (MY 2022)

Vehicle Category	Miles Warranted	Percent of Vehicle Population
HHDD	500,000	40%
	350,000	60%
MHDD	185,000	40%
	150,000	60%
LHDD	110,000	100%
HDO	50,000	100%

4.2. Mileage Covered Under Baseline Warranty

Warranty periods under the baseline are given as a mileage threshold and a year threshold. These thresholds end the warranty coverage based on whichever occurs first. The warranty year threshold is currently 5 years for all the considered categories, and the mileage threshold can be either the regulatory mileage period, or the customer-purchased extended warranty period.

The EMFAC2017 on-road vehicle emissions model categorizes the heavy-duty market by their vehicle service applications, and models their annual vehicle miles traveled. Using EMFAC's vehicle service applications, the mileage accumulated during the first five years per vehicle application was examined to estimate which vehicle types sold in California typically exhaust their warranties due to the mileage threshold (i.e., either by regulatory or customer-purchased extended warranties), and which do so due to the year threshold. The resulting baseline average miles traveled under warranty are shown in Table IX-11.

Table IX-11. Projected Baseline Warranty Average Miles Traveled Under the June 2018 Heavy-Duty Warranty Amendments for Each Vehicle Category (MY 2022)

Vehicle Category	Baseline Average Miles Traveled Under Warranty
HHDD	288,710
MHDD	138,756
LHDD	102,838
HDO	50,000

4.3. Cost of Repairs Under the Baseline Warranty

To establish the baseline costs, CARB staff determined the cost of repairs under the Step 1 warranty amendments, which will be in effect beginning with the 2022 MY. CARB staff did the analysis by using information from the warranty claims-related data, obtained under CARB's EWIR program (see Section A.6 of this chapter for a description of the EWIR program), and sales data from the engine certification applications (also given in Section A.6).

The total number of warranty claims for each engine component was added up and divided by the number of certified engines sold for each vehicle class to calculate the rate of repair under warranty, referred to as the warranty claims rate. The most recent EWIR complete 5-year warranty claims data set is with respect to the 2013 MY, so CARB staff used the 2013 MY engine certification reported sales to calculate the warranty claims rate.

The average repair costs, including both parts and labor, for each component were obtained through analysis of service station repair records and costs utilized in the June 2018 Step 1 warranty rulemaking (CARB, 2018f). Multiplying these average repair costs by the claims rate for each engine component provides an estimate of the average weighted repair costs that a typical heavy-duty vehicle experiences while still under warranty.

Using this approach, the weighted repair costs can be estimated for all the vehicle categories that are considered under this proposal. Additionally, beginning with the 2022 MY for HHDD, MHDD, and LHDD vehicles, the warranty coverage will also include emissions components that cause the OBD system's MIL to illuminate. The total average repair costs that take into account the costs associated with the indirect OBD components,[56] and the traditionally reported components are shown in Table IX-12.

[56] Indirect OBD components do not have a direct impact on the emissions, but are monitored by the OBD system because a malfunction of one of these input or output sensors, if undetected, could lead to incorrect diagnosis of emission malfunctions or even prevent the OBD system from checking for malfunctions.

Table IX-12. Total Average Baseline Warranty Repair Costs Per Vehicle Expected Under the June 2018 Step 1 Warranty Amendments (MY 2022) for Each Vehicle Category (2018$)

Vehicle Category	Average Repair Costs from 2013 MY EWIR Data	Expected Indirect Emissions Components Repair Costs Beginning in MY 2022 under Step 1 Warranty	Expected Total Average Baseline Repair Costs Beginning in MY 2022
HHDD	$2,400	$16	$2,416
MHDD	$2,769	$6	$2,775
LHDD	$1,073	$23	$1,096
HDO	$238	N/A	$238

4.4. Estimated Warranty Purchasing Business Practices Under the Proposed Warranty Amendments

Table IX-13 and Table IX-14 below show expected warranty purchasing practices for MY 2027 and 2031 heavy-duty vehicles under the Proposed Amendments. As Table IX-13 shows, CARB staff expects that for the 2027 MY, 40 percent of HHDD vehicles would still have warranties beyond the required minimum emissions warranty, while 60 percent would have the minimum warranty required by the Proposed Amendments. In the 2027 MY, all MHDD, LHDD, and HDO vehicles would rely on the regulatory warranty rather than buying an extended warranty. By the 2031 MY, all affected vehicles would rely on the proposed regulatory warranty. In other words, beginning in MY 2031, CARB staff assumes no heavy-duty vehicle purchasers buy emission warranties extending beyond those required by the Proposed Amendments.

Table IX-13. Estimated Warranty Purchasing Business Practices Due to the Proposed 2027 Phase-In Warranty Amendments (MY 2027)

Vehicle Category	Miles Warranted	Percent of Vehicle Population
HHDD	500,000	40%
	450,000	60%
MHDD	220,000	100%
LHDD	150,000	100%
HDO	110,000	100%

Table IX-14. Estimated Warranty Purchasing Business Practices Due to the Proposed 2031 Phase-In Warranty Amendments (MY 2031+)

Vehicle Category	Miles Warranted	Percent of Vehicle Population
HHDD	600,000	100%
MHDD	280,000	100%
LHDD	210,000	100%
HDO	160,000	100%

4.5. Average Mileage Driven Under the Proposed Warranty

CARB staff estimated the average miles traveled while under warranty for MY 2027 and 2031, with the proposed warranty amendments in place. The estimates were based on the warranty coverage practices, the mileage accumulated at the proposed years obtained from EMFAC, and equivalent mileage for the proposed hours periods derived from the CE-CERT vocational truck study. These average mileages traveled while under warranty are shown in Table IX-15 for each vehicle category, and take into account the miles, years, and hours to determine which occurs first.

Table IX-15. Estimated Average Miles Traveled Under the Proposed Step 2 Warranty Amendments

Vehicle Category	Average Miles Traveled Under Proposed Warranty Period for MY 2027- 2030	Average Miles Traveled Under Proposed Warranty Period for MY 2031 and Subsequent
HHDD	307,763	399,843
MHDD	171,667	220,816
LHDD	135,184	189,343
HDO	103,526	147,854

As shown in Table IX-15, the miles traveled under warranty are not the same as the warranty mileage period because some vehicles either are lost through attrition before they reach the new warranty mileage periods or they exhaust their warranty coverage via years or hours instead of miles.

4.6. Cost of Repairs Under the Proposed Warranty

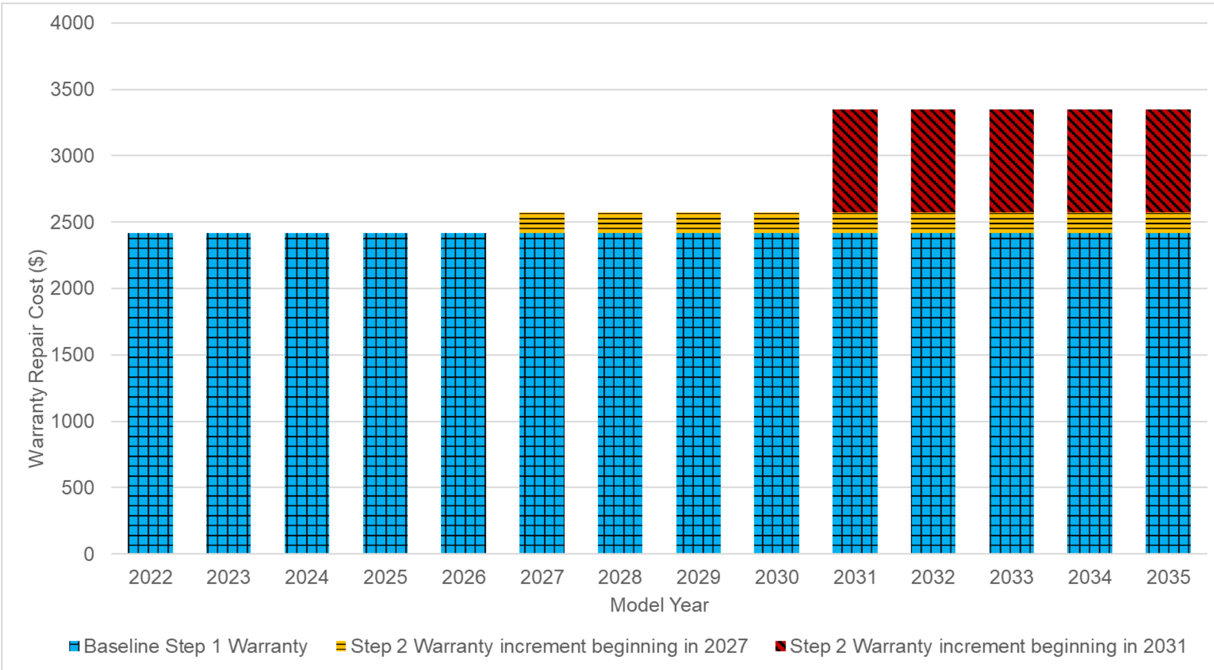
In order to calculate the incremental repair costs under the proposed lengthened warranty periods, the repair costs associated with the baseline are needed, along with the projected repair costs beginning in MY 2027, and the costs that begin in MY 2031. The total incremental repair costs associated with the lengthened warranty proposal was derived by adding the incremental repair cost beginning MY 2027 and the additional incremental repair cost beginning MY 2031. These total incremental repair costs represent the increase in warranty claim payments for repairs that are expected to be performed during the proposed lengthened warranty periods.

The projected repair costs for MYs 2027 and 2031 were determined by calculating a mileage ratio for each vehicle category for both parts of the phase-in. The mileage ratios assume a linear relationship between the vehicle odometer mileage and the warranty repair costs derived from the claims rate. An underlying aspect of this assumption is that components would continue to fail at the same rate for the duration of the lengthened warranty period. CARB staff understands that for mechanical systems there is often a non-linear "bathtub" curve (NIST, 2013) that generally characterizes the failure rates for such systems as being high initially due to manufacturing defects, then leveling off, and finally ramping up again as the system approaches the end of its life. However, the non-linear trend could only be quantified with data for different stages over the life cycle of each component, which CARB staff does not have. Therefore, the conservative approach that is used here assumes a linear relationship that gives a higher estimate of the costs and represents the most suitable approach for the projected estimates. The resulting values for the projected warranty costs are shown in Table IX-16 below. These costs are on a per vehicle basis for a heavy-duty vehicle. Figure IX-1 shows a visual representation of the incremental costs due to warranty, using a HHDD vehicle as an example. Figure IX-1 shows a two-step increase from the baseline, with the first step of $159 beginning in MY 2027 and the second step increase of $771 beginning in MY 2031. As Figure IX-1 shows, beginning in MY 2031, there would be a total of $930 incremental repair costs due to the warranty amendments for heavy-duty vehicles powered by HHDD engines.

Table IX-16. Estimated Per Vehicle Repair Costs and Incremental Repair Costs Associated with the Proposed Lengthened Step 2 Warranty Period Amendments (2018$)

Vehicle Category	Baseline Repair Costs	MY 2027 Phase-in Repair Costs	MY 2031 Phase-in Repair Costs	Incremental Repair Cost Beginning MY 2027	Additional Incremental Repair Cost Beginning MY 2031	Total Incremental Repair Costs
HHDD	$2,416	$2,576	$3,346	$159	$771	$930
MHDD	$2,775	$3,434	$4,417	$658	$983	$1,641
LHDD	$1,096	$1,441	$2,019	$345	$577	$922
HDO	$238	$494	$705	$255	$211	$467

Figure IX-1. Example Showing the Estimated Per Vehicle Baseline Repair Costs for a HHDD Vehicle and the Incremental Repair Costs Associated with the Proposed Lengthened Step 2 Warranty Period Amendments (2018$)



4.7. Cost to the Vehicle Purchaser Under the Proposed Warranty

The incremental repair costs for MY 2027-2030, and 2031 and subsequent MY heavy-duty vehicles due to the proposal represent the projected increases in costs that are expected to be passed on to the vehicle purchaser through an increase in the vehicle purchase price. Assuming vehicle purchases are made using a 5-year loan financed at a 6 percent interest rate, CARB staff calculated the total "capital" for each part of the phase-in as shown in Table IX-17. Therefore, the increase in "capital" costs to the vehicle purchaser is slightly higher than the incremental costs passed through by the manufacturer because of loan interest costs.

Table IX-17. Estimated Per Vehicle Capital Costs Associated with the Proposed Lengthened Step 2 Warranty Period Amendments (2018$)

Vehicle Category	Capital Cost Increase Per Vehicle Beginning MY 2027	Capital Cost Increase Per Vehicle Beginning MY 2031
HHDD	$189	$915
MHDD	$781	$1,167
LHDD	$409	$685
HDO	$303	$251

4.8. Total Statewide Costs

CARB staff used the capital costs in MYs 2027 and 2031 on a per vehicle basis and the EMFAC future vehicle sales projections to estimate the statewide annual increase in costs associated with the proposed Step 2 warranty amendments. The values are shown in Table IX-18 and represent the increased warranty cost for all new vehicle sales from calendar years 2027 to 2050.

Table IX-18. Total Annual Increase in Costs Per Year for Proposed Lengthened Step 2 Warranty Periods for Each Vehicle Class (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2027	$0	$0	$0	$1,069,205	$1,069,205
2028	$1,419,454	$8,297,974	$2,803,201	$1,090,640	$13,611,269
2029	$1,451,996	$8,503,710	$2,854,968	$1,093,817	$13,904,492
2030	$1,481,023	$8,598,437	$2,903,447	$1,086,085	$14,068,992
2031	$1,503,340	$8,712,100	$2,941,505	$2,006,817	$15,163,761
2032	$9,025,695	$22,331,185	$8,078,852	$2,012,986	$41,448,718
2033	$9,272,426	$22,671,578	$8,252,061	$2,032,316	$42,228,382
2034	$9,596,311	$23,415,016	$8,513,756	$2,051,948	$43,577,031
2035	$9,771,564	$23,842,490	$8,688,844	$2,071,074	$44,373,973
2036	$9,839,592	$23,950,094	$8,743,017	$2,105,329	$44,638,032
2037	$9,904,854	$24,173,681	$8,803,885	$2,123,200	$45,005,620
2038	$9,996,276	$24,235,668	$8,871,413	$2,141,459	$45,244,815
2039	$10,087,758	$24,412,150	$8,936,619	$2,158,682	$45,595,209
2040	$10,202,968	$24,498,206	$9,005,245	$2,175,598	$45,882,018
2041	$10,273,594	$24,599,397	$9,074,140	$2,192,323	$46,139,454
2042	$10,361,913	$24,786,359	$9,148,489	$2,208,680	$46,505,442
2043	$10,454,979	$24,920,219	$9,219,739	$2,224,630	$46,819,567
2044	$10,566,337	$25,120,490	$9,296,582	$2,240,124	$47,223,532
2045	$10,663,445	$25,315,750	$9,370,719	$2,255,277	$47,605,191
2046	$10,768,056	$25,493,839	$9,445,955	$2,269,992	$47,977,842
2047	$10,852,534	$25,679,558	$9,520,220	$2,284,441	$48,336,754
2048	$10,933,176	$25,902,786	$9,596,374	$2,298,594	$48,730,929
2049	$11,032,698	$26,050,036	$9,670,242	$2,312,371	$49,065,347
2050	$11,032,698	$26,050,036	$9,670,242	$2,312,371	$49,065,347
Total	**$200,492,689**	**$501,560,758**	**$183,409,516**	**$47,817,959**	**$933,280,923**

5. Lengthened Useful Life Costs

The lengthened useful life costs are intrinsically linked with the durability and costs of the technologies used to meet the proposed emission standards for certification of California heavy-duty engines and vehicles. Manufacturers would be required to certify that their engines and vehicles will comply with applicable emission standards throughout their useful lives. The described low NOx technology costs in Section A.1

above already included costs to meet the proposed lengthened useful life as part of the estimated hardware and research and development costs. Staff did not project any additional cost as a result of the lengthened useful life proposal.

6. Amended EWIR and Corrective Action Procedure Costs

To estimate the cost impact of the proposed EWIR and corrective action procedure amendments, a baseline scenario was first developed. The cost impact of the proposed EWIR and corrective action procedure amendments was then evaluated against the baseline scenario. The baseline scenario accounts for the current California required emission control system warranty, manufacturer provided warranties, and real-world purchasing behavior.

Manufacturers are currently required to provide an emissions warranty for heavy-duty diesel vehicles with a GVWR over 14,000 pounds, submit reports based on warranty claims, and take corrective action if the failure rate of an emission control component has exceeded the corrective action threshold. The Proposed Amendments would lengthen the warranty period, hence staff also proposed to adjust the thresholds for submitting reports and provide specificity when corrective action is required.

The estimated direct costs from the proposed EWIR and corrective action procedure amendments and the baseline scenario include upfront capital costs due to changes of corrective action thresholds, corrective action procedures, and reporting procedures. In general, costs for corrective action were obtained by determining the number of components subject to corrective action throughout the emissions warranty periods. This was done by using the most current and complete warranty data set for the 2013 MY and extrapolating those rates from the current warranty period of 5 years to the proposed lengthened warranty periods. The difference between extrapolated component failures at the end of the proposed extended warranty periods and applicable useful life periods and the current warranty periods was used to determine how many components would need corrective action.

6.1. Cost for Baseline Scenario

6.1.1. Repair Costs for Aftertreatment Components, Computers, and Non-Aftertreatment Components Subject to Recall

Manufacturers are currently required to recall emissions control components that exceed the applicable corrective action threshold. Repair costs were obtained through analysis of service station repair records and costs utilized in the June 2018 Step 1 warranty amendments (CARB, 2018f). CARB staff then segregated the costs into two categories: aftertreatment components and computers, and non-aftertreatment components that would be subject to recall, shown in Table IX-19. The average repair cost was determined by averaging the cost of repairs for components from all classes of vehicles and engines that were potentially subject to recall and for which EWIR data was available. Most manufacturers remedied the majority of in-use problems and component failures through software calibration reflashes.[57] Through analysis of historic data regarding recalls it was determined that over 83 percent of recalls resolve issues through software reflashes (CARB, 2019m). Based on this, to provide a conservative estimate, 70 percent of repairs were assumed to be software reflashes, at a cost of $400 per reflash, rather than part replacements.[58]

Table IX-19. Average Repair Costs for Components Subject to Recall (2018$)

	Aftertreatment Components and Computers	Non-Aftertreatment Components
Average Repair Cost	$1,292	$978

6.1.2. Recall Methodology

Table IX-20 provides a summary of the average recall rate of emissions control components per heavy-duty engine class, separated into aftertreatment component and computer claims, and non-aftertreatment component claims, for the 2013 MY. The 2013 MY was used because it is the most current data for which the five years of EWIR reporting has been completed. The average recall rate per engine class exceeded 100 percent for the MHDD engine class because some engines experienced multiple issues that were remedied through multiple recalls. The HDO class did not have claims for other components that exceeded the corrective action threshold.

[57] Software reflashes may resolve hardware issues by modifying engine performance in order to prevent damage to other components.

[58] The average part replacement cost for aftertreatment components and computers is $3,374. The average part replacement cost for non-aftertreatment components is $2,327. These part replacement costs account for 30% of recall repair costs while the other 70% of repairs are assumed to be the cost of a reflash, which is $400 because it has been observed that 70% of recall repairs are reflashes. The weighted average of these costs provides the average repair costs for repairs made under recall that can be seen in Table IX-20.

Table IX-20. Components Subject to Recall for the 2013 MY

Class	2013 Calendar Year Sales	Total Claims for Aftertreatment and Critical Components, and Computers	Total Claims for Other Components	Average Recall Rate Per Engine for Aftertreatment and Critical Components, and Computers	Average Recall Rate Per Engine for Other Components
HHDD	11,022	5,662	13,731	51.4%	124.6%
MHDD	4,967	5,270	4,405	106.1%	88.7%
LHDD	5,025	146	5,253	2.9%	104.5%
HDO	8,522	3405	0	40.0%	0.0%

6.1.3. Repair Costs for Components Subject to Existing Warranty Provisions

As stated above in Subsection 6, the cost impact of the proposed EWIR amendments was evaluated against a baseline scenario that accounts for the current California required emission control system warranty, manufacturer provided warranties, and real-world purchasing behavior.

Manufacturers often provide extended warranties for emissions control components that exceed applicable corrective action thresholds in lieu of recalling those components. Repair costs were obtained through analysis of service station repair records and costs utilized in the June 2018 Step 1 warranty amendments (CARB, 2018f). The average repair costs, shown in Table IX-21, were determined by averaging the cost of repairs of components from all heavy-duty vehicle classes. The average cost associated with repairing emissions control components is $1,587.

Table IX-21. Average Repair Costs for Components Subject to Existing Extended Warranty Provisions (2018$)

Components Subject to Existing Extended Warranties	Average Repair Cost
Average Existing Extended Warranty Repair Cost for All Components	$1,587

6.1.4. Existing Extended Warranty Methodology

Table IX-22 provides a summary for the 2013 MY population of vehicles/engines for each class, the number of unscreened warranty claims per class, and the average claim rate of emissions control components per engine class under existing warranty requirements. The 2013 MY data were used for a baseline because this EWIR reporting is the most current and complete for which the five years of reporting has been completed. The average component failure rate per engine is derived by linearly extrapolating the number of failed components that reach the corrective action threshold at the end of the warranty period, to the end of the applicable useful life period. The difference between the extrapolated failure rates at the end of the applicable useful life and at the end of the existing warranty periods is used to determine the number of failed components during the warranty period, which is divided by the sales volume to determine the average component failure rate per engine. All failures that occur within the existing warranty periods would be covered under those warranty periods and are therefore not included as part of the extended warranty cost.

Table IX-22. Components Subject to Existing Extended Warranty Provisions for the 2013 MY

Class	2013 MY Sales	Total Claims for Components	Average Claims Rate Per Engine Subject to Existing Extended Warranty Provisions
HHDD	11,022	4,115	37.3%
MHDD	4,967	301	6.1%
LHDD	5,025	1,109	22.1%
HDO	8,522	273	3.2%

6.1.5. Summary of Baseline

The total costs of the baseline scenario for the 2024 through 2050 calendar years are shown in Table IX-23. The costs were calculated using the estimated emission-related component failure rates, estimated repair costs, and projected new vehicles sales as modeled in EMFAC2017.

Table IX-23.Summary of Baseline Total Recall and Extended Warranty Costs (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2024	$0	$0	$0	$1,859,122	$1,859,122
2025	$16,527,602	$22,413,024	$8,648,945	$1,864,979	$49,454,551
2026	$16,892,615	$22,448,853	$8,825,701	$1,888,229	$50,055,398
2027	$17,256,401	$23,122,035	$8,994,054	$1,874,096	$51,246,586
2028	$17,573,496	$23,130,944	$9,150,647	$1,911,666	$51,766,753
2029	$17,976,378	$23,704,440	$9,319,636	$1,917,235	$52,917,690
2030	$18,335,740	$23,968,495	$9,477,888	$1,903,683	$53,685,806
2031	$18,612,034	$24,285,335	$9,602,122	$1,924,094	$54,423,586
2032	$19,157,633	$24,965,655	$9,861,002	$1,930,009	$55,914,300
2033	$19,681,335	$25,346,206	$10,072,421	$1,948,543	$57,048,505
2034	$20,368,802	$26,177,349	$10,391,845	$1,967,365	$58,905,360
2035	$20,740,789	$26,655,254	$10,605,556	$1,985,702	$59,987,301
2036	$20,885,182	$26,775,552	$10,671,679	$2,018,546	$60,350,958
2037	$21,023,706	$27,025,516	$10,745,973	$2,035,680	$60,830,875
2038	$21,217,753	$27,094,816	$10,828,398	$2,053,186	$61,194,153
2039	$21,411,930	$27,292,118	$10,907,989	$2,069,700	$61,681,736
2040	$21,656,472	$27,388,327	$10,991,753	$2,085,918	$62,122,470
2041	$21,806,380	$27,501,455	$11,075,846	$2,101,953	$62,485,635
2042	$21,993,843	$27,710,474	$11,166,595	$2,117,637	$62,988,549
2043	$22,191,382	$27,860,125	$11,253,563	$2,132,929	$63,437,999
2044	$22,427,745	$28,084,023	$11,347,357	$2,147,784	$64,006,909
2045	$22,633,865	$28,302,318	$11,437,849	$2,162,313	$64,536,344
2046	$22,855,907	$28,501,417	$11,529,681	$2,176,421	$65,063,426
2047	$23,035,219	$28,709,046	$11,620,329	$2,190,274	$65,554,868
2048	$23,206,385	$28,958,609	$11,713,281	$2,203,844	$66,082,119
2049	$23,417,629	$29,123,230	$11,803,445	$2,217,053	$66,561,357
2050	$23,417,629	$29,123,230	$11,803,445	$2,217,053	$66,561,357
Total	**$536,303,852**	**$685,667,846**	**$273,847,002**	**$54,905,013**	**$1,550,723,714**

6.2. Cost for EWIR Amendments

6.2.1. Costs Associated with Corrective Action Amendments

Corrective Action Threshold and Procedures

There would be three incremental increases in costs due to the proposed three corrective action thresholds for the 2024, 2027, and 2031 MYs. The first proposed amendment, effective in 2024 would modify the corrective action threshold from 4 percent or 50 failures, whichever is greater, to 4 percent or 25 failures, whichever is greater. This would result in a cost increase due to the increased amount of corrective actions that small volume engine families would be subject to. For the second proposed amendment, effective in 2027, the corrective action threshold would remain at 4 percent or 25 failures, whichever is greater, for the first five years of the reporting period, and increase to 5 percent or 35 failures, whichever is greater, for years 6-7. For the third proposed amendment, effective 2031, the corrective action threshold would remain at 4 percent or 25 failures, whichever is greater, for the first five years of the reporting period, remain at 5 percent or 35 failures, whichever is greater, for years 6-7, and increase to 7 percent of 50 failures, whichever is greater, for years 8-10. This is to account for the proposed extension of the emissions warranty and useful life periods effected by other elements of this rulemaking action.

Manufacturers would also be required to perform a recall for any components that reach a failure rate of 25 percent over a five-year period. If a component reaches a 25 percent failure rate within five years, it is clear that the problem is systemic in nature and the component would very likely fail in the majority of vehicles. Hence, the proposed amendments would ensure a manufacturer conducts a recall to address the issue expeditiously.

Also, if a component exhibits early failure rates indicating that component would exceed the corrective action threshold within the useful life period, it would be subject to recall. Therefore, the amendments now specify that if a component experiences a 25 percent failure rate within five years, it is subject to recall. This proposed amendment is based on staff’s projections that a component reaching this failure rate within five years is very likely to exceed existing corrective action thresholds within the useful life period.

CARB staff estimates the repair cost for such components to be $756, which is lower than the $1,587 repair cost assumed for components that are subject to existing extended warranties today. For components that would today typically be subject to extended warranty, but that, under the Proposed Amendments would have to be recalled because they have a failure rate greater than or equal to 25 percent within 5 years, it was assumed that 70 percent of repairs would be resolved through software reflashes as this is how manufacturers typically handle hardware warranty issues for recalls, at a cost of $400 per reflash.[59]

The costs associated with amending corrective action thresholds and procedures are shown in Table IX-24. Costs were calculated using the same methodology as was used to calculate the cost of the baseline scenario, except that the proposed amendment criteria were used. Component failure rates for future MYs were obtained by linearly extrapolating data from the 2013 MY. The cost of the corrective action and useful life lengthening are conservatively estimated as certain repairs were accounted for in both programs. This was due to both programs requiring manufacturers to address the similar in-use durability issues.

[59] The average repair cost for repairs made under extended warranties is $1,587, which does not average in the cost of a reflash because repairs made under extended warranties are typically part replacements. The average repair cost for components that need to be recalled because they have a failure rate greater than or equal to 25% within 5 years is $756, which was determined by assuming that 30% of the cost for the recall repair would be that of a part replacement that is $1,587, while the other 70% of repairs would be the cost of a reflash that is $400. This is because it has been observed that 70% of recall repairs are reflashes.

Table IX-24. Corrective Action Threshold and Procedures Cost Summary (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2024	$0	$0	$0	$2,176,752	$2,176,752
2025	$19,665,127	$28,218,968	$7,831,736	$2,183,610	$57,899,442
2026	$20,099,432	$28,264,079	$7,991,791	$2,210,833	$58,566,135
2027	$20,532,277	$29,111,643	$8,144,237	$2,231,322	$60,019,480
2028	$25,569,028	$33,230,004	$10,387,702	$2,276,053	$71,462,787
2029	$26,155,213	$34,053,890	$10,579,536	$2,282,684	$73,071,323
2030	$26,678,076	$34,433,233	$10,759,182	$2,266,548	$74,137,039
2031	$27,080,078	$34,888,407	$10,900,211	$2,087,075	$74,955,771
2032	$20,696,888	$26,920,641	$12,118,522	$2,093,491	$61,829,543
2033	$21,262,668	$27,330,992	$12,378,342	$2,113,594	$63,085,596
2034	$22,005,370	$28,227,219	$12,770,893	$2,134,011	$65,137,493
2035	$22,407,246	$28,742,547	$13,033,530	$2,153,902	$66,337,224
2036	$22,563,240	$28,872,265	$13,114,791	$2,189,527	$66,739,823
2037	$22,712,894	$29,141,803	$13,206,094	$2,208,113	$67,268,904
2038	$22,922,533	$29,216,529	$13,307,388	$2,227,102	$67,673,552
2039	$23,132,311	$29,429,282	$13,405,200	$2,245,014	$68,211,806
2040	$23,396,501	$29,533,024	$13,508,141	$2,262,607	$68,700,273
2041	$23,558,454	$29,655,012	$13,611,485	$2,280,000	$69,104,951
2042	$23,760,979	$29,880,398	$13,723,010	$2,297,012	$69,661,399
2043	$23,974,390	$30,041,768	$13,829,888	$2,313,599	$70,159,645
2044	$24,229,744	$30,283,198	$13,945,154	$2,329,713	$70,787,809
2045	$24,452,425	$30,518,588	$14,056,363	$2,345,472	$71,372,847
2046	$24,692,307	$30,733,277	$14,169,219	$2,360,776	$71,955,578
2047	$24,886,026	$30,957,165	$14,280,619	$2,375,802	$72,499,613
2048	$25,070,945	$31,226,270	$14,394,851	$2,390,521	$73,082,588
2049	$25,299,162	$31,403,783	$14,505,656	$2,404,849	$73,613,449
2050	$25,299,162	$31,403,783	$14,505,656	$2,404,849	$73,613,449
Total	**$612,102,476**	**$785,717,769**	**$324,459,197**	**$60,844,830**	**$1,783,124,271**

Parts Storage

Staff is proposing that manufacturers be required to store parts that are used for failure mode and failure rate analyses for the FIR for a period of two years after submitting the FIR. Manufacturers would face costs based on the number of parts that are stored, how long they are stored, and the amount of space (per square foot) that the parts take up. For the purposes of the parts storage subsection, component refers to the entire set of individual parts that make up a component. For example, if 100 percent of turbochargers failed for an engine family with a sales volume of 50 engines, there would be one component failure and 50 parts failures. Table IX-25 summarizes the information used to determine the costs for storing parts.

Table IX-25. Storage Cost Summary

Component Storage Information	
Retention Length in Years	2
Cost per Square Foot per Year	$18.00
No. of Parts per Report to be Retained	70
Average Square Feet per Part	2

Staff estimated number of stored components based on 2013 warranty claim and failure rate and projected 2024-2050 sales volumes. Table IX-26 summarizes staff's estimated number of stored components[60] and their associated storage costs. In order to provide a conservative estimate, it was assumed that each component would require storage for 70 parts, or 140 square feet of storage space on average.

[60] Components include categories of hardware such as turbochargers, DPFs, fuel injectors, etc.

Table IX-26. Number of Components Needed to be Stored by Year (2018$)

Calendar Year	Number of Components that Need to be Stored	Storage Cost
2024	2	$10,080
2025	174	$876,960
2026	178	$897,120
2027	182	$917,280
2028	197	$992,880
2029	201	$1,013,040
2030	205	$1,033,200
2031	207	$1,043,280
2032	214	$1,078,560
2033	218	$1,098,720
2034	225	$1,134,000
2035	228	$1,149,120
2036	230	$1,159,200
2037	232	$1,169,280
2038	234	$1,179,360
2039	235	$1,184,400
2040	236	$1,189,440
2041	238	$1,199,520
2042	240	$1,209,600
2043	242	$1,219,680
2044	244	$1,229,760
2045	246	$1,239,840
2046	248	$1,249,920
2047	250	$1,260,000
2048	252	$1,270,080
2049	253	$1,275,120
2050	253	$1,275,120
Total	**5,864**	**$29,554,560**

Administrative Costs for Additional Warranty Reporting and Corrective Action

CARB staff assumes that manufacturers are already tracking, gathering, and analyzing data and information needed to submit the additional warranty reports, corrective action documents, and quarterly progress reports. There are already systems in place to perform the task of gathering the data and information necessary to generate the reports. Therefore, the cost of submitting this information to CARB would be the cost of generating the anticipated increased number of reports to summarize the information collected by manufacturers and developing corrective action documents. CARB staff assumes that a junior engineer position would be sufficient to perform the duties of generating additional warranty reports and corrective action documents (hourly rate for a junior engineer is $70 (U.S. BLS, 2019)).

Due to the longer proposed warranty periods, manufacturers would be required to report for longer than the current 5-year reporting period. Starting with the 2027-2030 MYs it is proposed that manufacturers would be required to report warranty and failure rate information throughout the 7-year warranty period. For 2031 and subsequent MYs it is proposed that manufacturers would be required to report warranty and failure rate information throughout the 10-year warranty period. Warranty reporting is not required for the first year, therefore, for MYs 2027-2030 manufacturers would only be required to submit reports for six years, and for 2031 and subsequent MYs manufacturers would only be required to submit reports for nine years.

The total cost for the amended reporting thresholds and procedures are shown in Table IX-27.

Table IX-27. Cost of Generating Additional Warranty Reports and Corrective Action Documents (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2024	$0	$0	$0	$610	$610
2025	$72,419	$131,045	$36,357	$612	$240,432
2026	$74,018	$131,254	$37,100	$619	$242,992
2027	$75,612	$135,190	$37,808	$1,386	$249,996
2028	$96,950	$175,175	$54,551	$1,414	$328,089
2029	$99,172	$179,518	$55,558	$1,418	$335,666
2030	$101,155	$181,517	$56,502	$1,408	$340,582
2031	$102,679	$183,917	$57,242	$1,851	$345,690
2032	$129,897	$241,118	$78,771	$1,857	$451,643
2033	$133,448	$244,793	$80,460	$1,875	$460,576
2034	$138,109	$252,821	$83,012	$1,893	$475,835
2035	$140,631	$257,436	$84,719	$1,911	$484,697
2036	$141,610	$258,598	$85,247	$1,942	$487,398
2037	$142,550	$261,012	$85,841	$1,959	$491,361
2038	$143,865	$261,682	$86,499	$1,976	$494,021
2039	$145,182	$263,587	$87,135	$1,991	$497,895
2040	$146,840	$264,516	$87,804	$2,007	$501,167
2041	$147,857	$265,609	$88,476	$2,022	$503,964
2042	$149,128	$267,628	$89,201	$2,038	$507,993
2043	$150,467	$269,073	$89,895	$2,052	$511,487
2044	$152,070	$271,235	$90,645	$2,067	$516,016
2045	$153,467	$273,344	$91,367	$2,081	$520,259
2046	$154,973	$275,266	$92,101	$2,094	$524,434
2047	$156,189	$277,272	$92,825	$2,107	$528,393
2048	$157,349	$279,682	$93,568	$2,120	$532,719
2049	$158,781	$281,272	$94,288	$2,133	$536,474
2050	$158,781	$281,272	$94,288	$2,133	$536,474
Total	**$3,423,200**	**$6,164,832**	**$2,011,259**	**$47,574**	**$11,646,865**

6.2.2. Costs of Proposed EWIR and Corrective Action Procedure Amendments

The total costs of the proposed EWIR and corrective action procedure amendments are shown in Table IX-28. The cost was obtained by calculating the sum of the cost of the amended corrective action requirements from Table IX-24, storage costs from Table IX-26, and warranty reporting costs from Table IX-27.

Table IX-28. Summary of Costs of Proposed EWIR and Corrective Action Procedure Amendments (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2024	$0	$0	$0	$2,187,442	$2,187,442
2025	$20,080,266	$28,768,333	$7,973,933	$2,194,302	$59,016,835
2026	$20,526,250	$28,818,693	$8,139,771	$2,221,532	$59,706,246
2027	$20,965,730	$29,680,274	$8,292,925	$2,247,828	$61,186,756
2028	$26,054,058	$33,868,859	$10,568,253	$2,292,586	$72,783,756
2029	$26,647,505	$34,712,208	$10,761,094	$2,299,221	$74,420,029
2030	$27,182,431	$35,098,591	$10,946,723	$2,283,075	$75,510,820
2031	$27,590,997	$35,561,204	$11,088,493	$2,104,046	$76,344,741
2032	$21,250,145	$27,665,759	$12,333,373	$2,110,468	$63,359,746
2033	$21,829,556	$28,084,825	$12,599,922	$2,130,589	$64,644,892
2034	$22,592,040	$29,009,240	$12,995,024	$2,151,024	$66,747,328
2035	$23,001,477	$29,534,223	$13,264,409	$2,170,932	$67,971,041
2036	$23,163,491	$29,670,143	$13,346,198	$2,206,589	$68,386,420
2037	$23,319,124	$29,947,135	$13,438,094	$2,225,192	$68,929,545
2038	$23,535,118	$30,022,531	$13,545,088	$2,244,197	$69,346,934
2039	$23,746,213	$30,242,229	$13,643,535	$2,262,126	$69,894,102
2040	$24,017,101	$30,346,901	$13,747,145	$2,279,734	$70,390,880
2041	$24,185,111	$30,475,020	$13,851,160	$2,297,143	$70,808,434
2042	$24,393,947	$30,707,465	$13,963,411	$2,314,169	$71,378,992
2043	$24,613,737	$30,870,281	$14,076,023	$2,330,771	$71,890,812
2044	$24,875,733	$31,118,914	$14,192,039	$2,346,900	$72,533,585
2045	$25,104,852	$31,361,451	$14,303,970	$2,362,672	$73,132,945
2046	$25,351,280	$31,583,104	$14,417,560	$2,377,990	$73,729,933
2047	$25,546,215	$31,814,037	$14,534,724	$2,393,030	$74,288,006
2048	$25,737,334	$32,090,592	$14,649,699	$2,407,762	$74,885,387
2049	$25,972,023	$32,269,695	$14,761,224	$2,422,102	$75,425,044
2050	$25,972,023	$32,269,695	$14,761,224	$2,422,102	$75,425,044
Total	**$627,253,755**	**$805,591,401**	**$330,195,016**	**$61,285,524**	**$1,824,325,697**

6.2.3. Incremental Costs Due to Proposed EWIR and Corrective Action Procedure Amendments

The upfront incremental increase in cost between the proposed EWIR amendments scenario and baseline scenario is presented below in Table IX-29. The incremental cost is determined by subtracting the costs of the baseline scenario in Table IX-23 from the costs of the proposed scenario in Table IX-28. Manufacturers could avoid some or all of the costs shown in Table IX-28 and incremental costs shown in Table IX-29 if they made sufficiently durable components and did not trigger the need for warranty reporting and corrective action.

Table IX-29. Incremental Cost of the Proposed EWIR and Corrective Action Procedure Amendments (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	Total
2024	$0	$0	$0	$328,320	$328,320
2025	$3,552,664	$6,355,309	$0	$329,323	$10,237,296
2026	$3,633,635	$6,369,840	$0	$333,303	$10,336,778
2027	$3,709,329	$6,558,239	$0	$373,731	$10,641,299
2028	$8,480,562	$10,737,915	$1,417,606	$380,920	$21,017,003
2029	$8,671,127	$11,007,769	$1,441,458	$381,986	$21,502,340
2030	$8,846,691	$11,130,096	$1,468,835	$379,393	$21,825,015
2031	$8,978,962	$11,275,869	$1,486,371	$179,952	$21,921,155
2032	$2,092,512	$2,700,104	$2,472,371	$180,459	$7,445,446
2033	$2,148,221	$2,738,619	$2,527,501	$182,047	$7,596,388
2034	$2,223,238	$2,831,890	$2,603,180	$183,659	$7,841,967
2035	$2,260,688	$2,878,969	$2,658,853	$185,230	$7,983,740
2036	$2,278,309	$2,894,591	$2,674,519	$188,044	$8,035,462
2037	$2,295,418	$2,921,619	$2,692,121	$189,512	$8,098,670
2038	$2,317,365	$2,927,715	$2,716,689	$191,011	$8,152,780
2039	$2,334,283	$2,950,111	$2,735,546	$192,426	$8,212,366
2040	$2,360,629	$2,958,574	$2,755,392	$193,815	$8,268,410
2041	$2,378,730	$2,973,565	$2,775,315	$195,189	$8,322,800
2042	$2,400,104	$2,996,991	$2,796,816	$196,533	$8,390,443
2043	$2,422,355	$3,010,156	$2,822,460	$197,843	$8,452,813
2044	$2,447,988	$3,034,891	$2,844,682	$199,115	$8,526,676
2045	$2,470,987	$3,059,133	$2,866,121	$200,360	$8,596,601
2046	$2,495,373	$3,081,687	$2,887,879	$201,569	$8,666,507
2047	$2,510,996	$3,104,991	$2,914,395	$202,755	$8,733,137
2048	$2,530,949	$3,131,984	$2,936,418	$203,918	$8,803,268
2049	$2,554,394	$3,146,465	$2,957,779	$205,049	$8,863,687
2050	$2,554,394	$3,146,465	$2,957,779	$205,049	$8,863,687
Total	**$90,949,903**	**$119,923,555**	**$58,410,085**	**$6,380,511**	**$275,664,054**

7. Amended Averaging, Banking, and Trading Program Costs

The proposed ABT amendments would establish a new CA-ABT program. Under this program, on-road heavy-duty engine manufacturers would be required to implement a two-track system for ABT, a federal-ABT program and a CA-ABT program.

Based on CARB's 2018 MY certification data, fourteen heavy-duty engine manufacturers certified their engines with CARB and seventeen Class 4-8 ZEV manufacturers certified their vehicles with CARB. CARB staff assumed all fourteen heavy-duty engine manufacturers would participate in the CA-ABT program, and does not expect the number of certified manufacturers to increase over the 2022-2050 period. The increased CA-ABT costs would be the increased labor costs associated with the additional recordkeeping. Table IX-30 summarizes CARB staff's estimated total additional labor costs for all affected manufacturers to track the CA-ABT program from 2022 to 2050 calendar years. Since participation in the CA-ABT would be voluntary, CARB staff believes that some manufacturers may not choose to participate in the program. Therefore, the estimated incremental costs represent a conservative estimate of the costs associated with the proposed ABT amendments.

Table IX-30. Estimated Incremental Costs Relative to the 2018 MY Baseline for the Proposed ABT Amendments (2018$ for all Manufacturers)

Calendar Year	Incremental Costs for CA-ABT Program
2022	$217,000
2023	$43,400
2024	$43,400
2025	$43,400
2026	$43,400
2027	$43,400
2028	$43,400
2029	$43,400
2030	$43,400
2031	$43,400
2032	$43,400
2033	$43,400
2034	$43,400
2035	$43,400
2036	$43,400
2037	$43,400
2038	$43,400
2039	$43,400
2040	$43,400
2041	$43,400
2042	$43,400
2043	$43,400
2044	$43,400
2045	$43,400
2046	$43,400
2047	$43,400
2048	$43,400
2049	$43,400
2050	$43,400
Total 2022-2050 Calendar Years	**$1,432,200**

8. Amended Durability Demonstration and In-Use Emissions Data Reporting Costs

The proposed lengthened useful life would have direct impacts on the required hours of service accumulation for the durability demonstration program. Additionally, heavy-duty engine manufacturers would need to conduct three separate durability programs to cover 2024-2026, 2027-2030, and 2031 and subsequent MY products. CARB staff also proposed to use the information generated from the in-use emissions data reporting program to validate how accurately the durability demonstration program represents the deterioration of engines and emissions control systems in real-world conditions. Overall, the proposed durability demonstration program would require manufacturers to incur costs for performing the additional laboratory service accumulation for durability testing and costs for reporting in-use emissions to CARB.

The durability testing costs include:

- Program planning costs – CARB staff estimated an additional 40 hours of program planning labor for a junior engineer (at $70 per hour) for each manufacturer using the DAAC process.

- Emissions testing costs – The addition of the LLC cycle would increase the emissions testing costs. Due to increased DDP length, additional emission test points would also be required for all service classes. Based on survey of previous CARB contracts with emissions testing facilities (CARB, 2016b), staff used an estimate of $23,000 for an LLC emissions test, and an estimate of $68,000 for a set of emissions tests including FTP, RMC and LLC.

- Aging costs – CARB staff anticipated an increase in labor and material costs for aging the engine to the extra number of hours needed under the Proposed Amendments (approximately 900-3,800 increased hours at $160 per hour service accumulation rate).

- Break-in hours – The proposed longer break-in hours would also increase service accumulation costs (175 increased hours at $160 per hour service accumulation rate).

- Mule engine – To accelerate the chemical aging process, a mule engine[61] would be needed. CARB staff estimated an average fixed cost of $15,000 for a mule engine.

- Ash cleaning – The Proposed Amendments would require manufacturers to age the engine to full useful life. Some manufacturers will likely need to add an ash cleaning interval in their DDP. Based on the survey of data from repair facilities, CARB staff used an average fixed cost of $500 for each ash cleaning.

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[61] A mule engine is typically either an older engine or an engine with modified piston rings.

The in-use emission reporting costs include:

- Labor costs – CARB staff estimated one-time 1,000 hours for programming and database development and an on-going 100 hours for annual reporting of a junior engineer ($70 per hour) would be needed for each of the eight on-road heavy-duty diesel engine manufacturers.

- Data transfer costs via telematics – CARB staff estimated an average cost of $30 per vehicle for each time the data are submitted to CARB via telematics (GPS Insight, 2019).

- Database licensing and storage costs – In order to prepare the in-use emissions data reports, the data set submitted via telematics must be stored in a centralized database for each heavy-duty diesel manufacturer. CARB staff used a one-time upfront cost of $100,000 for procurement of the database license (Oracle, 2019) per manufacturer which includes software update and support. In addition, staff used an average cost of $0.026 per gigabyte per month (Google, 2019) to estimate the data storage costs.

Table IX-31 summarizes the estimated total incremental cost for the proposed durability amendments, which is the sum of the discussed durability testing cost and the in-use emission reporting cost.

Table IX-31. Estimated Incremental Costs Relative to the 2018 MY Baseline for the Proposed DDP Amendments (2018$ for all Manufacturers)

Calendar Year	Incremental costs for Laboratory Service Accumulation/Aging	Incremental Costs for In-use Emissions Data Reporting	Total Incremental Costs for Durability Demonstration Program
2022	$0	$0	$0
2023	$8,612,420	$0	$8,612,420
2024	$0	$850,000	$850,000
2025	$0	$140,810	$140,810
2026	$11,262,220	$248,956	$11,511,176
2027	$0	$869,431	$869,431
2028	$0	$754,981	$754,981
2029	$0	$1,137,957	$1,137,957
2030	$12,124,120	$1,421,019	$13,545,139
2031	$0	$1,707,090	$1,707,090
2032	$0	$2,001,917	$2,001,917
2033	$0	$2,041,017	$2,041,017
2034	$0	$2,085,403	$2,085,403
2035	$0	$2,131,965	$2,131,965
2036	$0	$2,175,676	$2,175,676
2037	$0	$2,211,745	$2,211,745
2038	$0	$2,242,112	$2,242,112
2039	$0	$2,262,263	$2,262,263
2040	$0	$2,277,510	$2,277,510
2041	$0	$2,292,944	$2,292,944
2042	$0	$2,308,595	$2,308,595
2043	$0	$2,324,872	$2,324,872
2044	$0	$2,341,762	$2,341,762
2045	$0	$2,359,323	$2,359,323
2046	$0	$2,378,024	$2,378,024
2047	$0	$2,396,662	$2,396,662
2048	$0	$2,415,887	$2,415,887
2049	$0	$2,434,502	$2,434,502
2050	$0	$2,449,278	$2,449,278
Total 2022-2050 Calendar Years	**$31,998,760**	**$50,261,702**	**$82,260,462**

Note: For medium-duty engines, there are no additional costs due to the DDP amendments because currently manufacturers of all medium-duty engines do not conduct a separate DDP for these engines. All California-certified medium-duty engines are sister families of either LHDD or MHDD engines. Therefore, manufacturers use the deterioration factors from the LHDD and MHDD engines and carry across the deterioration factors to the corresponding sister family medium-duty engines.

9. Powertrain Certification Test Procedure for Heavy-Duty Hybrid Vehicles

The Proposed Amendments would amend the existing powertrain testing procedure for certifying heavy-duty vehicles to GHG emission standards to allow it to also be used as an optional procedure to certify hybrid powertrains to criteria pollutants emission standards. The Proposed Amendments would give manufacturers of heavy-duty hybrid vehicles an added, voluntary option to certify their vehicles.

Currently, U.S. EPA offers a similar option to test for GHG emissions standards among the federal certification choices. For a more comprehensive emissions testing option, CARB is adding this certification option, which utilizes essentially the same test, equipment software, and facilities as the federal option, however the CARB option includes criteria pollution emission standards testing. Manufacturers may need to add instrumentation specific for criteria pollution testing, although our estimates show that the costs of extra instrumentation are negligible in nature. This Powertrain Certification option would be more convenient and more effective for manufacturers, as it would be more comprehensively harmonized with its federal counterpart optional procedures.

Overall, CARB staff anticipates that the powertrain test procedure amendments would not increase costs or savings for manufacturers or the cost of hybrid vehicles certified for sale in California. This is because CARB staff assumes a manufacturer would only choose to use the Powertrain Certification procedures if this option supports the logistics and flow of the production chain, does not impose more than negligible costs, and only if the manufacturer determines the benefits of using the proposed amendments outweigh the economic costs. CARB staff also assumes any savings due to use of the powertrain test procedures would be negligible.

10. Heavy-Duty Vehicle GHG Tractor APU Certification Amendments

CARB staff expects that the proposed APU certification amendments would not result in a cost increase to APUs that would be used in 2024 and subsequent MY tractors. Existing California APU certification requirements, reporting, and processes remain unchanged. The addition of 40 CFR §1039.699 in the California APU certification test procedures would allow harmonization with the federal certification requirements. Thus, no additional cost to APUs is projected.

11. California Phase 2 GHG Regulation Clean-up Items

As discussed previously in Chapter III, Section A.11, all of the proposed Phase 2 amendments are either minor clean-up items to ensure the functionality of the regulation or alignment with already proposed or adopted national standards. The California-specific Proposed Amendments would not affect the stringency of the emission standards or the testing standards of the already adopted California Phase 2 program. Because of this, CARB staff considers all of these Phase 2 amendments as no-cost changes.

12. Medium-Duty Engine Clarifications and Amendments

There would be no costs associated with the clarifications and amendments to medium-duty engines. The alteration to change the useful life to align with LEV III would not change the technology and durability of current medium-duty vehicles. There would not be additional costs associated with the prohibition of the use of medium-duty engines in vehicles greater than 14,000 pounds GVWR since this prohibition is currently reflected in existing regulations. Finally, limiting the existing provision (that allows heavy-duty vehicles and engines to be included in medium-duty vehicle test groups) to 2023 and earlier MYs would not result in additional costs because 2024 and subsequent MY heavy-duty engines and vehicles would simply be required to certify to the emission standards and other emission-related requirements discussed in this Staff Report, and the estimated compliance costs for those requirements are discussed at length in this section of the Staff Report.

13. On-Board Diagnostic Requirements

Regarding the proposed changes to the OBD malfunction criteria to effectively extend the use of higher (easier to meet) NOx and PM emission thresholds, there would be no costs associated with the changes. Engine manufacturers are already calibrating and certifying HD OBD systems to these emissions levels, and certification to the proposed lower NOx emission standards would only provide further separation between properly operating and malfunctioning emission control components making calibration efforts easier, not harder.

14. Total Statewide Costs

The Proposed Amendments would require engine manufacturers to produce lower-emitting heavy-duty combustion engines, which would increase upfront production and operational costs, compared to existing engines, and would result in direct and indirect incremental costs. The direct and indirect incremental costs would likely be passed on to the engine/vehicle operators. Elements contributing to increased costs include establishing more stringent emission standards over existing regulatory cycles, amendments to in-use test procedures, modifications to the durability demonstration procedure for certification, lengthened warranty periods, lengthened useful life periods, amendments to EWIR reporting and corrective action procedures, and requiring NOx data collection and reporting. Proposed associated amendments to the regulations that are not expected to have an incremental cost include the hybrid powertrain test procedures, heavy-duty vehicle GHG tractor APU certification amendments, Phase 2 GHG clean-up amendments, and medium-duty engine clarifications and amendments.

The Proposed Amendments would result in direct costs to the regulated industry through direct and indirect costs associated with the Proposed Amendments. Table IX-32 presents the total statewide incremental costs of the Proposed Amendments in California. All costs were evaluated relative to the baseline scenario in 2018 dollars. The second through seventh column in Table IX-32 represent costs the Proposed Amendments would impose on manufacturers, which they in turn would pass on to vehicle buyers. The eighth column sums these costs to show total cost imposed on manufacturers. The ninth column shows costs for additional annual DEF consumption due to the Proposed Amendments that vehicle owners would incur, and the rightmost column shows the total cost of the amendments passed on by the manufacturer.

Table IX-32. Proposed Amendments Estimated Incremental Increase in Costs for the Statewide Fleet

Calendar Year	Standards, Certification, and New Technology	In-Use Amendments	Lengthened Warranty	Durability Demonstration	EWIR Amendments	ABT	Total Costs on Manufacturers	Annual DEF Consumption	Total Costs Passed to Vehicle Buyers
2022	$0	$0	$0	$0	$0	$217,000	**$217,000**	$0	**$217,000**
2023	$0	$0	$0	$8,612,420	$0	$43,400	**$8,655,820**	$0	**$8,655,820**
2024	$1,825,884	$132,657	$0	$850,000	$328,320	$43,400	**$3,180,260**	$4,635	**$3,184,895**
2025	$45,200,392	$59,481	$0	$140,810	$10,237,296	$43,400	**$55,681,378**	$1,260,430	**$56,941,807**
2026	$45,745,702	$60,198	$0	$11,511,176	$10,336,778	$43,400	**$67,697,255**	$2,535,391	**$70,232,645**
2027	$40,982,758	$61,678	$1,069,205	$869,431	$10,641,299	$43,400	**$53,667,772**	$3,841,377	**$57,509,149**
2028	$109,539,586	$62,336	$13,611,269	$754,981	$21,017,003	$43,400	**$145,028,575**	$5,427,646	**$150,456,221**
2029	$111,797,840	$63,714	$13,904,492	$1,137,957	$21,502,340	$43,400	**$148,449,742**	$7,049,592	**$155,499,335**
2030	$96,736,169	$64,657	$14,068,992	$13,545,139	$21,825,015	$43,400	**$146,283,371**	$8,698,381	**$154,981,752**
2031	$96,282,989	$65,544	$15,163,761	$1,707,090	$21,921,155	$43,400	**$135,183,940**	$10,370,476	**$145,554,416**
2032	$134,783,615	$67,378	$41,448,718	$2,001,917	$7,445,446	$43,400	**$185,790,474**	$12,090,101	**$197,880,575**
2033	$137,481,896	$68,759	$42,228,382	$2,041,017	$7,596,388	$43,400	**$189,459,842**	$13,848,578	**$203,308,420**
2034	$121,521,857	$71,025	$43,577,031	$2,085,403	$7,841,967	$43,400	**$175,140,684**	$15,661,540	**$190,802,224**
2035	$121,265,142	$72,362	$44,373,973	$2,131,965	$7,983,740	$43,400	**$175,870,582**	$16,257,271	**$192,127,853**
2036	$119,537,729	$72,778	$44,638,032	$2,175,676	$8,035,462	$43,400	**$174,503,078**	$16,845,154	**$191,348,232**
2037	$118,057,423	$73,351	$45,005,620	$2,211,745	$8,098,670	$43,400	**$173,490,209**	$17,415,968	**$190,906,177**
2038	$116,470,502	$73,792	$45,244,815	$2,242,112	$8,152,780	$43,400	**$172,227,402**	$19,300,350	**$191,527,752**
2039	$115,117,319	$74,373	$45,595,209	$2,262,263	$8,212,366	$43,400	**$171,304,929**	$19,920,738	**$191,225,667**
2040	$114,501,103	$74,900	$45,882,018	$2,277,510	$8,268,410	$43,400	**$171,047,341**	$20,226,153	**$191,273,494**
2041	$113,726,998	$75,347	$46,139,454	$2,292,944	$8,322,800	$43,400	**$170,600,943**	$20,516,054	**$191,116,997**
2042	$113,194,894	$75,954	$46,505,442	$2,308,595	$8,390,443	$43,400	**$170,518,728**	$20,797,440	**$191,316,168**
2043	$112,594,172	$76,498	$46,819,567	$2,324,872	$8,452,813	$43,400	**$170,311,322**	$22,756,630	**$193,067,953**
2044	$112,202,975	$77,180	$47,223,532	$2,341,762	$8,526,676	$43,400	**$170,415,525**	$23,028,468	**$193,443,993**
2045	$112,437,873	$77,817	$47,605,191	$2,359,323	$8,596,601	$43,400	**$171,120,205**	$23,601,250	**$194,721,455**
2046	$112,674,805	$78,451	$47,977,842	$2,378,024	$8,666,507	$43,400	**$171,819,028**	$24,142,753	**$195,961,781**
2047	$112,834,056	$79,048	$48,336,754	$2,396,662	$8,733,137	$43,400	**$172,423,058**	$24,348,447	**$196,771,505**
2048	$113,036,856	$79,688	$48,730,929	$2,415,887	$8,803,268	$43,400	**$173,110,029**	$24,554,099	**$197,664,128**
2049	$113,193,816	$80,268	$49,065,347	$2,434,502	$8,863,687	$43,400	**$173,681,021**	$24,753,806	**$198,434,827**
2050	$113,193,816	$80,268	$49,065,347	$2,449,278	$8,863,687	$43,400	**$173,695,797**	$24,936,098	**$198,631,895**
Total	**$2,775,938,169**	**$1,999,501**	**$933,280,923**	**$82,260,462**	**$275,664,054**	**$1,432,200**	**$4,070,575,309**	**$424,188,827**	**$4,494,764,136**

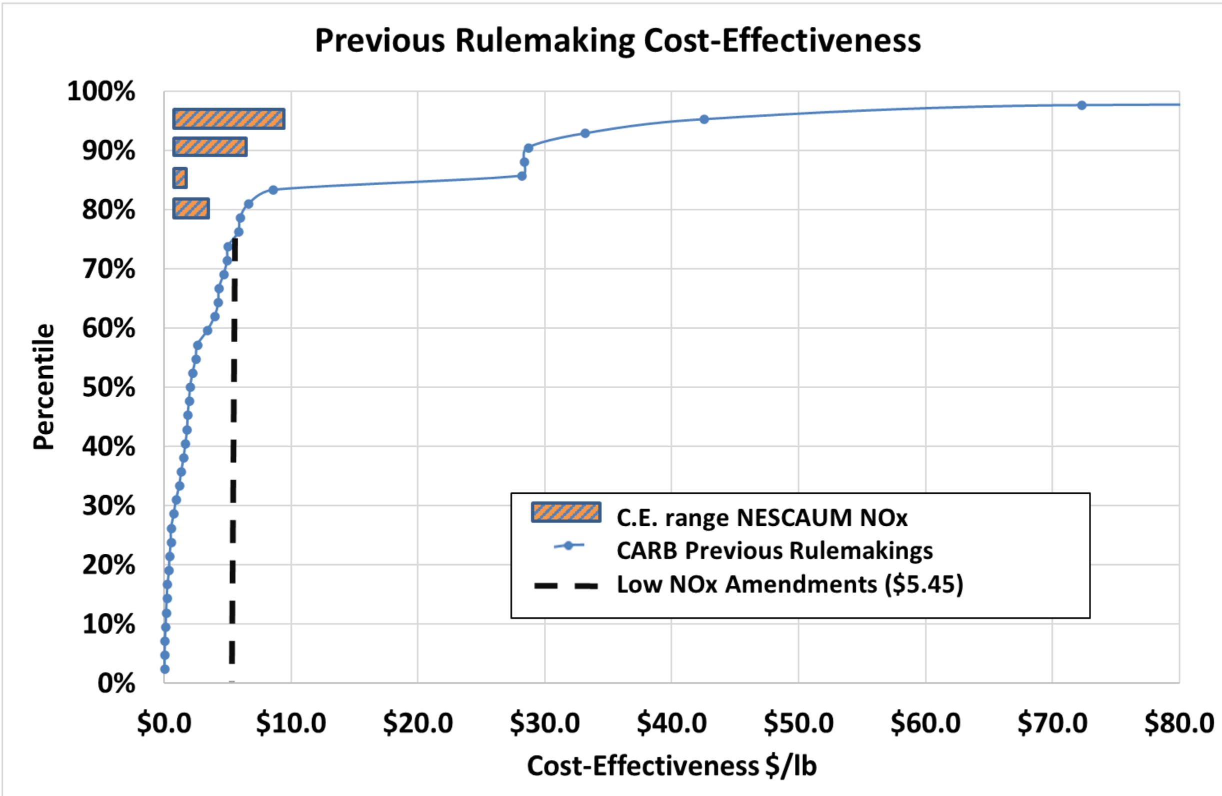
15. Cost-Effectiveness

The cost-effectiveness of the Proposed Amendments based on the savings described in Chapter V, costs in Chapter IX, and the baseline NOx emission benefits in Chapter VI is presented in Table IX-33 below. The cost-effectiveness of the Proposed Amendments is estimated to be $5.45 per pound of NOx. Figure IX-2 shows the Proposed Amendments' cost-effectiveness in comparison to past CARB regulations as well as NOx reducing measures reported by the Northeast States for Coordinated Air Use Management (NESCAUM) for stationary sources. The Proposed Amendments' cost-effectiveness is approximately in the 80th percentile as compared to previous CARB regulations and within the NESCAUM's stationary-source NOx reducing measures' cost-effectiveness range.

Table IX-33. Summary of Cost-Effectiveness for the Proposed Amendments

	Total Cost of Regulation	Total Savings of the Regulation	Total NOx Benefits [Tons]	Cost-Effectiveness $/Ton	Cost-Effectiveness $/lb
Proposed Amendments	$4,494,764,136	$650,574,767	352,797	$10,896	$5.45

Figure IX-2. Cost-Effectiveness of the Proposed Amendments Versus Previous CARB Measures and Previous Stationary Source Measures



C. Direct Costs on Businesses and Individuals

1. Direct Costs on Typical Businesses

Medium- and heavy-duty engine/vehicle manufacturers are the regulated entities under the Proposed Amendments. Because these manufacturers are located outside of California,[62] CARB staff assumed those manufacturers would pass the direct compliance costs of the Proposed Amendments onto the California vehicle fleets that purchase the California-certified vehicles and engines that are subject to the Proposed Amendments. Typical businesses are defined here to be California fleets with four or more medium- and heavy-duty vehicles (GVWR >10,000 pounds).

The actual cost impact on fleets would depend on the number of new California-certified heavy-duty vehicles that fleets would purchase during the lifetime of this cost analysis. A lifetime analysis including initial purchase price increase, lifetime DEF consumption, lifetime savings from warranty and EWIR amendments, net lifetime cost impact, and percent increase in lifetime cost from the assumed purchase price is presented in

[62] Refer to footnote 5555.

Tables IX-34, IX-35, and IX-36 for vehicle purchases with 2024 and subsequent MY engines for each vehicle class.

Table IX-34. Lifetime Analysis for Vehicles with 2024 to 2026 MY Engines

	Increase in Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Assumed Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$3,761	$898	$60	$4,599	$169,637	2.7%
MHDD	$2,469	$370	$0	$2,839	$103,165	2.8%
LHDD	$1,687	$366	$0	$2,053	$57,694	3.6%
HDO	$506	$0	$143	$363	$94,089	0.4%
MDDE-3	$1,554	$196	$0	$1,751	$52,040	3.4%
MDOE-3	$412	$0	$0	$412	$44,459	0.9%
Population Average	**$2,355**	**$455**	**$34**	**$2,776**	**$107,782**	**2.6%**

Table IX-35. Lifetime Analysis for Vehicles with 2027 to 2030 MY Engines

	Increase in Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Assumed Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$7,423	$1,186	$791	$7,819	$171,107	4.6%
MHDD	$6,063	$488	$1,234	$5,317	$104,217	5.1%
LHDD	$4,741	$527	$345	$4,923	$58,258	8.5%
HDO	$821	$0	$368	$453	$98,583	0.5%
MDDE-3	$3,916	$235	$0	$4,151	$52,424	7.9%
MDOE-3	$412	$0	$0	$412	$44,843	0.9%
Population Average	**$5,437**	**$617**	**$789**	**$5,264**	**$109,559**	**5.2%**

Table IX-36. Lifetime Analysis for Vehicles with 2031 and Subsequent MY Engines

	Increase in Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Assumed Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$8,478	$1,294	$930	$8,841	$171,107	5.2%
MHDD	$6,923	$532	$1,641	$5,814	$104,217	5.6%
LHDD	$6,041	$659	$1,143	$5,557	$58,258	9.5%
HDO	$1,015	$0	$582	$433	$98,583	0.4%
MDDE-3	$4,354	$235	$0	$4,589	$52,424	8.8%
MDOE-3	$412	$0	$0	$412	$44,843	0.9%
Population Average	**$6,410**	**$700**	**$1,197**	**$5,912**	**$109,889**	**5.8%**

As an example, CARB staff estimated costs for a fleet that would buy 20 new MHDD vehicles with 2024, 2027, and 2031 MY engines in Table IX-37. As shown in Table IX-37, the lifetime net cost impact to the business for 20 new vehicles is $56,780, $106,340, and $116,280 for 2024, 2027 and 2031 MY engine purchases.

Table IX-37. Lifetime Cost Analysis of 20 MHDD Vehicles

Engine MY	Lifetime Net Cost Per Vehicle	Lifetime Net Cost of 20 Vehicles
2024	$2,839	$56,780
2027	$5,317	$106,340
2031	$5,814	$116,280

2. Direct Costs on Small Businesses

Based on California DMV 2017 registration data, small businesses, defined here as fleets of three or fewer medium- and heavy-duty vehicles (GVWR >10,000 pounds), represent 52 percent of the affected vehicle population due to the Proposed Amendments.

The final compliance date for the Truck and Bus Regulation is January 1st, 2023. As of that date, heavy-duty vehicle owners are required to fully turn over their fleet to 2010 standard compliant engines. Small business fleets throughout California will likely comply with the Truck and Bus Regulation via accelerated turnover (i.e., by purchasing new trucks or newer used trucks). Because such small business fleets would have just recently purchased trucks to comply with the Truck and Bus Regulation, they would not likely immediately purchase trucks with new 2024 or subsequent MY engines. However, small fleets would eventually purchase trucks with such engines as their trucks need replacing or as their fleets grow over time.

Similar to typical fleets, the actual cost impact on small fleets would depend on the number of new California-certified heavy-duty vehicles that fleets would purchase during the lifetime of this cost analysis. As shown in Table IX-37 above, for a small fleet that would buy one new MHDD vehicle with a 2024, 2027, or 2031 MY engine, the net lifetime cost due to the Proposed Amendments is estimated to be $2,839, $5,317, or $5,814, respectively.

3. Direct Costs on Individuals

There are no direct costs on individuals as a result of the Proposed Amendments. Individuals may see health benefits as described in Chapter V, Section E due to the statewide, regional, and local emission benefits of the Proposed Amendments. CARB staff estimates that manufacturers and fleets would see increased costs as a result of this rule and would likely pass the costs through to businesses that buy vehicles with affected engines in the state, as discussed in earlier sections. Individuals may see macroeconomic indirect and induced benefits and costs; these costs are discussed further below in Section E of this chapter.

D. Fiscal Impacts

1. Local Government

1.1. Local Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Amendments would increase the cost of each new vehicle with 2024 and subsequent MY engines sold in the state by about 0.5 to 10.4 percent. The Proposed Amendments would also require additional DEF fluid consumption in California which would result in a direct increase in sales tax revenue collected by local governments. The average local tax rate in California is 0.853 percent (CARB, 2019e). In addition, local governments also collect about 54 percent of the total sales tax revenue (i.e., approximately 4.7 percent out of 8.6 percent sales tax rate). Hence, the overall revenue to local governments would be 5.55 percent of all sales. The annual tax revenue to local governments from 2022 to 2050 is summarized in Table IX-38.

1.2. Local Government Fleet Costs

Local government fleets are estimated to own 10.7 percent of California's total heavy-duty vehicles using EMFAC and DMV registration data. The same proportion of the total costs outlined in Table IX-32 are assumed to pass through to local government, for new government fleet purchases. So, for example, in calendar year 2025, local government fleets would face approximately $6.09 million of the total statewide cost of $56.9 million due to the Proposed Amendments.

1.3. Fiscal Impact on Local Government

Table IX-38 shows the estimated fiscal impact to local governments due to the Proposed Amendments relative to baseline conditions. The net fiscal impact on local government in 2022 would be a cost of $11,000 and the ongoing fiscal impact on local government would range from $165,000 to $10.5 million in cost within the Proposed Amendments' lifetime of 29 years.

Table IX-38. Fiscal Impacts on Local Government (2018$)

Calendar Year	Local Government Fleet Costs	Local Tax Revenue*	Net Fiscal Impact
2022	$23,219	($11,989)	$11,230
2023	$926,173	($478,234)	$447,939
2024	$340,784	($175,997)	$164,786
2025	$6,092,773	($3,147,174)	$2,945,600
2026	$7,514,893	($3,881,758)	$3,633,135
2027	$6,153,479	($3,179,106)	$2,974,373
2028	$16,098,816	($8,318,724)	$7,780,091
2029	$16,638,429	($8,597,558)	$8,040,871
2030	$16,583,048	($8,570,491)	$8,012,557
2031	$15,574,323	($8,050,615)	$7,523,708
2032	$21,173,222	($10,946,753)	$10,226,468
2033	$21,754,001	($11,249,055)	$10,504,946
2034	$20,415,838	($10,560,903)	$9,854,935
2035	$20,557,680	($10,636,198)	$9,921,482
2036	$20,474,261	($10,594,952)	$9,879,309
2037	$20,426,961	($10,574,293)	$9,852,668
2038	$20,493,469	($10,612,553)	$9,880,917
2039	$20,461,146	($10,599,639)	$9,861,508
2040	$20,466,264	($10,604,203)	$9,862,061
2041	$20,449,519	($10,599,349)	$9,850,170
2042	$20,470,830	($10,614,221)	$9,856,609
2043	$20,658,271	($10,715,271)	$9,943,000
2044	$20,698,507	($10,740,011)	$9,958,497
2045	$20,835,196	($10,814,830)	$10,020,366
2046	$20,967,911	($10,883,717)	$10,084,193
2047	$21,054,551	($10,928,689)	$10,125,862
2048	$21,150,062	($10,978,266)	$10,171,796
2049	$21,232,526	($11,021,070)	$10,211,456
2050	$21,253,613	($11,032,015)	$10,221,597
Total	**$480,939,763**	**($249,117,634)**	**$231,822,130**

* Values presented in the table in parentheses represent income.

2. State Government

2.1. CARB Staffing and Resources

Implementation of the Proposed Amendments would create additional workload on CARB staff that would be impossible to absorb with existing staff resources. CARB staff estimated an addition of 10 positions (2 Air Pollution Specialists and 8 Air Resources Engineers) would be needed for the implementation of the Proposed Amendments:

- Two Air Resources Engineers would be required starting in 2024 to review certification applications using new strategies and technologies, as well as manage and review the new standardized extended durability testing.
- Two additional Air Resources Engineers would be required starting in 2024 to coordinate test plans with manufacturers, implement new procedures, and verify submitted test data with the amended HDIUT program.
- Two additional Air Resources Engineers would be required starting in 2024 to handle the NOx sensor data submissions and certify the additional OBD certification requirements associated with the newer technologies expected in low NOx engines.
- Two Air Resources Engineers would be required starting in 2024 for increased enforcement at dealerships due to the difference in emission standards compared to the federal program.
- Two Air Pollution Specialists would be required starting in 2027 to process anticipated increased EWIR claims and recall.

The summary of incremental CARB staff costs due to the Proposed Amendments is presented in Table IX-39.

2.2. State Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Amendments would result in the sale of more expensive (higher upfront cost) heavy-duty vehicles as well as increased DEF consumption in those vehicles in California, which would result in higher sales taxes collected by the state government. The entire population of new California-sold heavy-duty vehicles and DEF consumption over the entire state were used for this analysis. State government collects about 46 percent of the total sales tax revenue (i.e., approximately 3.9 percent out of 8.6% sales tax rate) based on data from the Regional Economic Models, Inc. (REMI) model.

As discussed further earlier in Chapter V, Section A, although it is possible the Proposed Amendments could encourage California fleets to hold onto their existing vehicles slightly longer, to purchase used vehicles in lieu of new vehicles in California, or to purchase more out-of-state vehicles, in estimating the costs for the Proposed

Amendments, for the reasons outlined in Chapter V, Section A, CARB staff did not attempt to quantify any such changes in fleet purchase behavior and hence any state sales tax impacts of such changes in fleet purchase behavior are also not included.

A summary of annual state sales tax revenue from 2022 to 2050 is presented in Table IX-39.

2.3. State Fleet Costs

The state government fleet is estimated to make up 3.3 percent of California's fleet using data from EMFAC2017 and DMV registration data. A proportionate amount of the total costs outlined above in Table IX-32 are assumed to pass through to the state government. The state government fleet costs are presented in Table IX-39.

2.4. Fiscal Impacts on State Government

Table IX-39 shows the estimated fiscal impacts to the state government due to the Proposed Amendments relative to baseline conditions. The net fiscal impact on state government in 2022 and 2023 would be $1,000 and $55,000 in revenue, respectively. Starting in 2024, state government would have annual fiscal cost impacts ranging from $561,000 to $1,496,000 within the Proposed Amendments' period of analysis.

Table IX-39. Summary of Fiscal Impacts to State Government (Millions 2018$)

Calendar Year	CARB Staffing	State Government Fleet Costs	State Sales Tax Revenue	Net Fiscal Impact
2022	$0	$7,161	($8,550)	($1,389)
2023	$0	$285,642	($341,039)	($55,397)
2024	$1,512,000	$105,102	($125,485)	$1,491,617
2025	$1,504,000	$1,879,080	($2,243,507)	$1,139,572
2026	$1,504,000	$2,317,677	($2,767,166)	$1,054,511
2027	$1,864,000	$1,897,802	($2,265,860)	$1,495,941
2028	$1,862,000	$4,965,055	($5,927,975)	$899,080
2029	$1,862,000	$5,131,478	($6,126,674)	$866,804
2030	$1,862,000	$5,114,398	($6,106,281)	$870,117
2031	$1,862,000	$4,803,296	($5,734,844)	$930,452
2032	$1,862,000	$6,530,059	($7,796,495)	$595,564
2033	$1,862,000	$6,709,178	($8,010,352)	$560,826
2034	$1,862,000	$6,296,473	($7,517,608)	$640,866
2035	$1,862,000	$6,340,219	($7,569,837)	$632,382
2036	$1,862,000	$6,314,492	($7,539,120)	$637,371
2037	$1,862,000	$6,299,904	($7,521,703)	$640,200
2038	$1,862,000	$6,320,416	($7,546,193)	$636,222
2039	$1,862,000	$6,310,447	($7,534,291)	$638,156
2040	$1,862,000	$6,312,025	($7,536,176)	$637,850
2041	$1,862,000	$6,306,861	($7,530,010)	$638,851
2042	$1,862,000	$6,313,434	($7,537,857)	$637,577
2043	$1,862,000	$6,371,242	($7,606,877)	$626,365
2044	$1,862,000	$6,383,652	($7,621,693)	$623,958
2045	$1,862,000	$6,425,808	($7,672,025)	$615,783
2046	$1,862,000	$6,466,739	($7,720,894)	$607,845
2047	$1,862,000	$6,493,460	($7,752,797)	$602,662
2048	$1,862,000	$6,522,916	($7,787,967)	$596,950
2049	$1,862,000	$6,548,349	($7,818,332)	$592,017
2050	$1,862,000	$6,554,853	($7,826,097)	$590,756
Total	**$49,210,000**	**$148,327,216**	**($177,093,707)**	**$20,443,510**

* Values presented in the table in parentheses represent income.

E. Macroeconomic Impacts

CARB staff used REMI Policy Insight Plus Version 2.2.8 to estimate the macroeconomic impacts of the Proposed Amendments and associated amendments on the California economy. REMI is a structural economic forecasting and policy analysis model that integrates input-output, computable general equilibrium, econometric and economic geography methodologies.[63] REMI Policy Insight Plus provides year-by-year estimates of the total impacts of the Proposed Amendments, pursuant to the requirements of Senate Bill 617 and the California Department of Finance (CLI, 2019b; DGS, 2019). CARB uses the REMI single-region, 160-sector model with the model reference case adjusted to reflect the Department of Finance conforming forecasts. These forecasts include California population figures dated May 2019, U.S. real gross domestic product forecast, and civilian employment growth numbers dated April 2019. More details on the methodology can be found in the original SRIA submitted to Department of Finance in Appendix C-1.

While the analysis methodology remained the same as utilized in the SRIA, the cost figures used in this analysis were updated to reflect the current Proposed Amendments. A summary of these changes can be found in Section A of this chapter.

Subsection 1 below summarizes the macroeconomic modeling results. Subsection 2 discusses employment impacts in more detail. Subsection 3 discusses business impacts, such as on industry output. Finally, Subsection 4 discusses investment impacts on the California economy.

1. Summary and Agency Interpretation of Results

CARB staff estimates the Proposed Amendments would be unlikely to have a significant impact on the California economy. The results of the macroeconomic analysis of the Proposed Amendments are summarized in Table IX-40 below. These results represent the annual incremental change from the implementation of the Proposed Amendments relative to the baseline. Overall, CARB staff expects the Proposed Amendments would cause no more than a 0.02 percent decrease in California employment, gross state product (GSP), and output in any year from 2022 to 2050. The California economy is forecasted to grow through 2050, therefore, negative impacts reported here should be interpreted as a slowing of growth and positive impacts as an acceleration of growth resulting from the Proposed Amendments. Overall, the Proposed Amendments would result in a small decrease in growth in the major sectors of the economy of California.

[63] For further information and model documentation see: https://www.remi.com/model/pi/.

Table IX-40. Summary of California Macroeconomic Impacts of Proposed Amendments

Summary of Macroeconomic Impacts of Proposed Amendments										
	GSP		Personal Income		Employment		Output		Private Investment	
Calendar Year	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change	Total California Employment	% Change	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change
2022	2,531,251	0.00%	2,973,287	0.00%	24,692,675	0.00%	4,124,017	0.00%	370,891	0.00%
2023	2,571,386	0.00%	3,091,732	0.00%	24,885,355	0.00%	4,188,289	0.00%	376,073	0.00%
2024	2,614,454	0.00%	3,213,765	0.00%	25,076,789	0.00%	4,256,616	0.00%	380,467	0.00%
2025	2,660,195	0.00%	3,358,602	0.00%	25,266,932	0.00%	4,328,114	0.00%	384,647	0.00%
2026	2,704,479	0.00%	3,500,990	0.00%	25,455,691	0.00%	4,396,032	0.00%	388,945	0.00%
2027	2,752,966	0.00%	3,651,381	0.00%	25,644,170	0.00%	4,471,622	0.00%	392,880	-0.01%
2028	2,802,148	0.00%	3,822,474	0.00%	25,832,756	0.00%	4,549,225	0.00%	398,310	-0.01%
2029	2,852,844	0.00%	3,977,462	0.00%	26,019,386	0.00%	4,630,803	0.00%	404,643	-0.01%
2030	2,904,631	-0.01%	4,139,557	-0.01%	26,203,839	-0.01%	4,715,893	-0.01%	411,658	-0.02%
2031	2,958,068	-0.01%	4,309,018	-0.01%	26,389,035	-0.01%	4,805,766	-0.01%	419,200	-0.02%
2032	3,012,872	-0.01%	4,486,396	-0.01%	26,572,763	-0.01%	4,900,404	-0.01%	426,860	-0.01%
2033	3,068,934	-0.01%	4,671,796	-0.01%	26,752,682	-0.01%	4,999,912	-0.01%	434,653	-0.01%
2034	3,126,236	-0.01%	4,865,759	-0.01%	26,928,730	-0.01%	5,104,572	-0.01%	442,645	-0.01%
2035	3,185,382	-0.01%	5,069,079	-0.01%	27,103,814	-0.01%	5,215,718	-0.01%	450,956	-0.01%
2036	3,245,685	-0.01%	5,279,496	-0.01%	27,272,990	-0.01%	5,332,629	-0.01%	459,169	-0.01%
2037	3,307,478	-0.01%	5,499,544	-0.01%	27,439,642	-0.01%	5,452,764	-0.01%	467,353	-0.01%
2038	3,370,542	-0.01%	5,729,812	-0.01%	27,603,039	-0.01%	5,575,783	-0.01%	475,509	-0.01%
2039	3,434,971	-0.01%	5,970,215	-0.01%	27,763,011	-0.01%	5,701,868	-0.01%	483,741	-0.01%
2040	3,500,578	-0.01%	6,220,321	-0.01%	27,918,975	-0.01%	5,830,768	-0.01%	491,946	-0.01%
2041	3,567,376	-0.01%	6,480,535	-0.01%	28,070,856	-0.01%	5,962,543	-0.01%	500,111	-0.01%
2042	3,635,494	-0.01%	6,750,680	-0.01%	28,220,305	-0.01%	6,097,443	-0.01%	508,124	-0.01%
2043	3,704,751	-0.01%	7,031,921	-0.01%	28,366,180	-0.01%	6,235,226	-0.01%	516,085	-0.01%
2044	3,774,783	-0.01%	7,323,407	0.00%	28,506,702	-0.01%	6,375,337	-0.01%	524,001	-0.01%
2045	3,845,988	-0.01%	7,626,747	0.00%	28,644,601	-0.01%	6,518,455	-0.01%	531,975	-0.01%
2046	3,918,321	-0.01%	7,942,359	-0.01%	28,779,582	-0.01%	6,664,542	-0.01%	540,005	-0.01%
2047	3,991,764	-0.01%	8,269,707	-0.01%	28,911,206	-0.01%	6,813,631	-0.01%	548,086	-0.01%
2048	4,066,345	-0.01%	8,609,687	-0.01%	29,039,779	-0.01%	6,965,804	-0.01%	556,227	-0.01%
2049	4,142,074	-0.01%	8,962,334	-0.01%	29,165,880	-0.01%	7,121,125	-0.01%	564,428	-0.01%
2050	4,218,560	-0.01%	9,323,767	-0.01%	29,287,128	-0.01%	7,278,970	-0.01%	572,536	-0.01%

Note: The columns labeled “Total” in Table IX-40 represent the adjusted values including the effect of the Proposed Amendments. The columns labeled “% change” are the percent change from the baseline without the Proposed Amendments.

2. California Employment Impacts

Table IX-41 presents the impact of the Proposed Amendments on total employment in California across all industries. As Table IX-41 shows, the Proposed Amendments would result in a slightly negative employment impact from about 2022 to 2050. The REMI model shows a decrease in employment of 1,207 in 2028 and 2,003 in 2050. The maximum impact on jobs in any year is in 2030, where the REMI model estimates there would be 2,707 fewer jobs than would exist in the absence of the Proposed Amendments. CARB staff expects the change in employment due to the Proposed Amendments would represent no more than 0.01 percent of baseline California employment in any year.

Table IX-41. California Employment Impacts of Proposed Amendments

California Employment Impacts			
Calendar Year	**Change in Total Jobs**	**% Change**	**California Employment**
2022	0	0.00%	24,692,675
2023	-185	0.00%	24,885,355
2024	-20	0.00%	25,076,789
2025	-215	0.00%	25,266,932
2026	-491	0.00%	25,455,691
2027	-1,161	0.00%	25,644,170
2028	-1,207	0.00%	25,832,756
2029	-1,154	0.00%	26,019,386
2030	-2,707	-0.01%	26,203,839
2031	-2,523	-0.01%	26,389,035
2032	-1,627	-0.01%	26,572,763
2033	-1,592	-0.01%	26,752,682
2034	-2,179	-0.01%	26,928,730
2035	-1,985	-0.01%	27,103,814
2036	-1,693	-0.01%	27,272,990
2037	-1,648	-0.01%	27,439,642
2038	-1,583	-0.01%	27,603,039
2039	-1,714	-0.01%	27,763,011
2040	-1,674	-0.01%	27,918,975
2041	-1,632	-0.01%	28,070,856
2042	-1,590	-0.01%	28,220,305
2043	-1,557	-0.01%	28,366,180
2044	-1,523	-0.01%	28,506,702
2045	-1,483	-0.01%	28,644,601
2046	-2,050	-0.01%	28,779,582
2047	-2,036	-0.01%	28,911,206
2048	-2,037	-0.01%	29,039,779
2049	-2,035	-0.01%	29,165,880
2050	-2,003	-0.01%	29,287,128

Table IX-42 displays the employment impact on major sectors such as retail and wholesale trade, transportation, manufacturing, and construction, all of which are sectors that would be impacted by the Proposed Amendments. CARB staff's analysis predicts that as the requirements of the Proposed Amendments would go into effect, affected sectors would experience increases in production costs and hence slightly lower employment than they otherwise would have. The largest decrease in employment would manifest in the manufacturing, construction, transportation, and retail and wholesale trade sectors, which are estimated to realize an increase in production costs driven by the increased heavy-duty truck prices due to the Proposed Amendments. All sectors except construction and manufacturing still are predicted to have an increase in employment every year, even with the Proposed Amendments in place. The construction sector shows a decline in employment from 2022 through 2029 due to the anticipated production costs of the Proposed Amendments. The manufacturing sector shows declines in employment over the lifetime of the regulation. In the REMI results of the simulation, the decline of jobs in manufacturing are equally spread over the various industries in the manufacturing sector, with some exceptions. Industries that manufacture raw materials, capital goods, food, and chemical goods each show decline in employment growth between 0 and 2 jobs for most years of implementation. The motor vehicle manufacturing, motor vehicle parts manufacturing, and basic chemical manufacturing industries showed gains in the range of 1 to 21 jobs per year, even with the Proposed Amendments in place.

It is important to note that overall, in total for all sectors, the impact of the Proposed Amendments is expected to be insignificant and not enough to make the total number of jobs decrease from one year to the next. Instead, CARB staff predicts the impact would be a small decrease in the job growth that would otherwise occur.

Table IX-42. California Employment Impacts of Proposed Amendments by Major Sector (Total jobs with Proposed Amendments in place, % fewer jobs in each year vs. baseline)

Sector:	Government		Retail & Wholesale		Services		Construction		Transportation		Manufacturing		Financial Services		Information Services	
Calendar Year	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change	Total Jobs	% Change
2022	2,352,826	0.00%	3,181,461	0.00%	2,188,297	0.00%	1,190,459	0.00%	930,781	0.00%	1,402,001	0.00%	1,099,151	0.00%	670,638	0.00%
2023	2,370,742	0.00%	3,195,620	0.00%	2,212,947	0.00%	1,185,452	0.00%	938,108	-0.01%	1,393,118	0.00%	1,110,135	0.00%	677,086	0.00%
2024	2,385,213	0.00%	3,206,661	0.00%	2,240,453	0.00%	1,174,153	0.00%	945,481	0.00%	1,388,659	0.00%	1,121,170	0.00%	682,443	0.00%
2025	2,400,160	0.00%	3,212,633	0.00%	2,269,744	0.00%	1,159,033	0.00%	952,469	-0.01%	1,381,345	0.00%	1,131,941	0.00%	687,220	0.00%
2026	2,419,025	0.00%	3,210,894	0.00%	2,302,030	0.00%	1,143,552	0.00%	959,082	-0.02%	1,371,469	0.00%	1,141,961	0.00%	691,536	0.00%
2027	2,433,065	0.00%	3,210,423	-0.01%	2,334,447	0.00%	1,126,987	-0.01%	965,853	-0.04%	1,361,438	0.00%	1,153,203	0.00%	696,673	0.00%
2028	2,444,986	0.00%	3,211,246	-0.01%	2,366,702	0.00%	1,115,583	-0.01%	972,603	-0.04%	1,348,871	0.00%	1,164,501	0.00%	702,575	0.00%
2029	2,454,108	0.00%	3,212,480	-0.01%	2,397,085	0.00%	1,110,927	-0.01%	978,992	-0.04%	1,339,984	0.00%	1,175,271	0.00%	708,406	0.00%
2030	2,462,736	0.00%	3,213,887	-0.03%	2,426,852	0.00%	1,110,987	-0.02%	984,886	-0.09%	1,331,486	-0.01%	1,185,583	-0.01%	715,008	0.00%
2031	2,470,849	0.00%	3,216,316	-0.02%	2,456,344	0.00%	1,114,108	-0.02%	991,381	-0.08%	1,323,847	-0.01%	1,195,433	-0.01%	722,604	0.00%
2032	2,477,720	0.00%	3,220,330	-0.02%	2,485,075	0.00%	1,119,495	-0.02%	998,028	-0.07%	1,316,905	-0.01%	1,204,872	0.00%	730,946	0.00%
2033	2,483,063	0.00%	3,225,463	-0.02%	2,512,976	0.00%	1,126,641	-0.01%	1,004,539	-0.06%	1,310,713	-0.01%	1,213,933	0.00%	740,045	0.00%
2034	2,486,610	0.00%	3,232,011	-0.02%	2,539,790	0.00%	1,135,389	-0.02%	1,010,811	-0.08%	1,305,263	-0.01%	1,222,639	-0.01%	749,845	0.00%
2035	2,489,386	0.00%	3,240,232	-0.02%	2,566,110	0.00%	1,145,423	-0.01%	1,017,412	-0.08%	1,301,182	-0.01%	1,230,792	0.00%	760,616	0.00%
2036	2,490,999	0.00%	3,249,625	-0.02%	2,591,946	0.00%	1,155,498	-0.01%	1,024,106	-0.07%	1,297,461	-0.01%	1,238,131	0.00%	772,409	0.00%
2037	2,493,301	0.00%	3,258,251	-0.02%	2,617,852	0.00%	1,164,600	-0.01%	1,030,563	-0.06%	1,293,777	-0.01%	1,245,131	0.00%	784,479	0.00%
2038	2,495,378	0.00%	3,266,510	-0.02%	2,643,318	0.00%	1,172,922	-0.01%	1,036,862	-0.06%	1,289,951	-0.01%	1,251,986	0.00%	796,664	0.00%
2039	2,497,329	0.00%	3,274,239	-0.02%	2,668,435	0.00%	1,180,624	-0.01%	1,042,935	-0.07%	1,286,249	-0.01%	1,258,618	0.00%	808,980	0.00%
2040	2,498,998	0.00%	3,281,432	-0.02%	2,693,050	0.00%	1,187,878	-0.01%	1,048,852	-0.06%	1,282,304	-0.01%	1,265,016	0.00%	821,380	0.00%
2041	2,500,477	0.00%	3,287,875	-0.02%	2,717,280	0.00%	1,194,496	-0.01%	1,054,541	-0.06%	1,278,171	-0.01%	1,271,074	0.00%	833,916	0.00%
2042	2,501,708	0.00%	3,293,800	-0.02%	2,741,132	0.00%	1,200,640	0.00%	1,060,054	-0.06%	1,273,842	-0.01%	1,276,892	0.00%	846,587	0.00%
2043	2,502,609	0.00%	3,298,962	-0.02%	2,764,524	0.00%	1,206,410	0.00%	1,065,372	-0.06%	1,269,289	-0.01%	1,282,461	0.00%	859,374	0.00%
2044	2,502,838	0.00%	3,303,271	-0.02%	2,787,057	0.00%	1,211,955	0.00%	1,070,444	-0.05%	1,264,515	-0.01%	1,287,738	0.00%	872,146	0.00%
2045	2,502,734	0.00%	3,307,190	-0.02%	2,809,058	0.00%	1,217,786	0.00%	1,075,348	-0.05%	1,259,474	-0.01%	1,292,895	0.00%	884,981	0.00%
2046	2,502,339	0.00%	3,310,541	-0.02%	2,830,640	0.00%	1,223,644	-0.01%	1,079,926	-0.07%	1,254,220	-0.01%	1,297,859	-0.01%	897,919	0.00%
2047	2,501,765	0.00%	3,313,243	-0.02%	2,851,872	0.00%	1,229,420	-0.01%	1,084,449	-0.07%	1,248,803	-0.01%	1,302,483	-0.01%	911,017	0.00%
2048	2,500,912	0.00%	3,315,246	-0.02%	2,872,764	0.00%	1,235,116	-0.01%	1,088,783	-0.06%	1,243,212	-0.01%	1,306,861	-0.01%	924,280	0.00%
2049	2,499,782	0.00%	3,316,736	-0.02%	2,893,328	0.00%	1,240,876	-0.01%	1,092,956	-0.06%	1,237,489	-0.01%	1,311,035	-0.01%	937,719	0.00%
2050	2,498,146	0.00%	3,317,413	-0.02%	2,913,273	0.00%	1,246,664	-0.01%	1,096,874	-0.06%	1,231,516	-0.01%	1,314,902	-0.01%	951,232	0.00%

3. California Business Impacts

Gross output is used as a measure for business impacts because it represents total industries' sales or receipts and tracks the quantity of goods or services produced in a given time period. Gross output is the sum of goods or services in each private industry (including state and local government) whether for final consumption or for further production. Gross output is affected by production cost and demand changes. If production cost increases or demand decreases, output is expected to contract; conversely, if production costs decline or demand increases, industry will likely experience output growth.

The Proposed Amendments are modeled to decrease output by $201 million in 2028 and by $535 million in 2050, the year of maximum impact, as shown in Table IX-43. Annual impacts on total California output are predicted to never exceed 0.01 percent. There are small negative impacts on major sectors of the California economy, but the overall predicted trend is still for output growth each year. The impact of the Proposed Amendments would be to slightly slow the predicted output growth. Table IX-44 displays the output impact by major sector. The decreases of output in the transportation, retail and wholesale trade sectors, construction sectors and others would be due to increased production costs due to the increased heavy-duty truck prices driven by the Proposed Amendments.

The sector most significantly impacted would be the transportation sector and the years of maximum impact would be 2030 and 2034. In 2030 and 2034, transportation output would be expected to be 0.11 percent lower than it otherwise would be. It is important to note that for no sector is the impact of the Proposed Amendments expected to be enough to actually make the total amount of output value decrease from year to year, with the exception of the construction sector from 2025 to 2027. Instead, CARB staff predicts the impact would be a small decrease in the output growth that would otherwise occur.

Table IX-43. California Output Impacts of Proposed Amendments

California Output Impacts			
Calendar Year	Change in Total Output (2018M$)	% Change	California Output (2018M$)
2022	0	0.00%	4,124,017
2023	-27	0.00%	4,188,289
2024	-4	0.00%	4,256,616
2025	-33	0.00%	4,328,114
2026	-76	0.00%	4,396,032
2027	-181	0.00%	4,471,622
2028	-201	0.00%	4,549,225
2029	-197	0.00%	4,630,803
2030	-450	-0.01%	4,715,893
2031	-432	-0.01%	4,805,766
2032	-309	-0.01%	4,900,404
2033	-309	-0.01%	4,999,912
2034	-415	-0.01%	5,104,572
2035	-389	-0.01%	5,215,718
2036	-346	-0.01%	5,332,629
2037	-345	-0.01%	5,452,764
2038	-340	-0.01%	5,575,783
2039	-373	-0.01%	5,701,868
2040	-372	-0.01%	5,830,768
2041	-371	-0.01%	5,962,543
2042	-371	-0.01%	6,097,443
2043	-372	-0.01%	6,235,226
2044	-372	-0.01%	6,375,337
2045	-371	-0.01%	6,518,455
2046	-504	-0.01%	6,664,542
2047	-512	-0.01%	6,813,631
2048	-523	-0.01%	6,965,804
2049	-532	-0.01%	7,121,125
2050	-535	-0.01%	7,278,970

Table IX-44. California Output Impacts of Proposed Amendments by Major Sector

Sector:	Government		Retail & Wholesale		Services		Construction		Transportation		Manufacturing		Financial Services		Information Services	
Calendar Year	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change	Agg. Value (2018$M)	% Change
2022	333,702	0.00%	446,814	0.00%	337,356	0.00%	168,992	0.00%	115,736	0.00%	673,611	0.00%	179,251	0.00%	385,035	0.00%
2023	337,179	0.00%	455,995	0.00%	343,388	0.00%	169,914	0.00%	117,497	-0.01%	681,225	0.00%	182,960	0.00%	395,671	0.00%
2024	340,323	0.00%	465,169	0.00%	350,140	0.00%	169,988	0.00%	119,350	0.00%	691,358	0.00%	186,819	0.00%	406,051	0.00%
2025	343,770	0.00%	474,166	0.00%	357,526	0.00%	169,581	0.00%	121,255	-0.01%	701,203	0.00%	190,813	0.00%	416,460	0.00%
2026	347,422	0.00%	481,827	0.00%	365,133	0.00%	168,895	0.00%	123,023	-0.02%	709,850	0.00%	194,521	0.00%	426,177	0.00%
2027	350,916	0.00%	490,500	-0.01%	373,377	0.00%	168,255	-0.01%	125,049	-0.05%	719,368	0.00%	198,757	0.00%	437,323	0.00%
2028	354,237	0.00%	499,603	-0.01%	381,871	0.00%	168,405	-0.01%	127,122	-0.06%	727,919	0.00%	203,134	0.00%	449,188	0.00%
2029	357,371	0.00%	509,147	-0.01%	390,346	0.00%	169,663	-0.01%	129,223	-0.05%	738,277	0.00%	207,620	0.00%	461,434	0.00%
2030	360,614	0.00%	519,130	-0.03%	398,998	0.00%	171,737	-0.03%	131,328	-0.11%	749,192	0.00%	212,197	-0.01%	474,485	0.00%
2031	363,995	0.00%	529,758	-0.02%	407,923	0.00%	174,412	-0.03%	133,633	-0.10%	761,013	-0.01%	216,886	-0.01%	488,562	0.00%
2032	367,426	0.00%	541,156	-0.02%	417,069	0.00%	177,595	-0.02%	136,072	-0.08%	773,778	0.00%	221,717	0.00%	503,706	0.00%
2033	370,885	0.00%	553,309	-0.02%	426,450	0.00%	181,233	-0.01%	138,609	-0.08%	787,602	0.00%	226,711	0.00%	520,007	0.00%
2034	374,340	0.00%	566,307	-0.02%	436,043	0.00%	185,325	-0.02%	141,232	-0.11%	802,551	-0.01%	231,889	-0.01%	537,518	0.00%
2035	377,946	0.00%	580,263	-0.02%	445,972	0.00%	189,838	-0.01%	144,048	-0.10%	819,163	0.00%	237,221	-0.01%	556,458	0.00%
2036	381,655	0.00%	595,160	-0.02%	456,264	0.00%	194,586	-0.01%	147,029	-0.09%	836,960	0.00%	242,665	0.00%	576,941	0.00%
2037	385,567	0.00%	610,406	-0.02%	466,824	0.00%	199,308	-0.01%	150,050	-0.09%	855,378	0.00%	248,194	0.00%	598,254	0.00%
2038	389,543	0.00%	626,051	-0.02%	477,561	0.00%	204,028	-0.01%	153,120	-0.08%	874,268	0.00%	253,851	0.00%	620,339	0.00%
2039	393,598	0.00%	642,086	-0.02%	488,496	0.00%	208,773	-0.01%	156,226	-0.09%	893,781	-0.01%	259,623	0.00%	643,227	0.00%
2040	397,707	0.00%	658,506	-0.02%	499,602	0.00%	213,570	-0.01%	159,385	-0.09%	913,705	-0.01%	265,508	0.00%	666,911	0.00%
2041	401,884	0.00%	675,283	-0.02%	510,904	0.00%	218,382	-0.01%	162,584	-0.08%	934,089	0.00%	271,485	0.00%	691,442	0.00%
2042	406,120	0.00%	692,463	-0.02%	522,407	0.00%	223,237	-0.01%	165,831	-0.08%	954,926	-0.01%	277,577	0.00%	716,858	0.00%
2043	410,393	0.00%	709,990	-0.02%	534,088	0.00%	228,148	-0.01%	169,117	-0.08%	976,180	0.00%	283,779	0.00%	743,154	0.00%
2044	414,644	0.00%	727,831	-0.02%	545,866	0.00%	233,141	0.00%	172,428	-0.08%	997,743	0.00%	290,083	0.00%	770,250	0.00%
2045	418,921	0.00%	746,079	-0.02%	557,798	0.00%	238,315	0.00%	175,777	-0.07%	1,019,657	0.00%	296,524	0.00%	798,242	0.00%
2046	423,227	0.00%	764,702	-0.02%	569,902	0.00%	243,622	-0.01%	179,128	-0.09%	1,041,949	-0.01%	303,083	-0.01%	827,171	0.00%
2047	427,576	0.00%	783,687	-0.02%	582,191	0.00%	249,041	-0.01%	182,546	-0.09%	1,064,666	-0.01%	309,723	-0.01%	857,099	0.00%
2048	431,950	0.00%	803,023	-0.02%	594,670	0.00%	254,574	-0.01%	185,997	-0.09%	1,087,807	-0.01%	316,466	-0.01%	888,063	0.00%
2049	436,341	0.00%	822,739	-0.02%	607,331	0.00%	260,249	-0.01%	189,483	-0.09%	1,111,377	-0.01%	323,316	-0.01%	920,098	0.00%
2050	440,706	0.00%	842,756	-0.02%	620,110	0.00%	266,061	-0.01%	192,984	-0.09%	1,135,262	-0.01%	330,248	-0.01%	953,132	0.00%

3.1. Creation, Elimination, or Expansion of Businesses

Although the REMI model cannot directly estimate the creation, elimination, or expansion of businesses, it can be used to understand some potential impacts. The decreased output due to the Proposed Amendments for the transportation industry has the potential to result in a small decrease in business creation or expansion in this industry if sustained over time. Increased production costs may marginally increase the risk of business elimination. However, even for the most heavily impacted sector, transportation, the macroeconomic analysis results only show impacts up to a 0.11 percent decrease in output (as shown in Table IX-44).

3.2. Competitive Advantage or Disadvantage

Staff considered whether some California state fleets would be competitively advantaged or disadvantaged compared to out-of-state fleets that transport goods on an interstate scale. Because California emission standards would be stricter beginning in 2024 than federally and hence California-certified trucks slightly more expensive than federally-certified trucks (about 0.5 to 10.4 percent increase in purchase price and about 0.4 to 9.5 percent increase in net lifetime cost compared to federally-certified trucks, as discussed above in Table IX-34, IX-35, and IX-36), it is possible that California fleets involved in interstate transport may be competitively disadvantaged compared to out-of-state fleets for whom it would be easier to purchase cheaper, higher emitting new trucks outside California. However, for the following reasons, CARB staff is not certain whether such a competitive impact would occur:

- The Proposed Amendments would provide manufacturers the option to certify 2024 through 2026 MY engines under the 50-state-directed option described above in Chapter III, Section A.1.1.2. Each manufacturer taking advantage of the 50-state-directed option would be meeting the same engine standards nationwide, thereby eliminating any competitive disadvantage for California fleets that buy their products.
- Even for manufacturers not utilizing the 50-state-directed option, the cost increase is expected to be small compared to the purchase price of a truck, on average.
- The Proposed Amendments could encourage California and out-of-state fleets operating in California to hold onto their existing vehicles slightly longer or to consider purchasing used vehicles in-state or out-of-state in lieu of new vehicles in California.

Overall, although the REMI analysis above gives CARB staff a general understanding of the expected impacts of the Proposed Amendments on California competitiveness, CARB staff concluded it is not possible to precisely quantify impacts on California competitiveness. CARB staff was unable to obtain complete information on business level responses to regulatory costs due to the highly competitive nature of the truck transportation industry. In addition, CARB staff searched the literature and concluded that empirical research focused on the impact of regulatory costs on heavy-duty vehicle and engine prices does not exist. A number of studies have explored the relationship between general cost increases and the likelihood of out-of-state or used truck and engine purchases. These studies found that there is a very wide range of estimates for how increased costs may impact purchasing behavior (Askin et al., 2015; Greene, 2001), the estimates are highly uncertain, and that these estimates may change markedly in the span of only several years due to the dynamics of industry, and modern global economics.

3.3. Incentives for Innovation

The Proposed Amendments contain several elements that encourage innovation. The warranty, useful life, and EWIR and corrective action amendments would incentivize production of more durable engine add-ons, parts, and systems. Engines operating with more durable parts would need less scheduled replacements and potentially could result in overall lower maintenance requirements with resulting savings. Manufacturing engines with more durable parts (or parts replaced less frequently) would result in generally more reliable operation, which would represent a positive externality resulting from the Proposed Amendments.

The proposed low load cycle and more rigorous durability testing, and the option to transmit “real-time” data via telematics in lieu of some durability testing would provide CARB staff additional assurances that the engine’s emission control technologies are effective and durable throughout the useful life of the engine. At the same time, they would help manufacturers better identify problems and take more immediate corrective action to improve their emission control systems. These more thorough testing techniques would help accelerate innovation and allow manufacturers to better optimize emission control systems, which could also eventually help reduce manufacturer costs associated with corrective action and recalls. All in all, the Proposed Amendments would support improved emission control technology performance while at the same time encourage innovation by manufacturers to meet the more stringent standards.

4. California Investment Impacts

REMI’s investment variable is used as a measure for business investment because it represents the propensity of entities to purchase capital goods (including replacements) and other investment vehicles in a given time period. If production cost increases or demand decreases, investment is expected to contract. Conversely, if production costs decline or demand increases, industry will likely experience investment growth.

The Proposed Amendments are modeled to decrease investment by $38 million in 2028 and by $48 million in 2050, as shown in Table IX-45. The year of maximum impact would be 2031, which would have a decrease in investment of $76 million. There are small negative impacts across the California economy, but never an impact in any year of more than 0.02 percent. The decreasing investment impacts between 2034 and 2045 are likely due to the increased savings generated by the Proposed Amendments in those times. The decreased statewide investment activity would be due to increased production costs due to the increased heavy-duty truck prices driven by the Proposed Amendments.

Table IX-45. Impact of Proposed Amendments on California Investment

California Investment Impacts			
Calendar Year	Change in Total Investment (2018$M)	% Change	California Investment (2018$M)
2022	0	0.00%	370,891
2023	-4	0.00%	376,073
2024	-2	0.00%	380,467
2025	-6	0.00%	384,647
2026	-13	0.00%	388,945
2027	-31	-0.01%	392,880
2028	-38	-0.01%	398,310
2029	-38	-0.01%	404,643
2030	-72	-0.02%	411,658
2031	-76	-0.02%	419,200
2032	-58	-0.01%	426,860
2033	-49	-0.01%	434,653
2034	-57	-0.01%	442,645
2035	-53	-0.01%	450,956
2036	-43	-0.01%	459,169
2037	-37	-0.01%	467,353
2038	-33	-0.01%	475,509
2039	-34	-0.01%	483,741
2040	-34	-0.01%	491,946
2041	-33	-0.01%	500,111
2042	-32	-0.01%	508,124
2043	-31	-0.01%	516,085
2044	-30	-0.01%	524,001
2045	-29	-0.01%	531,975
2046	-43	-0.01%	540,005
2047	-47	-0.01%	548,086
2048	-49	-0.01%	556,227
2049	-49	-0.01%	564,428
2050	-48	-0.01%	572,536

5. The Benefits of the Regulation to the Health and Welfare of California Residents, Worker Safety, and the State's Environment

As discussed in Chapter V, Sections A and F, the Proposed Amendments would help California to attain the national air quality standards for ozone and PM and thus benefit the health of California's residents. The health benefits have been monetized by year for the Proposed Amendments in Table V-4 to be $36.8 billion over the 29-year timeframe of the Proposed Amendments from 2022 to 2050 due to the reduction in premature mortality, hospitalizations, and emergency room visits. The monetized health benefits of the Proposed Amendments, $36.8 billion, offset the total cost of the Proposed Amendments, $4.49 billion, many times over.

F. Sensitivity Analysis of Indirect Incremental Warranty Cost Using NREL Survey Warranty Responses

As described in Sections B.4 and B.6 of this chapter, CARB staff estimated costs for the Proposed Amendments' lengthened warranty and EWIR and corrective action amendments based on data on parts costs, the rates at which parts currently fail (as reported to CARB under today's warranty regulations), and the rate at which vehicles of various classes accumulate mileage. As mentioned in Section B.1 of this chapter, NREL conducted a cost survey and analysis under contract to help CARB understand the cost impacts of the Proposed Amendments. Although CARB staff used the results of the NREL study extensively to estimate costs associated with the technology packages needed to meet the Proposed Amendments, CARB staff did not use NREL's survey responses related to lengthened warranty, which were very high, over $23,000 per vehicle for the largest diesel trucks. CARB staff believes the incremental warranty costs from the NREL survey are likely significantly overstated and are less reliable than the cost estimates derived as described in Sections B.4 and B.6 for the reasons outlined in Section F.2 below.

However, for completeness, CARB staff analyzed what it would mean if the incremental warranty costs from the NREL survey were incorporated. The results of that sensitivity analysis are presented in Table IX-46 below. As Table IX-46 shows, if the incremental warranty costs from the NREL survey were incorporated, the total statewide cost for the Proposed Amendments and the cost-effectiveness, i.e., cost per unit of NOx reductions, would increase about 26 percent. The cost-effectiveness would still be reasonable when compared to those of recent CARB rulemakings.

Table IX-46. Cost and Cost-Effectiveness for Sensitivity Analysis Incorporating Incremental Warranty Costs from the NREL Survey

	Total Cost	Total Savings	Cost-Effectiveness [$/lb]
CARB Staff's Primary Economic Analysis	$4.49 billion	$651 million	$5.45
Estimate Incorporating Incremental Warranty Costs from the NREL Survey	$6.62 billion	$1.77 billion	$6.88

Section F.1 provides further description of the NREL survey, particularly related to warranty provisions. Section F.2 describes limitations and doubts concerning the incremental warranty costs from the NREL survey. Section F.3 describes the method used to conduct a sensitivity analysis using the incremental warranty costs from the NREL survey.

1. Overview of NREL's Cost Analysis Survey as it Relates to Warranty

NREL staff collected data for the cost analysis from industry association groups, Tier 1 suppliers, and engine OEMs. At the time this survey was conducted, CARB staff's proposal was still being developed. Consequently, for the survey, manufacturers considered the proposed lengthened useful life and warranty periods shown in Table IX-47, which are greater than those being proposed in this Staff Report. Further, these lengthened useful life and warranty periods were associated with different emission control technologies that would be used for meeting a potential 0.02 g/bhp-hr NOx emission standard regulation beginning in MY 2027 for a California-only population.

Table IX-47. Lengthened Useful Life and Warranty Periods Used In NREL's Report Cost Analysis

	LHDD	MHDD	HHDD	Natural Gas – Otto	Heavy-Duty – Otto
Vehicle GVWR (lbs.)	14,001–19,500	19,501–33,000	>33,000	>33,000	14,000
Lengthened useful life	550,000 miles/ 15 years	550,000 miles/ 15 years	1,000,000 miles/ 15 years	1,000,000 miles/ 15 years	250,000 miles/ 15 years
Warranty period with lengthened useful life	440,000 miles/ 12 years	440,000 miles/ 12 years	800,000 miles/ 12 years	800,000 miles/ 12 years	220,000 miles/ 12 years

The survey responses received for the diesel engine and aftertreatment technology packages included both direct and indirect cost estimates for low, average, and high estimates based on the relative costs for the different technology packages specified. The resulting low, average, and high ranges of estimated indirect incremental warranty cost responses are shown in Table IX-48.

Table IX-48. NREL Report's Cost Analysis Results for Indirect Incremental Warranty Costs (2018$)

Diesel Technology Package	Engine Displacement (liter)	Low Cost Responses	Average Cost Responses	High Cost Responses
Low Cost	6-7	$10,800	$10,800	$10,800
	12-13	$7,840	$23,061	$38,282
Average Cost	6-7	$10,800	$10,800	$10,800
	12-13	$7,840	$23,061	$38,282
High Cost	6-7*	--	--	--
	12-13	$38,621	$38,621	$38,621

* NREL received an insufficient number of responses for this technology package, with respect to indirect costs, to allow sufficient aggregation. Therefore, indirect incremental costs were not calculated.

Overall, the NREL report concluded that the total incremental costs were dominated by the warranty incremental costs, where in some cases, as shown in Table IX-48, the warranty had a high incremental cost estimate over $38,000. The NREL report concluded that these high indirect incremental cost estimates were likely a result of the OEMs' uncertainty regarding warrantying unfamiliar technology out to longer useful life periods indicated in Table IX-47, that go far beyond today's useful life periods. Thus, according to the NREL report, these indirect incremental warranty costs may be interpreted to represent "worst case" due to these uncertainties.

2. Limitations of the Incremental Warranty Costs Estimated from the NREL Survey Warranty Responses

The limitations described below cast doubt on the indirect incremental warranty cost estimates in the NREL survey:

1. The OEMs considered greater lengthened useful life and warranty periods than are currently being proposed, while still needing to meet a lower NOx standard (for example, useful life out to 1,000,000 miles for HHDD vs. the proposed 800,000 miles in the Proposed Amendments). This means that the high estimates for the indirect incremental warranty costs from the NREL report are likely biased high to account for the longer periods.

2. The survey was specifically for a California-only population. In the time since that NREL survey was conducted, U.S. EPA announced their Advanced Notice of Proposed Rulemaking for the Cleaner Truck Initiative Rulemaking (FR, 2020).

This announcement suggests that there will be a national standard, and so the consideration for a California-only population would no longer be appropriate.

3. There were a low number of responses for the survey. The NREL report states that the survey responses were from a few OEMs. Such a small sample size may have resulted in a high level of variation of any results, which would cause it to not be necessarily representative of indirect incremental warranty costs for all OEMs. Thus, these variations would likely introduce significant uncertainties for the resulting incremental indirect warranty cost estimates. As such, NREL attempted to be judicious when aggregating and reporting the results of the data, as demonstrated in Table IX-48 for the high-cost diesel technology package where the incremental warranty costs were not calculated.

4. A major limitation of directly using the incremental warranty costs from the NREL report involves the ambiguity of how OEMs developed the survey responses. For example, the NREL report states that OEMs did not break down the warranty costs into how much was attributed to the longer useful life versus the longer warranty period. Additionally, the report does not reveal what other possible warranty-related considerations were used in the estimate. CARB staff believes that some possible cost considerations could include those needed to cover either one or more replacement of the emissions control systems and aftertreatment systems, to address preventive or corrective actions arising under California's warranty reporting requirements, and for any planned increases to the warranty accruals that are used to bolster the company's warranty reserves.

5. Lastly, it is possible that some OEMs may have strategically inflated their survey responses to make any resulting conclusions less supportive of CARB staff's Proposed Amendments.

3. Sensitivity Analysis Using the Incremental Warranty Costs from the NREL Survey

To better understand the impact if the incremental warranty costs from the NREL report had been used to estimate the indirect incremental indirect warranty costs due to the Proposed Amendments, CARB staff conducted a sensitivity analysis. This sensitivity analysis varied the costs for the warranty-related elements (i.e., lengthened warranty periods and EWIR and corrective action plan amendments) to show how estimates of overall costs and cost-effectiveness for the Proposed Amendments would change if the NREL survey incremental warranty costs were used.

<u>Scaling the Incremental Warranty from the NREL Results</u>

The NREL report's indirect incremental warranty costs that were used for the sensitivity analysis were the average cost for the diesel technology package as shown in Table IX-49 because that technology package is the closest to the engine test configuration that was used in the SwRI tests (see Chapter III, Section A.1. of this Staff Report for further details about the SwRI Low NOx testing program).

Table IX-49. NREL Report's Indirect Incremental Warranty Costs Used in Sensitivity Analysis

Engine Primary Intended Service Class	NREL Report's Useful Life Mileage (miles)	NREL Report's Indirect Incremental Warranty Costs (2018$)
HHDD	1,000,000	$23,061
MHDD	550,000	$10,800
LHDD	550,000	$10,800

CARB staff's primary economic analysis' average useful life miles, shown in Table IX-50, were used to scale the NREL report's indirect incremental warranty costs. These average useful life values were chosen instead of CARB's calculated average warranty miles because the indirect incremental warranty costs from the NREL report did not clearly specify how much of the incremental cost was attributed to the longer useful life versus the longer warranty period. Also, given the close relationship that CARB's EWIR requirements have to the useful life, it is a reasonable approach to use the average useful life miles to calculate the scaled indirect incremental warranty costs from the NREL report.

Table IX-50. CARB's Average Useful Life Miles for Phased-in Proposal

Engine Primary Intended Service Class	Average Useful Life Miles 2027-2030 MY	Average Useful Life Miles 2031-2050 MY
HHDD	406,268	514,278
MHDD	246,124	265,587
LHDD	178,774	251,923
HDO	155,000	200,000

Using CARB staff's phased-in average useful life to scale the indirect incremental warranty costs from the NREL report yielded the values shown in Table IX-51. Note that the HDO category was not included because that category had few responses from the OEMs to the NREL survey. So the NREL report estimated the HDO category's indirect incremental warranty costs as zero dollars.

Table IX-51. Scaled Indirect Incremental Warranty Costs from the NREL Report (2018$)

Engine Primary Intended Service Class	NREL Report's Indirect Incremental Costs 2024-2026 MY[a]	NREL Report's Indirect Incremental Costs 2027-2030 MY	NREL Report's Indirect Incremental Costs 2031-2050 MY
HHDD	N/A	$9,369	$11,860
MHDD	N/A	$4,833	$5,215
LHDD	N/A	$3,510	$4,947

[a] The indirect incremental warranty costs from the NREL report were not scaled for the 2024 MY because engines and vehicles produced in the 2024-2026 MYs would not be subject to the proposed Step 2 warranty and useful life amendments, and so no adjustments were required.

<u>Warranty Repair and EWIR and Corrective Action Costs that Incorporates the NREL Report Results</u>

Because of the limitations outlined in Section F.2 above, CARB staff believes the NREL survey warranty responses likely overstate warranty cost and did not think it was appropriate to use the NREL survey warranty responses directly in the sensitivity analysis. Instead, CARB staff averaged the scaled indirect incremental warranty costs derived from the NREL report with the sum of the CARB warranty and EWIR and corrective action costs determined from CARB staff's primary economic analysis, and used that averaged cost in the sensitivity analysis. These averaged costs are shown in Table IX-52 below.

Table IX-52. Average of CARB Staff's Primary Economic Analysis' Warranty Repair and EWIR and Corrective Action Costs, and the Scaled Indirect Incremental Warranty Costs from the NREL Report (Per Vehicle) (2018$)

Engine Primary Intended Service Class	Avg. Indirect Incremental Cost 2024-2026 MY*	Avg. Indirect Incremental Cost 2027-2030 MY	Avg. Indirect Incremental Cost 2031-2050 MY
HHDD	$504	$5,329	$6,523
MHDD	$618	$3,251	$3,546
LHDD	$0	$2,031	$3,102
HDO**	$94	$361	$516

* NREL report data not available for 2024-2026 MYs, therefore EWIR 2024- 2026 MY costs were used.
**NREL report data not available, therefore CARB staff's primary economic analysis' HDO values were used.

In order to utilize these combined averaged costs to do the sensitivity analysis, they first needed to be separated back into the individual CARB warranty and EWIR and corrective action costs so that the vehicle purchasing financing costs could be applied to the warranty portion. Performing this calculation resulted in the new CARB indirect incremental warranty and indirect incremental EWIR and corrective action costs as shown in Tables IX-53 and IX-54, respectively.

Table IX-53. New CARB Indirect Incremental Warranty Repair Costs with Loan Financing Per Vehicle (2018$)

Engine Primary Intended Service Class	Avg. Indirect Incremental Cost w/ Loan 2024-2026 MY	Avg. Indirect Incremental Cost w/ Loan 2027-2030 MY	Avg. Indirect Incremental Cost w/ Loan 2031-2050 MY
HHDD	N/A	$782	$6,073
MHDD	N/A	$1,522	$3,681
LHDD	N/A	$1,507	$2,701
HDO	N/A	$303	$554

Table IX-54. New CARB Indirect Incremental EWIR and Corrective Action Costs Per Vehicle (2018$)

Engine Primary Intended Service Class	Indirect Incremental Costs 2024-2026 MY	Indirect Incremental Costs 2027-2030 MY	Indirect Incremental Costs 2031-2050 MY
HHDD	$504	$4,671	$1,406
MHDD	$618	$1,969	$445
LHDD	$0	$762	$826
HDO	$94	$106	$49

<u>Warranty Repair and EWIR and Corrective Action Cost Savings that Incorporates the NREL Survey Warranty Responses</u>

CARB staff's primary economic analysis also included a determination of the warranty repair and EWIR and corrective action cost savings. However, in order to determine what these savings values would be when incorporating the NREL report results required using a different approach than what was used in the earlier calculations for the new indirect incremental warranty repair and EWIR and corrective action costs. This need for a different approach was because the NREL report did not include any information that could be used to scale and average the cost savings estimates.

Instead, the approach for determining the new warranty repair and EWIR and corrective action cost savings required using their respective costs and cost savings values from CARB staff's primary economic analysis. Specifically, for each of these proposal elements, the cost savings percentages in relation to the total warranty-related costs from the primary economic analysis (i.e., sum of the warranty repairs and EWIR costs) were calculated, and are shown in Tables IX-55 and IX-56.

Table IX-55. CARB's Primary Economic Analysis Warranty Repair Cost Savings Percentage to Total Warranty and EWIR and Corrective Action Cost Per Vehicle

Engine Primary Intended Service Class	Warranty Repair Savings Percentage of Total Warranty and EWIR and Corrective Action Costs 2024-2026 MY	Warranty Repair Savings Percentage of Total Warranty and EWIR and Corrective Action Costs 2027-2030 MY	Warranty Repair Savings Percentage of Total Warranty and EWIR and Corrective Action Costs 2031-2050 MY
HHDD	0.00%	12.08%	68.41%
MHDD	0.00%	36.72%	75.16%
LHDD	0.00%	55.96%	64.51%
HDO	0.00%	62.44%	77.36%

Table IX-56. CARB's Primary Economic Analysis EWIR and Corrective Action Cost Savings Percentage to Total Warranty and EWIR and Corrective Action Cost Per Vehicle

Engine Primary Intended Service Class	EWIR Savings Percentage of Total Warranty and EWIR Costs 2024-2026 MY	EWIR Savings Percentage of Total Warranty and EWIR Costs 2027-2030 MY	EWIR Savings Percentage of Total Warranty and EWIR Costs 2031-2050 MY
HHDD	11.97%	47.82%	0.00%
MHDD	0.00%	32.11%	0.00%
LHDD	0.00%	0.03%	15.47%
HDO	152.71%	27.59%	19.15%

Next, those cost saving percentages were applied to the new total warranty-related costs in to which the NREL report's indirect incremental warranty costs were already factored (i.e., the new warranty plus the new EWIR and corrective action costs, which are the sum of the corresponding values from Table IX-53 and Table IX-54). Therefore, the new cost savings that factors in the costs from the NREL report for both the warranty repair and EWIR and corrective action cost savings are shown in Tables IX-57 and IX-58, respectively.

Table IX-57. New Average Warranty Repair Cost Savings per Vehicle (2018$)

Engine Primary Intended Service Class	Warranty Repair Cost Savings 2024-2026 MY	Warranty Repair Cost Savings 2027-2030 MY	Warranty Repair Cost Savings 2031-2050 MY
HHDD	$0	$659	$5,116
MHDD	$0	$1,282	$3,101
LHDD	$0	$1,269	$2,276
HDO	$0	$255	$467

Table IX-58. New Average EWIR and Corrective Action Cost Savings per Vehicle (2018$)

Engine Primary Intended Service Class	EWIR and Corrective Action Cost Savings 2024-2026 MY	EWIR and Corrective Action Cost Savings 2027-2030 MY	EWIR and Corrective Action Cost Savings 2031-2050 MY
HHDD	$60	$2,607	$0
MHDD	$0	$1,121	$0
LHDD	$0	$1	$546
HDO	$143	$113	$115

<u>Sensitivity Analysis on the Proposed Amendments Using the New Cost and New Cost Savings</u>

Using both the new per-vehicle costs and cost savings, the overall impact of incorporating the NREL survey's indirect incremental warranty responses on cost of the Proposed Amendments was calculated.

As with CARB staff's primary economic analysis, the calculations for costs and benefits were conducted for the 29 years of the analysis period between 2022 and 2050. The total statewide cost for the Proposed Amendments, and for the new approach that incorporates the NREL report's indirect incremental warranty costs, were estimated to be $4.49, and $6.62 billion, respectively. The estimated total statewide NOx benefit using the EMFAC2017 model was unchanged for this sensitivity analysis, and remained at 352,797 tons of NOx reduced for both approaches.

The cost-effectiveness, which is defined as the cost per unit of NOx reductions, was calculated as $5.45 and $6.88 per pound NOx reduction, respectively, for the Proposed Amendments and the new approach using indirect incremental warranty costs from the NREL report. This represents a 26 percent increase for the cost-effectiveness overall, but which CARB staff considers to still be a reasonable cost-effectiveness when compared to those of recent CARB rulemakings. A summary of the cost, savings, NOx benefits, and cost-effectiveness are presented in Table IX-59.

Table IX-59. Cost, NOx Benefits, and Cost-Effectiveness of the Proposed Amendments and the New Approach Using NREL Report

	Total Cost	Total Savings	Total NOx Benefits [Tons]	Cost-Effectiveness [$/Ton]	Cost-Effectiveness [$/lb]
CARB Staff's Primary Economic Analysis	$4.49 billion	$651 million	352,797	$10,896	$5.45
Estimate Incorporating Incremental Warranty Costs from the NREL Survey	$6.62 billion	$1.77 billion	352,797	$13,755	$6.88

G. Sensitivity Analysis for the Adoption of the Low NOx Optional 50-State-Directed Engine Standards

As described above in Chapter III, Section A.1.1.2, the optional 50-state directed engine standards would provide manufacturers the flexibility to certify their 2024 through 2026 MY engines to a less stringent NOx standard, if they meet that standard for every engine family they produce nationwide. The optional less stringent FTP, RMC-SET, and LLC NOx standards would be set at 0.10, 0.10, and 0.30 g/bhp-hr, respectively. Because the 50-state-directed standards are less stringent, it would be cheaper for manufacturers to comply with them on a per engine basis. Because it is unclear how many, if any, manufacturers would utilize the 50-state-directed option, the primary cost analysis described in this Staff Report assumes no manufacturers participate in the 50-state-directed option.[64] This section provides a sensitivity analysis of the change in costs on a per engine basis, total cost, and the cost-effectiveness of the program if there were 50 percent or 100 percent utilization of the optional 50-state-directed engine standards.

[64] Refer to footnote 37.

1. Technology Costs for a 50-State-Directed Engine

Incremental Engine and Aftertreatment Technology Costs

For diesel engines, the incremental aftertreatment technology costs would be the same as for the primary standards in the Proposed Amendments. However, there would be zero incremental engine technology costs because EGR-cooler bypass technology would not be required to meet the 0.10 FTP and RMC-SET or 0.30 LLC NOx emission standards. A summary of diesel engine technology and cost estimates for the optional 50-state-directed engine standards is presented in Table IX-60, which can be compared to the cost for the primary cost analysis shown in Table IX-4 above. As shown, the technology costs for the 50-state-directed option would be $243 and $302 lower for 6/7-liter and 12/13-liter diesel engines, respectively. CARB staff assumed costs associated with Otto-cycle engines meeting the optional 50-state-directed engine standards would be minimal because some Otto-cycle engines already certify to optional standards as low or lower than the proposed 50-state-directed standards.

Table IX-60. Summary of Technologies and Adjusted Incremental Costs (2018$) for Meeting the 2024 to 2026 Optional 50-State-Directed Engine Standards Based on NREL Survey

		6/7-Liter Diesel	12/13-Liter Diesel
Applicable MYs		**2024-2026**	**2024-2026**
Engine Technology[a]	EGR Cooler Bypass	na	na
	Cylinder Deactivation	na	na
	Other	na	na
Aftertreatment Technology[a]	Light-off SCR	na	na
	DOC (subtotal)	$10	$89
	DPF (2018 baseline system only)[b]	-$17	-$44
	SCR + ASC + DEF Dosing (subtotal)	$621	$784
	OBD sensors and controllers (NOx, Ammonia, temp sensors)	$333	$330
	Other*	$175	$150
Total Incremental Hardware Cost to Manufacturer		**$1,122**	**$1,309**
Incremental Research and Development Costs to Manufacturer[c]		**$85**	**$354**
Incremental Cost to Simultaneously Meet Phase 2 GHG Standards[d]		**$100**	**$501**
Total Incremental Cost		**$1,307**	**$2,164**

[a] Values are only shown for technologies applicable to that application.
[b] Values in parentheses represent savings compared to the baseline 2018 technology and costs.
[c] Note that the research and development costs in Table IX-60 were estimated by NREL based on original equipment manufacturer shareholder reports and adjusted by CARB staff to fit the Proposed Amendments. They are intended to represent fixed research and development costs distributed on a per engine basis, based on the population of engines expected to be subject to the Proposed Amendments in the legal baseline.
[d] Incremental cost to meet Phase 2 GHG emission standards was derived using U.S. EPA's cost estimate for the federal Phase 2 GHG Regulation.

2. DEF Consumption Costs

Because the Proposed Amendments would require SCR systems to operate during more of vehicles' actual operating hours than today's engines, for example, even during low load conditions, the optional 50-state-directed engine standards would require the consumption of more DEF. Because the optional 50-state-directed engine standards would be less stringent than the MY 2024-2026 standards in the Proposed Amendments, this increased DEF consumption would be less than for the Proposed Amendments, as summarized in Table IX-61.

Table IX-61. Incremental Annual DEF Consumption Costs by Engine Class (2018$ per engine)

Engine Class	Proposed Amendments Primary Cost Analysis: MY 2024-2026	Optional 50-State-Directed: MY 2024-2026
HHDD	$89.84	$59.89
MHDD	$36.97	$24.65
LHDD	$36.63	$24.42
MDDE-3	$19.61	$13.07
MDOE-3	$0.00	$0.00
HDO	$0.00	$0.00

3. Sensitivity Cost Analysis of Full Adoption of the Optional 50-State-Directed Engine Standards

The cost and cost-effectiveness of the Proposed Amendments with 0, 50, and 100 percent utilization of the optional 50-state-directed engine standards is presented in Table IX-62 below. As shown in Table IX-62, because the total program costs are dominated by the cost in meeting the 2027 standards, the utilization of the optional 50-state-directed engine standards makes a relatively small difference in overall cost of the Proposed Amendments. For example, 50 percent utilization of the optional 50-state-directed engine standards would decrease the total costs from 2022 through 2050 calendar years by only $17 million dollars when compared to the primary standards in the Proposed Amendments, while full utilization of the optional 50-state-directed engine standards would decrease the total costs from 2022 through 2050 calendar years by $35 million. Because the optional 50-state-directed engine standards would increase emission benefits while at the same time reducing cost, their impact on cost-effectiveness is greater, reducing the overall cost in dollars per pound of NOx reduced from $5.45 to $4.95, which is 9 percent more cost-effective, if all manufacturers used the optional 50-state-directed engine standards.

Table IX-62. Summary of Cost-Effectiveness for the Proposed Amendments with Various Levels of Utilization of the 50-State-Directed Option

Percent of Manufacturers Using 50-State-Directed Option	Total Cost of the Regulation	Total Savings of the Regulation	Total NOx Benefits [Tons]	Cost-Effectiveness $/Ton	Cost-Effectiveness $/lb
Proposed Amendments (0% of Mfrs)	$4,494,764,136	$650,574,767	352,797	$10,896	$5.45
(50% of Mfrs)	$4,477,271,875	$650,574,767	368,841	$10,375	$5.19
(100% of Mfrs)	$4,459,779,614	$650,574,767	384,886	$9,897	$4.95

The actual cost impact on fleets would depend on the number of new California-certified heavy-duty vehicles that fleets would purchase during the lifetime of this cost analysis. A lifetime analysis including initial purchase price increase, lifetime DEF consumption, lifetime savings from warranty and EWIR amendments, net lifetime cost impact, and percent increase in lifetime cost from the assumed purchase price is presented in Table IX-63 for vehicle purchases with 2024 through 2026 MY engines utilizing the optional 50-state-directed engine standards for each vehicle class. This lifetime analysis for the 50-state-directed option can be compared to Table IX-34 for the primary cost analysis, which shows a 2.6 percent increase in purchase price for 2024 through 2026 MY engines.

Table IX-63. Lifetime Analysis for Vehicles with 2024 to 2026 MY Engines with the Optional 50-State-Directed Engine Standards

	Increase in Purchase Price	Lifetime DEF Cost	Lifetime Savings	Lifetime Net Impact	Assumed Baseline Purchase Price	Net Costs as % of Purchase Price
HHDD	$3,459	$599	$60	$3,998	$169,637	2.4%
MHDD	$2,226	$246	$0	$2,472	$103,165	2.4%
LHDD	$1,444	$244	$0	$1,688	$57,694	2.9%
HDO	$96	$0	$143	-$48	$94,089	-0.1%
MDDE-3	$1,311	$131	$0	$1,442	$52,040	2.8%
MDOE-3	$2	$0	$0	$2	$44,459	0.0%
Population Average	$2,075	$303	$34	$2,345	$107,782	2.2%

X. EVALUATION OF REGULATORY ALTERNATIVES

Government Code section 11346.2, subdivision (b)(4) requires CARB to consider and evaluate reasonable alternatives to the proposed regulatory action and provide reasons for rejecting those alternatives. As required by Health and Safety Code section 57005 and Government Code section 11346.2, CARB staff evaluated alternatives submitted to CARB and considered whether there is a less costly alternative or combination of alternatives that would be equally as effective in achieving increments of environmental protection in full compliance with statutory mandates within the same amount of time as the proposed regulatory amendments. This chapter discusses alternatives evaluated and provides reasons why these alternatives were not included in the proposal. As explained below, no alternative proposed was found to be less burdensome and equally effective in achieving the purposes of the regulation in a manner than ensures full compliance with the authorizing law. The Board has not identified any reasonable alternatives that would lessen any adverse impact on small business.

Government Code sections 11346.2(b)(4)(A) and section 11346.2(b)(1) contain requirements for proposed regulations that would mandate the use of specific technologies or equipment. However, because the Proposed Amendments are performance based and do not mandate the use of specific technologies or equipment, these Government Code requirements are not applicable.

A. Alternative 1: Accelerated Timeline

Alternative 1 was proposed by the South Coast Air Quality Management District (SCAQMD) in their letter to CARB staff on May 24, 2019, titled “Comments for Staff White Paper – California Air Resources Board Staff Current Assessment of the Technical Feasibility of Lower NOx Standards and Associated Test Procedures for 2022 and Subsequent MY Medium-Duty and Heavy-Duty Diesel Engine” (SCAQMD, 2019). Under this alternative, the same elements for the Proposed Amendments would be implemented on an earlier timeline than the scheduled outlined in CARB staff’s proposal.

This alternative would move the revised NOx standards for the FTP, RMC-SET, Clean Idle, PM standards, and new LLC, as well as initial implementation of new in-use procedures with the MAW two years earlier than the Proposed Amendments, from 2024 to 2022 MY engines. The amendments to the standards on the FTP, RMC-SET, and LLC and the in-use amendments in 2027 would also be accelerated to 2024. A summary of the accelerated timeline for this alternative is provided in Table X-1. Alternative 1 would result in a quicker transition to the sale of low NOx engines in the State of California and a faster achievement of emission reductions.

Table X-1. Summary and Timeline of Alternative 1, SCAQMD Alternative

	Standards, Test Procedures, and Elements	Units	Baseline (B)	MY 2022	MY 2024	MY 2027	MY 2031
1)	FTP/RMC-SET	g/bhp-hr NOx	0.2	0.050	0.020	0.020	0.020
2)	LLC	g/bhp-hr NOx	---	0.20	0.040	0.040	0.040
3)	Idling	g/hr NOx	30	10	5	5	5
4)	HDIUT						
	Method		Current NTE	Binned MAW	Binned MAW w/ Cold Start	Binned MAW w/ Cold Start	Binned MAW w/ Cold Start
	In-Use Threshold	g/bhp-hr NOx	0.45	1.5x Standards	1.5x Standards	1.5x Standards	1.5x Standards
5)	DDP		(35-50)% × UL	Baseline	100% UL aging	100% UL aging	100% UL aging
6)	UL (HHD/MHD/LHD/HDO)	10^3×miles	435/185/110/110	Baseline	Baseline	600/270/190/155	800/350/270/200
7)	Warranty (HHD/MHD/LHD/HDO)	10^3×miles	350/150/110/50	Baseline	Baseline	450/220/150/110	600/280/210/160
8)	EWIR	---	EWIR	Baseline	Mod EWIR	Mod EWIR	Mod EWIR

FTP/RMC-SET = Current and proposed NOx standards certified under the heavy-duty transient Federal Test Procedure and the Ramped Modal Cycle of the supplemental emissions test.
LLC = Proposed NOx standards certified under the Low Load Cycle.
Idling = Current and proposed NOx standards certified under the supplemental idling test procedure.
HDIUT Method = Current and proposed Heavy-Duty In-Use Test Methods.
HDIUT In-Use Threshold = Current and proposed NOx standards using the HDIUT Methods.
DDP = Current and proposed modifications to the Durability Demonstration Program.
UL = Current and proposed useful life periods for heavy-duty diesel- and Otto-cycle engines/vehicles.
Warranty = Current and proposed warranty period for heavy-duty diesel- and Otto-cycle engines/vehicles.
EWIR = Current and proposed modifications to the Emissions Warranty Information and Reporting Program and Corrective Actions.

1. Costs

The total costs of Alternative 1 were assessed using the same baseline conditions used for the Proposed Amendments. The annual costs for the elements of Alternative 1 are presented in Table X-2. The overall cost of Alternative 1 is approximately $4.74 billion over the 29 years of the analysis period, 2022 through 2050. Thus, the cost of this alternative is estimated at $250 million more than the Proposed Amendments ($4.49 billion), a 5.56 percent increase in cost during the period of analysis.

Table X-2. Annual Summary of Costs Associated with Alternative 1 (2018$)

Calendar Year	Standards, Certification, and New Technology	Annual DEF Consumption	In-Use Amendments	Lengthened Warranty	Durability Demonstration	EWIR Amendments	ABT	Total Costs
2022	$1,789,577	$4,377	$132,624	$0	$0	$0	$217,000	$2,143,577
2023	$43,649,446	$1,230,638	$56,957	$0	$8,612,420	$0	$43,400	$53,592,861
2024	$43,692,958	$2,432,885	$57,078	$0	$850,000	$328,320	$43,400	$47,404,642
2025	$90,786,372	$3,939,839	$59,481	$0	$140,810	$10,237,296	$43,400	$105,207,197
2026	$91,816,698	$5,469,792	$60,198	$0	$11,511,176	$10,336,778	$43,400	$119,238,042
2027	$80,045,679	$7,035,917	$61,678	$1,069,205	$869,431	$10,641,299	$43,400	$99,766,610
2028	$109,539,586	$8,622,186	$62,336	$13,611,269	$754,981	$21,017,003	$43,400	$153,650,761
2029	$111,797,840	$10,244,132	$63,714	$13,904,492	$1,137,957	$21,502,340	$43,400	$158,693,874
2030	$96,736,169	$11,892,921	$64,657	$14,068,992	$13,545,139	$21,825,015	$43,400	$158,176,292
2031	$96,282,989	$13,565,016	$65,544	$15,163,761	$1,707,090	$21,921,155	$43,400	$148,748,956
2032	$134,783,615	$15,280,264	$67,378	$41,448,718	$2,001,917	$7,445,446	$43,400	$201,070,738
2033	$137,481,896	$15,812,480	$68,759	$42,228,382	$2,041,017	$7,596,388	$43,400	$205,272,322
2034	$121,521,857	$16,427,830	$71,025	$43,577,031	$2,085,403	$7,841,967	$43,400	$191,568,513
2035	$121,265,142	$16,772,402	$72,362	$44,373,973	$2,131,965	$7,983,740	$43,400	$192,642,983
2036	$119,537,729	$17,105,293	$72,778	$44,638,032	$2,175,676	$8,035,462	$43,400	$191,608,370
2037	$118,057,423	$17,415,968	$73,351	$45,005,620	$2,211,745	$8,098,670	$43,400	$190,906,177
2038	$116,470,502	$19,300,350	$73,792	$45,244,815	$2,242,112	$8,152,780	$43,400	$191,527,752
2039	$115,117,319	$19,920,738	$74,373	$45,595,209	$2,262,263	$8,212,366	$43,400	$191,225,667
2040	$114,501,103	$20,226,153	$74,900	$45,882,018	$2,277,510	$8,268,410	$43,400	$191,273,494
2041	$113,726,998	$20,516,054	$75,347	$46,139,454	$2,292,944	$8,322,800	$43,400	$191,116,997
2042	$113,194,894	$20,797,440	$75,954	$46,505,442	$2,308,595	$8,390,443	$43,400	$191,316,168
2043	$112,594,172	$22,440,736	$76,498	$46,819,567	$2,324,872	$8,452,813	$43,400	$192,752,059
2044	$112,202,975	$23,028,468	$77,180	$47,223,532	$2,341,762	$8,526,676	$43,400	$193,443,993
2045	$112,437,873	$23,601,250	$77,817	$47,605,191	$2,359,323	$8,596,601	$43,400	$194,721,455
2046	$112,674,805	$24,142,753	$78,451	$47,977,842	$2,378,024	$8,666,507	$43,400	$195,961,781
2047	$112,834,056	$24,348,447	$79,048	$48,336,754	$2,396,662	$8,733,137	$43,400	$196,771,505
2048	$113,036,856	$24,554,099	$79,688	$48,730,929	$2,415,887	$8,803,268	$43,400	$197,664,128
2049	$113,193,816	$24,753,806	$80,268	$49,065,347	$2,434,502	$8,863,687	$43,400	$198,434,827
2050	$113,193,816	$24,936,098	$80,268	$49,065,347	$2,449,278	$8,863,687	$43,400	$198,631,895
Total	**$2,993,964,163**	**$455,818,331**	**$2,113,504**	**$933,280,923**	**$82,260,462**	**$275,664,054**	**$1,432,200**	**$4,744,533,637**

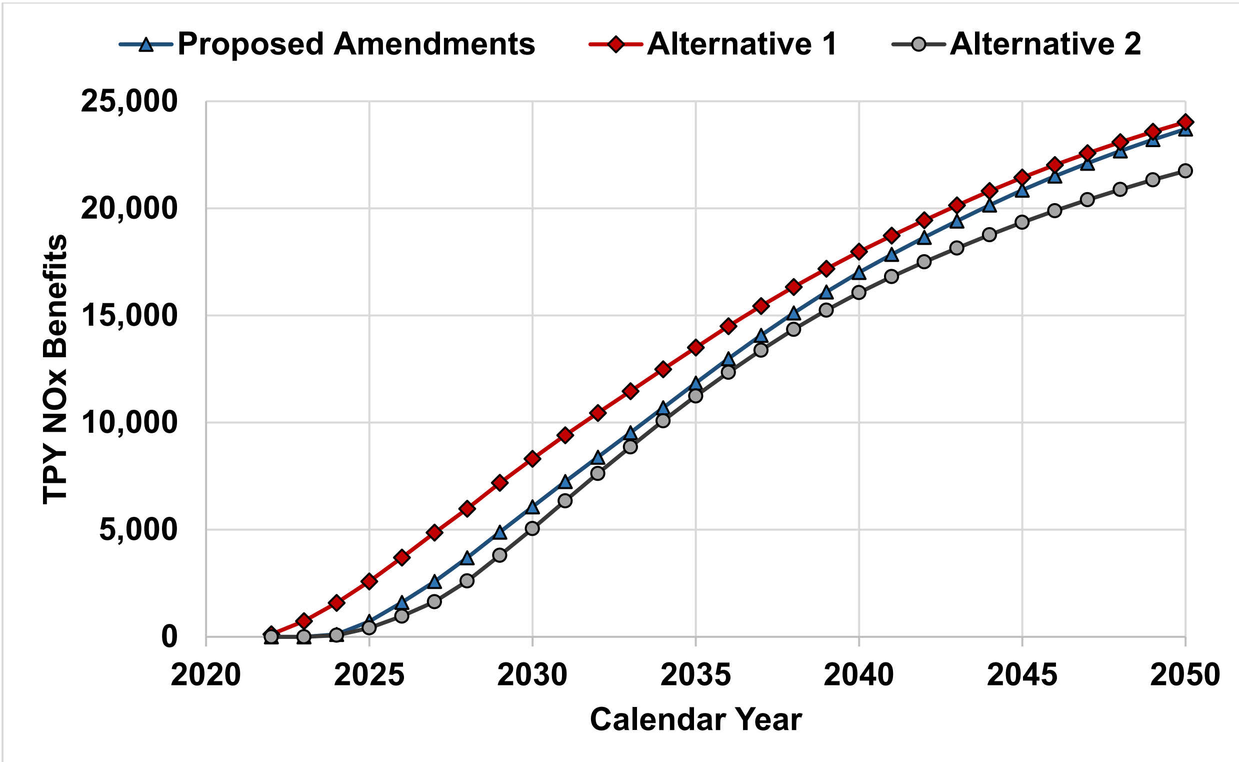
2. Benefits

The benefits for Alternative 1 with respect to the baseline are presented in Table X-3. Figures X-1 and X-2 show the benefits expected from Alternative 1 compared to those for the Proposed Amendments and for Alternative 2. The estimated total NOx benefit of Alternative 1 is estimated to be 389,127 tons of NOx over the 29 years compared to the baseline. The accelerated implementation schedule of Alternative 1 would provide additional NOx benefits compared to the Proposed Amendments. The tons per year benefits of the Proposed Amendments and both alternatives are plotted in Figure X-1 for calendar years 2022 through 2050.

Table X-3. NOx Benefits with Alternative 1

Calendar Year	NOx Tons Per Year Benefits
2022	114
2023	718
2024	1,564
2025	2,560
2026	3,672
2027	4,833
2028	5,953
2029	7,159
2030	8,282
2031	9,382
2032	10,418
2033	11,437
2034	12,463
2035	13,478
2036	14,475
2037	15,421
2038	16,311
2039	17,160
2040	17,963
2041	18,712
2042	19,431
2043	20,126
2044	20,799
2045	21,431
2046	22,019
2047	22,567
2048	23,085
2049	23,572
2050	24,022
Total	**389,127**

Figure X-1. Annual Benefits in Tons Per Year: Proposed Amendments vs. Alternatives 1 and 2 (Versus Legal Baseline)



The health benefits resulting from Alternative 1 are presented in Table X-4. Alternative 1 was modeled to avoid 4,272 cases of premature mortality, which is about 10 percent more than the Proposed Amendments. It was estimated that a total of $40.3 billion in monetized health benefits from avoided mortality, hospitalizations, and emergency room visits would result from Alternative 1. Table X-5 indicates the change in economic indicators modeled due to Alternative 1 relative to the baseline; the impacts on economic indicators under Alternative 1 would be larger than for both the Proposed Amendments and for Alternative 2.

Table X-4. Valuation of Statewide Health Benefits for Alternative 1

Outcome	Avoided Incidents	Valuation
Avoided Premature Mortality	4,272	$40.2 billion
Avoided Cardiovascular Hospitalizations	672	$38.0 million
Avoided Acute Respiratory Hospitalizations	802	$39.6 million
Avoided Emergency Room Visits	1,980	$1.60 million
Total	**7,726**	**$40.3 billion**

Note: Total valuation has been rounded.

Table X-5. Change in Economic Indicators for Alternative 1 Relative to Baseline

Summary of Macroeconomic Impacts of Alternative 1										
	GSP		Personal Income		Employment		Output		Private Investment	
Calendar Year	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change	Total California Employment	% Change	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change
2022	2,531,247	0.00%	2,973,284	0.00%	24,692,632	0.00%	4,124,010	0.00%	358,145	0.00%
2023	2,571,301	0.00%	3,091,654	0.00%	24,884,370	0.00%	4,188,145	0.00%	365,110	0.00%
2024	2,614,361	0.00%	3,213,670	0.00%	25,075,743	0.00%	4,256,458	0.00%	370,890	0.00%
2025	2,660,005	-0.01%	3,358,408	-0.01%	25,264,816	-0.01%	4,327,792	-0.01%	376,050	-0.01%
2026	2,704,282	-0.01%	3,500,771	-0.01%	25,453,531	-0.01%	4,395,697	-0.01%	380,435	-0.01%
2027	2,752,863	-0.01%	3,651,242	-0.01%	25,643,083	-0.01%	4,471,445	-0.01%	384,589	-0.02%
2028	2,801,993	-0.01%	3,822,281	-0.01%	25,831,117	-0.01%	4,548,960	-0.01%	388,880	-0.02%
2029	2,852,678	-0.01%	3,977,249	-0.01%	26,017,649	-0.01%	4,630,519	-0.01%	392,841	-0.02%
2030	2,904,613	-0.01%	4,139,494	-0.01%	26,203,705	-0.01%	4,715,861	-0.01%	398,269	-0.02%
2031	2,958,059	-0.01%	4,308,975	-0.01%	26,388,979	-0.01%	4,805,750	-0.01%	404,601	-0.02%
2032	3,012,774	-0.01%	4,486,261	-0.01%	26,571,765	-0.01%	4,900,235	-0.01%	411,656	-0.02%
2033	3,068,827	-0.01%	4,671,643	-0.01%	26,751,610	-0.01%	4,999,726	-0.01%	419,212	-0.02%
2034	3,126,215	-0.01%	4,865,700	-0.01%	26,928,561	-0.01%	5,104,535	-0.01%	426,855	-0.01%
2035	3,185,366	-0.01%	5,069,030	-0.01%	27,103,684	-0.01%	5,215,688	-0.01%	434,640	-0.01%
2036	3,245,646	-0.01%	5,279,425	-0.01%	27,272,639	-0.01%	5,332,560	-0.01%	442,650	-0.01%
2037	3,307,441	-0.01%	5,499,473	-0.01%	27,439,305	-0.01%	5,452,697	-0.01%	450,965	-0.01%
2038	3,370,499	-0.01%	5,729,733	-0.01%	27,602,655	-0.01%	5,575,707	-0.01%	459,174	-0.01%
2039	3,434,925	-0.01%	5,970,131	-0.01%	27,762,606	-0.01%	5,701,788	-0.01%	467,357	-0.01%
2040	3,500,529	-0.01%	6,220,231	-0.01%	27,918,540	-0.01%	5,830,680	-0.01%	475,510	-0.01%
2041	3,567,324	-0.01%	6,480,439	-0.01%	28,070,408	-0.01%	5,962,450	-0.01%	483,739	-0.01%
2042	3,635,441	-0.01%	6,750,580	-0.01%	28,219,855	-0.01%	6,097,348	-0.01%	491,941	-0.01%
2043	3,704,695	-0.01%	7,031,815	-0.01%	28,365,713	-0.01%	6,235,127	-0.01%	500,105	-0.01%
2044	3,774,727	-0.01%	7,323,297	-0.01%	28,506,236	-0.01%	6,375,237	-0.01%	508,117	-0.01%
2045	3,845,930	-0.01%	7,626,631	-0.01%	28,644,122	-0.01%	6,518,349	-0.01%	516,077	-0.01%
2046	3,918,261	-0.01%	7,942,238	-0.01%	28,779,099	-0.01%	6,664,434	-0.01%	523,992	-0.01%
2047	3,991,704	-0.01%	8,269,582	-0.01%	28,910,729	-0.01%	6,813,521	-0.01%	531,966	-0.01%
2048	4,066,286	-0.01%	8,609,559	-0.01%	29,039,308	-0.01%	6,965,694	-0.01%	539,996	-0.01%
2049	4,142,016	-0.01%	8,962,203	-0.01%	29,165,435	-0.01%	7,121,016	-0.01%	548,077	-0.01%
2050	4,218,502	-0.01%	9,323,633	-0.01%	29,286,689	-0.01%	7,278,861	-0.01%	556,217	-0.01%

Note: The macroeconomic indicator percent changes shown in this table can be compared to those for the Proposed Amendments, which are shown in Table IX-40.

3. Economic Impacts

Alternative 1 would impose the same standards but on an accelerated schedule compared to the Proposed Amendments. The accelerated schedule of producing low NOx engines early, compared to the Proposed Amendments, would increase the total number of low NOx engines to be sold in the 2022 through 2050 time period. This would result in an overall increase of 5.56 percent in cost over the time period of analysis compared to the Proposed Amendments. This cost increase compared to the Proposed Amendments is mainly due to the accelerated timeframe. Table X-5 shows the impact on select macroeconomic indicators in the economy. The analysis of Alternative 1 shows that the major macroeconomic indicators would decrease versus the baseline from 2022 to 2050. The major macroeconomic indicators show a greater decrease by Alternative 1 compared with Alternative 2's results during the period of analysis. Overall, Alternative 1 would have greater impacts to the Californian economy than the impacts of Alternative 2 and the Proposed Amendments.

4. Reason for Rejecting

Alternative 1 would achieve greater NOx reductions sooner and have higher costs in earlier years. The cost-effectiveness of Alternative 1 would be $5.26 per pound of NOx reduced, slightly more cost-effective compared to the Proposed Amendments at $5.45 per pound of NOx reduced over the course of the regulation. However, the accelerated schedule of Alternative 1 would not provide enough lead time for the development of the interim engines in 2022 and the low NOx engines in 2024. Without sufficient time for engine manufacturers to conduct research, development, and durability testing, products will not be able to meet the stringent criteria. Manufacturers have identified that five to six years of lead time would be required for full product development from proof of concept to production product. The Proposed Amendments provide manufacturers with necessary lead time for engineering development for the changes required in 2024 (CARB, 2019c) and the more significant changes needed in 2027 (i.e., cylinder deactivation and light-off SCR). Because Alternative 1 did not provide the necessary lead time for engineering development, it was rejected.

B. Alternative 2: Voluntary National Program

Under Alternative 2, engine manufacturers would volunteer to nationally certify to a NOx standard that would be less stringent than the standard in the Proposed Amendments. Alternative 2 would be less stringent and achieve less emission reductions than the Proposed Amendments and Alternative 1. Alternative 2 is based on input received during an online workgroup meeting held in June 2019. Timothy French of EMA submitted a nationwide program alternative (EMA, 2019a). Under Alternative 2, California would not only benefit from cleaner California-certified engines than today but would also benefit from cleaner out-of-state vehicles that operate in California.

Under this alternative, the national NOx emission standard would be 0.15 g/bhp-hr on the FTP and the RMC-SET cycle, an in-use HDIUT threshold of 0.22 g/bhp-hr, and adoption of the LLC at 0.7 g/bhp-hr for 2024 to 2026 MY engines. EMA's proposal also stated an approximate 50 percent reduction in the real-world in-use NOx standard for 2027 and subsequent MYs. CARB staff interpreted this statement to correspond to a reduction of the standards on the FTP, RMC-SET, and in-use HDIUT threshold by half of the current emission rates for 2027 and subsequent MY engines. A summary of Alternative 2 is presented in Table X-6.

Table X-6. Summary and Timeline of Alternative 2, EMA Alternative

	Standards, Test Procedures, and Elements	Units	Baseline (B)	MY 2024	MY 2027
1)	FTP/RMC-SET	g/bhp-hr NOx	0.20	0.15	0.10
2)	LLC	g/bhp-hr NOx	---	0.70	0.70
3)	Idling	g/hr NOx	30	Baseline	Baseline
4)	HDIUT				
	Method		Current NTE	EMA modified NTE	EMA modified NTE
	In-Use Threshold	g/bhp-hr NOx	0.45	0.22	0.22
5)	DDP		(35-50)% × UL	Baseline	Baseline
6)	UL (HHD/MHD/LHD/HDO)	10^3×miles	435/185/110/110	Baseline	Baseline
7)	Warranty (HHD/MHD/LHD/HDO)	10^3×miles	350/150/110/50	Baseline	Baseline
8)	EWIR	---	EWIR	Baseline	Baseline

FTP/RMC-SET = Current and proposed NOx standards certified under the heavy-duty transient Federal Test Procedure and the Ramped Modal Cycle of the supplemental emissions test.
LLC = Proposed NOx standards certified under the Low Load Cycle.
Idling = NOx standards certified under the supplemental idling test procedure.
HDIUT Method = Current and proposed Heavy-Duty In-Use Test Methods.
HDIUT In-Use Threshold = Current and proposed NOx standards using the HDIUT Methods.
DDP = Durability Demonstration Program.
UL = Useful life periods for heavy-duty diesel- and Otto-cycle engines/vehicles.
Warranty = Warranty periods for heavy-duty diesel- and Otto-cycle engines/vehicles.
EWIR = Emissions Warranty Information and Reporting Program and Corrective Actions.

1. Costs

The total costs of Alternative 2 were assessed using the same baseline conditions used for the Proposed Amendments. The annual costs for the elements of Alternative 2 are presented in Table X-7. The overall cost of Alternative 2 is approximately $900 million over the 29 years of the analysis period, 2022 through 2050. Thus, the cost of this alternative is estimated at $3.59 billion less than the Proposed Amendments ($4.49 billion), about 80 percent less in cost in the period of analysis.

Table X-7. Annual Summary of Costs Associated with Alternative 2 (2018$)

Calendar Year	Standards, Certification, and New Technology	Annual DEF Consumption	Total Costs
2022	$0	$0	$0
2023	$0	$0	$0
2024	$20,088	$1,545	$21,633
2025	$3,941,570	$420,143	$4,361,713
2026	$4,008,132	$845,130	$4,853,263
2027	$4,353,185	$1,281,636	$5,634,820
2028	$33,840,077	$2,162,896	$36,002,973
2029	$34,546,979	$3,063,977	$37,610,956
2030	$29,702,274	$3,979,971	$33,682,246
2031	$29,455,548	$4,908,913	$34,364,461
2032	$29,627,069	$5,864,260	$35,491,329
2033	$29,606,469	$6,841,192	$36,447,661
2034	$29,937,065	$7,849,423	$37,786,488
2035	$29,855,919	$8,459,450	$38,315,369
2036	$29,612,892	$9,069,376	$38,682,268
2037	$29,427,955	$9,675,538	$39,103,493
2038	$29,207,663	$9,844,221	$39,051,884
2039	$29,038,930	$10,001,759	$39,040,689
2040	$28,862,853	$10,153,279	$39,016,133
2041	$28,842,124	$10,298,525	$39,140,648
2042	$28,880,753	$10,426,204	$39,306,957
2043	$28,898,479	$10,540,653	$39,439,132
2044	$28,966,883	$10,632,570	$39,599,453
2045	$29,015,942	$10,715,051	$39,730,993
2046	$29,258,239	$10,800,873	$40,059,113
2047	$29,481,631	$10,887,552	$40,369,183
2048	$29,717,967	$10,975,872	$40,693,839
2049	$29,940,915	$11,064,447	$41,005,361
2050	$29,940,915	$11,144,126	$41,085,041
Total	**$697,988,516**	**$201,908,583**	**$899,897,099**

2. Benefits

The total NOx benefit for Alternative 2 is estimated to be 324,922 tons over the 29 years of analysis and is presented in Table X-8. Implementation would begin in 2024, with both new California and out-of-state engines contributing to the NOx reduction benefits. In 2027, the FTP and RMC-SET standard would be further reduced to 0.1 g/bhp-hr NOx. As shown in Figure X-1 above, Alternative 2 would achieve less benefits each year than the Proposed Amendments when considering benefits versus the legal baseline.

Table X-8. NOx Benefits with Alternative 2

Calendar Year	NOx Tons Per Year Benefits
2022	0
2023	0
2024	74
2025	416
2026	965
2027	1,639
2028	2,606
2029	3,805
2030	5,051
2031	6,345
2032	7,624
2033	8,867
2034	10,085
2035	11,243
2036	12,343
2037	13,381
2038	14,351
2039	15,249
2040	16,067
2041	16,812
2042	17,499
2043	18,145
2044	18,764
2045	19,346
2046	19,890
2047	20,400
2048	20,880
2049	21,330
2050	21,746
Total	**324,922**

The statewide health benefits of Alternative 2 are presented in Table X-9. A total of 3,592 cases of avoided premature mortality were estimated between 2022 and 2050. It was estimated that a total of $33.9 billion in monetized health benefits from avoided mortality, hospitalizations, and emergency room visits would result from Alternative 2. Table X-10 indicates the change in economic indicators for Alternative 2 relative to the baseline. Alternative 2 is modeled to have about 7.8 percent less health benefits than the Proposed Amendments, and because it is not clear whether all, or indeed any engine manufacturers would follow through with utilizing this Alternative, these modeled benefits are arguably speculative.

Table X-9. Valuation of Statewide Health Benefits for Alternative 2

Outcome	Avoided Incidents	Valuation (2018$)
Avoided Premature Mortality	3,592	$33.8 billion
Avoided Cardiovascular Hospitalizations	569	$32.2 million
Avoided Acute Respiratory Hospitalizations	679	$33.5 million
Avoided Emergency Room Visits	1,660	$1.3million
Total	**6,500**	**$33.9 billion**

Note: Total valuation has been rounded. This table assumes Alternative 2 could be fully enforced, which is doubtful, as discussed below, because it involves engines certified and sold outside California.

Table X-10. Change in Economic Indicators for Alternative 2 Relative to Baseline

Summary of Macroeconomic Impacts of Alternative 2										
	GSP		Personal Income		Employment		Output		Private Investment	
Calendar Year	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change	Total California Employment	% Change	Total Value (2018M$)	% Change	Total Value (2018M$)	% Change
2022	2,531,250.89	0.00%	2,973,287.06	0.00%	24,692,674	0.00%	4,124,016.60	0.00%	370,890.61	0.00%
2023	2,571,402.36	0.00%	3,091,747.41	0.00%	24,885,545	0.00%	4,188,317.40	0.00%	376,077.60	0.00%
2024	2,614,455.79	0.00%	3,213,768.06	0.00%	25,076,813	0.00%	4,256,619.99	0.00%	380,468.61	0.00%
2025	2,660,206.29	0.00%	3,358,614.31	0.00%	25,267,060	0.00%	4,328,134.68	0.00%	384,650.91	0.00%
2026	2,704,514.11	0.00%	3,501,026.65	0.00%	25,456,082	0.00%	4,396,093.32	0.00%	388,954.62	0.00%
2027	2,753,061.63	0.00%	3,651,481.07	0.00%	25,645,212	0.00%	4,471,785.47	0.00%	392,906.98	0.00%
2028	2,802,197.31	0.00%	3,822,533.05	0.00%	25,833,235	0.00%	4,549,312.15	0.00%	398,330.49	0.00%
2029	2,852,885.66	0.00%	3,977,513.58	0.00%	26,019,765	0.00%	4,630,876.22	0.00%	404,658.36	-0.01%
2030	2,904,823.90	0.00%	4,139,771.19	0.00%	26,205,825	0.00%	4,716,225.15	0.00%	411,708.31	-0.01%
2031	2,958,247.26	0.00%	4,309,236.75	0.00%	26,390,829	0.00%	4,806,076.38	0.00%	419,255.04	-0.01%
2032	3,012,977.48	0.00%	4,486,537.05	0.00%	26,573,659	0.00%	4,900,589.88	0.00%	426,897.87	0.00%
2033	3,069,038.11	0.00%	4,671,935.32	0.00%	26,753,543	0.00%	5,000,096.06	0.00%	434,683.53	0.00%
2034	3,126,399.09	0.00%	4,865,967.52	0.00%	26,930,172	0.00%	5,104,859.40	0.00%	442,684.80	0.00%
2035	3,185,529.54	0.00%	5,069,278.99	0.00%	27,105,067	0.00%	5,215,977.47	0.00%	450,992.08	0.00%
2036	3,245,806.28	0.00%	5,279,671.18	0.00%	27,273,957	0.00%	5,332,844.44	0.00%	459,196.49	0.00%
2037	3,307,597.47	0.00%	5,499,718.66	0.00%	27,440,567	0.00%	5,452,976.36	0.00%	467,376.36	0.00%
2038	3,370,656.90	0.00%	5,729,984.39	0.00%	27,603,909	0.00%	5,575,989.81	0.00%	475,528.66	0.00%
2039	3,435,103.91	0.00%	5,970,412.34	0.00%	27,764,022	0.00%	5,702,107.65	0.00%	483,762.11	0.00%
2040	3,500,709.79	0.00%	6,220,522.60	0.00%	27,919,951	0.00%	5,831,005.03	0.00%	491,966.81	0.00%
2041	3,567,505.41	0.00%	6,480,738.95	0.00%	28,071,795	0.00%	5,962,777.43	0.00%	500,130.78	0.00%
2042	3,635,621.88	0.00%	6,750,886.56	0.00%	28,221,204	0.00%	6,097,675.30	0.00%	508,142.82	0.00%
2043	3,704,878.00	0.00%	7,032,130.78	0.00%	28,367,050	0.00%	6,235,457.88	0.00%	516,103.63	0.00%
2044	3,774,909.10	0.00%	7,323,618.95	0.00%	28,507,542	0.00%	6,375,567.73	0.00%	524,018.30	0.00%
2045	3,846,112.36	0.00%	7,626,960.73	0.00%	28,645,408	0.00%	6,518,681.95	0.00%	531,992.26	0.00%
2046	3,918,516.46	0.00%	7,942,679.30	0.00%	28,780,958	0.00%	6,664,900.95	0.00%	540,035.79	0.00%
2047	3,991,962.24	0.00%	8,270,047.83	0.00%	28,912,572	0.00%	6,813,995.53	0.00%	548,121.41	0.00%
2048	4,066,548.18	0.00%	8,610,048.56	0.00%	29,041,151	0.00%	6,966,178.15	0.00%	556,263.36	0.00%
2049	4,142,279.97	0.00%	8,962,711.77	0.00%	29,167,256	0.00%	7,121,506.31	0.00%	564,464.83	0.00%
2050	4,218,766.58	0.00%	9,324,157.58	0.00%	29,288,481	0.00%	7,279,353.78	0.00%	572,571.91	0.00%

Note: The macroeconomic indicator percent changes shown in this table can be compared to those for the Proposed Amendments, which are shown in Table IX-40, and to those for Alternative 1, which are shown in Table X-5.

3. Economic Impacts

Alternative 2 would implement less stringent requirements in 2024 and 2027 compared to the Proposed Amendments. The total cost of Alternative 2 ($900 million) would be about 80 percent less than the Proposed Amendments ($4.49 billion) over the years between 2022 and 2050. Table X-10 shows the impact on select macroeconomic indicators in the economy. The analysis of Alternative 2 shows that there would be nearly negligible impact on all major macroeconomic indicators. Overall, the Proposed Amendments and Alternative 1 would both have greater impacts to the California economy than the impacts of Alternative 2.

4. Reason for Rejecting

Alternative 2 would achieve about eight percent less benefits than the Proposed Amendments. Alternative 2 would achieve 324,922 tons of NOx benefits, which is 27,875 tons of NOx less than the Proposed Amendments. Alternative 2 also costs $3.6 billion less than the Proposed Amendments. The total cost-effectiveness of Alternative 2 is modeled to be $1.38 per pound of NOx reduced, significantly less than the Proposed Amendments at $5.45 per pound of NOx reduced over the course of the regulation. It is important to note however that the cost-effectiveness calculated for Alternative 2 is somewhat misleading because it only accounts for the cost of engines purchased in California but includes the benefits of out-of-state vehicles operating in California. The costs, benefits, and cost-effectiveness would significantly change if the cost impacts on engines sold outside of California were taken into account. Although Alternative 2 could be more cost-effective than the Proposed Amendments and would achieve nearly as many benefits, it was rejected for several reasons.

First, Alternative 2 would achieve less reductions of NOx emissions than the Proposed Amendments. Furthermore, CARB staff also believes there is an intrinsic advantage to the Proposed Amendments pushing manufacturers to deploy technically forcing, yet technically feasible, cost-effective technology with dramatically lower NOx emissions than today’s truck engines as quickly as possible. The success of California’s standards in 2024 and beyond will set a model for U.S. EPA to follow and make it more likely that federally certified trucks of the future are lower-emitting. Accordingly, Alternative 2 was rejected.

However, staff is cognizant of the potential advantages that nationally harmonized standards provide, including simplicity, efficiency, and cost savings. Hence, to encourage manufacturers to design and produce a harmonized set of 50-state engines and vehicles, the Proposed Amendments include a proposed optional 50-state-directed engine standard for manufacturers to voluntarily certify to the same standard nationally beginning in MY 2024, as discussed further in Section A.1.1.2 of Chapter III. CARB staff is hopeful that many manufacturers will choose to use this option in the years that the CARB’s Heavy-Duty Omnibus Regulation is in effect but before the U.S. EPA’s Cleaner Truck Initiative has been adopted and implemented.

XI. JUSTIFICATION FOR ADOPTION OF REGULATIONS DIFFERENT FROM FEDERAL REGULATIONS CONTAINED IN THE CODE OF FEDERAL REGULATIONS

This chapter is intended to satisfy Government Code section 11346.2(b)(6), which requires CARB to describe its efforts to avoid unnecessary duplication or conflicts with federal regulations that address the same issues. As explained further below, within this Staff Report, CARB staff is proposing regulations different from federal regulations contained in the CFR addressing the same issues because it is necessary, authorized by law, and justified by the benefit to the health of Californians.

Both California and U.S. EPA have comparable, yet distinct authorities to set emission standards for new motor vehicles and for new motor vehicle engines. CARB's legal authority to set emission standards and other emission-related requirements for new motor vehicles and new motor vehicle engines are described in Chapter II, Sections A and B. U.S. EPA's authority to set comparable emission standards and emission-related requirements is contained in Section 202(a) of the Clean Air Act. U.S. EPA must meet federal stability and lead time requirements in Section 202(a)(3)(C) of the Clean Air Act that specify that standards must apply for no less than three MYs and apply no earlier than four MYs after promulgation.

For the past several decades, California and U.S. EPA heavy-duty engine emission standards and other emission-related requirements have largely been harmonized, to enable the regulated industry to design and produce a single product line of engines and vehicles which can be certified to both U.S. EPA and CARB emission standards and sold in all 50 states. These so-called ''50-state'' standards enable technology suppliers and manufacturers to efficiently produce a single set of reliable and compliant products.

However, as described above in Chapter II, Section A, heavy-duty vehicles comprise the largest NOx emission source category in California, and California urgently needs to achieve significant emission reductions from on-road heavy-duty vehicles in order to meet the State's SIP commitments and protect public health. As described in greater detail in earlier chapters, this Staff Report presents CARB staff's Proposed Amendments to achieve such needed emission reductions. CARB staff's Proposed Amendments to the regulations and test procedures are found in Appendices A and B. As described above in Chapter III, CARB's Proposed Amendments would take effect with minor improvements effective with MY 2022 and much stricter emission standards effective with MY 2024. U.S. EPA currently does not have emission standards or emission-related requirements that are as stringent as those proposed in this rulemaking action.

Recognizing the contribution of heavy-duty trucks to the NOx inventory nationwide, more than 20 organizations, including state and local air agencies from across the country, petitioned U.S. EPA in the summer of 2016 to develop more stringent NOx emission standards for on-road heavy-duty engines (Brakora, 2019). U.S. EPA responded to the petition on December 20, 2016, noting that an opportunity exists to develop a new, harmonized national NOx reduction strategy for heavy-duty highway engines (Brakora, 2019). On November 13, 2018, U.S. EPA announced the "Cleaner Trucks Initiative" to develop regulations to reduce NOx emissions from on-road heavy-duty vehicles and engines (U.S. EPA, 2018). On January 6, 2020, U.S. EPA released an Advance Notice of Proposed Rulemaking soliciting pre-proposal comments on the Cleaner Trucks Initiative (FR, 2020). Due to the federal lead time requirements described above and because U.S. EPA began their effort after CARB began work on the Proposed Amendments, the Cleaner Trucks Initiative will likely take effect a few years later than the Proposed Amendments, most likely beginning with the 2027 MY.

For several years, CARB staff and U.S. EPA staff responsible for the development of the federal Cleaner Trucks Initiative have been meeting on a biweekly basis to exchange ideas, share data, and coordinate on data gathering and heavy-duty testing needs to support their respective programs. CARB and U.S. EPA have also collaborated to conduct and fund important related work. For example, U.S. EPA contributed nearly $500,000 to CARB's low NOx heavy-duty engine demonstration work at SwRI. As another example, U.S. EPA is also undertaking development of a diesel aftertreatment rapid-aging protocol that manufacturers could use for both federal- and California-certified engines.

As mentioned above, U.S. EPA's Cleaner Truck Initiative would likely be implemented with 2027 and subsequent MY engines. California has been developing its Proposed Amendments for many years and its air quality needs require significant emission reductions as soon as possible. However, to maintain a future harmonized national heavy-duty program, CARB staff has encouraged U.S. EPA to align with the Proposed Amendments described in this Staff Report as much as possible in the Cleaner Truck Initiative (Corey, 2020). In addition, to encourage manufacturers to make one set of 50-state clean vehicles, CARB staff has proposed that the amendments would include the option for manufacturers to certify to the same standard nationally beginning in MY 2024. CARB staff is hopeful that many manufacturers will choose this option in the years that the Proposed Amendments are in effect but the Cleaner Truck Initiative has not yet been implemented, in particular for MYs 2024 to 2026.

XII. PUBLIC PROCESS FOR DEVELOPMENT OF THE PROPOSED ACTION (PRE-REGULATORY INFORMATION)

Consistent with Government Code sections 11346, subdivision (b), and 11346.45, subdivision (a), and with the Board's long-standing practice, CARB staff held public workshops, workgroup meetings, and other meetings with the heavy-duty engine industry and other interested stakeholders during the development of the Proposed Amendments. These informal pre-rulemaking discussions provided CARB staff with useful information that was considered during development of the Proposed Amendments.

A. Collaboration with U.S. EPA

CARB staff has been working with U.S. EPA staff over the past several years in developing the Proposed Amendments. Since November 14, 2016, CARB staff has been collaborating with the U.S. EPA staff responsible for developing the federal Cleaner Trucks Initiative on a biweekly basis to exchange ideas on regulatory concepts, share data, and coordinate data gathering and heavy-duty testing needs to support their respective programs.

B. Workgroup Meetings

In November 2016, CARB staff created technical workgroups to exchange ideas and provide updates on regulatory concepts and the low NOx research projects at SwRI. The Heavy-Duty Omnibus Low NOx workgroup has more than 150 members and includes representatives from heavy-duty engine manufacturers, component suppliers, academia, non-governmental organizations, trade associations, and other interested persons with some of the technical professionals based outside the United States. Since March 2017, CARB staff held eight workgroup meetings, all of which were conducted using online webinars. Table XII-1 shows the list of workgroup meetings that have been held.

Table XII-1. Workgroup Meetings

Date	Topics Discussed
3/6/2017	At this first workgroup meeting, CARB staff discussed rulemaking timelines, status of CARB's SwRI Stage 1, 2, and 3 Low NOx Testing Program, and proposed changes to the ABT program. CARB staff also solicited out-of-the-box ideas that would provide equivalent emission reductions as CARB staff's proposed concepts.
8/2/2018	CARB staff discussed and solicited feedback regarding proposed concepts on revisions to the current heavy-duty in-use testing program and changes to the emissions crediting (or ABT) program.
10/29/2018	CARB staff discussed and solicited feedback regarding proposed concepts on revisions to the heavy-duty durability demonstration procedures during certification, useful life and Step 2 warranty, and warranty rate based corrective action requirements.
12/6/2018	SwRI discussed the low load cycle development and approach. In addition, SwRI also briefly discussed the status of SwRI Stages 1b, 2, and 3 Low NOx Testing Programs.
5/7/2019	CARB staff discussed the content of CARB staff's White Paper: Current Assessment of the Technical Feasibility of Lower NOx Standards and Associated Test Procedures for 2022 and Subsequent MY Medium-Duty and Heavy-Duty Diesel Engines and solicited feedback from stakeholders. In addition, CARB staff provided an update on the proposed concepts on useful life and Step 2 warranty.
6/26/2019	CARB staff discussed and solicited feedback regarding the proposed LLC including preconditioning procedures, regulatory concepts applicable to Otto-cycle heavy-duty engines, and CARB staff's plans to develop powertrain test procedures for heavy-duty vehicles. CARB staff also requested public input on alternatives to the draft Omnibus regulatory proposals discussed in that workgroup, as well as those discussed in previous workgroups, public workshops, and presented in the White Paper. In particular, CARB staff encouraged public input on alternative approaches that may yield the same or greater benefits than those associated with the Proposed Amendments or may achieve the goals at lower cost.
11/21/2019	CARB staff discussed and solicited feedback regarding revised proposals, which staff had developed based on stakeholder input on lengthening the useful life and Step 2 warranty period requirements for heavy-duty diesel- and Otto-cycle engines.
4/20/2020	CARB staff discussed and solicited feedback on proposals for Optional 50-State-Directed Engine Emission Standards for New 2024 through 2026 Model Heavy-Duty Engines, revisions to the HDIUT and HDIUC programs including the 3B-MAW method analysis, HDIUT fail criteria (3-vehicle), and HDIUT data reporting, and revisions to the preconditioning procedures.

Consistent with Senate Bill 617 requirements, at the June 26, 2019 workgroup meeting, CARB staff requested public input on alternatives to the draft Proposed Amendments, as well as alternatives discussed in previous workgroups, public workshops, and in the CARB Staff White Paper. In particular, CARB staff encouraged public input on alternative approaches that may yield the same or greater benefits than those associated with the Proposed Amendments, or alternatives that may achieve the goals at a lower cost. In response, CARB staff received alternative proposals from EMA and SCAQMD, which are the two alternative proposals evaluated as part of this Staff Report.

C. SwRI Low NOx Testing Program Advisory Group

CARB staff also formed an advisory group consisting of various key stakeholders to guide and provide input to the SwRI Low NOx Testing Programs at various stages of the research program. The group referred to as the Program Advisory Group consisted of stakeholders from various groups including the U.S. EPA, the U.S. Department of Energy, the SCAQMD, the California Energy Commission, EMA, MECA, and various individual heavy-duty engine manufacturers. Program progress was presented to this group at several meetings early in the program and at the conclusion of key program tasks. This group provided important feedback and input on program direction and conduct.

D. Workshop Meetings

In addition to workgroup meetings, CARB staff also held three public workshops regarding the Proposed Amendments, on November 3, 2016, January 23, 2019, and September 26, 2019. At these workshops, CARB staff discussed concepts to the Proposed Amendments. Attendees included engine manufacturers, trade associations, component suppliers, members of academia, non-governmental organizations, and members of the general public. To reach a wider audience, the workshops were also webcasted.

An additional workshop (also webcasted) was held on July 24, 2019 to specifically discuss California Phase 2 GHG Regulation clean-up items. Representatives from truck and trailer associations and component suppliers were invited to solicit input on the Proposed Amendments. Table XII-2 shows the list of workshops that have been held.

Table XII-2. Workshop Meetings

Date/Location	Topics Discussed
11/3/2016 Diamond Bar, CA	First public workshop: CARB staff discussed the need for NOx emission reductions, heavy-duty vehicle NOx emissions inventory, SwRI Low NOx Testing Program and CARB staff plans to revise and develop new NOx emissions standards; the need for a new low load certification cycle; and the need to revise in-use test procedures, lengthen useful life and warranty requirements, emissions warranty reporting information, and durability demonstration procedures. Furthermore, CARB staff announced the formation of technical workgroups to discuss the various elements of the heavy-duty low NOx program development.
01/23/2019 Sacramento, CA	Second public workshop: CARB staff shared proposed concepts on the various elements of the heavy-duty low NOx program and received constructive feedback from stakeholders.
09/26/2019 Diamond Bar, CA	Third public workshop: CARB staff shared proposed concepts on the various elements of the heavy-duty low NOx program including Phase 2 GHG Regulation clean-up items and received constructive feedback from stakeholders. Workshop participants were also updated on the results from the various research programs under contract with SwRI.
07/24/2019 Sacramento, CA	Additional workshop: CARB staff specifically discussed the Phase 2 GHG Regulation Clean-up Items. Representatives from truck and trailer associations and component suppliers were invited to solicit input on the Proposed Amendments.

E. Other Meetings

In addition to holding workgroup meetings and workshops, CARB staff also met interested stakeholders individually including EMA, the members of MECA, the International Council on Clean Transportation, environmental organizations, and Environment and Climate Change Canada. CARB staff also met one-on-one individually with engine manufacturers and component suppliers multiple times at CARB offices in El Monte and Sacramento. CARB staff met with every heavy-duty engine manufacturer at each of their headquarters, toured their facilities, met with their compliance and regulatory affairs CARB staff and discussed their concerns. Furthermore, CARB staff also presented and discussed the Proposed Amendments at more than 20 technical conferences and workshops, at seven meetings with members of clean air agencies and associations such as the National Association of Clean Air Agencies, the Lake Michigan Air Directors Consortium, Northeast States for Coordinated Air Use Management, SCAQMD Clean Fuels Advisory Board, etc., and at more than five industry, non-governmental, and trade group meetings.

A list of the specific Program Advisory Group, conference, and other meetings, as well as individual meetings with stakeholders, is provided in Appendix G.

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B. APPENDIX C-1: STANDARDIZED REGULATORY IMPACT ASSESSMENT REFERENCES

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XIV. APPENDICES

Appendix A: Proposed Regulation Order

Appendix A-1: Proposed Title 13 Regulation Order
Appendix A-2: Proposed Title 17 Regulation Order

Appendix B: Proposed Test Procedures

Appendix B-1: Proposed Amendments to the Diesel Test Procedures
Appendix B-2: Proposed Amendments to the Otto-Cycle Test Procedures
Appendix B-3: Proposed Amendments to the Greenhouse Gas Test Procedures
Appendix B-4: Proposed Amendments to California Environmental Performance Label Specifications
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Appendix C: Economic Impacts Assessment

Appendix C-1: Original SRIA Submitted to DOF
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Appendix D: Emissions Inventory Methods and Results for the Proposed Amendments

Appendix E: Health Benefits Analysis

Appendix F: Purpose and Rationale

Appendix F-A-1: Purpose and Rationale for Proposed Title 13 Regulation Order
Appendix F-A-2: Purpose and Rationale for Proposed Title 17 Regulation Order
Appendix F-B-1: Purpose and Rationale for Proposed Amendments to the Diesel Test Procedures
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