Appendix C-1

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APPENDIX C-1

State of California
AIR RESOURCES BOARD

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 In-Use Testing Program, Emissions Warranty Period and Useful Life Requirements, Emissions Warranty Information and Reporting Requirements, In-Use NOx Emissions Data Reporting Requirements, and Phase 2 Heavy-Duty Greenhouse Gas Regulations and Powertrain Test Procedures

Standardized Regulatory Impact Assessment (SRIA)

DATE OF RELEASE:

Air Resources Board
1001 I Street
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LIST OF ACRONYMS AND ABBREVIATIONS

50-State	Federal Level
ABT	Averaging, Banking, and Trading
ACT	Advanced Clean Trucks
APU	Auxiliary Power Units
CA-ABT	California-Averaging, Banking, and Trading
CARB or Board	California Air Resources Board
CCR	California Code of Regulations
CFR	Code of Federal Regulations
DAAAC	Diesel Aftertreatment Accelerated Aging Cycle
DDP	Durability Demonstration Program
DEF	Diesel Exhaust Fluid
DMV	Department of Motor Vehicles
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EAS	Engine and Aftertreatment System
EGR	Exhaust Gas Recirculation
EIR	Emissions Information Report
EMA	Truck and Engine Manufacturers Association
EWIR	Emissions Warranty Information and Reporting
FIR	Field Information Report
FTP	Federal Test Procedure
g/bhp-hr	Grams Per Brake Horsepower-Hour
g/hour	Grams Per Hour
GHG	Greenhouse Gas
GSP	Gross State Product
HD	Heavy-Duty
GVWR	Gross Vehicle Weight Rating
HDHV	Heavy-Duty Hybrid Vehicle
HDIUT	Heavy-Duty In-Use Testing
HDO	Heavy-Duty Otto-Cycle
HHD	Heavy Heavy-Duty
HHDD	Heavy Heavy-Duty Diesel
HSC	California Health and Safety Code
ICT	Innovative Clean Transit
LEV III	Low-Emission Vehicle III
LHD	Light Heavy-Duty
LHDD	Light Heavy-Duty Diesel
LLC	Low Load Cycle
MAW	Moving Average Window
MDDE	Medium-Duty Diesel Engine
MDOE	Medium-Duty Otto-Cycle Engine
MECA	Manufacturers of Emission Controls Association
MHD	Medium Heavy-Duty
MHDD	Medium Heavy-Duty Diesel
MIL	Malfunction Indicator Light
NAICS	North American Industry Classification System
NMHC	Non-Methane Hydrocarbons
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory

NTE	Not-to-Exceed
OBD	On-Board Diagnostics
PM / PM2.5	Particulate Matter
Proposed Regulation	Proposed Heavy-Duty Omnibus Low NOx Regulation
REAL	Real Emissions Assessment Logging
REMI	Regional Economic Models, Inc.
RMC-SET	Supplemental Emission Test Ramped Modal Cycle
RPC	Regional Purchase Coefficient
SCR	Selective Catalytic Reduction
SIP	State Implementation Plan
SRIA	Standardized Regulatory Impact Assessment
SwRI	Southwest Research Institute
U.S. EPA	United States Environmental Protection Agency
UL	Useful Life

A. INTRODUCTION

On-road heavy-duty vehicles contribute significantly to California's poor air quality with elevated levels of ozone and particulate matter (PM or PM2.5). Statewide, about 12 million Californians live in communities that exceed the National Ambient Air Quality Standards for ozone and PM2.5. Exposure to PM2.5 and ozone are associated with increased risk of premature mortality, which has been estimated to contribute to 7,500 premature deaths each year in California.[1] Two areas of the state with the most critical air quality challenges are the South Coast and the San Joaquin Valley air basins. These regions are the only two areas in the nation with an "Extreme" classification for nonattainment with the federal ozone standard, and also experience some of the nation's highest PM levels. Achieving federal air quality standards in these regions, as well as across the state, will provide essential public health protection by reducing hospitalizations for heart and lung related causes, decreasing emergency room visits, and reducing incidences of asthma.

Heavy-duty trucks over 10,000 pounds gross vehicle weight rating (GVWR) are responsible for over 60 percent of oxides of nitrogen (NOx) emissions from on-road mobile sources and over 30 percent of NOx from all sources. NOx emissions lead to the formation of ambient ozone and PM2.5 in California. In order to meet California's air quality goals, further reductions of heavy-duty truck NOx emissions are necessary.[2]

The proposed amendments make changes to the exhaust emission standards and test procedures for 2024 and subsequent model year heavy-duty engines and vehicles, heavy-duty in-use testing (HDIUT) program, emissions warranty period and useful life requirements, emissions warranty information and reporting requirements (EWIR), emissions averaging, banking, and trading (ABT) program, durability demonstration program (DDP), and in-use NOx emissions data reporting requirements, and are hereinafter collectively referred to as the Proposed Regulation.

The Proposed Regulation would implement two on-road heavy-duty measures in the 2016 State Strategy for the State Implementation Plan (SIP) – "Low-NOx Engine Standard" and "Lower In-Use Emission Performance Level."[3] The "Low-NOx Engine Standard" measure was aimed at reducing heavy-duty NOx emission standards by up to 90 percent from current levels. The "Lower In-Use Emission Performance Level" measure was intended to ensure that heavy-duty vehicles remain at their cleanest possible level in-use and to address in-use emissions and compliance and to decrease engine deterioration.

The Proposed Regulation is critical for California to attain federal ambient air quality standards for ozone in 2031 in the South Coast and San Joaquin Valley air basins, as well as PM2.5 standards in the next decade. In addition to revisions impacting NOx emissions,

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[1] (CARB, 2017b) Revised Proposed 2016 State Strategy for the State Implementation Plan, California Air Resources Board, March 7, 2017. https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf
[2] (CARB, 2017a) CEPAM: 2016 SIP - Standard Emission Tool (2019 calendar year), California Air Resources Board, webpage last updated February 15, 2017, accessed September 2019. https://www.arb.ca.gov/app/emsinv/fcemssumcat2016.php
[3] (CARB, 2017b) Revised Proposed 2016 State Strategy for the State Implementation Plan, California Air Resources Board, March 7, 2017. https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf

this rulemaking includes “associated amendments” to the Phase 2 greenhouse gas (GHG) regulations to provide clarity to manufacturers and harmonize certain requirements with the federal Phase 2 heavy-duty GHG regulations such as proposed PM control requirements for auxiliary power units (APU) and powertrain test procedures.

1. Regulatory History

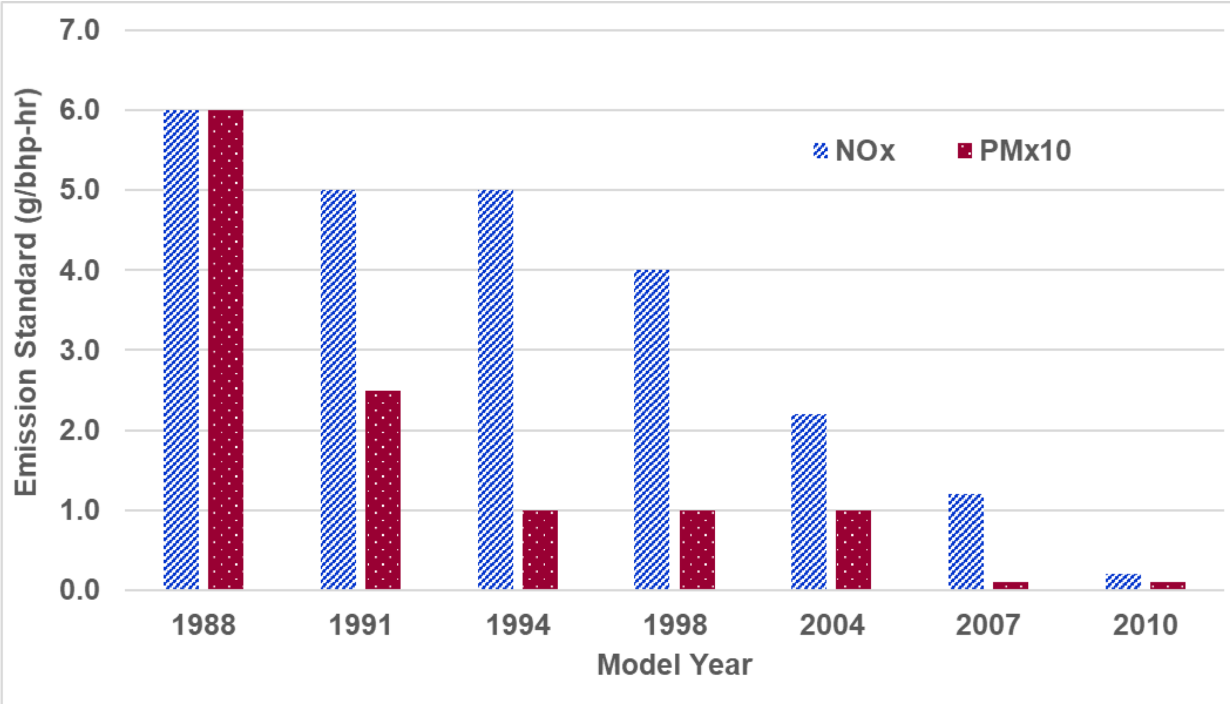
The first heavy-duty engine emission standards that set limits on tailpipe carbon monoxide and combined hydrocarbon plus NOx emissions were adopted by the California Air Resources Board (CARB or Board) in 1970 and became effective in California in 1973. The same standards were implemented federally in 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 for NOx and PM emissions.

Currently, California and the United States Environmental Protection Agency (U.S. EPA) regulations require manufacturers to meet the emission standards by testing heavy-duty engines on an engine dynamometer on standardized test cycles and procedures. For certification, California and U.S. EPA require heavy-duty engines to be tested on the heavy-duty transient Federal Test Procedure[4] (FTP) and the Supplemental Emission Test Ramped Modal Cycle[5] (RMC-SET). The FTP test cycle was developed in the 1970s from in-use heavy-duty vehicle activity data and represents a transient medium load duty cycle. The RMC-SET is a 13-mode steady-state test cycle, introduced by the U.S. EPA as part of the 1998 consent decrees with engine manufacturers, and simulates steady-state engine operation during suburban and highway truck speeds. The FTP and RMC-SET have the same numerical standard. In addition to the FTP and RMC-SET, California also requires engines to certify to a NOx idling emission standard in lieu of compliance with the non-programmable 5-minute engine shutdown system. The idling NOx standard was introduced by CARB to control NOx emissions that may occur during extended idling periods.

Figure A-1 illustrates the evolution of FTP NOx and PM 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 federal U.S. EPA standards, although in a few cases implementation in California began one or more years ahead of the federal standards.

[4] “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.
[5] “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.

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



Currently, heavy-duty diesel engines are subject to a PM standard of 0.01 g/bhp-hr, a NOx standard of 0.20 g/bhp-hr, and a non-methane hydrocarbon (NMHC) standard of 0.14 g/bhp-hr. The PM standard became effective beginning in 2007, and diesel particulate filters (DPF) were used to meet it. The NOx and NMHC standards were phased-in from 2007 through 2010. Manufacturers used urea-based selective catalytic reduction (SCR) NOx aftertreatment control technologies to comply with the 2010 NOx standard of 0.20 g/bhp-hr. SCR systems require use of an aqueous urea solution made up of a mix of ammonia and water known as Diesel Exhaust Fluid (DEF), which is stored on-board the vehicle. Manufacturers must demonstrate and ensure compliance with the emission standards for a period of time called the regulatory useful life by aging engines and aftertreatment for a period intended to be equivalent to regulatory useful life and then testing emissions. The procedures used to demonstrate durability are known as the DDP. In addition to requiring manufacturers to demonstrate compliance with emission standards as part of certification of engine families before they can legally be sold, to help ensure that emissions from medium- and heavy-duty diesel engines are controlled under real-world conditions, CARB and U.S. EPA require manufacturers to conduct testing of in-use heavy-duty trucks via the HDIUT program. CARB does its own in-use testing via the Heavy-Duty In-Use Compliance program as well. Under the HDIUT program, CARB and U.S. EPA jointly select engine families to be tested and manufacturers recruit fleets and conduct the testing. These programs utilize portable emissions measurement systems for measuring emissions and are currently based on a procedure called Not-to-Exceed (NTE) test procedure.[6]

CARB and U.S. EPA also have emission warranty requirements intended to provide a level of assurance to owners that their vehicles, engines, and associated emission control systems are free from defects in materials and workmanship. If such defects do occur during the warranty period, the manufacturers are liable for fixing them. The heavy-duty emission warranty requirements were last amended on June 28, 2018, the Board approved amendments via the June 2018 “Step 1” warranty amendments.

CARB’s current EWIR program requires manufacturers to track and report warranty claims and failure rates for emission-related parts for the heavy-duty engine’s warranty period. Warranty reporting enables CARB staff to monitor and assess in-use performance of emission-related parts. Manufacturers must take corrective action, such as recalling faulty parts and offering extended warranties, when corrective action thresholds are exceeded.

In 2005, CARB adopted regulations codified in title 13 of the California Code of Regulations, section 1971.1 (13 CCR 1971.1) that required on-board diagnostic (OBD) systems in heavy-duty engines applicable to 2010 and later model years, and subsequently adopted a heavy-duty OBD-specific enforcement regulation, (13 CCR 1971.5) in 2009. OBD systems monitor virtually every component and system of the vehicle that can cause increases in emissions. When an emission-related malfunction is detected, the OBD system alerts the vehicle operator by illuminating the malfunction indicator light, or MIL, on the instrument panel so that repairs can be performed promptly. The system also stores important information about any detected malfunction so that a repair technician can accurately find and fix the problem.[7] Since 2005, CARB staff has regularly met with manufacturers and has proposed amendments several times over the years to heavy-duty OBD regulations, which the Board adopted. Most recently in 2018, CARB staff amended the OBD requirements to include, among other things, tracking and reporting of data that characterize NOx and carbon dioxide emissions in-use starting in the 2022 model year. This data collection program referred to as the Real Emissions Assessment Logging, or REAL, can be used to identify populations of vehicles for additional testing, identify the conditions in-use where vehicles are not performing as expected with regard to emissions control, and generally better inform CARB’s inventory, regulatory, certification, and enforcement programs.

In 2013, California established optional low NOx standards[8] with the most aggressive standard being 0.02 g/bhp-hr, which is 90 percent below the current standard. The

[6] After manufacturers were caught in the 1990s calibrating their engines to improve fuel economy at the expense of excess NOx emissions above the standards during high speed cruise operation, CARB and U.S. EPA developed the NTE test method to prevent future such violations. Since 2005, manufacturers have been required to self-test a portion of their engine families using the NTE. The NTE control area requires compliant emission over a range of engine torque and speeds.

[7] (CARB, 2019j) Final Regulation Order: 13 CCR 1971.1. On-Board Diagnostic System Requirements--2010 and Subsequent Model-Year Heavy-Duty Engines, California Air Resources Board, accessed October 9, 2019. https://www.arb.ca.gov/regact/2018/hdobd18/fro1971-1.pdf

[8] (CARB, 2019m) Final Regulation Order: Phase 1 Greenhouse Gas Regulations, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/regact/2013/hdghg2013/hdghgfrot13.pdf

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 and incentivizing potential customers to purchase these low NOx engines. For the 2018 model year, more than ten engines, some using natural gas and others using liquefied petroleum gas, were certified to the optional low NOx standards.[9]

In addition to the increasingly more stringent new engine standards, California has also adopted programs that provide substantial in-use emission reductions, such as vehicle idling restrictions,[10] and in-use fleet rules such as the Drayage Truck Regulation[11] and the Truck and Bus Regulation.[12] Specifically, the Truck and Bus Regulation requires the upgrade of older trucks and buses to newer, cleaner engines meeting the current 2010 emission standards by 2023.

In 2010, California implemented the Tractor-Trailer GHG Regulation that applied to heavy-duty tractor-trailers that operate in California.[13] This regulation reduces GHG emissions by requiring 53-foot or longer box-type trailers and the tractors[14] that pull them to be equipped with U.S. EPA SmartWay verified aerodynamic devices and low rolling resistance tires that meet specified GHG emissions reduction performance. Furthermore, in 2013, California adopted the Phase 1 heavy-duty GHG standards that were phased-in for 2013 through 2017 model year heavy-duty engines and vehicles.[15] Most recently, in 2018, California adopted the Phase 2 heavy-duty GHG emission standards that will significantly reduce GHG emissions from heavy-duty pick-up trucks and vans, vocational vehicles, tractors, and trailers.[16] The Phase 2 GHG emission standards will be phased-in for 2021 through 2027 model year engines and vehicles. Additionally, to limit toxic diesel PM emissions, the Phase 2 GHG Regulation also requires APUs used as a compliance pathway for meeting the 2024 and subsequent model year Phase 2 GHG tractor standards to comply with a PM standard of 0.02 g/bhp-hr.

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[9] (CARB, 2019h) CARB Executive Orders for 2018 Model Year Heavy-Duty Engines: A-452-0001; A-021-0680; A-021-0674; A-021-0678; A-021-0681; A-021-0679; A-436-0004; A-436-0005-1; A-436-0006; A-344-0082-1; A-344-0086; A-344-0080-1; A-344-0083-1; A-344-0087, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2018/2018.php

[10] (CARB, 2019f) 13 CCR § 2485. Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/msprog/truck-idling/13CCR2485_09022016.pdf

[11] (CARB, 2019l) Final Regulation Order: Drayage Truck Regulation, California Air Resources Board, accessed October 9, 2019. https://www.arb.ca.gov/msprog/onroad/porttruck/finalregdrayage.pdf

[12] (CARB, 2019k) Final Regulation Order: 13 CCR 2025. Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles (Truck and Bus Regulation), California Air Resources Board, accessed October 9, 2019. https://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf

[13] (CARB, 2019o) Final Regulation Order: Tractor-Trailer Greenhouse Gas Regulation, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/cc/hdghg/documents/ttghg_reg_clean_01062017.pdf

[14] Throughout this report, “tractor” is used to denote an on-road truck containing a driver's cab that is designed to pull a large trailer. It does not refer to off-road tractors commonly used in agriculture.

[15] (CARB, 2019m) Final Regulation Order: Phase 1 Greenhouse Gas Regulations, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/regact/2013/hdghg2013/hdghgfrot13.pdf

[16] (CARB, 2019n) Final Regulation Order: Phase 2 Greenhouse Gas Regulations and Tractor-Trailer GHG Regulations, California Air Resources Board, accessed October 9, 2019. https://www.arb.ca.gov/regact/2018/phase2/finalatta.pdf

However, despite all of these efforts, on-road heavy-duty vehicles still constitute a significant source of NOx and PM emissions in the state, and are responsible for about 30 percent of total statewide NOx emissions.[17] In order to meet California's air quality goals and GHG emissions and petroleum use reduction targets, CARB is aiming to encourage the use of zero-emission vehicles and equipment where possible, while simultaneously ensuring conventional technologies are as low-emitting as feasible. CARB has already approved the Innovative Clean Transit (ICT) Regulation, for example, which requires public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040. In addition, CARB has proposed the Advanced Clean Trucks (ACT) Regulation,[18] which includes manufacturer sales requirements for zero-emission medium- and heavy-duty vehicles from Class 2B to Class 8. Staff is also in the process of assessing and developing proposals for new heavy-duty vehicle strategies to achieve the transition from conventional combustion technologies to zero-emission technology for vehicle applications that are best suited for zero-emission technology.

In September 2019, Governor Newsom signed Senate Bill 210,[19] directing CARB to implement a heavy-duty diesel vehicle inspection and maintenance (HD I/M) program. Senate Bill 210 (Leyva; Chapter 298, Statutes of 2019) directs CARB to develop and implement a comprehensive HD I/M program in consultation with the California Department of Motor Vehicles (DMV) and the Bureau of Automotive Repair. CARB is now undertaking efforts[20] to develop such a program to ensure that emission control systems on heavy-duty vehicles are properly functioning and remain low-emitting throughout their entire operating life.

The Proposed Regulation is part of CARB's overall strategy to reduce emissions from heavy-duty vehicles. Together, these approaches are designed to achieve progressively cleaner in-use fleet emission levels.

2. Proposed Regulation and Associated Amendments

The Proposed Regulation is aimed at substantially reducing NOx emissions compared to today's engines, both when engines are newly certified and as they are used on the road. The rulemaking package for which this SRIA was prepared includes the Proposed Regulation, as well as amendments to other associated regulations, with some elements beginning in 2022 and other elements beginning with the 2024 and 2027 model years. Sections a. through i. describe the proposed amendments to the NOx and PM emissions

[17] (CARB, 2017a) CEPAM: 2016 SIP - Standard Emission Tool (2019 calendar year), California Air Resources Board, webpage last updated February 15, 2017, accessed September 2019. https://www.arb.ca.gov/app/emsinv/fcemssumcat2016.php

[18] (CARB, 2019p) Staff Report: Initial Statement of Reasons, "Public Hearing to Consider the Proposed Advanced Clean Trucks Regulation," California Air Resources Board, October 22, 2019. https://ww3.arb.ca.gov/regact/2019/act2019/isor.pdf

[19] (CLI, 2019a) SB-210 Heavy-Duty Vehicle Inspection and Maintenance Program (Leyva; Chapter 298, Statutes of 2019), California Legislative Information, accessed October 2019. http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB210

[20] (CARB, 2019r) Heavy-Duty Inspection and Maintenance Program: Meetings & Workshops, California Air Resources Board, website accessed October 2019. https://ww2.arb.ca.gov/our-work/programs/inspection-and-maintenance-program/Meetings-and-Workshops

standards, HDIUT program, emissions warranty period and useful life requirements, EWIR requirements, emissions ABT program, and DDP procedures, including new in-use NOx emissions data reporting requirements; while sections j. through l. describe proposed powertrain test procedures, proposed heavy-duty tractor APU certification requirements, and Phase 2 GHG technical amendments, respectively.

a. New NOx Standards for 2024 and Later Model Year Heavy-Duty Engines

The goal of the Proposed Regulation is to achieve the greatest degree of real-world NOx emission reductions that are technologically feasible and cost-effective. To achieve this, the Proposed Regulation would require new heavy-duty engines to meet more stringent NOx emission standards during certification, as well as supplemental actions to address in-use emissions. The proposed new heavy-duty engine emission standards would include lower NOx standards on the existing heavy-duty certification cycles, which are the heavy-duty transient FTP, the RMC-SET and idling test procedures,[21] and on a new low load certification cycle (LLC) developed to demonstrate emissions are controlled under low load and low speed urban driving operations. The Proposed Regulation would apply to diesel-cycle and Otto-cycle engines and vehicle classifications outlined in Table A-1. Specifically, the Proposed Regulation would affect engines used in heavy-duty vehicles with GVWR greater than 14,000 pounds and engines used in incomplete[22] medium-duty vehicles with GVWR between 10,001 and 14,000 pounds. The proposed NOx standards are shown in Table A-2.

[21] Idling test procedure is the duty cycle specified in subsection 35.B.4 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/hdoetps_hdghg_phase2_april2019.pdf
[22] An incomplete vehicle is defined in 40 CFR §86.085-20 - Incomplete vehicles, classification.

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

Engine Cycle	Vehicle Class	GVWR (lbs.)	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)[23]
Otto-Cycle	4-8	> 14,000	Heavy-Duty Otto (HDO)
	3	10,001 – 14,000	Medium-Duty Otto Engine (MDOE)[24]

Table A-2. Proposed Heavy-Duty Diesel- and Otto-Cycle Engine NOx Standards

Model Years	Heavy-Duty Diesel-Cycle				Heavy-Duty Otto-Cycle
	FTP[25] (g/bhp-hr)	RMC-SET[26] (g/bhp-hr)	LLC[27] (g/bhp-hr)	Idling[28] (g/hour)	FTP (g/bhp-hr)
2024 - 2026	0.05	0.05	0.05	10	0.05
2027 and subsequent	0.02	0.02	0.02	1	0.02

i. Amendments to the NOx Emission Standards (FTP, RMC-SET, 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 model year engines, and the second step applicable to 2027 and subsequent model year engines. As stated earlier, Table A-2 shows a summary of the proposed NOx standards.

Model Years 2024 through 2026 Heavy-Duty and Medium-Duty Diesel-Cycle Engines

Meeting the proposed 2024 FTP and RMC-SET NOx standards will be feasible using a combination of strategies that provide improved thermal management and improved SCR conversion efficiency during cold starts and at lower engine loads. This is likely to include engine calibration strategies such as high EGR rates to reduce engine-out NOx and higher

[23] Only diesel-cycle engines used in incomplete medium-duty vehicles are included in this category.
[24] Only Otto-cycle engines used in incomplete medium-duty vehicles are included in this category.
[25] The FTP certification test cycle represents transient medium load operation.
[26] The RMC-SET certification test cycle simulates steady-state engine operation during suburban and highway truck speeds.
[27] The LLC certification test cycle simulates operations that may occur under low load, low speed, city driving operations.
[28] The idling certification test cycle involves idling test at curb idle without load and elevated idle with accessory loads to simulate workday idling as well as extended idling during layover hours.

idle speeds to reduce engine warm-up time to better control cold start emissions. In addition, SCR system improvements such as larger SCR catalysts and better catalyst substrates will enable manufacturers to meet the proposed standards. Improvements in thermal management of the SCR system is also likely with improved packaging of the aftertreatment system and improved urea dosing strategies, such as heated urea dosing systems.

The technical feasibility of the proposed 2024 FTP NOx standards is supported by data from many sources including the Southwest Research Institute (SwRI) Stage 1 Low NOx Program,[29] certification data for 2019 model year heavy-duty diesel engines,[30] CARB technology assessments for low NOx engines,[31] and simulation modeling[32] by the Manufacturers of Emission Controls Association (MECA).

Model Year 2027 and Subsequent Heavy-Duty Diesel-Cycle Engines

For 2027 and subsequent model year heavy-duty engines, staff is proposing a NOx standard of 0.02 g/bhp-hr on the FTP and RMC-SET test cycles and an idling standard of 1 g/hour on the idling test procedure.

The proposed 2027 and subsequent model year heavy-duty diesel-cycle engine FTP and RMC-SET standards will be feasible to meet using engine calibration strategies, engine hardware changes such as cylinder deactivation, as well as advanced aftertreatment systems. For this SRIA, staff assumed that the 2027 and subsequent model year standards would be met with cylinder deactivation, split SCR system with dual dosing and a light off SCR system close coupled to the engine (Figure A-2), and engine calibration strategies for exhaust thermal management. As discussed in further detail in Chapter C, the estimated incremental costs for this technology package (for hardware and research and development costs) ranges from about $2,100 to $2,900 per engine depending on engine size.

[29] (Sharp et al., 2017) “Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles,” Christopher A. Sharp, Cynthia C. Webb, Gary D. Neely, & Ian Smith, Southwest Research Institute Project No. 19503 Final Report, April 2017. https://ww3.arb.ca.gov/research/apr/past/13-312.pdf

[30] (CARB, 2019i) CARB Executive Orders for 2019 Model Year Heavy-Duty Engines: A-452-0002; A-452-0003; A-452-0004; A-436-0007; A-436-0008; A-436-0009; A-344-0094; A-344-0096; A-344-0100; A-344-0101; A-344-0089; A-344-0090; A-344-0095-1; A-344-0097-1, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2019/2019.php

[31] (CARB, 2015) Draft Technology Assessment: Lower NOx Heavy-Duty Diesel Engines, California Air Resources Board, September 2015. https://www.arb.ca.gov/msprog/tech/techreport/diesel_tech_report.pdf; Draft Technology Assessment: Low Emission Natural Gas and Other Alternative Fuel Heavy-Duty Engines, California Air Resources Board, September 2015. https://www.arb.ca.gov/msprog/tech/techreport/ng_tech_report.pdf

[32] (MECA, 2019) Technology Feasibility for Model Year 2024 Heavy-Duty Diesel Vehicles in Meeting Lower NOx Standards, Manufacturers of Emissions Control Association (MECA), June 2019. http://www.meca.org/resources/MECA_MY_2024_HD_Low_NOx_Report_061019.pdf

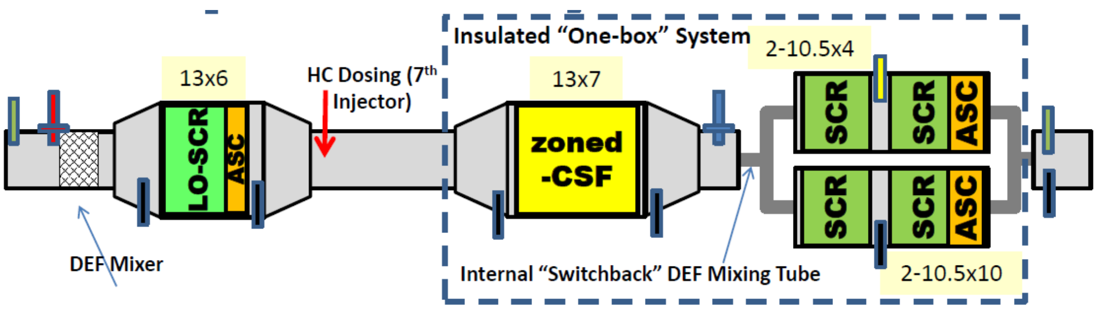

Figure A-2. SwRI Stage 3 Final Aftertreatment System

Proposed NOx Standards for Heavy-Duty Otto-Cycle Engines

Current heavy-duty Otto-cycle engines use a three-way catalyst to control NOx emissions and to meet the current FTP NOx standard of 0.2 g/bhp-hr. Staff is proposing a 0.05 g/bhp-hr NOx standard on the FTP for the 2024 through 2026 model years and a 0.02 g/bhp-hr NOx standard on the FTP for 2027 and subsequent model year engines. Analysis of 2019 model year certification data[33] indicate there are currently six heavy-duty Otto-cycle engines certified to the 0.02 g/bhp-hr optional NOx standards on the FTP and RMC-SET standards. These optional NOx-certified engines employ improved air-fuel ratio control and larger three-way catalysts or improved three-way catalyst substrate formulations. Similarly, current heavy-duty Otto-cycle engines can easily meet the proposed NOx standards for both the 2024 and 2027 model year engines with improved three-way catalysts as well as better air-fuel ratio controls

ii. New NOx Certification LLC and Associated NOx Emission Standards for 2027 and Later Model Year Engines

The Proposed Regulation includes requirements for manufacturers to prove their engines and aftertreatment meet emission standards when operating in low load conditions via a new certification cycle called the LLC. Since model year 2010, all new heavy-duty diesel trucks in the United States that meet the 0.2 g/bhp-hr NOx standard have been equipped with SCR catalyst technology. SCR effectiveness is dependent on elevated engine exhaust temperatures; at temperatures below about 200°C, SCR systems do not perform well. Most heavy-duty trucks operate their diesel engines some of the time at moderate to high loads, producing adequate exhaust temperatures for the SCR aftertreatment to work. However, these trucks also spend a considerable amount of time at idle or in operations at lower speeds and loads, resulting in lower exhaust temperatures that significantly reduce the effectiveness of today's SCR aftertreatment systems.[34] The new LLC and associated certification standards are needed to reduce emissions by requiring manufacturers to keep

[33] (CARB, 2019i) CARB Executive Orders for 2019 Model Year Heavy-Duty Engines: A-452-0002; A-452-0003; A-452-0004; A-436-0007; A-436-0008; A-436-0009; A-344-0094; A-344-0096; A-344-0100; A-344-0101; A-344-0089; A-344-0090; A-344-0095-1; A-344-0097-1, California Air Resources Board, accessed October 9, 2019. https://ww3.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2019/2019.php

[34] (Pondicherry et al., 2019) "In-Use Activity and NOx Emissions from On-Highway Vehicles Using Tail-pipe NOx Sensor," Rasik Pondicherry, Berk Demirgok, Batishahe Selimi, Marc Besch, Arvind Thiruvengadam, & Daniel Carder, Center for Alternative Fuels, Engines, and Emissions, West Virginia University, 29th CRC Real-World Emissions Workshop, March 2019.

heavy-duty diesel engine exhaust temperatures adequately warm at low loads and/or to design SCR systems to function better at lower temperatures.

The current medium- and heavy-duty engine certification cycles, namely the FTP and RMC-SET, are inadequate for testing the performance during the low load operations explained above. To address this deficiency, staff has developed a new supplemental test cycle, i.e., the LLC, through a contract with SwRI and the National Renewable Energy Laboratory (NREL).[35] The proposed new LLC more accurately represents real-world operation and would require engine manufacturers to demonstrate that hardware and controls needed to deal with low load challenges are present and functional.

Staff is proposing to require 2024 and later model year medium- and heavy-duty engines (both diesel and Otto-cycle) to meet NOx emission standards over the LLC that are at the same level as the FTP NOx emission standards described above in Table A-2.

b. New PM Standards for 2024 and Later Model Year Heavy-Duty Engines

Staff is proposing lower PM standards to ensure that manufacturers continue to use the best DPF technologies to enable adequate control of toxic diesel PM emissions. The current PM standards for heavy-duty engines are 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 model years 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 DPFs and maintain current robust PM emission control performance near 0.001 g/bhp-hr levels, staff is proposing a lower PM standard of 0.005 g/bhp-hr, starting with the 2024 model year. This standard is feasible with existing DPF aftertreatment systems.

[35] (CARB, 2019a) "Low Load Cycle Development – Heavy-Duty Low NOx Program Workshop," California Air Resources Board, January 23, 2019. https://ww3.arb.ca.gov/msprog/hdlownox/files/workgroup_20190123/02-llc_ws01232019-1.pdf

c. Heavy-Duty In-Use Test Procedure Amendments

To address deficiencies in the current HDIUT program that exempt the bulk of real-world operation and ensure emissions are adequately controlled during all operations, staff is proposing amendments to the HDIUT test procedure. As described above, the HDIUT currently is based on the NTE test procedure.

An assessment of the NTE test procedure has shown it to be deficient as it does not actually evaluate the vast majority of driving conditions.[36] For example, operations under certain temperatures or under certain loads are completely excluded under the NTE test procedure. These limitations and inadequacies have compelled staff to propose a new test procedure based on Moving Average Windows (MAW), similar to what is currently in place in Europe.

Briefly speaking, the MAW approach involves subdividing the test results into windows, where a window is a set of contiguous test points. The windows are defined such that their lengths are based on the work from the engine over the FTP. This proposed test procedure is far superior to the NTE because it eliminates most of the test point exclusions of the NTE approach, thus enabling evaluation of a much greater fraction of collected in-use data.

A high-level summary of the proposed amendments to the in-use compliance procedure is presented in Table A-3 below:

Table A-3. Summary of Proposed Amendments to the In-Use Compliance Procedure

Model Years	Amendment Details
2022-2023	Continue with current NTE procedure with some minor modifications to the test data exclusions. Request reporting of analysis results following the MAW test procedure.
2024-2026	Switch to the new MAW test procedure.
2027 and later	Tighten requirements of the MAW test procedure by removing certain exclusions and including cold-start emissions.

[36] (Bartolome et al., 2018) "Toward Full Duty Cycle Control: In-Use Emissions Tools For Going Beyond The NTE," Christian Bartolome, Lee Wang, Henry Cheung, Stephan Lemieux, Kim Heroy-Rogalski, William Robertson, California Air Resources Board, 28th CRC Real-World Emissions Workshop, March 2018.

d. Warranty Period Amendments

The Proposed Regulation includes longer emissions warranties for heavy-duty engines and vehicles and changes to required minimum maintenance intervals to help ensure emission controls are durable, maintained and repaired as needed, in order to minimize excess emissions. Emissions warranties are intended to provide a level of assurance to owners that their vehicles, engines, and associated emission control systems are free from defects in materials and workmanship that would cause warranted parts to not be identical to the parts as described in the manufacturers' applications for certification. If such defects do occur during the warranty period, the manufacturers are liable for fixing them.

On June 28, 2018, the Board approved amendments (called June 2018 Step 1 warranty amendments) to strengthen the California on-road heavy-duty vehicle and heavy-duty engine warranty regulations. The approved warranty periods are shown in the second column of Table A-4 and are applicable to 2022 and later model year engines and vehicles. The June 2018 Step 1 warranty amendments did not apply to either heavy-duty Otto-cycle engines nor to the optionally engine-dynamometer-certified engines used in medium-duty vehicles, but the relevant values for such engines are also shown in Table A-4 for completeness. Additionally, the June 2018 Step 1 warranty amendments were not applicable to vehicles that are propelled by battery electric systems, fuel cells, hybrid-electric systems,[37] or other hybrid systems.

The proposal for Step 2 warranty amendments[38] is shown in the third column of Table A-4 and would lengthen the warranty periods for heavy-duty vehicles beginning in model year 2027.

[37] 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. For engine families certified for use in hybrid vehicles exclusively, the warranty will remain 5 years/100,000 miles.
[38] Step 1 refers to the warranty lengthening that takes effect in model year 2022. Step 2 refers to the warranty lengthening proposed to take effect with model year 2027.

Table A-4. Step 1 Warranty Periods for 2022 and Later Model Year, and Proposed Step 2 Warranty Periods for Heavy-Duty Engines Beginning in Model Year 2027

Vehicle / Engine Category Gross Vehicle Weight Rating (GVWR)	Step 1 Warranty 2022 and Later Model Year (Miles)	Proposal for Step 2 Warranty Beginning Model Year 2027 (Miles)
Heavy Heavy-Duty Diesel Class 8 GVWR >33,000 lbs.	350,000 5 years	800,000 14 years
Medium Heavy-Duty Diesel Class 6-7 19,500 < GVWR ≤ 33,000 lbs.	150,000 5 years	360,000 14 years
Light Heavy-Duty Diesel Class 4-5 14,000 lbs. < GVWR ≤ 19,500 lbs.	110,000 5 years	280,000 14 years
Heavy-Duty Otto GVWR >14,000 lbs.	50,000[a] 5 years	200,000 14 years
Medium-Duty Diesel Engine[b] Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs. GVWR	100,000 [a,c] 5 years / 3,000 hours	280,000 14 years
Medium-Duty Otto Engine[b] Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs. GVWR	50,000 [a,c] 5 years	200,000 14 years

[a] These warranty values were not revised under CARB's June 2018 Step 1 warranty amendments. The miles and years are the current warranted values and are shown here for completeness.

[b] Class 3 medium-duty engines are normally installed in chassis-certified medium-duty vehicles weighing between 10,001- 14,000 pounds GVWR and are subject to the LEV III regulations. Currently manufacturers have the option to engine-dynamometer-certify Class 3 medium-duty engines under 13 CCR 1956.8. The Proposed Regulation's useful life and Step 2 warranty amendments would apply if these Class 3 optionally engine-dynamometer-certified engines are installed in vehicles that are greater than 14,000 pounds GVWR. The LEV III useful life and warranty are not changed by this proposal.

[c] Medium-duty engine warranty periods as described in 13 CCR 2036(c)(4)(A), and 13 CCR 2036(c)(8).

Currently, California emissions warranty coverage is applicable to California-certified vehicles, and the California-certified engines used in those vehicles, only if they are registered in California. Under the proposed amendments, California emissions warranty coverage would be expanded to California-certified vehicles with California-certified engines, even if they are registered outside California. The Step 2 warranty amendments mean that the warranty would apply to California-certified engines regardless of where the vehicles that they are installed in are registered, and that the warranty would follow these vehicles even if they are subsequently sold and registered outside of California. The reasoning behind this proposed amendment is that heavy-duty vehicles originating in California can be sold and registered outside of California, and under the normal course of business some of those vehicles eventually return for use in California. Having the warranty remain with the vehicle incentivizes timely repairs for faulty emission-related components so that if the vehicles eventually return and are used in California, they are emissions-compliant. 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 certified for other states. This higher residual value would provide some benefit, upon the vehicle's resale, for first, and subsequent, owners of the California-certified vehicles by retaining some of the value of the vehicle's lengthened warranty periods.

Similar to the June 2018 Step 1 warranty amendments, the proposed Step 2 warranty amendments would apply to the vehicle and engine parts that affect regulated criteria pollutant emissions, including any parts that illuminate the OBD system's MIL.

While the June 2018 Step 1 warranty amendments were not applicable to diesel-fueled engines used exclusively in hybrid vehicles, the proposed amendments would be applicable to such engines, as well as engines that are fueled by gasoline and alternative fuels. However, zero-emission vehicles would not be subject to the proposed Step 2 warranty amendments.

e. Useful Life Period Amendments

The Proposed Regulation includes longer regulatory useful lives for heavy-duty engines to ensure engines and emission controls are durable enough to function properly over modern service lives. The goal of the revised, longer regulatory useful life provisions is to reduce emissions by making manufacturers demonstrate emission controls over a longer period in order to legally sell engines and lengthening the period during which manufacturers are subject to consequences such as recall if their products are found noncompliant in the field. CARB's regulatory useful life provisions require heavy-duty engines to demonstrate 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. Manufacturers are responsible for making sure their engines meet emission standards at the time of certification (via the DDP procedures discussed later), and also at production and for the regulatory useful life of the engines.

Table A-5 shows the current useful life and the proposed values for the useful life amendments beginning with the 2027 engine model year. These longer useful life values were based on the mileages seen in real-world vehicle usage coming from CARB's Emissions Factor (EMFAC) inventory model, as well as data coming from California's Bureau of Automotive Repair inspection and maintenance program (i.e., smog check),[39] and a U.S. EPA report published in September 2013 that studies the heavy-duty diesel engine rebuilding industry.[40]

[39] (CARB, 2019s) "Aggregated Data for Vehicle Odometer Mileages from the Bureau of Automotive Repair's Smog Check Program in Calendar Year 2017," California Air Resources Board, November 2019.
[40] (U.S. EPA, 2013) "Industry Characterization of Heavy Duty Diesel Engine Rebuilds," United States Environmental Protection Agency, September 2013.

Table A-5. Current Useful Life and Proposal for Useful Life for Heavy-Duty Engines Beginning in Model Year 2027

Vehicle / Engine Category Gross Vehicle Weight Rating (GVWR)	Current Useful Life (Miles)	Proposal for Useful Life Beginning Model Year 2027 (Miles)
Heavy Heavy-Duty Diesel Class 8 GVWR >33,000 lbs.	435,000 10 years / 22,000 hours	850,000 18 years/ 22,000 hours[a]
Medium Heavy-Duty Diesel Class 6-7 19,500 < GVWR ≤ 33,000 lbs.	185,000 10 years	450,000 18 years
Light Heavy-Duty Diesel Class 4-5 14,000 lbs. < GVWR ≤ 19,500 lbs.	110,000 10 years	350,000 18 years
Heavy-Duty Otto GVWR >14,000 lbs.	110,000 10 years	250,000 18 years
Medium-Duty Diesel Engine[b] Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs. GVWR	110,000[c] 10 years	350,000 18 years
Medium-Duty Otto Engine[b] Class 3 Engine-Dyno Certified Used in vehicles weighing >14,000 lbs. GVWR	110,000[c] 10 years	250,000 18 years

[a] Note that this value is unchanged from the current value, and it is shown here for completeness.
[b] Class 3 medium-duty engines are normally installed in chassis-certified medium-duty vehicles weighing between 10,001-14,000 pounds GVWR and are subject to the LEV III regulations. Currently manufacturers have the option to engine-dynamometer-certify Class 3 medium-duty engines under 13 CCR 1956.8. The Proposed Regulation's useful life and Step 2 warranty amendments would apply if these Class 3 optionally engine-dynamometer-certified engines are installed in vehicles that are greater than 14,000 pounds GVWR. The LEV III useful life and warranty are not changed by this proposal.
[c] Medium-duty engine useful life values as described in California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines and Vehicles, §86.004-2, and California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles, §86.004-2.

f. Emissions Warranty Information and Reporting Amendments

The overall goal of the EWIR amendments is to reduce emissions by allowing the current EWIR program to function more effectively and enact more expeditious corrective actions, and adapt to the proposed Step 2 warranty and useful life periods. This would be accomplished through several changes. The proposed amendments would rely on failure rates to determine if corrective action is necessary, modify warranty reporting and corrective action thresholds, and make other minor clarifying changes to make the program more robust. The categories affected include class 4-8 California-certified heavy-duty diesel and Otto-cycle vehicles, and engines, including medium-duty diesel and Otto-cycle engines, used in such vehicles.

i. Amended Warranty Reporting and Failure Thresholds

The current EWIR warranty reporting requirements require manufacturers to track the number of unscreened warranty claims for each emissions control component.[41] Unscreened warranty claims refer to the number of warranty claims that occurred, for any reason, regardless of whether the part being replaced or repaired was actually verified to be 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 quarterly EWIR reports tracking the warranty claims rate. The proposed amendment would reduce the reporting threshold to an unscreened rate of 1 percent or 12 claims, whichever is greater starting with the 2022 model year. This is important because issues with engine families with a population of less than 2,500 engines are not required to report warranty claims data until they exceed 25 warranty claims, which in some cases, depending on the size of the engine family population, can account for a large percentage of the engine family. This results in CARB being unaware of potential issues with their emission control components 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 the amount of warranty reporting manufacturers must conduct.

Currently, once the unscreened warranty claims rate reaches 4 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 failure rate. This allows 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 amendments would reduce the reporting threshold so that FIRs must be submitted when the unscreened warranty claims rate reaches 4 percent or 25 claims, whichever is greater, for the 2022 through 2026 model years. The reason why the proposed reporting threshold is being reduced to 25 claims for the 2022 through 2026 model years is to require a FIR sooner, especially for small volume engine families. For 2027 and subsequent model years, it is proposed that the reporting threshold also be reduced to 4 percent or 25 claims, whichever is greater, for the first five years of the

[41] In this SRIA'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.

reporting period, 7 percent or 50 claims, whichever is greater, for years 6-10, and 10 percent or 70 claims, whichever is greater, for years 11-14. The reason why staff is proposing to reduce the reporting threshold to 25 claims for the first five years is also to account for small volume engine families. The reason why the reporting threshold is proposed to be increased to 7 percent or 50 claims, whichever is greater, for years 6-10, and 10 percent or 70 claims, whichever is greater, for the remaining years of the reporting period is to account for the proposal to lengthen the warranty period for the affected vehicles and engines. It is therefore logical to similarly increase the reporting threshold as well.

Currently, once an emission control component exceeds a failure rate of 4 percent or 50 failures, whichever is greater, manufacturers are required to submit an Emissions Information Report (EIR), to assess the emission impact of the failure. Manufacturers are required to take corrective action in the form of recalls for components that have a failure rate greater than 4 percent or 50 failures, whichever is greater. Often times manufacturers have proposed to extend warranty periods as an alternative to conducting recalls, and 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 amendments would reduce the reporting threshold so that EIRs must be submitted when the failure rate of a component reaches 4 percent or 25 failures, whichever is greater, for the first five years of reporting for the 2022 through 2026 model years. The corrective action threshold for the 2022 through 2026 model years is also proposed to be reduced to 4 percent or 25 failures. The reason why staff is proposing to reduce the warranty reporting and corrective action thresholds for the 2022 through 2026 model years is to allow for defects to be identified sooner for small volume engine families. For 2027 and subsequent model years, the EIR reporting threshold and corrective action threshold is also proposed to be reduced to 4 percent or 25 failures, whichever is greater, for the first five years of the reporting period, 7 percent or 50 failures, whichever is greater, for years 6-10, and 10 percent or 70 failures, whichever is greater, for years 11-14. The rationale for these proposed changes is the same as that for the changes to the FIR reporting thresholds (see above). A summary of the current and proposed reporting and corrective action thresholds can be seen in Table A-6.

Table A-6. Proposed Reporting and Corrective Action Thresholds

Model Years	EWIR	FIR	EIR	Corrective Action
Current	1% or 25 Unscreened Claims	4% or 50 Unscreened Claims	4% or 50 Failures	4% or 50 Failures
2022-2026	1% or 12 Unscreened Claims	4% or 25 Unscreened Claims	4% or 25 Failures	4% or 25 Failures
2027 and later	1% or 12 Unscreened Claims	Years 1-5 4% or 25 Unscreened Claims Years 6-10 7% or 50 Unscreened Claims Years 11-14 10% or 70 Unscreened Claims	Years 1-5 4% or 25 Failures Years 6-10 7% or 50 Failures Years 11-14 10% or 70 Failures	Years 1-5 4% or 25 Failures Years 6-10 7% or 50 Failures Years 11-14 10% or 70 Failures

(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.)

Model years 2027 and subsequent have multiple reporting and corrective action thresholds depending on how long the model year has been in service. The thresholds for years 6-10 and 11-14 were obtained by linearly extrapolating the threshold of 4 percent or 25, whichever is greater for years 1-5 out to 14 years.

ii. Required Corrective Actions

The current program requires manufacturers to conduct a recall once the failure rate of an emission control component has exceeded the corrective action threshold. On occasion, CARB has allowed manufacturers to issue extended warranties to full useful life for certain components as an alternative to recall if CARB staff determines that extending the warranty of the component to full useful life would be as effective as conducting a recall.

The proposed amendments would require manufacturers to perform recalls for aftertreatment components, computers, and critical emission control components for 2022 and subsequent model years once their failure rate exceeds the corrective action thresholds specified in Table A-6. Manufacturers would also be required to perform recalls for other emission control components that reach a failure rate of 25 percent within five years. If a component reaches a 25 percent failure rate within five years, it is clear that the problem is systemic in nature and would very likely fail in 100 percent of vehicles within the useful life period. Therefore, it is proposed that a manufacturer would be required to conduct a recall to address the issue expeditiously.

Manufacturers would also be required to provide extended warranties to full useful life for all components that exceed the corrective action thresholds for 2022 and subsequent model years, including those components that were also recalled due to exceeding the corrective action threshold.

iii. Parts Storage/Warranty Reporting Verification

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. The proposed amendments would require manufacturers to store parts that are analyzed to gather information for FIR reports for a period of two years after the FIR is submitted and, upon request, 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 (especially for parts deemed "no trouble found").

g. Emissions Averaging, Banking, and Trading Program Amendments

The Proposed Regulation includes amendments to current ABT provisions to account for the fact that California heavy-duty emission standards would be more stringent than federal ones. The current emission standards include ABT provisions that allow manufacturers to certify some engines that are higher-emitting than the standard as long as they offset the emission increases by certifying some that are lower-emitting.[42]
The regulations define four separate ABT averaging sets (pools) of credits for heavy-duty engines. These include:

- Heavy-Duty Otto-cycle (HDO) engines, including medium-duty[43] Otto-cycle engines;
- Light heavy-duty diesel (LHDD) engines, including medium-duty diesel engines;
- Medium heavy-duty diesel (MHDD) engines; and
- Heavy heavy-duty diesel (HHDD) engines.

Historically, ABT of emission credits have been performed at the national level (50-State). Given that the emission standards have historically been harmonized between CARB and U.S. EPA, and the fact that manufacturers certify engine families as 50-State families, this approach simplifies the ABT calculations and the credits are calculated based on the national sales volume of on-road heavy-duty engines. However, the proposed amendments would set a more stringent California set of NOx and PM emission standards for on-road heavy-duty engines. Therefore, the current (national) accounting mechanism would no longer be sustainable and a new California ABT program (CA-ABT) would be needed starting with the 2024 model year.

[42] The mechanism to participate in the 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, §86.007-15, and California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles, §86.007-15.
[43] Medium-duty engines refer to engines certified through 13 CCR 1956.8 standards and test procedures for engines used in incomplete medium-duty vehicles.

i. Credit Transfer Mechanism

Under the proposed amendments, on-road heavy-duty engine manufacturers would be able to initiate their CA-ABT program by transferring a portion of their national credits into the CA-ABT account during the 2024 model year. NOx and PM credits that were generated prior to the 2010 model year would not be transferrable to the CA-ABT account. Thus, only credits generated from 2010 through 2023 model year engines would be considered for the transfer of credits from the national credits pool to a new California credit pool (i.e., CA-ABT).

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 each ABT averaging set during the preceding five model years (2019-2023). The percentage of California sales to national sales over this five-year period would be the percentage cap for the transfer of national credits generated from the 2010 through 2023 model years.

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

h. Heavy-Duty Engine Durability Demonstration Program Amendments

The Proposed Regulation strengthens durability demonstration requirements to assure that results from the DDP are representative of the real-life operations of the engine and aftertreatment system. 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 through 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 an Executive Order can be issued, allowing the manufacturer to sell products in the California market.

The time period over which the engine and aftertreatment system (EAS) are aged for durability demonstration is referred to as service accumulation. For example, a service accumulation schedule might include aging 100 percent of useful life on an engine dynamometer. Another service accumulation schedule might include such aging for only part of the useful life, with the remaining useful life represented by artificially accelerated aging (for example by exposing the aftertreatment to heat or chemicals to simulate what would happen to it during actual operation).

Based on a review of available certification and in-use testing data, 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 in the 2027 model year, manufacturers would need to account for the lengthened useful life in the existing procedures for the durability demonstration.

For on-road heavy-duty diesel engines, staff is proposing to amend the current DDP protocols to more accurately represent real-life operations. Recently, the largest diesel engine manufacturer in the U.S. recalled[44] over 500,000 trucks due to defective SCR systems. These trucks had all followed the proper DDP protocols. Based on the analysis of data from this recall program, staff has determined that the current DDP protocols do not yield results that are comparable to real-life aging of on-road heavy-duty diesel engines.

Starting with model year 2024 engines, the amendments to the on-road heavy-duty diesel engine DDP protocols would standardize the amount of time that is needed to prepare EAS for official emissions testing (i.e., increase the length of service accumulation), standardize the protocols for aging the EAS, and require additional testing time so that EAS could be evaluated to their full useful life. As an option, engine manufacturers could utilize the Diesel Aftertreatment Accelerated Aging Cycle (DAAAC)[45] procedures in order to reduce testing time. However, this would require additional in-use NOx emissions data reporting on engines sold over their useful life.

Table A-7 specifies the service accumulation schedules to be applicable to the various on-road heavy-duty diesel engines for the 2024 through 2026 model year period. Note that for the 2024 to 2026 model years, the DAAAC protocol would only be an option for HHDDs.

Table A-7. 2024 - 2026 Model Year DDP Service Accumulation Schedules

Primary Intended Service Class	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	110,000	2,500 hours (100% UL)	0
MHDD	185,000	4,200 hours (100% UL)	0
HHDD	435,000	4,900 hours (50% UL)*	600 hours (50% UL)
		9,800 hours (100% UL)**	0

* Option 1: This option would require the submittal of in-use NOx emissions data, as discussed further in A.2.i. below.

** Option 2: Although this option is available, staff expects few manufacturers to use this option because it would be time consuming.

44 (CARB, 2018c) "CARB investigation leads to nationwide recall of 500,000+ Cummins heavy-duty trucks." California Air Resources Board, July 31, 2018. https://ww2.arb.ca.gov/news/carb-investigation-leads-nationwide-recall-500000-cummins-heavy-duty-trucks

45 (Bartley, 2012) "The DAAAC Protocol for Accelerated Aging of Diesel Aftertreatment Systems," Gordon Bartley, Southwest Research Institute, 15th CLEERS Workshop, 2012. https://cleers.org/wp-content/uploads/formidable/3/Bartley_CLEERS2012.pdf

The anticipated DDP for 2027 and subsequent model year on-road heavy-duty diesel engines would rely on the same elements used in the optional aging protocol for 2024 through 2026 model year 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 NOx data from in-use engines covering the full useful life period. However, because the proposed amendments lengthen the applicable useful life values as discussed above in A.2.e., the proposed service accumulation schedules, as shown in Table A-8, would be applicable.

Table A-8. 2027 and Subsequent Model Year 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	350,000	1,500 hours (19% UL)	780 (81% UL)
LHDD	350,000	1,500 hours (19% UL)	780 (81% UL)
MHDD	450,000	2,000 hours (20% UL)	1,000 (80% UL)
HHDD	850,000	3,600 hours (19% UL)	1,900 hours (81% UL)

The proposed amendments for 2027 and subsequent model year on-road heavy-duty diesel engines would require all manufacturers to submit periodic in-use NOx emissions data, as described further in A.2.i. below.

i. In-Use NOx Emissions Data Reporting Amendments

Because the Proposed Regulation includes much longer useful life requirements (equivalent to several years of consecutive hours), it will become less feasible for manufacturers to age engines on a dynamometer out to the full useful life. Hence, the Proposed Regulation includes provisions to allow manufacturers to submit in-use NOx emissions data in lieu of dynamometer aging.[46] The proposed amendments include

[46] Although the Proposed Regulation would give manufacturers the option of collecting and submitting data from their customers' vehicles in lieu of some upfront durability dynamometer testing, no "personal information" such as name, address, social security number, etc., for any customers would need to be collected or submitted. Hence, the Proposed Regulation would be compliant with the California Consumer Privacy Law.
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The law defines personal information as follows:

optional submittal of in-use NOx emissions data reports to CARB starting with the 2024 model year as part of durability demonstration and mandatory submittal of such data beginning with the 2027 model year. Current OBD regulations[47] require the tracking of a set of parameters known as REAL within the engine electronic control unit for 2024 and subsequent model year heavy-duty diesel engines. The REAL parameters can be used to represent the in-use NOx emissions characteristics of the engine. The proposed amendments would require heavy-duty diesel engines to report in-use NOx emissions data to the engine manufacturers via telematics. Given the wide use of telematics[48] currently used by fleets, staff believes that the capability to transmit the REAL data via telematics to engine manufacturers from each new 2024 and subsequent model year on-road heavy-duty diesel truck would be feasible.

j. Powertrain Certification Test Procedure for Heavy-Duty Hybrid Vehicles Amendments

Staff is proposing a new powertrain certification procedure for heavy-duty hybrid vehicles (HDHV) intended to make it more feasible for manufacturers to certify heavy-duty hybrids as a way to meet the Proposed Regulation's stricter NOx standards. CARB's current Phase 2 GHG emission standards for medium- and heavy-duty engines and vehicles include powertrain test procedures that allow manufacturers to certify heavy-duty vehicles to the GHG 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 procedures are only for GHG certification and do not constitute a certification process for NOx or other criteria

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"Personal information" means information that identifies, relates to, describes, is capable of being associated with, or could reasonably be linked, directly or indirectly, with a particular consumer or household. Personal information includes, but is not limited to, the following:
(A) Identifiers such as a real name, alias, postal address, unique personal identifier, online identifier Internet Protocol address, email address, account name, social security number, driver's license number, passport number, or other similar identifiers.
(B) Any categories of personal information described in subdivision (e) of Section 17 98.80.
(C) Characteristics of protected classifications under California or federal law.
(D) Commercial information, including records of personal property, products or services purchased, obtained, or considered, or other purchasing or consuming histories or tendencies.
(E) Biometric information.
(F) Internet or other electronic network activity information, including, but not limited to, browsing history, search history, and information regarding a consumer's interaction with an Internet Web site, application, or advertisement.
(G) Geolocation data.
(H) Audio, electronic, visual, thermal, olfactory, or similar information.
(I) Professional or employment-related information.
(J) Education information, defined as information that is not publicly available personally identifiable information as defined in the Family Educational Rights and Privacy Act (20 U.S.C. section 1232g, 34 C.F.R. Part 99).
(K) Inferences drawn from any of the information identified in this subdivision to create a profile about a consumer reflecting the consumer's preferences, characteristics, psychological trends, preferences, predispositions, behavior, attitudes, intelligence, abilities, and aptitudes.

[47] 13 CCR 1971.1 (h)(5.3) through (h)(5.7)
[48] (Teletrac Navman, 2019) "What is Telematics?" Teletrac Navman, accessed September 2019. https://www.teletracnavman.com/telematics-definitions/what-is-telematics

pollutant emission standards. CARB's current Phase 2 GHG powertrain test procedures mirror the U.S. EPA's GHG powertrain test procedures. As such, this option will allow for a convenient way for manufacturers to undergo comprehensive testing, so long as the needed instrumentation for criteria pollutants is available. The proposed amendments would provide a voluntary option for certifying HDHVs to criteria pollutant emission standards including the NOx standards using the powertrain testing procedure.

k. Heavy-Duty Vehicle GHG Tractor APU Certification Amendments

Staff is proposing to amend requirements that pertain to APUs for tractors to better harmonize California certification procedures with the federal ones. In the Phase 2 GHG regulation, adopted by the Board on February 8, 2018, an APU that will be used in a new 2024 and subsequent model tractor is required to be certified to the PM emission standard specified in title 40, Code of Federal Regulations, section 1039.699 (40 CFR 1039.699). Rather than reference the federal emission standard, staff is proposing to amend the existing California certification procedures for APUs to include 40 CFR 1039.699 and to require an APU that would be used in a new 2024 and subsequent model year tractor to be certified to the California APU certification procedures. The proposed amendments would allow California the ability to enforce APU compliance with 40 CFR 1039.699 to ensure that they meet the emission standards in-use.

l. Technical Amendments and Clean-up Items

The Proposed Regulation includes minor corrections to California's Phase 2 GHG regulations to fix small errors and add clarity. Since CARB adopted the Phase 2 GHG standards and began implementing them, staff has become aware that several minor clarifications and corrections are needed. Staff is therefore proposing some minor changes to the Phase 2 regulation, such as clarifying definitions, clarifying that end of year reports should include California-specific data, correcting references to California recall provisions, correcting the font size on labels, and clarifying the Executive Officer's ability to exempt specific trailer configurations if no technology is available to meet the standard. None of the minor amendments and clean-up items are expected to have significant cost impacts.

3. Statement of the Need of the Proposed Regulation

The Proposed Regulation and associated GHG related amendments are driven by the need to meet the National Ambient Air Quality Standards for ozone and PM2.5 and the state's climate emission reduction goals.

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

As mentioned above, 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. 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 about 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 is compliant with the 2010 standard, the 2031 and more stringent 2037 National Ambient Air Quality Standards requirements for ambient ozone will not be attained in California without further reductions of ozone precursor emissions.

The current 2010 PM emissions standard for heavy-duty vehicles is 0.01 g/bhp-hr. Today's DPFs are very effective in controlling PM emissions with high efficiencies. However, most of the PM currently coming from heavy-duty engines is produced from the secondary formation of PM from NOx emissions. Thus, reducing NOx emissions will also provide PM2.5 emission benefits contributing significantly to solving the PM2.5 air quality challenge in the San Joaquin Valley air basin.

In California, although heavy-duty trucks only account for about 8 percent of the statewide GHG emissions from all sources, they still account for about 20 percent of carbon dioxide emissions from the transportation sector.[49] Thus, in order to meet the climate emission reduction goals, further reductions in GHG emissions are needed from heavy-duty vehicles. The Phase 2 heavy-duty GHG regulations adopted in 2018 will contribute significantly to the state's climate emission reduction goals. However, in this rulemaking, staff's proposed amendments would address clarifications and corrections needed to effectively implement the Phase 2 heavy-duty GHG regulations, and therefore, the amendments are not expected to provide additional GHG emission reductions beyond those claimed in the Phase 2 regulations.

The establishment of 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. As discussed above, additional measures in the 2016 State SIP Strategy involve requirements to ensure effective in-use performance and the durability of emissions control equipment, as well as the deployment of near-zero and zero-emission technologies. The Proposed Regulation is responsible for nearly a third of the entire NOx emission reduction commitment in the SIP for 2031.

a. Regulatory Authority

CARB has been granted broad authority under the California Health and Safety Code (HSC) to adopt the proposed amendments. The California Legislature has designated CARB as the state agency that is "charged with coordinating efforts to attain and maintain

[49] (CARB, 2017c) Staff Report: Initial Statement of Reasons for Proposed Rulemaking, "Proposed California Greenhouse Gas Emissions Standards for Medium- and Heavy-Duty Engines and Vehicles and Proposed Amendments to the Tractor-Trailer GHG Regulation," California Air Resources Board, December 19, 2017. https://ww3.arb.ca.gov/regact/2018/phase2/isor.pdf

ambient air quality standards, to conduct research into the causes of and solution to air pollution, and to systematically attack the serious problem caused by motor vehicles, which is the major source of air pollution in many areas of the State" (HSC 39003) and has authorized CARB 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)), and that will expeditiously reduce NOx emissions from diesel vehicles, "which significantly contribute to air pollution problems" (HSC 43013(h)).

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." California 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 GHG emissions in 1990, no later than December 31, 2030. California 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.

4. Major Regulation Determination

Per 1 CCR 2000-2004,[50] any agency that anticipates promulgating a regulation that will have an economic impact on California business enterprises and individuals in an amount exceeding $50 million in any 12-month period between the date they are filed with the Secretary of State through 12 months after they are fully implemented (defined as major regulation) is required to submit a SRIA. The Proposed Regulation and associated amendments would be fully implemented in 2027 and would result in an economic impact exceeding $50 million starting in 2025, which triggers the threshold for a major regulation and the requirement for a SRIA. CARB staff has estimated that the Proposed Regulation could result in direct costs to regulated entities of up to $162 million in a given year.

5. Baseline "Business-as-Usual" Information

For this SRIA, the economic and emissions impacts of the Proposed Regulation are evaluated against a baseline scenario each year for the analysis period from 2022 through 2032. The baseline for the Proposed Regulation, referred to as the "legal baseline," reflects implementation of currently existing state and federal laws and regulations including the Truck and Bus Regulation, Drayage Truck Regulation, idling restrictions and

[50] (DOF, 2019) Major Regulations, California Department of Finance, accessed September 2019. http://www.dof.ca.gov/Forecasting/Economics/Major_Regulations/

the Certified Clean Idle Regulation, Phases 1 and 2 GHG Regulation, ICT Regulation, and the Optional Low NOx Program. The legal baseline vehicle inventory includes the same vehicle sales and population growth assumptions currently reflected in CARB's EMFAC[51] emissions inventory model for combustion engines that are engine certified and intended for use in vehicles greater than 10,000 pounds GVWR.

The ICT Regulation requires set percentages of newly purchased buses to be zero-emission buses depending on fleet size starting in 2023. In 2029 and later years, 100 percent of newly purchased buses must be zero-emission buses. Zero-emission bus sales attributed to the ICT Regulation were removed from new sales applicable to the Proposed Regulation.

This cost analysis takes into account the ICT Regulation requirement for newly purchased bus internal combustion engine propulsion systems to be low NOx engines as defined in 13 CCR 2208(c)(18). The ICT Regulation cost analysis already quantified costs for low-emission compressed natural gas bus engines, and so those costs are not included in this cost analysis. However, because the ICT Regulation cost analysis did not include costs to make diesel bus engines as low-emitting as the Proposed Regulation would require, this analysis accounts for those diesel engine costs.

The Proposed ACT Regulation is a regulation that will affect the same manufacturers and vehicles as the Proposed Regulation and that is due to go into effect approximately the same time as the Proposed Regulation. So as not to overstate the benefits and costs of the Proposed Regulation, the legal baseline was modified to take into account the ACT Regulation. This baseline, hereinafter referred to as the "modeled baseline," is the baseline used to model the costs and benefits of the Proposed Regulation.

The Proposed ACT Regulation would require manufacturers producing engines in vehicles with weight classes 8,500 pounds and greater to have a percentage of new sales to be zero-emission vehicles. The Proposed ACT Regulation would begin affecting new engine sales starting in 2023 and phases in greater percentages until 2030. The Proposed ACT Regulation was presented at the December 2019 CARB Board Hearing and is expected to be approved in May 2020, thus prior to the board hearing considering the Proposed Regulation.

Zero-emission vehicle sales attributed to the proposed ACT Regulation were removed from new sales applicable to the Proposed Regulation. Accounting for the ACT rule in the modeled baseline reduces the number of vehicles affected by the Proposed Regulation, resulting in a more accurate estimate of the costs and a conservative estimate of the benefits of the Proposed Regulation. Since fewer vehicles remain to be subject to the Proposed Regulation in the modeled baseline once the ACT Regulation is taken into account, the emissions benefits associated with the Proposed Regulation in the modeled baseline are less than in the legal baseline scenario, for example by about 17 percent in 2031. The modeled baseline has 9 percent fewer heavy-duty engines subject to the Proposed Regulation in 2031 (because the remainder are assumed to be zero-emission, per ACT rule requirements). Furthermore, fixed costs such as research and development

[51] (CARB, 2019e) EMFAC2017 Web Database, California Air Resources Board, accessed September 2019. https://www.arb.ca.gov/emfac/2017/

costs (i.e., costs that do vary by number of vehicles) for the Proposed Regulation would be distributed over a fewer number of vehicles in the modeled baseline than in the legal baseline. The smaller heavy-duty engine population subject to the Proposed Regulation in the modeled baseline increases the cost by $20 per engine, which equates to about a 0.4 percent average total incremental increase per engine.[52] Finally, the cost per ton of NOx reduction of the Proposed Regulation with the modeled baseline would be 8 percent greater (i.e., 8 percent worse cost-effectiveness) than calculated with the legal baseline.

Including the Proposed ACT Regulation allows for a more realistic analysis and does not bias or distort the results, as excluding it would increase benefits, costs and decrease cost-effectiveness assigned to the Proposed Regulation. As the Proposed ACT Regulation has not been finalized through the Office of Administrative Law it would not be used in the legal baseline. However, the inclusion of the Proposed ACT Regulation in the modeled baseline provides results that are more informative and likely to reflect the real impacts of the Proposed Regulation.

6. Public Outreach and Input

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 Regulation. These informal pre-rulemaking discussions provided staff with useful information that was considered during development of the Proposed Regulation.

a. Collaboration with U.S. EPA

CARB staff has been working with U.S. EPA staff over the past several years on the development of the Proposed Regulation. Since December 19, 2016, 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.

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 January 2017, CARB staff held more than eight workgroup meetings, all of which were conducted using online webinars.

[52] The total weighted incremental increase in cost per engine is estimated to be $5,520 as shown in Table C-45 of this document.

Consistent with Senate Bill 617 requirements, at a June 26, 2019 workgroup meeting, CARB staff requested public input on alternatives to the draft regulatory proposals, as well as alternatives discussed in previous workgroups, public workshops, and in the CARB Staff White Paper.[53] In particular, CARB staff encouraged public input on alternative approaches that may yield the same or greater benefits than those associated with the Proposed Regulation, or alternatives that may achieve the goals at a lower cost. In response, staff received alternative proposals from the Truck and Engine Manufacturers Association (EMA) and the South Coast Air Quality Management District, which are the two alternative proposals evaluated in this SRIA.

c. Workshop Meetings

In addition to workgroup meetings, CARB staff also held three public workshops, one on November 3, 2016, another on January 23, 2019, and another on September 26, 2019. At these workshops, CARB staff discussed proposed concepts to the Proposed Regulation. 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.

d. Other Meetings

In addition to holding workgroup meetings and workshops, staff also met interested stakeholders individually including EMA, the members of MECA, the International Council on Clean Transportation, environmental organizations, and Transport Canada. Staff also met one-on-one individually with engine manufacturers and component suppliers multiple times at CARB offices in El Monte and Sacramento. Staff met with every engine manufacturer at their headquarters, toured their facilities, met with their compliance and regulatory affairs staff and discussed their concerns. Furthermore, staff also presented and discussed the Proposed Regulation at more than 20 technical conferences and workshops, at seven meetings of 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, South Coast Air Quality Management District Clean Fuels Advisory Board, etc., and at more than five industry, non-governmental, and trade group meetings.

B. BENEFITS

The Proposed Regulation is an important measure in the 2016 State SIP Strategy. It is designed to reduce NOx emissions from today’s heavy-duty vehicles by up to 90 percent, contributing nearly a third of the emission reductions committed in the SIP for attainment of ozone air quality standards in 2031.

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

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[53] (CARB, 2019b) 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 Model Year Medium-Duty and Heavy-Duty Diesel Engines,” California Air Resources Board, April 18, 2019. https://ww3.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf

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 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 Regulation also includes 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 HDHVs 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, they would make implementation of the 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 Regulation amendments.

Section 1 below discusses in greater detail the emission benefits of the Proposed Regulation. Section 2 discusses benefits to typical businesses. Section 3 discusses benefits to small businesses. Finally, section 4 discusses benefits to individuals.

1. Emission Benefits

The Proposed Regulation is 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 incomplete 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 standards 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.

a. Inventory Methodology

On-road mobile source emissions in California are currently calculated using the EMFAC2017 model.[54] To calculate emissions benefits from the Proposed Regulation,

[54] 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.

EMFAC2017 is first modified to establish the modeled baseline by taking into account recently adopted regulations that have not been reflected in the current model and account for the impacts of the Proposed ACT Regulation. As noted above, since both the ACT and Proposed Regulations impact the same vehicles during the same timeframe, the modeled baseline includes the Proposed ACT Regulation, even though the legal baseline does not. The inclusion of the Proposed ACT Regulation in this analysis provides more informative and realistic results of showing the impacts of the Proposed Regulation. The inclusion of the Proposed ACT Regulation reduces the emission reductions estimated for the Proposed Regulation. (In other words, if the ACT Regulation were not included in the modeled baseline, the expected emission benefits of the Proposed Regulation would be biased high.) The modeled baseline is modified to reflect the requirements in the Proposed Regulation to establish the emissions inventory with the Proposed Regulation. The emission benefits are estimated as the difference between the modeled baseline and the Proposed Regulation inventories. For simplicity, the remaining discussions in the SRIA will use the term “baseline” to mean the “modeled baseline.”

Because the Proposed Regulation would increase new vehicle purchase prices, it is possible it could encourage California fleets to hold onto their existing vehicles slightly longer or to consider purchasing used vehicles in lieu of new vehicles in California. However, as described further in section C.1.m. below, the expected percent increases in vehicle cost are relatively small (about 2.5 percent in 2024 and less than 6 percent in 2027) and will generate some savings discussed in section B.2.b. below. 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. Hence, in estimating the emission benefits for this SRIA, staff did not attempt to quantify any such changes in fleet purchase behavior.

In addition, to the extent that the Proposed Regulation makes emission standards more stringent in California than outside California, it is possible that it could encourage California fleets to purchase slightly used vehicles out-of-state in lieu of buying new vehicles in California. California fleets are prevented from purchasing new vehicles out-of-state because it is illegal to register new vehicles in California if they are not California certified. As discussed further below, U.S. EPA is currently in the process of developing their own package of NOx emission standards called the Cleaner Trucks Initiative, which is scheduled to take effect in approximately the same timeframe as the Proposed Regulation, most likely taking effect with the 2027 model year. Because the Proposed Regulation is likely to take effect before the Cleaner Trucks Initiative, discussions are underway regarding a potential national voluntary program to enable cleaner trucks nationally during the years before the Cleaner Trucks Initiative takes effect. Due to the uncertainty regarding the extent to which California standards will diverge from federal standards and the duration of any difference, in estimating the emission benefits for this SRIA, staff did not model changes to projected new truck sales in California, nor any changes in out-of-state purchases of used vehicles. The possibility of new engine sales moving to out-of-state purchases of used vehicles is discussed further below in section E.4.h.

b. Criteria Pollution Emission Benefits

i. Emission Benefits of NOx Standard Amendments

Figure B-1 shows projected statewide NOx emissions inventory for the baseline scenario and the Proposed Regulation scenario. In 2031, the target SIP date to meet the 2008 ozone ambient air quality standards, NOx emission benefits are estimated to be approximately 21.9 tons per day statewide and 6.6 tons per day in the South Coast Air Basin. The Proposed Regulation is projected to reduce NOx emissions by approximately 134,000 tons statewide between the years 2022 through 2040. Table B-1 shows the projected statewide NOx emission benefits for each calendar year 2022 through 2032.

Figure B-1. Projected Statewide NOx Emissions for the Baseline and Proposed Regulation Scenarios (Total California and Federally Certified Heavy-Duty Vehicles with GVWR > 10,000 pounds)

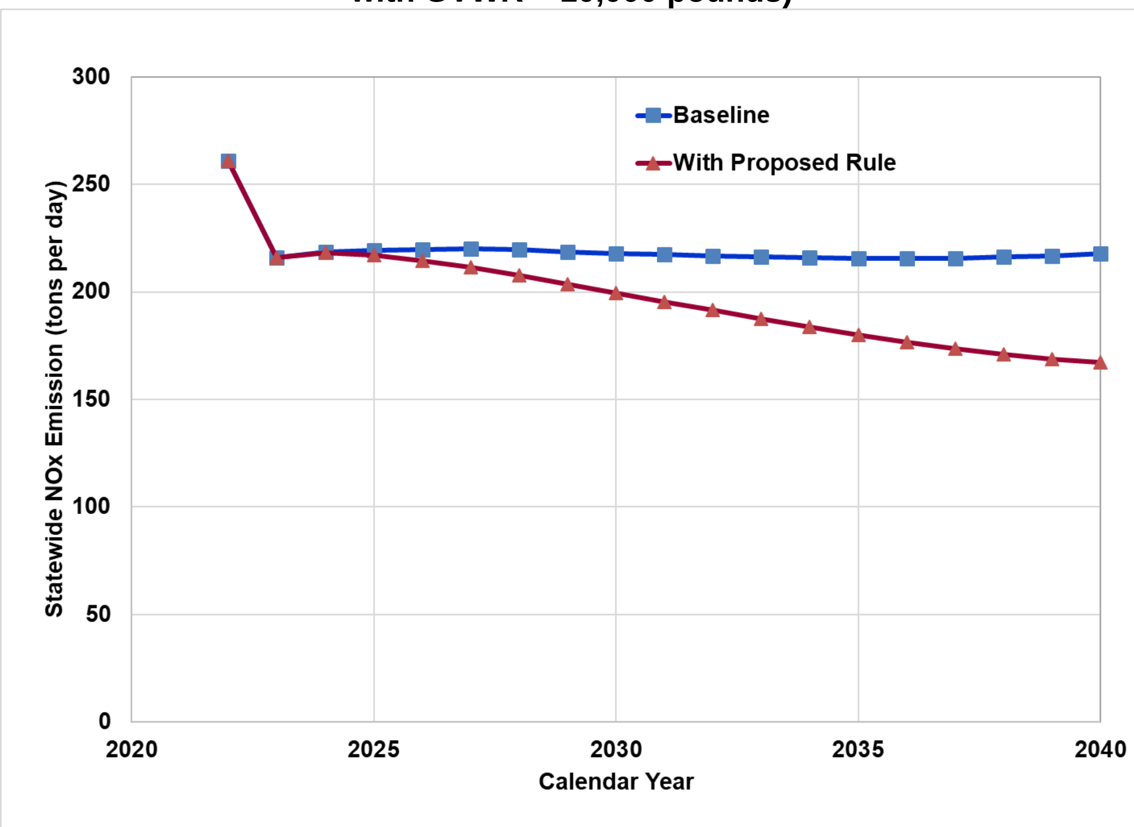

Table B-1. Projected Statewide NOx Emission Benefits from the Proposed Regulation for 2022 through 2032

Calendar Year	NOx Benefits (tons per day)
2022	0.0
2023	0.1
2024	0.6
2025	2.6
2026	5.4
2027	8.4
2028	11.6
2029	15.2
2030	18.5
2031	21.9
2032	25.4

ii. Emission Benefits of PM Standard Amendments

As discussed above, the proposed PM standard of 0.005 g/bhp-hr is intended to encourage manufacturers to continue using current robust PM emissions control performance at 0.001 g/bhp-hr levels and prevent from backsliding to use less robust DPFs. 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 B.4.

2. Benefits to Typical Businesses

Typical businesses that may benefit from the proposed requirements include original equipment manufacturer component suppliers and individual truck and bus owners, including fleets (trucking or bus operations). Except for truck and bus owners, none of these businesses are located in California. Section a. below discusses benefits for original equipment manufacturer component suppliers, and section b. below discusses benefits for truck and bus owners.

a. Original Equipment Manufacturer Component Suppliers

Original equipment manufacturer 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.

b. Truck and Bus Owners

Although, overall the Proposed Regulation would increase truck prices and DEF consumption and thereby impose costs on truck and bus owners, the regulation would provide savings to truck and bus owners as well. Three parts of the proposed amendments would provide savings to truck and bus owners: the Lengthened Warranty, the Lengthened Useful Life, and the EWIR amendments. 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 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 the truck or bus owner. Finally, the EWIR amendments would mean more extended warranties and recalls, which would result in savings for vehicle purchasers because components that they previously had to pay for out-of-pocket would now be repaired or replaced under an extended warranty or recall.

<u>Savings for Lengthened Warranty</u>

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 be passed on to the consumers in the form of an increased purchase price for the trucks, vehicle buyers would gradually recoup some of the initial increase in purchase price as they save money on repairs.

Staff assumes that the vehicle purchaser receives repair savings beginning in the sixth year of vehicle ownership and continues to receive them in equal annual amounts each year until the end of the warranty period. The current HD Warranty (Step 1) Regulation covers vehicles through the fifth year of ownership. Therefore, as shown in detail below in Table B-3, when the Proposed Regulation's Warranty program (Step 2) is implemented in 2027, the first year that the savings are realized is in 2032 and would continue to the end of the proposed new warranty period of 14 years.

<u>Savings for Lengthened Useful Life</u>

Staff expects that the longer useful life would encourage development of more durable components to 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.

<u>Savings from Proposed EWIR Amendments</u>

The proposed 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 that they previously had to pay for out-of-pocket would now be repaired or replaced under an extended warranty or recall. Savings attributed to the EWIR amendments do not occur until the new lengthened warranty periods have ended. For the 2022 through 2026 model years, for example, the warranty period is 5 years, so savings related to the EWIR amendments would start after the warranty period has ended. For model year 2027 and later, the proposed new warranty period would be 14 years, so savings related to the EWIR amendments would be realized starting in the 15th year.

Overall Savings For a Typical Vehicle from the Proposed Regulation

Tables B-2 and B-3 below show estimates of the lifetime savings per vehicle due to the Proposed Regulation for vehicle purchases made between 2022 through 2026 and for 2027 and later, respectively. Lifetime savings estimates include savings from Warranty (Step 2) and the EWIR amendments. Depending on the service class, truck owners could save up to $2,540 and $5,065 per truck for truck purchases during the 2022 through 2026 and 2027 and later time periods, respectively.

Table B-2. Lifetime Savings to Vehicle Owners from a Vehicle Purchased in 2022-2026 Calendar Years Due to the Proposed Regulation (2018$ Per Vehicle)

Vehicle Service Class	EWIR Amendments	Total Per Vehicle Savings
HHDD	$520	$520
MHDD	$2,540	$2,540
LHDD	$545	$545
HDO	$620	$620
MDDE-3	$0	$0
MDOE-3	$0	$0
New Sales Population Weighted Average	**$1,279**	**$1,279**

Table B-3. Lifetime Savings to Vehicle Owners from a Vehicle Purchased in 2027 and Subsequent Calendar Years Due to the Proposed Regulation (2018$ Per Vehicle)

Vehicle Service Class	Step 2 Lengthened Warranty	EWIR Amendments	Total Per Vehicle Savings
HHDD	$2,574	$416	$2,990
MHDD	$3,033	$2,032	$5,065
LHDD	$1,674	$436	$2,110
HDO	$711	$496	$1,207
MDDE-3	$873	$0	$873
MDOE-3	$153	$0	$153
New Sales Population Weighted Average	**$2,298**	**$1,047**	**$3,345**

To estimate what these savings would mean for affected fleets, staff considered an example large fleet that buys 20 vehicles in a year. A large fleet buying 20 MHDD vehicles in 2024 would expect to save $50,800 over the vehicles' lifetimes with the proposed amendments. As another example, a large fleet buying 20 MHDD vehicles in 2027 would expect to save $101,300 over the vehicles' lifetimes with the proposed amendments. These savings represent repair costs that vehicle owners would have had to pay for out-of-pocket, but now would be covered by the amendments. Section C.2. below discusses costs for typical businesses, and provides estimated costs and net impact from the Proposed Regulation for this same example large fleet.

3. Benefits to Small Businesses

Small businesses that may be affected by the Proposed Regulation include small fleets and engine repair facilities. As mentioned above, small fleets[55] may benefit financially in having to pay less for engine repairs over the lifetime of the vehicle and less overall downtime. This is because under the Proposed Regulation, 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.

As an example, a small fleet that buys one HHDD model year 2024 vehicle would save $520 over the lifetime of the vehicle as a result of the proposed amendments, as shown in Table B-2. As another example, a small fleet purchasing one HHDD in 2027 would expect to save $2,990 over the lifetime of the vehicle as a result of the proposed amendments.

The savings would partially offset the increased purchase costs that vehicle buyers would incur due to the Proposed Regulation. Costs for small businesses are discussed below in section C.3.

4. Benefits to Individuals

The Proposed Regulation would benefit California residents mainly from the reductions in NOx resulting in reduced ozone exposure and reduced PM exposure from the secondary formation of NOx to PM2.5, and from improvements in California air quality and reduced adverse health impacts.

a. Health Benefits

The Proposed Regulation would reduce NOx emissions and thereby reduce the secondary formation of PM2.5, resulting in health benefits for individuals in California. The value of these health benefits is due to fewer instances of premature mortality, fewer hospital and emergency room visits, and fewer lost days of work. As part of setting the National Ambient Air Quality Standards for Ozone, the U.S. EPA quantifies the health risk from

[55] Small businesses are defined here to be California fleets within the trucking industry with three or fewer heavy-duty vehicles.

exposure to PM2.5,[56] 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 proposed Low Carbon Fuel Standard 2018 Amendments, the Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program, and the ACT Regulation.

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.[57] The U.S. EPA examined other health endpoints such as cancer, 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 the U.S. EPA.

The 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.

A detailed summary of the health modeling methodology is included in section H. Health Modeling Methodology Appendix of this SRIA.

i. Results

Table B-4 shows the estimated avoided premature mortality, hospitalizations, and emergency room visits because of the Proposed Regulation for 2022 through 2032 by California air basin, relative to the baseline. Only the regions with values of one or higher are shown, and regions with zero or insignificant impacts are not shown. Values in parentheses represent the 95 percent confidence intervals of the central estimate. As detailed in the previous section, the Proposed Regulation is estimated to reduce overall emissions of NOx in most years, and lead to a net reduction in adverse health outcomes

[56] (U.S. EPA, 2010) "Quantitative Health Risk Assessment for Particulate Matter," United States Environmental Protection Agency, EPA-452/R-10-005, June 2010. https://www3.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf

[57] In this SRIA, we have quantified health benefits due to the reduction in secondary PM 2.5 expected from the Proposed Regulation. We expect the Proposed Regulation would also lead to additional, smaller health benefits due to ambient ozone reductions, but they are not quantified here.

statewide, relative to the baseline. Table B-5 shows the annually estimated statewide-avoided premature morality, hospitalization, and emergency room visits.

The Proposed Regulation may 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 B-4. Regional and Statewide Avoided Mortality and Morbidity Incidents from 2022 through 2032 Under the Proposed Regulation*

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits
Great Basin Valleys	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Lake County	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Lake Tahoe	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Mojave Desert	3 (1 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Mountain Counties	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
North Central Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
North Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Northeast Plateau	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Sacramento Valley	16 (12 - 17)	0 (0 - 3)	0 (0 - 0)	5 (4 - 8)
Salton Sea	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	13 (10 - 16)	0 (0 - 3)	0 (0 - 0)	5 (3 - 7)
San Francisco Bay	26 (19 - 31)	2 (0 - 8)	4 (0 - 7)	15 (9 - 20)
San Joaquin Valley	69 (54 - 85)	8 (0 - 15)	9 (0 - 16)	26 (16 - 36)
South Central Coast	4 (3 - 5)	0 (0 - 0)	0 (0 - 0)	0 (0 - 2)
South Coast	196 (154 - 240)	31 (0 - 61)	38 (0 - 66)	102 (64 - 140)
Statewide	**334 (262 - 406)**	**48 (0 - 94)**	**57 (13 - 100)**	**160 (102 - 219)**

*Values in parentheses represent the 95% confidence interval. Totals may not add due to rounding but are within the 95% confidence interval.

Table B-5. Annual Statewide Avoided Mortality and Morbidity Incidents Under the Proposed Regulation

Calendar Year	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits	Total Incidents
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	27
2027	24	3	4	12	44
2028	35	5	6	17	62
2029	46	7	8	22	82
2030	57	8	10	27	102
2031	68	10	12	33	123
2032	80	12	14	38	144
Total	**334**	**48**	**57**	**160**	**599**

*Rounded to whole numbers

In accordance with U.S. EPA practice, health outcomes are monetized by multiplying each incident by a standard value derived from the economic studies. The value per incident is shown in Table B-6. The value for avoided premature mortality is based on willingness to pay, which is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year. While the savings associated with premature mortality is important to account for in the analysis, the valuation of avoided premature mortality does not correspond to changes in expenditures and is not included in the macroeconomic modeling (section E). As avoided hospitalizations and emergency room visits correspond to reductions in household expenditures on health care, these values are included in the macroeconomic modeling.

Unlike mortality valuation, the savings for avoided hospitalizations and emergency room visits are based on a combination of typical costs associated with hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, post-hospitalization medical care, out-of-pocket expenses, and lost earnings of both individuals and family members, lost recreation value, and lost household production (e.g., valuation of time-losses from inability to maintain the household or provide childcare). These monetized benefits from avoided hospitalizations and emergency room visits are included in macroeconomic modeling (section E).

Table B-6. Valuation Per Incident for Avoided Health Outcomes

Outcome	Value Per Incident (2018$)
Avoided Premature Mortality	$9,419,320
Avoided Cardiovascular Hospitalizations	$56,588
Avoided Acute Respiratory Hospitalizations	$49,359
Avoided Emergency Room Visits	$810

Statewide valuation of health benefits was calculated by multiplying the value per incident in Table B-6 by the statewide total number of incidents for 2022 through 2032 as shown in Table B-5. Annual statewide valuation of health benefits is presented in Table B-7. The estimated total statewide health benefits derived from criteria emission reductions is estimated to be $3.15 billion, with $3.14 billion resulting from reduced premature mortality and $5.7 million resulting from reduced hospitalizations and emergency room visits. The spatial distribution of these benefits across the state follows the distribution of the health impacts by air basin as described in Table B-4.

Table B-7. Statewide Valuation from Avoided Health Outcomes Under the Proposed Regulation

Outcome	Avoided Incidents	Valuation (Million 2018$)
Avoided Premature Mortality	334	$3,144.20
Avoided Cardiovascular Hospitalizations	48	$2.71
Avoided Acute Respiratory Hospitalizations	57	$2.82
Avoided Emergency Room Visits	160	$0.13
Total	**599**	**$3,149.86**

C. DIRECT COSTS

The Proposed Regulation would require engine manufacturers to produce lower-emitting heavy-duty combustion engines, which will likely increase upfront production and operational costs, compared to preexisting engines. These costs will likely be passed on to the engine/vehicle operators. Many, but not all, parts of the Proposed Regulation would impose costs, as delineated in Table C-1.

Table C-1. Proposed Regulation and Associated Amendments

Section	Proposal Elements	Cost/Savings[58] Impact
a	Low NOx Standards Compliance	Cost
b	Lower PM Standards Compliance	Cost
c	Heavy-Duty In-Use Amendments	Cost
d	Lengthened Warranty	Cost and Savings
e	Lengthened Useful Life	Cost and Savings
f	EWIR Amendments	Cost and Savings
g	ABT Amendments	Cost
h	DDP Amendments	Cost
i	In-Use NOx Emissions Data Reporting	Cost
j	Powertrain Test Procedures	None
k	Heavy-Duty Vehicle GHG Tractor APU Certification	None
l	Tech Amendments and Clean-up Items for GHG Phase 2	None

To assess the potential impact on the California economy, staff evaluated the costs assuming that all the increased costs in producing low NOx engines will be passed on to the businesses purchasing those engines. This analysis is performed by comparing the costs under the baseline scenario to the costs under the Proposed Regulation for calendar years 2022 through 2032. The baseline for this analysis includes the Proposed ACT Regulation for the reasons outlined in section A.5 above. The Proposed ACT Regulation will impact the same vehicle populations in the same timeframe. In order to provide the most informative and realistic results, our analysis includes the Proposed ACT Regulation as a part of the baseline. Without the Proposed ACT Regulation included, costs would appear higher, but benefits would rise more which would make the cost-effectiveness for the Proposed Regulation appear better than it actually is expected to be. Including ACT in the baseline is therefore a more accurate and realistic method to portray the impact of the Proposed Regulation. All costs are presented in 2018 calendar year constant dollars.

As discussed further above in section B.1.a., although it is possible the Proposed Regulation 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

[58] Savings from the Proposed Regulation are discussed in section B. BENEFITS.

out-of-state vehicles, in estimating the costs for this SRIA, for the reasons outlined in section B.1.a., staff did not attempt to quantify any such changes in fleet purchase behavior. Instead, in the Direct Costs section all sales populations and incremental increases are based on baseline new sales in California with no change in trends to buy out-of-state.

1. Direct Cost Inputs

Staff divided the affected engine population into six categories based on fuel type due to their different costs associated to meet the Proposed Regulation requirements. The engine categories for this analysis are medium-duty diesel (MDDE-3), light heavy-duty diesel (LHDD), medium heavy-duty diesel (MHDD), heavy heavy-duty diesel (HHDD), medium-duty Otto-cycle (MDOE-3), and heavy-duty Otto-cycle (HDO) engines as summarized in Table C-2.

Table C-2. Truck and Engine Classification

Fuel Type	Truck Class	Engine Category	Engine Displacement (liters)	GVWR (lbs.)	EMFAC2017 Categories
Diesel	Class 3	Medium-Duty (MDDE-3)	6-7 L (300HP)	10,001 - 14,000	Light Heavy-Duty 2
Diesel	Class 4-5	Light Heavy-Duty (LHDD)	6-7 L (300HP)	14,001 - 19,500	T6 Small T6 Heavy School Bus, All Other Buses
Diesel	Class 6-7	Medium Heavy-Duty (MHDD)	6-7 L (300HP)	19,501 - 33,000	T6 Small T6 Heavy School Bus All Other Buses
Diesel	Class 8	Heavy Heavy-Duty (HHDD)	12-13 L (475HP)	> 33,000	T7 Motor Coach Urban Bus
Gasoline	Class 3	Medium-Duty (MDOE-3)	6 L	10,001 - 14,000	Light Heavy-Duty 2 T6 Tractors School Bus Other Bus-Gasoline
Gasoline	Class 4-8	Heavy-Duty (HDO)	6 L	> 14,000	Urban Bus

In this analysis, all estimates for annual California sales are from CARB's EMFAC2017 inventory model. EMFAC2017 includes vehicle population growth, mileage accrual rates over time, vehicle fuel usage and associated emission factors, and vehicle attrition over time. The vehicle categories in EMFAC2017 were matched to the Proposed Regulation's vehicle groups as shown in Table C-2.

The engine sales by class were projected starting in year 2022 through 2032 by EMFAC2017 based on California DMV registration datasets. Engines spanning the LHDD and MHDD classifications were mixed into a single category by EMFAC. The LHDD and MHDD service classes in the 14,000 to 33,000 pounds GVWR range were split into 42 percent and 58 percent of new sales, respectively, based on an average of six years of certification sales data. A summary of projected new engine sales by intended service class is provided in Table C-3.

Table C-3. Projected California New Engine Sales by Intended Service Class for Years 2022 through 2032

Calendar/ Purchase Year	Diesel				Gasoline	
	MDDE-3	LHDD	MHDD	HHDD	MDOE-3	HDO
2022	223	5,793	8,984	6,803	68	3,488
2023	217	6,213	9,408	7,202	61	3,586
2024	234	6,358	9,798	6,703	54	3,377
2025	227	6,473	10,316	6,778	62	3,341
2026	211	6,607	10,330	6,827	31	3,325
2027	206	6,733	10,641	6,877	29	3,245
2028	211	6,850	10,641	6,800	38	3,008
2029	202	6,976	10,905	6,726	27	2,652
2030	186	7,095	11,025	6,625	11	2,252
2031	188	7,189	11,172	6,723	11	2,273
2032	189	7,382	11,485	6,919	11	2,335

This rulemaking package includes the Proposed 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 analyses will focus on the Proposed Regulation amendments. The direct cost inputs for the various parts of the package are described in the sections below as follows:

a. Low NOx Compliance Costs (FTP, RMC-SET, LLC, and Idle)

Compliance with the new low NOx standards would increase costs by requiring new technologies to be added to engines and requiring additional certification testing (LLC and longer break-in periods), and would impact the operational costs of the engines by requiring more diesel exhaust fluid. Manufacturers would also be expected to incur research and development costs.

CARB staff contracted with NREL to conduct a cost analysis to estimate costs associated with new technology and upgrades to engine hardware, costs to upgrade the aftertreatment system, research and development costs, and additional testing time compared to the 2018 technology baseline. In February 2019, NREL staff presented findings based on literature review and calculations.[59]

[59] (NREL, 2019) "Low NOx Technology Cost Study Update – Task 1 Deliverable," National Renewable Energy Laboratory, February 15, 2019.

Table C-4 below presents a summary of technologies and incremental cost for each engine type to meet the 2024 and 2027 standards based on NREL's February 2019 findings.

Table C-4. Engine Technology, Aftertreatment Technology, and Research and Development and Overall Incremental Cost Estimates for Meeting the 2024 and 2027 Low NOx Standards

		6/7-liter Diesel		12/13-liter Diesel		6-liter Gasoline	
		2024-2026 MY engines	2027+ MY engines	2024-2026 MY engines	2027+ MY engines	2024-2026 MY engines	2027+ MY engines
Engine Technology	EGR Cooler Bypass	$243		$243			
	Cylinder Deactivation		$720		$794		
Aftertreatment Technology	Light-off SCR		$358		$700		
	DOC (subtotal)	($12)	$13	$232	$232		
	DPF (2018 baseline system only)	($23)	($23)	($73)	($73)		
	SCR + Ammonia Slip Catalyst + DEF Dosing (subtotal)	$727	$727	$885	$885		
	OBD sensors and controllers (NOx, Ammonia, temp sensors)	$74	$74	$88	$88		
	TWC					$381	$381
Research and Development Cost[60]	Engineering Cost	$250	$250	$250	$250	$100	$100
Total Incremental Hardware Cost to Manufacturer		$1,009	$1,869	$1,375	$2,626	$381	$381
Total Incremental Research and Development Costs to Manufacturer		$250	$250	$250	$250	$100	$100
Total Incremental Cost		**$1,259**	**$2,119**	**$1,625**	**$2,876**	**$481**	**$481**

*Values are only shown for technologies applicable to that application.
**Values in parentheses represent savings compared to the baseline 2018 technology and costs.

[60] The research and development costs in Table C-4 were estimated by NREL based on original equipment manufacturer shareholder reports. 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 Regulation in the modeled baseline (i.e., after implementation of the ACT Regulation).

The annual incremental cost to meet the proposed low NOx standards was based on three configurations: 6/7-liter diesel, 12/13-liter diesel, and 6/7-liter gasoline, as shown in Table C-5. A steep learning curve,[61] used in previous U.S. EPA analyses, was applied to technologies required for the Proposed Regulation to reflect improvements and cost reductions in the manufacturing processes over time.

Table C-5. Incremental Costs Based on Engine Size and Fuel Type to Meet the Proposed HD Low NOx FTP, RMC-SET, LLC, and Idle Standards for Model Year 2022 through 2032 Engines (2018$ per engine)

Calendar Year	6/7-liter Diesel	12/13-liter Diesel	6/7-liter Gasoline
2022	$0	$0	$0
2023	$0	$0	$0
2024	$1,259	$1,625	$481
2025	$1,259	$1,625	$481
2026	$1,053	$1,335	$405
2027	$2,119	$2,876	$481
2028	$1,741	$2,336	$405
2029	$1,695	$2,271	$396
2030	$1,651	$2,209	$387
2031	$1,608	$2,148	$378
2032	$1,567	$2,089	$370

The additional costs of meeting the new LLC were calculated based off of the number of anticipated engine families to be tested. On-road heavy-duty diesel engine manufacturers certified a total of 34 engine families in the 2018 model year. Using this number as the baseline, manufacturers would have to conduct an additional LLC emissions test for all these engine families first in the 2024 model year, and subsequently in the 2027 model year. Staff used the assumption that the 2024 model year LLC emissions data could also be used to certify 2025-2026 model year engines, and that the 2027 model year LLC emissions data could be used to certify the 2028-2032 model year engines. This type of “carryover” of emissions and durability data from one model year to subsequent model years is standard industry practice, and means that LLC certification testing would not need to be done for the 2025-2026 and 2028-2032 model year engines.

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

[61] (U.S. EPA, 2016) “Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2,” Regulatory Impact Analysis, United States Environmental Protection Agency, EPA-420-R-16-900, August 2016. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF

work to optimize NOx emissions under the LLC. Thus, staff is assuming that the cost for the technology package and calibration development to comply with the proposed idling standards would be absorbed by the technology and engine development costs needed to meet the LLC.

Staff also assumed that the emissions testing would be performed in the calendar year preceding the applicable model year. The standard industry practice is to complete all emissions testing for certification prior to the beginning of the model year. Therefore, the cost of 2024 model year LLC emissions testing would appear as a 2023 calendar year cost and cost of 2027 model year LLC emissions testing would appear in calendar year 2026.

Based on a survey of LLC emission test costs paid by CARB during the development of the LLC,[62] staff used an average cost of $23,000 for performing the LLC emissions test. It should be noted that this is the estimated cost of performing the emissions test by contracting out the emissions testing. All on-road heavy-duty diesel manufacturers perform the required emissions testing at their corporate facilities, so the actual cost of performing the LLC emissions test should be a fraction of the $23,000 cost used here.

The Proposed Regulation also would increase the break-in period for heavy-duty diesel engines to 300 hours from the current 125 hours baseline. Based on a survey of previous contracts with emissions testing facilities,[63] staff used an estimated cost of $160/hour for service accumulation. This cost would cover both labor and material (fuel, power, water, maintenance, etc.) costs for the extra number of break-in hours needed under the Proposed Regulation. It should be noted that since the manufacturers use their own facilities and personnel for service accumulation, the actual cost is most likely a fraction of the value used here.

[62] (CARB, 2016) 15MSC010, Contract with Southwest Research Institute, California Air Resources Board, signed September 21, 2016.
[63] (CARB, 2013a) 13-312, Contract with Southwest Research Institute, California Air Resources Board, signed September 20, 2013.

Using these assumptions, a conservative estimate of the incremental costs of the proposed certification emissions testing requirements are shown in Table C-6 below.

Table C-6. Estimated Incremental Costs Relative to the 2018 Model Year Baseline for the Proposed Certification Testing Requirements (2018$)

Calendar Year	Incremental Costs for Certification Testing
2022	$0
2023	$1,734,000
2024	$0
2025	$0
2026	$1,734,000
2027	$0
2028	$0
2029	$0
2030	$0
2031	$0
2032	$0
Total	**$3,468,000**

Because the Proposed Regulation would require SCR systems to operate during more of vehicles' actual operating hours, for example, even during low load conditions, the Proposed Regulation would lead to the consumption of more DEF. The annual total incremental change in operational costs for DEF consumption for 2024 and 2027 technologies are summarized by year in Table C-7. The incremental DEF consumption was estimated by calculating the increased NOx conversion efficiency required to meet the 2024 and 2027 standards and were determined to be 5.36 percent and 6.43 percent, respectively. The increased conversion efficiency would require an equal increase in DEF consumption. Annual mileages for the vehicle classes were determined using EMFAC2017. The baseline DEF consumption was estimated using the methods described by Cummins[64] and the vehicle miles per engine category based on EMFAC2017. The quantity of DEF was conservatively estimated to be 5 percent of the diesel fuel consumption.[65] The price of DEF fluid is currently $2.91 per gallon.[66] The incremental annual DEF costs are presented in Table C-7 by engine weight class.

[64] (Cummins, 2016) "6 Answers About Diesel Exhaust Fluid," Cummins Inc., January 4, 2016, accessed September 2019. https://www.cummins.com/news/2016/01/04/5-answers-about-diesel-exhaust-fluid
[65] (Cummins, 2016) "6 Answers About Diesel Exhaust Fluid," Cummins Inc., January 4, 2016, accessed September 2019. https://www.cummins.com/news/2016/01/04/5-answers-about-diesel-exhaust-fluid
[66] (Discover DEF, 2019) Diesel Exhaust Fluid Tracker, Discover DEF, accessed September 19, 2019. https://www.discoverdef.com/

Table C-7. Incremental Annual DEF Consumption Costs by Engine Class (2018$ per engine)

Engine Class	Model Year 2024	Model Year 2027
HHDD	$93.02	$111.63
MHDD	$21.46	$25.76
LHDD	$14.53	$17.44
MDDE-3	$19.61	$23.53
MDOE-3	$0.00	$0.00
HDO	$0.00	$0.00

b. Lower PM Standards Compliance Costs (FTP and RMC-SET)

Analysis of 2018 model year 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. Staff assume that the cost for reducing PM emissions would be absorbed by the engineering cost required to optimize NOx emissions (included in Table C-4) and that there would be no additional cost to meet the proposed PM standard. As a result, staff estimates that there would be no additional cost to meet the proposed PM standard.

c. Amended Heavy-Duty In-Use Test Procedure Costs

Additional costs were estimated assuming that the thirteen manufacturers would spend 80 hours each at an engineer’s compensation rate of $100/hour for coordinating test plans with CARB staff as a result of amendments to the HDIUT program. No other aspects of the testing are changed and no additional costs are expected. The annual incremental increase in costs to the industry is estimated to be $104,000 for the amendments to the HDIUT procedures.

d. Lengthened Warranty Costs

In order to estimate the incremental costs associated with the Step 2 warranty amendments, the current warranty practices and coverages must first be quantified. This is achieved by establishing the warranty purchasing practices for the heavy-duty market, and then determining the average miles driven and associated costs while under warranty. From there the projected costs can be found and the overall incremental costs for Step 2 warranty can be estimated.

i. Current Warranty Purchasing Business Practices

Once the June 2018 Step 1 warranty amendments are implemented beginning with the 2022 model year, 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 model year 2022 is expected to have a profile as shown in Table C-8 for heavy-duty diesel vehicles. These values come from the estimates based on a survey conducted by the Sacramento Institute for Social Research, and discussions with manufacturers and third-party warranty providers, all accomplished as part of CARB's June 2018 Step 1 warranty amendment rulemaking effort.[67] The baseline used in this analysis (which was already established in the HD Warranty Regulation) accounts for real-world purchasing behavior and focuses on the out-of-pocket expenses that would be covered under the Proposed Regulation. The table shows that for the HHDD vehicle, and the MHDD vehicle categories, 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. As Table C-8 indicates, for the LHDD vehicle category, it is estimated that 100 percent of the vehicles will have a warranty coverage of 110,000 miles, the minimum required by the June 2018 Step 1 warranty amendments.

Table C-8. Projected Warranty Purchasing Business Practices Due to the June 2018 Heavy-Duty Warranty Amendments

HHDD		MHDD		LHDD	
Miles Warranted	**% of Vehicle Population**	**Miles Warranted**	**% of Vehicle Population**	**Miles Warranted**	**% of Vehicle Population**
500,000	40%	185,000	40%	110,000	100%
350,000	60%	150,000	60%		

[67] (CARB, 2018a) Appendix C: Economic Impact Analysis / Assessment for the Rulemaking: "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles" (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/appc.pdf?_ga=2.203012433.1791822584.1568703793-1642656111.1560298095

Because heavy-duty vehicles with either Otto-cycle engines or medium-duty engines were not included in the June 2018 Step 1 warranty amendments, a similar breakdown based on the Sacramento Institute for Social Research survey was not developed for those categories. 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. Based on this assumption, the warranty practices for both heavy-duty Otto-cycle engines and optionally engine-dynamometer-certified Class 3 medium-duty engines are shown in Table C-9.

Table C-9. Warranty Purchasing Practices for Heavy-Duty Otto-cycle and Class 3 Medium-Duty Engines that are Engine-Dynamometer-Certified

HDO		MDDE-3		MDOE-3	
Miles Warranted	% of Vehicle Population	Miles Warranted	% of Vehicle Population	Miles Warranted	% of Vehicle Population
50,000	100%	100,000	100%	50,000	100%

ii. Mileage Covered Under Warranty

Warranty periods under baseline are given as a mileage threshold, a year threshold, and for the optionally engine-dynamometer-certified Class 3 medium-duty diesel engines, an hourly 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 subcategory as shown in Table C-10. The 2022 model year populations from EMFAC were used in the baseline, and their population percentages are shown in Table C-10.

Table C-10. EMFAC Vehicle Service Application Population Percentages for Model Year 2022

HHDD Class 8 Vehicles T7: > 33,000 lbs. GVWR		MHDD Class 6-7 Vehicles T6: 19,501 – 33,000 lbs. GVWR		LHDD Class 4-5 Vehicles T6: 14,001 – 19,500 lbs. GVWR		HDO GVWR > 14,000 lbs.		MDDE/MDOE Class 3 Vehicles GVWR 10,001 – 14,000 lbs.	
Vehicle Subcategory	Population%	Vehicle Subcategory	Population%	Vehicle Subcategory	Population%	Vehicle Subcategory	Population%	Vehicle Subcategory	Population%
Motor Coach	1.31%	T6 CAIRP Heavy	0.80%	T6 CAIRP Heavy	0.58%	OBUS	16.18%	**Diesel**	
T7 CAIRP	13.15%	T6 CAIRP Small	0.43%	T6 CAIRP Small	0.31%	SBUS	8.29%	LHD2-DSL	92.30%
T7 CAIRP Construction	1.19%	T6 Instate Construction Heavy	2.28%	T6 Instate Construction Heavy	1.65%	T6TS	68.15%	UBUS	7.70%
T7 Other Port	0.70%	T6 Instate Construction Small	7.00%	T6 Instate Construction Small	5.07%	T7IS	0.17%	**TOTAL**	**100%**
T7 POAK	2.57%	T6 Instate Heavy	9.86%	T6 Instate Heavy	7.14%	UBUS-GAS	7.22%		
T7 POLA	7.74%	T6 Instate Small	31.39%	T6 Instate Small	22.73%			**Otto**	
T7 Public	11.01%	T6 Public	5.17%	T6 Public	3.74%			LHD2-GAS	92.28%
T7 Single	11.79%	T6 Utility	1.06%	T6 Utility	0.77%			UBUS-GAS	7.72%
T7 Single Construction	8.29%	All Other Buses*	2.53%						
T7 SWCV	7.18%	SBUS*	4.04%						
T7 Tractor	21.75%	UBUS*	4.28%						
T7 Tractor Construction	5.54%								
T7 Utility	0.27%								
UBUS	7.50%								
TOTAL	**100%**	**TOTAL (% of T6)**	**58%**	**TOTAL (% of T6)**	**42%**	**TOTAL**	**100%**	**TOTAL**	**100%**

*** EMFAC bus categories for T6 grouped into GVWR range from 19,501- 33,000 lbs**

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. An example using this approach is given in Table C-11 for HHDD.

Table C-11. Table Showing the Calculations for the Mileage Covered Under Warranty for the Heavy Heavy-Duty Diesel Category

HHDD Warranty Mileage Estimates			
	60% covered to 350,000 miles		
Vehicle Subcategory	**Population %**	**5 Year Mileage**	**Warranty Mileage**
Motor Coach	1.31%	352,917	350,000
T7 CAIRP	13.15%	584,953	350,000
T7 CAIRP Construction	1.19%	584,953	350,000
T7 Other port	0.70%	488,987	350,000
T7 POAK	2.57%	488,987	350,000
T7 POLA	7.74%	488,987	350,000
T7 Public	11.01%	49,896	350,000
T7 Single	11.79%	211,768	350,000
T7 Single Construction	8.29%	211,768	350,000
T7 SWCV	7.18%	100,325	350,000
T7 Tractor	21.75%	488,987	350,000
T7 Tractor Construction	5.54%	488,987	350,000
T7 Utility	0.27%	46,656	350,000
UBUS	7.50%	194,564	350,000
		Weighted Average Miles Covered for 60%	**258,793**
	40% covered to 500,000 miles		
Vehicle Subcategory	**Population %**	**5 Year Mileage**	**Warranty Mileage**
Motor Coach	1.31%	352,917	500,000
T7 CAIRP	13.15%	584,953	500,000
T7 CAIRP Construction	1.19%	584,953	500,000
T7 Other Port	0.70%	488,987	500,000
T7 POAK	2.57%	488,987	500,000
T7 POLA	7.74%	488,987	500,000
T7 Public	11.01%	49,896	500,000
T7 Single	11.79%	211,768	500,000
T7 Single Construction	8.29%	211,768	500,000
T7 SWCV	7.18%	100,325	500,000
T7 Tractor	21.75%	488,987	500,000
T7 Tractor Construction	5.54%	488,987	500,000
T7 Utility	0.27%	46,656	500,000
UBUS	7.50%	194,564	500,000
		Weighted Average Miles Covered for 40%	**333,586**
		Overall Weighted Average Mileage Covered	**288,710**

Applying the same weighted average approach to the other vehicle categories results in the baseline average miles traveled under warranty, as shown in Table C-12.

Table C-12. Current Average Miles Traveled Under Warranty for Each Vehicle Category

Vehicle Category	Baseline Average Miles Traveled Under Warranty
HHDD	288,710
MHDD	95,536
LHDD	43,192
HDO	50,000
MDDE-3	75,635
MDOE-3	50,000

iii. Cost of Repairs Under the Current Warranty

The approach used for establishing the baseline costs was to determine the cost of repairs under the covered warranty periods. This was found by utilizing information from the warranty claims-related data, obtained under CARB's EWIR program (see C.1.f. for a description of the EWIR program), and sales data from the engine-dynamometer-certification applications (also given in section C.1.f.).

The total number of warranty claims for each engine component was added up and divided by the number of engine-dynamometer-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 dataset is with respect to the 2013 model year, and so the 2013 model year engine certification reported sales were also used to calculate the warranty claims rate.

The average repair costs that include both parts and labor for each component were obtained through analysis of service station repair records and costs utilized in the 2018 heavy-duty warranty lengthening rulemaking.[68] Multiplying these average repair costs by the claims rate for each engine component provides an estimate for the average weighted repair costs that a typical heavy-duty vehicle experiences while still under warranty. An example using this approach is shown in Table C-13 for the HHDD category which had 11,022 engines sold for the 2013 model year.

68 (CARB, 2018b) Staff Report: Initial Statement of Reasons for the for Rulemaking: "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles" (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf?_ga=2.169925923.2011115175.1568077425-1788626826.1465349672

Table C-13. 2013 Model Year Warranty Claims Rates and Costs for the Heavy Heavy-Duty Diesel Vehicle Category (2018$)

Component	Total Claims[69]	Warranty Claims Rate	Average Repair Cost	Weighted Repair Cost
CAT	0	0.0%	$2,500	$0.00
DOC	893	8.1%	$3,800	$307.88
DPF	118	1.1%	$2,600	$27.84
ECU	653	5.9%	$1,725	$102.20
SCR	138	1.3%	$5,371	$67.25
DEF DOSER	1,010	9.2%	$1,178	$107.95
DPF DOSER	778	7.1%	$1,178	$83.15
EGR COOLER	1,059	9.6%	$3,100	$297.85
EGR VALVE	358	3.2%	$1,200	$38.98
FUEL INJECTOR	659	6.0%	$2,208	$132.02
TURBOCHARGER	1,082	9.8%	$5,100	$500.65
BLOWBY FILTER	0	0.0%	$150	$0.00
BOOST CONTROL VALVE	12	0.1%	$450	$0.49
CHARGE AIR COOLER	2	0.0%	$3,000	$0.54
CHARGE AIR DUCT	28	0.3%	$300	$0.76
CLAMP	8	0.1%	$50	$0.04
CRANKCASE SEPARATOR	22	0.2%	$1,029	$2.05
CYL HEAD	26	0.2%	$5,000	$11.79
DEF PUMP	454	4.1%	$1,445	$59.52
DEF TANK	27	0.2%	$1,000	$2.45
ECU REPROGRAM	3,246	29.5%	$400	$117.80
ELECTRICAL HARNESS	122	1.1%	$277	$3.07
EXHAUST MANIFOLD	369	3.3%	$2,500	$83.70
EXHAUST VALVE	81	0.7%	$3,500	$25.72
FUEL LINE	6	0.1%	$1,362	$0.74
FUEL PUMP	370	3.4%	$1,624	$54.52
FUEL TANK	0	0.0%	$2,000	$0.00
GASKET	111	1.0%	$100	$1.01
IGNITION CONTROL MODULE	282	2.6%	$550	$14.07
INTAKE MANIFOLD	2	0.0%	$2,500	$0.45
NOx SENSOR	1,677	15.2%	$670	$101.94
OIL PUMP	35	0.3%	$1,293	$4.11
OIL RAIL	16	0.1%	$1,638	$2.38
OIL SEPARATOR	879	8.0%	$500	$39.87
OTHER SENSORS	3,206	29.1%	$670	$194.88
PRESS CONTROL VALVE	41	0.4%	$500	$1.86
RUBBER HOSE	25	0.2%	$250	$0.57
THROTTLE VALVE	138	1.3%	$805	$10.08
VACUUM PUMP	0	0.0%	$550	$0.00
TOTAL	**17,933**	**162.7%**		**$2,400**

[69] Note that the total claims values shown are for HHDD and urban buses. This was done in order to remain consistent with CARB's certification requirements that define an urban bus as a bus that is normally powered by a heavy heavy-duty engine and weighs greater than 33,000 pounds GVWR.

Using this approach, the weighted repair costs can be found for all the vehicle categories that are considered under this proposal. Additionally, beginning with the 2022 model year for HHDD, MHDD, and LHDD, 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,[70] and the traditionally reported components are shown in Table C-14.

Table C-14. Total Average Repair Costs Per Vehicle Expected Under the Step 1 Warranty Requirements for Each Vehicle Category (2018$)

Vehicle Category	Average Repair Costs from 2013 Model Year EWIR Data	Expected Indirect Emissions Components Repair Costs Beginning in Model Year 2022 under Step 1 Warranty	Expected Total Average Repair Costs Beginning in Model Year 2022 under Step 1 Warranty
HHDD	$2,400	$16	$2,416
MHDD	$2,769	$6	$2,775
LHDD	$1,073	$23	$1,096
HDO	$238	N/A	$238
MDDE-3	$651	N/A	$651
MDOE-3	$0	N/A	$64[71]

iv. Average Mileage Driven Under the Proposed Warranty

As was done for the baseline average miles traveled while covered under warranty, the average miles traveled under the proposed lengthened warranty amendments are based on the estimated warranty coverage practices shown in Table C-15.

[70] 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.

[71] The cost associated with the Otto-cycle optionally engine-dynamometer-certified Class 3 medium-duty engines was actually zero dollars when using the EWIR warranty claims data, because in the 5 year warranty reporting period, there were no claims for medium-duty vehicles that used the Otto-cycle optionally engine-dynamometer-certified medium-duty engine families. However, this would have caused the projected costs to remain unreasonably at zero dollars under the proposed lengthened warranty periods, and so an alternative approach was used to estimate costs for this vehicle class. This alternative method used the ratio of the HHDD to the HDO and multiplied it by the MDDE-3 costs to get an estimate for costs associated with the MDOE-3 baseline. This conservative approach allowed for the projected estimate to have an associated cost at the longer proposed warranty period.

Table C-15. Proposed Lengthened Warranty Mileages and Estimated Warranty Practices Under the Proposed Step 2 Warranty Amendments

Vehicle Category	Proposed Warranty Period	Percent of Vehicle Population that Relies on the New Regulatory Warranty
HHDD	800,000 miles/ 14 years	100%
MHDD	360,000 miles/ 14 years	100%
LHDD	280,000 miles/ 14 years	100%
HDO	200,000 miles/ 14 years	100%
MDDE-3	280,000 miles/ 14 years	100%
MDOE-3	200,000 miles/ 14 years	100%

For each category it is expected that the proposed warranty periods will generally provide sufficient coverage so that 100 percent of vehicles would rely on the regulatory warranty rather than buying an extended warranty. Using a comparison between the proposed mileage and the mileage at 14 years, yields weighted average miles under the proposed warranty provisions. These values are shown in Table C-16, along with the baseline miles. As shown in Table C-16, the miles traveled under warranty are not the same as the warranty period because some vehicles either are lost through attrition before they reach the new warranty periods or they exhaust their warranty coverage via years instead of miles.

Table C-16. Baseline Average Miles and Projected Average Miles Under Warranty Due to the Proposed Step 2 Warranty Amendments for Each Vehicle Category

Vehicle Category	Baseline Avg. Miles Traveled Under Warranty	Projected Avg. Miles Traveled Under Proposed Step 2 Warranty Amendments
HHDD	288,710	587,367
MHDD	95,536	199,915
LHDD	43,192	109,317
HDOE	50,000	200,000
MDDE-3	75,635	176,761
MDOE-3	50,000	170,605

v. Costs Under Proposed Warranty

In order to calculate the incremental costs of the proposed lengthened warranty periods, the costs associated with the baseline are needed, along with the projected costs out to the proposed periods. The difference between the baseline costs and the projected costs will represent the incremental costs associated with the lengthened warranty proposal.

The projected costs were determined by calculating a mileage ratio for each vehicle category. This ratio was obtained from dividing the average mileage traveled under the proposed warranty periods by the average miles traveled under the BAU warranty analysis done earlier. The resulting quotient yields a mileage ratio for each vehicle category that was applied to the BAU costs to determine the cost of repairs for the proposed lengthened warranty periods. Inherently this assumes a linear relationship between the vehicle odometer mileage and the warranty costs derived from the claims rate. An underlying aspect of this assumption is that parts would continue to fail at the same rate for the duration of the warranty period. Yet CARB staff understands that for mechanical systems there is often a non-linear “bathtub” curve[72] 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 part, which CARB 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 C-17 below. These costs are on a per vehicle basis for a heavy-duty vehicle.

Table C-17. Estimated Per Vehicle Repair Costs Associated with the Proposed Lengthened Step 2 Warranty Period Amendments (2018$)

Vehicle Category	Warranty Baseline		Proposed Step 2 Warranty		
	Avg. Miles Traveled Under Warranty	Warranty Cost	Projected Avg. Miles Traveled Under Warranty	Projected Warranty Cost	Incremental Repair Costs Under Proposal
HHDD	288,710	$2,416	587,367	$4,992	$2,576
MHDD	95,536	$2,775	199,915	$5,809	$3,034
LHDD	43,192	$1,096	109,317	$2,775	$1,678
HDO	50,000	$238	200,000	$954	$715
MDDE-3	75,635	$651	176,761	$1,522	$871
MDOE-3	50,000	$64	170,605	$219	$155

The incremental repair costs for the warranty proposal were determined from the difference between the baseline and the projected value of the warranty costs under the proposal and are also shown in Table C-17. These costs represent the increase in warranty claims payments for repairs that are expected to be done during the proposed lengthened warranty periods.

Assuming vehicle purchases are made using a 5-year loan financed at a 6 percent interest rate, CARB staff calculated the annual incremental costs associated with the proposed

[72] (NIST, 2013) 8.1.2.4. "Bathtub" curve, NIST/SEMATECH e-Handbook of Statistical Methods, National Institute of Standards and Technology, U.S. Department of Commerce, last updated 2013, accessed October 16, 2019. https://www.itl.nist.gov/div898/handbook/apr/section1/apr124.htm

Step 2 warranty amendments. The values are shown in Table C-18 and represent the repair costs for all new vehicle sales beginning in 2027.

Table C-18. Total Annual Incremental Costs Per Year for Proposed Lengthened Step 2 Warranty Periods for Each Vehicle Class (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2027	$21,025,561	$38,320,805	$13,413,385	$2,754,820	$212,863	$5,307	$75,732,740
2028	$20,789,883	$38,319,346	$13,646,879	$2,553,403	$217,933	$6,929	$75,534,373
2029	$20,562,704	$39,270,389	$13,898,855	$2,251,676	$208,803	$5,026	$76,197,453
2030	$20,254,880	$39,702,323	$14,134,821	$1,911,724	$191,854	$1,957	$76,197,559
2031	$20,553,584	$40,230,232	$14,322,157	$1,929,297	$193,836	$1,977	$77,231,083
2032	$21,154,249	$41,359,010	$14,708,168	$1,982,263	$195,785	$1,997	$79,401,473

e. Lengthened Useful Life Costs

As indicated in Table A-5, the Proposed Regulation would lengthen the “useful life,” i.e., the period during which an engine is required to demonstrate compliance with applicable emission standards. Costs for the repairs that would be needed between the end of the lengthened warranty period through the lengthened useful life, are used to estimate the costs associated with the proposed lengthened useful life period. Manufacturers could respond to the longer useful life requirements by paying for needed repairs or by improving durability. Staff assumes manufacturers would only do the latter if it is cheaper for them than just paying for needed replacements/repairs; hence, staff’s cost estimate based on paying for repairs is conservative (high).

The relevant proposed lengthened warranty repair costs used in the useful life estimation calculation are the projected warranty costs discussed above and shown in Table C-17 and repeated below in Table C-19 on a per vehicle basis. Also shown in Table C-19 are the useful life costs estimated using the same methodology as used above for lengthened warranty repair costs but projected out to the proposed lengthened useful life periods. The projected average mileages are also shown in Table C-19.

Table C-19. Incremental Repair Costs Per Vehicle for Proposed Lengthened Useful Life (2018$)

Vehicle Category	Projected Avg. Miles Traveled Under Warranty	Projected Step 2 Warranty Costs Under the Proposal	Projected Avg. Miles Traveled Under Useful Life	Projected Useful Life Costs Under the Proposal	Incremental Repair Costs Under the Proposal
HHDD	587,367	$4,992	623,637	$5,300	$308
MHDD	199,915	$5,809	231,446	$6,725	$916
LHDD	109,317	$2,775	136,480	$3,464	$690
HDO	200,000	$954	250,000	$1,192	$238
MDDE-3	176,761	$1,522	197,298	$1,699	$177
MDOE-3	170,605	$219	197,310	$254	$34

Table C-20 indicates the annual incremental costs of the proposed lengthened useful life periods for each vehicle class.

Table C-20. Total Annual Incremental Costs for Proposed Lengthened Useful Life for Each Vehicle Category (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2027	$2,119,786	$9,749,849	$4,642,125	$773,620	$36,419	$990	$17,322,788
2028	$2,096,025	$9,749,478	$4,722,933	$717,058	$37,287	$1,293	$17,324,072
2029	$2,073,121	$9,991,449	$4,810,137	$632,325	$35,725	$938	$17,543,694
2030	$2,042,086	$10,101,344	$4,891,800	$536,858	$32,825	$365	$17,605,279
2031	$2,072,201	$10,235,659	$4,956,634	$541,793	$33,164	$369	$17,839,820
2032	$2,132,760	$10,522,850	$5,090,225	$556,667	$33,497	$373	$18,336,373

f. Amended EWIR Costs

To estimate the cost impact of the proposed EWIR amendments, a baseline scenario was first developed. The cost impact of the proposed EWIR amendments was then evaluated against the baseline scenario. The baseline scenario accounts for the California required emission control system warranty, manufacturer provided warranties, and real-world purchasing behavior.

As discussed above and shown in Tables A-4 and A-6, manufacturers are currently required to provide a 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 Regulation would lengthen the warranty period and adjust the thresholds for submitting reports or initiating corrective action.

The estimated direct costs from the proposed EWIR amendments and the baseline scenario include upfront capital costs from changes to 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 at the end of the warranty periods and useful life periods. This was done by extrapolating the most current and complete dataset from the 2013 model year for the current warranty period of 5 years to the proposed lengthened warranty period. As explained in further detail in the next subsection, this is how the costs of the recalls based on the proposed warranty periods were estimated. The difference between extrapolated values at the end of the proposed useful life period and proposed warranty periods is the estimated cost of extended warranties.

i. Cost for Baseline Scenario

Correlation Between the Unscreened Warranty Claims Rate to Screened Failure Rate

Staff estimated the cost to manufacturers under the current EWIR program by analyzing unscreened warranty claims and failure rate data submitted to CARB by manufacturers in EWIR and FIR reports. Staff considered examining screened failure data as an alternative approach, but manufacturers are not required to submit screened failure rate data unless the unscreened rate exceeds 4 percent. Therefore, it was determined that unscreened data should be used for cost estimates as it contains information on a larger number of engine families and parts and is more representative of the in-use population.

Staff used unscreened warranty claims rates to estimate screened failure rates in order to determine the increase in corrective action and warranty reporting costs. An analysis of available EWIR and failure rate data indicates that there is a correlation between the average unscreened warranty claims rate of 7 percent and the screened failure rate of 4 percent, which would trigger corrective action.[73] This means that on average when a manufacturer analyzes unscreened warranty claims, 4 out of 7 of the returned warranty parts that are analyzed are found to be failures.

Population Projection

Table C-3 indicates the projected population of each vehicle class from 2022 through 2032. The population numbers were obtained from EMFAC2017.

[73] (CARB, 2019f) Aggregate EWIR and Failure Rate Data, California Air Resources Board, October 9, 2019.

Repair Costs for Aftertreatment Components, Computers, and Non-Aftertreatment Components Subject to Recall

Repair costs were obtained through analysis of service station repair records and costs utilized in the 2018 heavy-duty warranty lengthening process.[74] Staff broke down costs into two categories: aftertreatment components and computers, and non-aftertreatment components that would be subject to recall, shown in Table C-21.[75] The average repair cost was determined by averaging the cost of repairs for components from all classes that potentially could be subject to recall and for which EWIR data was submitted. As CARB staff reviewed and approved recalls, it was observed that manufacturers remedied the majority of in-use problems and part failures through software calibration reflashes. Based on this, 70 percent of repairs were assumed to be software reflashes, at a cost of $400 per reflash, rather than part replacements.[76]

Table C-21. Average Repair Costs for Components Subject to Recall (2018$)

	Aftertreatment and Critical Components, and Computers	Non-Aftertreatment Components
Average Repair Cost	$1,292	$978

Recall Methodology

Table C-22 provides a summary for the 2013 model year of the population of vehicles and engines for each class and the number of unscreened warranty claims per class separated by aftertreatment component and computer claims, and non-aftertreatment component claims that would be subject to recall. The 2013 model year 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 may exceed 100 percent as some engines had multiple issues remedied through multiple recalls. The MDDE-3 and MDOE-3 classes did not have claims for aftertreatment components and computers that exceeded the corrective action threshold. The HDO, MDDE-3, and MDOE-3 classes did not have claims for other components that exceeded the corrective action threshold.

74 (CARB, 2018b) Staff Report: Initial Statement of Reasons for the for Rulemaking: "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles" (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf?_ga=2.169925923.2011115175.1568077425-1788626826.1465349672

75 Aftertreatment claims consist of claims for DPFs, SCR, and DOCs. The non-aftertreatment claims consist of other critical emission control components that would be subject to recall.

76 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 provide the average repair costs for repairs made under recall that can be seen in Table C-21.

Table C-22. Components Subject to Recall for the 2013 Model Year

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	6,375	14,649	57.8%	132.9%
MHDD	4,967	7,663	4,828	154.3%	97.2%
LHDD	5,025	170	5,243	3.4%	104.3%
HDO	8,522	3460	0	40.6%	0.0%
MDDE-3	232	0	0	0.0%	0.0%
MDOE-3	844	0	0	0.0%	0.0%

The costs of recalls estimated for the 2022 through 2032 calendar years can be seen for each vehicle class in Table C-23. The costs were obtained by applying the percentage of the population subject to recall in Table C-22 to the projected 2022 through 2032 calendar year sales volume and then multiplying by the appropriate cost in Table C-21. The costs were then multiplied by 93 percent which is the typical capture rate that is achieved by manufacturers when conducting recalls with a California DMV tie-in. Not all vehicles are captured by a recall due to several factors such as vehicles moving out-of-state or no longer being in service. Staff assumed that the percentage of the population subject to recall would remain similar to the 2013 model year for later model years. Costs listed as $0 indicate that past model year data shows that those classes did not have failure rates for components that exceeded the corrective action threshold.

Table C-23. Baseline Recall Costs (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$11,909,357	$18,703,986	$5,711,648	$1,675,039	$0	$0	$38,000,030
2023	$12,608,129	$19,585,796	$6,125,924	$1,721,637	$0	$0	$40,041,487
2024	$11,734,999	$20,397,119	$6,268,332	$1,621,350	$0	$0	$40,021,800
2025	$11,866,064	$21,476,552	$6,381,804	$1,604,346	$0	$0	$41,328,767
2026	$11,952,284	$21,505,750	$6,513,469	$1,596,545	$0	$0	$41,568,049
2027	$12,039,110	$22,153,441	$6,637,692	$1,558,082	$0	$0	$42,388,325
2028	$11,904,161	$22,152,598	$6,753,237	$1,444,164	$0	$0	$42,254,161
2029	$11,774,080	$22,702,401	$6,877,929	$1,273,512	$0	$0	$42,627,922
2030	$11,597,822	$22,952,103	$6,994,698	$1,081,241	$0	$0	$42,625,865
2031	$11,768,858	$23,257,290	$7,087,403	$1,091,179	$0	$0	$43,204,731
2032	$12,112,796	$23,909,843	$7,278,422	$1,121,136	$0	$0	$44,422,197
Total	**$131,267,661**	**$238,796,881**	**$72,630,558**	**$15,788,233**	**$0**	**$0**	**$458,483,332**

Repair Costs for Components Subject to Extended Warranty

Staff is proposing that manufacturers be required to provide extended warranties to full useful life for all components that exceed the corrective action threshold. This extended warranty would cover parts replaced through recall. Repair costs were obtained through analysis of service station repair records and costs utilized in the 2018 heavy-duty warranty lengthening rulemaking.[77] The average repair costs, shown in Table C-24, were determined by averaging the cost of repairs for components from all classes that potentially could be subject to extended warranty where EWIR data was submitted. The average extended warranty repair cost for all components is $1,587. The average extended warranty repair cost for components subject to recall because they have a failure rate greater than or equal to 25 percent within 5 years is $756. Based on historical data regarding recalls it was determined that over 83 percent of recalls resolve issues through software reflashes.[78] Therefore, for components that would typically be subject to

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[77] (CARB, 2018b) Staff Report: Initial Statement of Reasons for the for Rulemaking: “Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles” (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf?_ga=2.169925923.2011115175.1568077425-1788626826.1465349672

[78] (CARB, 2019q) “Aggregate Data for Heavy-Duty Recalls,” California Air Resources Board, October 24, 2019.

extended warranty, but need 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.[79]

Table C-24. Average Repair Costs for Components Subject to Extended Warranty (2018$)

Components Subject to Extended Warranty	Average Repair Cost
Average Extended Warranty Repair Cost for All Components	$1,587
Average Extended Warranty Repair Cost for Components with a Failure Rate ≥ 25% within 5 Years	$756

<u>Extended Warranty Methodology</u>

Table C-25 provides a summary for the 2013 model year population of vehicles and engines for each class and the number of unscreened warranty claims per class for components proposed for extended warranty under EWIR amendments. The 2013 model year data was 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 rate per engine subject to extended warranty is derived by linearly extrapolating the number of components that reach the corrective action threshold at the end of the warranty period and to the end of the useful life period. The difference between the extrapolated values from the most complete warranty data set for five years to the end of the proposed useful life and warranty periods is used to determine the number of components subject to extended warranty, which is divided by the sales volume to determine the average rate per engine subject to extended warranty. All failures that occur within the warranty period would be covered under warranty and therefore are not included as part of the extended warranty cost. The MDDE-3 and MDOE-3 classes did not have claims for components that exceeded the corrective action threshold.

[79] 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 percent within 5 years is $756, which was determined by assuming that 30 percent of the cost for the recall repair would be that of a part replacement that is $1,587, while the other 70 percent of repairs would be the cost of a reflash that is $400. This is because it has been observed that 70 percent of recall repairs are reflashes.

Table C-25. Components Subject to Extended Warranty for the 2013 Model Year

Class	2013 Model Year Sales	Total Claims for Components	Average Rate Per Engine Subject to Extended Warranty
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%
MDDE-3	232	0	0.0%
MDOE-3	844	0	0.0%

The cost of extended warranties for the 2022 through 2032 calendar years can be seen in Table C-26. The costs were obtained by applying the percentage of the population subject to extended warranty in Table C-25 to the projected sales volume for the 2022 through 2032 calendar years and then multiplying by the appropriate cost in Table C-24. Costs listed as $0 indicate that past model year data show that those classes did not have failure rates for components that exceeded the corrective action threshold.

Table C-26. Baseline Extended Warranty Costs (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$4,030,664	$864,044	$2,029,068	$177,351	$0	$0	$7,101,128
2023	$4,267,161	$904,780	$2,176,240	$182,285	$0	$0	$7,530,466
2024	$3,971,654	$942,260	$2,226,831	$171,667	$0	$0	$7,312,411
2025	$4,016,012	$992,125	$2,267,142	$169,867	$0	$0	$7,445,145
2026	$4,045,193	$993,474	$2,313,916	$169,041	$0	$0	$7,521,623
2027	$4,074,579	$1,023,394	$2,358,046	$164,968	$0	$0	$7,620,987
2028	$4,028,906	$1,023,355	$2,399,094	$152,907	$0	$0	$7,604,262
2029	$3,984,881	$1,048,754	$2,443,391	$134,838	$0	$0	$7,611,863
2030	$3,925,227	$1,060,289	$2,484,873	$114,481	$0	$0	$7,584,870
2031	$3,983,114	$1,074,387	$2,517,806	$115,533	$0	$0	$7,690,840
2032	$4,099,517	$1,104,532	$2,585,666	$118,705	$0	$0	$7,908,421
Total	**$44,426,909**	**$11,031,394**	**$25,802,073**	**$1,671,642**	**$0**	**$0**	**$82,932,018**

Summary of Baseline

The cost of the baseline scenario for the 2022 through 2032 calendar years can be seen in Table C-27. The cost was obtained by calculating the sum of the costs from Tables C-23 and C-26. Costs listed as $0 indicate that past model year data show that those classes did not have failure rates for components that exceeded the corrective action threshold.

Table C-27. Summary of Baseline Total Recall and Extended Warranty Costs (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$15,940,021	$19,568,031	$7,740,716	$1,852,391	$0	$0	$45,101,159
2023	$16,875,290	$20,490,576	$8,302,164	$1,903,922	$0	$0	$47,571,953
2024	$15,706,652	$21,339,379	$8,495,162	$1,793,017	$0	$0	$47,334,211
2025	$15,882,077	$22,468,677	$8,648,945	$1,774,213	$0	$0	$48,773,912
2026	$15,997,477	$22,499,224	$8,827,385	$1,765,586	$0	$0	$49,089,673
2027	$16,113,688	$23,176,835	$8,995,738	$1,723,050	$0	$0	$50,009,312
2028	$15,933,068	$23,175,953	$9,152,331	$1,597,071	$0	$0	$49,858,423
2029	$15,758,961	$23,751,155	$9,321,320	$1,408,350	$0	$0	$50,239,786
2030	$15,523,050	$24,012,392	$9,479,571	$1,195,721	$0	$0	$50,210,735
2031	$15,751,972	$24,331,678	$9,605,209	$1,206,712	$0	$0	$50,895,571
2032	$16,212,313	$25,014,375	$9,864,089	$1,239,841	$0	$0	$52,330,617
Total	**$175,694,570**	**$249,828,274**	**$98,432,631**	**$17,459,875**	**$0**	**$0**	**$541,415,350**

ii. Cost for New EWIR Amendments

New Emissions Warranty and Useful Life Periods and Impact on EWIR

The emissions warranty periods have been modified for the 2022 through 2026 model years and staff is proposing to lengthen the emissions warranty and useful life periods for the 2027 and subsequent model years as listed in Tables A-4 and A-5.

Costs Associated with Corrective Action Amendments

- Corrective Action Thresholds and Procedures

There are two incremental increases in costs due to the two corrective action thresholds that are being amended for the 2022 and 2027 model years. The first amendment effective in 2022 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 action that small volume engine families would be subject. The second amendment effective in 2027 would have a larger impact on costs. The corrective action threshold would remain at 4 percent or 25 failures, whichever is greater, for the first five years of the reporting period, 7 percent or 50 failures, whichever is greater, for years 6-10, and 10 percent and 70 failures, whichever is greater, for years 11-14. This is to account for the new warranty and useful life periods.

With the warranty period being increased it is reasonable to adjust the corrective action threshold rate as well as to account for the longer warranty reporting period. Starting with the 2027 model year it is proposed that manufacturers be required to report warranty and failure rate information for a period of 14 years instead of 5 years.

Also, if a component that would normally be subject to extended warranty, has early failure rates that indicate that approximately 100 percent of the population would fail within the useful life period, it would be subject to recall. This is a 14-year projection based on the failure rate reaching 25 percent within five years.

The costs associated with amending corrective action thresholds and procedures can be seen in Table C-28. Costs were calculated using the same methodology as was used to calculate the cost of the baseline scenario, except that the proposed amendment criteria was used. Failure rates for future model years were obtained by linearly extrapolating data from the 2013 model year. 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.

Table C-28. Corrective Action Thresholds and Procedures Cost Summary (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$18,591,831	$30,559,002	$10,025,049	$2,423,845	$0	$0	$61,599,727
2023	$19,682,693	$31,999,722	$10,752,184	$2,491,274	$0	$0	$64,925,874
2024	$18,319,639	$33,325,280	$11,002,137	$2,346,155	$0	$0	$64,993,211
2025	$18,524,247	$35,088,883	$11,201,303	$2,321,549	$0	$0	$67,135,983
2026	$18,658,846	$35,136,588	$11,432,401	$2,310,261	$0	$0	$67,538,096
2027	$18,039,470	$23,543,471	$10,052,574	$1,613,850	$70,488	$0	$53,319,852
2028	$17,837,263	$23,542,575	$10,227,564	$1,495,855	$72,167	$0	$53,175,423
2029	$17,642,348	$24,126,876	$10,416,406	$1,319,094	$69,143	$0	$53,573,868
2030	$17,378,243	$24,392,246	$10,593,249	$1,119,941	$63,531	$0	$53,547,210
2031	$17,634,524	$24,716,582	$10,733,647	$1,130,236	$64,187	$0	$54,279,175
2032	$18,149,881	$25,410,079	$11,022,940	$1,161,265	$64,833	$0	$55,808,998
Total	**$200,458,985**	**$311,841,305**	**$117,459,453**	**$19,733,324**	**$404,348**	**$0**	**$649,897,416**

- Parts Storage

Staff is proposing that manufacturers be required to store parts that are used for failure mode and failure rate analysis 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 C-29 summarizes the information used to determine the costs for storing parts.

Table C-29. 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

Through an online phone survey of California storage facilities,[80] it was determined that the approximate cost to store parts would be approximately $9.80 per square foot. This was marked up by approximately 100 percent to $18.00 per square foot so that the estimate

[80] (CARB, 2020) Parts Storage Survey, California Air Resources Board, January 21, 2020.

would be more conservative. Each part would require approximately two square feet of space as certain parts may be stacked upon each other during storage.

Table C-30 shows the number of components[81] with parts that would need to be analyzed for warranty, based on 2013 warranty claim and failure rate trends applied to 2022 through 2032 projected sales volumes. 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.

Currently, some manufacturers do retain returned warranty parts as part of their standard business practice. However, in order to provide a more conservative cost estimate it was assumed that all manufacturers are not currently retaining parts. Estimated storage costs for each year can be seen in Table C-30.

Table C-30. Number of Components Needed to be Stored by Year (2018$)

Calendar Year	Number of Components that Need to be Stored	Storage Cost
2022	160	$806,400
2023	168	$846,720
2024	167	$841,680
2025	173	$871,920
2026	174	$876,960
2027	191	$962,640
2028	191	$962,640
2029	191	$962,640
2030	192	$967,680
2031	194	$977,760
2032	200	$1,008,000
Total	**2001**	**$10,085,040**

- Administrative Costs for Additional Warranty Reporting and Corrective Action

It is assumed that manufacturers are already tracking, gathering, and analyzing data and information that will be required 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 will be the cost of generating the reports to summarize the information collected by manufacturers and developing corrective action documents. Therefore, it is estimated that a junior engineer position would be sufficient to perform the duties of generating additional warranty reports and corrective

[81] Components include categories of hardware such as turbocharger, DPF, fuel injector, etc.

action documents. Table C-31 summarizes the information used to determine the administrative costs.

Table C-31. Additional Warranty Reporting Summary

Additional Warranty Reporting Information	
Junior Engineer Salary ($/hour)	70
Time Required for 1 EWIR Report Submitted Quarterly for 4 Years 2022-2026, for 9 Years for 2027 and Subsequent Years (hours)	0.5
Time Required for 1 FIR/EIR Report Submitted Once (hours)	1
Time Required to Generate Corrective Action Documents (hours)	16
Additional EWIR Reports Submitted Due to Lower Thresholds	30% Increase in Number of Reports

Costs were determined by estimating the increase in number of reports and documents that need to be submitted and the time required to generate them. The hourly rate for a junior engineer is $70.00.[82] Table C-32 shows the estimated increase in percentage for the number of each type of report or document that would need to be submitted. The increase in percentage of reports and documents was estimated by analyzing warranty data for the 2013 model year and determining how many additional reports would be submitted under the new thresholds of the proposed amendments.

[82] (U.S. BLS, 2019) "Employer Costs for Employee Compensation, Supplementary Tables, National Compensation Survey," United States Department of Labor, Bureau of Labor Statistics, accessed September 2019. https://www.bls.gov/web/ecec/ecsuptc.txt

Table C-32. Percent Increase in Number of Reports or Documents to be Submitted Relative to Population

EWIR Reports		
Class	2022-2032	
HHDD	0.7%	
MHDD	1.1%	
LHDD	0.6%	
HDO	0.0%	
MDDE-3	0.3%	
MDOE-3	0.0%	
FIR Reports		
Class	2022-2026	2027-2032
HHDD	0.2%	0.3%
MHDD	0.3%	0.3%
LHDD	0.2%	0.3%
HDO	0.0%	0.0%
MDDE-3	0.9%	0.9%
MDOE-3	0.0%	0.0%
EIR Reports		
Class	2022-2026	2027-2032
HHDD	0.5%	0.6%
MHDD	0.5%	0.6%
LHDD	0.2%	0.2%
HDO	0.0%	0.0%
MDDE-3	0.0%	1.3%
MDOE-3	0.0%	0.0%
Corrective Action Documents		
Class	2022-2026	2027-2032
HHDD	0.5%	0.6%
MHDD	0.5%	0.6%
LHDD	0.2%	0.2%
HDO	0.0%	0.0%
MDDE-3	0.0%	1.3%
MDOE-3	0.0%	0.0%

The percentage increase is applied to the projected population for each year to determine how many additional reports and documents need to be submitted for each year. Once the additional number of reports and documents is established, the number of hours needed to generate a warranty report or document and hourly rate for a junior engineer are applied to the number of reports to determine the cost. The cost for the amended reporting thresholds and procedures can be seen in Table C-33.

Table C-33. Cost of Generating Additional Warranty Reports and Corrective Action Documents (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$69,844	$114,411	$32,539	$607	$458	$0	$217,860
2023	$73,942	$119,805	$34,899	$624	$444	$0	$229,715
2024	$68,822	$124,767	$35,711	$588	$480	$0	$230,367
2025	$69,590	$131,370	$36,357	$582	$466	$0	$238,366
2026	$70,096	$131,549	$37,107	$579	$433	$0	$239,764
2027	$108,734	$223,242	$71,203	$1,631	$3,781	$0	$408,590
2028	$107,515	$223,233	$72,442	$1,512	$3,871	$0	$408,573
2029	$106,340	$228,774	$73,780	$1,333	$3,709	$0	$413,935
2030	$104,748	$231,290	$75,033	$1,132	$3,408	$0	$415,610
2031	$106,293	$234,365	$76,027	$1,142	$3,443	$0	$421,270
2032	$109,399	$240,941	$78,076	$1,174	$3,477	$0	$433,067
Total	**$995,322**	**$2,003,748**	**$623,174**	**$10,905**	**$23,969**	**$0**	**$3,657,119**

Summary of Costs of Proposed EWIR Amendments

The cost of the proposed EWIR amendments can be seen in Table C-34. The cost was obtained by calculating the sum of the cost of the amended corrective action requirements from Table C-28, storage costs from Table C-30, and warranty reporting costs from Table C-33. MDOE-3 costs were found to be $0.00 as warranty claim and failure rate information did not exceed the reporting threshold. Therefore, it is expected that any costs for future MDOE-3 model years would be minor and negligible.

Table C-34. Summary of Costs of Proposed EWIR Amendments (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$18,994,316	$31,041,332	$10,153,348	$2,434,532	$458	$0	$62,623,987
2023	$20,109,436	$32,502,567	$10,887,884	$2,501,978	$444	$0	$66,002,309
2024	$18,716,061	$33,848,208	$11,143,688	$2,356,823	$480	$0	$66,065,259
2025	$18,926,478	$35,643,614	$11,343,500	$2,332,211	$466	$0	$68,246,269
2026	$19,061,582	$35,691,497	$11,580,388	$2,320,920	$433	$0	$68,654,820
2027	$18,501,003	$24,235,433	$10,249,777	$1,625,561	$79,308	$0	$54,691,083
2028	$18,297,577	$24,234,528	$10,426,006	$1,507,447	$81,077	$0	$54,546,636
2029	$18,096,448	$24,834,450	$10,616,186	$1,325,468	$77,892	$0	$54,950,443
2030	$17,825,710	$25,107,376	$10,799,322	$1,126,113	$71,978	$0	$54,930,500
2031	$18,088,577	$25,439,827	$10,940,714	$1,136,418	$72,670	$0	$55,678,206
2032	$18,617,120	$26,155,020	$11,237,096	$1,167,478	$73,350	$0	$57,250,065
Total	**$205,234,308**	**$318,733,852**	**$119,377,908**	**$19,834,950**	**$458,557**	**$0**	**$663,639,575**

Overall Summary Explaining Incremental Cost Differences

The upfront incremental increase in cost between the proposed EWIR amendments scenario and baseline scenario can be seen in Table C-35. The incremental cost is determined by subtracting the costs from the baseline scenario in Table C-27 from the costs of the proposed scenario in Table C-34. Incremental increase in cost for 2027 and later HDO engines is expected to be slightly negative compared to the baseline. The reason for the negative cost is because the proposed longer warranty period accounts for many of the part replacements that would be covered by a recall from the EWIR amendments. This results in the baseline cost being larger than the cost of the proposed amendments resulting in a negative cost which for purposes of the analysis was considered zero.

Table C-35. Upfront Incremental Cost Increase (2018$)

Calendar Year	HHDD	MHDD	LHDD	HDO	MDDE-3	MDOE-3	Total
2022	$3,054,294	$11,473,302	$2,412,632	$582,141	$458	$0	$17,522,828
2023	$3,234,145	$12,011,991	$2,585,719	$598,056	$444	$0	$18,430,356
2024	$3,009,408	$12,508,829	$2,648,526	$563,806	$480	$0	$18,731,048
2025	$3,044,401	$13,174,936	$2,694,554	$557,998	$466	$0	$19,472,356
2026	$3,064,105	$13,192,273	$2,753,003	$555,334	$433	$0	$19,565,147
2027	$2,387,315	$1,058,598	$1,254,039	$0	$79,308	$0	$4,681,771
2028	$2,364,510	$1,058,575	$1,273,675	$0	$81,077	$0	$4,688,214
2029	$2,337,487	$1,083,295	$1,294,866	$0	$77,892	$0	$4,710,657
2030	$2,302,661	$1,094,984	$1,319,750	$0	$71,978	$0	$4,719,765
2031	$2,336,605	$1,108,150	$1,335,505	$0	$72,670	$0	$4,782,635
2032	$2,404,807	$1,140,645	$1,373,007	$0	$73,350	$0	$4,919,448
Total	**$29,539,738**	**$68,905,578**	**$20,945,277**	**$2,857,335**	**$458,557**	**$0**	**$122,224,225**

Table C-36 shows the incremental cost for the proposed EWIR amendments on a per vehicle basis. This was calculated by dividing the total cost over 10 years by the total projected sales over 10 years for each class.

Table C-36. Incremental Costs Per Vehicle (2018$)

Vehicle Service Class	Proposed EWIR Incremental Cost Per Vehicle Basis
HHDD	$394
MHDD	$601
LHDD	$284
HDO	$87
MDDE-3	$200
MDOE-3	$0
Weighted Average	**$410**

g. *Amended ABT Costs*

The proposed ABT amendments would lead to the creation of a 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.

Implementation of a two-track ABT system would lead to additional bookkeeping/labor costs. There would be no material costs for implementation of separate ABT programs. Staff has analyzed the current federal-ABT account balances for all on-road heavy-duty engine manufacturers. Staff believes that there would be a one-time, upfront labor cost of approximately 1,400 hours (100 hours per manufacturer) for a junior engineer (at $70/hour)[83] in the 2024 calendar year to establish the CA-ABT program on an industry-wide basis. The required hours will be needed to calculate the portion of the existing banked federal-credits which will be transferred to the CA-ABT program, and to set up the accounting system for the future CA-ABT program.

Thereafter, staff estimates that each on-road heavy-duty engine manufacturer would need to allocate approximately 20 hours of labor (junior engineer) per year to track the CA-ABT credits separately. Currently there are a total of eight on-road heavy-duty diesel and seven on-road heavy-duty Otto-cycle engine manufacturers that certified products in the California market (Table C-38). Ford was the only company that certified both diesel and Otto-cycle on-road heavy-duty engines. This analysis does not assume that the number of manufacturers will increase.

Table C-38. California Certified On-Road Heavy-Duty Engine Manufacturers List (Baseline 2018 Model Year)

Diesel Standards and Test Procedures	Otto-Cycle Standards and Test Procedures
• Cummins Inc. • Detroit Diesel Corporation • Ford Motor Company • Hino Motors, LTD. • Isuzu Motors LTD. • Navistar, Inc. • Paccar Inc. • Volvo Group Trucks Technology	• Agility Power Systems, LLC • Encore Tec LLC • FCA US LLC • Ford Motor Company • General Motors LLC • Power Solutions International Inc. • Roush Industries, Inc.

The additional labor costs for tracking the CA-ABT program for the 2022 through 2032 calendar years, shown in Table C-39.

[83] (U.S. BLS, 2019) "Employer Costs for Employee Compensation, Supplementary Tables, National Compensation Survey," United States Department of Labor, Bureau of Labor Statistics, accessed September 2019. https://www.bls.gov/web/ecec/ecsuptc.txt

Table C-39. Estimated Incremental Costs Relative to the 2018 Model Year Baseline for the Proposed ABT Amendments (2018$)

Calendar Year	Incremental Costs for CA-ABT Program
2022	$0
2023	$0
2024	$98,000
2025	$19,600
2026	$19,600
2027	$19,600
2028	$19,600
2029	$19,600
2030	$19,600
2031	$19,600
2032	$19,600
Total	**$254,800**

h. Amended Durability Demonstration Costs

The proposed amendments would increase the overall costs of the DDP by increasing the amount of time that is needed to prepare engines for official emissions testing, requiring standardized protocols used for testing, and require additional testing time so that engines could be evaluated to their full useful life. The following assumptions were made in calculating the incremental costs:

- Program planning costs – Because of the testing time required to age an EAS to its full useful life, staff anticipates that all HHDD engine manufacturers would use the DAAAC process in the 2024 through 2026 model year timeframe and all heavy-duty diesel manufacturers to use the DAAAC process for the 2027 and subsequent model years. In order to use DAAAC, engineering calculations must be performed to determine the required temperature profiles, and the required level of chemical aging. DAAAC would also require that manufacturers to submit in-use NOx emissions data to CARB during those model years. Covers the labor costs for DDP planning and scheduling. Staff estimates an additional (incremental) 40 hours of program planning labor for a junior engineer (at $70/hour) for each manufacturer using the DAAAC process. This covers the labor costs for DDP planning and scheduling.

- Emissions testing costs – Under the baseline, each on-road heavy-duty engine manufacturer was required to conduct at least three emissions tests (one test at the beginning of the DDP, one test at the DDP midpoint, one test at the DDP endpoint) using the FTP and RMC-SET cycles. The FTP and RMC-SET cycles are the current baseline emissions testing cycles for the 2018 model year. The LLC cycle is a new emissions testing cycle that would be required under the proposed amendments starting with the 2024 model year.

- The addition of the LLC cycle would increase the emissions testing cost by $69,000 for each durability parent engine ($23,000 multiplied by three emissions tests for each durability parent engine). The estimated cost for performing the LLC emissions test was derived from the survey of previous CARB contracts with emissions testing facilities.[84]

- Under the current baseline DDP, manufacturers only age the durability engine to a portion of the useful life. The proposed amendments increase the DDP period to the full useful life of the EAS. Due to the increase in the length of the DDP, ash cleaning may be required under the proposed durability amendments. In cases where an ash cleaning interval is needed during the DDP, manufacturers must perform emissions tests before and after the ash cleaning interval. This would lead to the requirement of an additional emissions test. Based on a survey of previous CARB contracts with emissions test facilities, staff used an additional fixed cost of $68,000 per emissions test (includes FTP, RMC-SET and LLC and clean idle). As noted earlier, staff believes that this is a conservative overestimation of the actual emissions testing costs because the manufacturers conduct the required emissions testing at their own facilities.

- Aging costs – Based on a survey of information from previous CARB contracts with emissions testing facilities, staff used an estimated cost of $160/hour for service accumulation. This cost would cover both labor and material (fuel, power, water, maintenance, etc.) costs for aging the engine to the extra number of hours needed under the proposed amendments. The required service accumulation period is a function of the EAS primary intended service class. On average, the increase in the number of hours for DDP range from 900 to 3,800 hours depending on the primary intended service class.

- Break-in hours – As indicated earlier, the required break-in hours would be increased from 125 hours for the 2018 model year baseline to 300 hours for 2024 and subsequent model years. For service accumulation, staff used an estimate of $160/hour for additional break-in requirements.

- Mule engine – In order to accelerate the chemical aging process, DAAAC usually relies on the use of a mule engine with high oil consumption rates. This is typically either an older engine or an engine with modified piston rings. Based on an internet survey of used on-road heavy-duty diesel engine prices,[85] staff used an average fixed cost of $15,000 for a mule engine. This number is a conservative estimate because all on-road heavy-duty diesel engine manufacturers have access to a large supply of used engines through their engine rebuild divisions.

[84] (CARB, 2016) 15MSC010, Contract with Southwest Research Institute, California Air Resources Board, September 21, 2016.
[85] (Adelman, 2019) Adelman's Used Diesel Engines, Adelman, accessed September 2019. http://www.adelmans.com/diesel-engines

- Ash cleaning – The proposed amendments would require manufacturers to age the engine to full useful life. As such, some manufacturers would probably have to add an ash cleaning interval in their DDP. Based on the survey of data from repair facilities, staff used an average fixed cost of $500 for each ash cleaning.

Staff assumed that the DDP would be performed in the calendar year preceding the applicable model year, that the 2024 model year DDP would cover the engines produced from the 2024 through 2026 model years, and the 2027 model year DDP would cover the deterioration factors for on-road heavy-duty diesel engine productions from the 2027 through 2032 model years. The incremental DDP costs therefore appear discretely in the 2023 and 2026 calendar years. Staff anticipates that all HHDD engine manufacturers would use the DAAAC process in the 2024 through 2026 model year timeframe and would therefore submit in-use NOx emissions data to CARB during those model years. For 2027 and subsequent model years, staff anticipates all heavy-duty diesel manufacturers to use the DAAAC process. Table C-40 shows a summary of the estimated incremental costs for the proposed DDP amendments for all of the heavy-duty diesel manufacturers combined.

Table C-40. Estimated Incremental Costs Relative to the 2018 Model Year Baseline for the Proposed DDP Amendments (2018$)

Calendar Year	Incremental Costs for DDP
2022	$0
2023	$8,718,820
2024	$0
2025	$0
2026	$8,244,920
2027	$0
2028	$0
2029	$0
2030	$0
2031	$0
2032	$0
Total	**$16,963,740**

***** 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 carryacross the deterioration factors to the corresponding sister family medium-duty engines.

A breakdown of incremental costs for the various elements of the DDP for the 2024 model year is shown in Table C-41. As shown, the most significant contribution is due to the additional aging and break-in hours. A similar process was used to estimate the incremental costs for the 2027 model year.

Table C-41 Estimated Break-down of Incremental Costs Relative to the 2018 Model Year Baseline for the proposed 2024 Model Year DDP Amendments (2018$)

	Number of Durability Engine Families	Mule Engine Costs for DAAAC	DAAAC Planning Labor Costs	Ash Cleaning Costs	Emissions Testing Costs	Aging & Break-in Costs	Total Incremental Costs
LHDD	3	$0	$0	$0	$207,000	$418,880	$625,880
MHDD	6	$0	$0	$0	$414,000	$2,271,840	$2,685,840
HHDD*	7	$105,000	$19,600	$3,500	$959,000	$4,320,000	$5,407,100
						Total	$8,718,820

* Uses the DAAAC Process

i. In-Use NOx Emissions Data Reporting Costs

Reporting of the in-use NOx emissions data collected and stored by the engine would be a new requirement for on-road heavy-duty diesel engine manufacturers. As such, there were no baseline costs in the 2018 model year associated with this program. It is expected that the data collected and stored by each in-use engine would be telematically retrieved by the engine manufacturers.

The costs for collecting reported NOx emissions data can be broken into several components including:

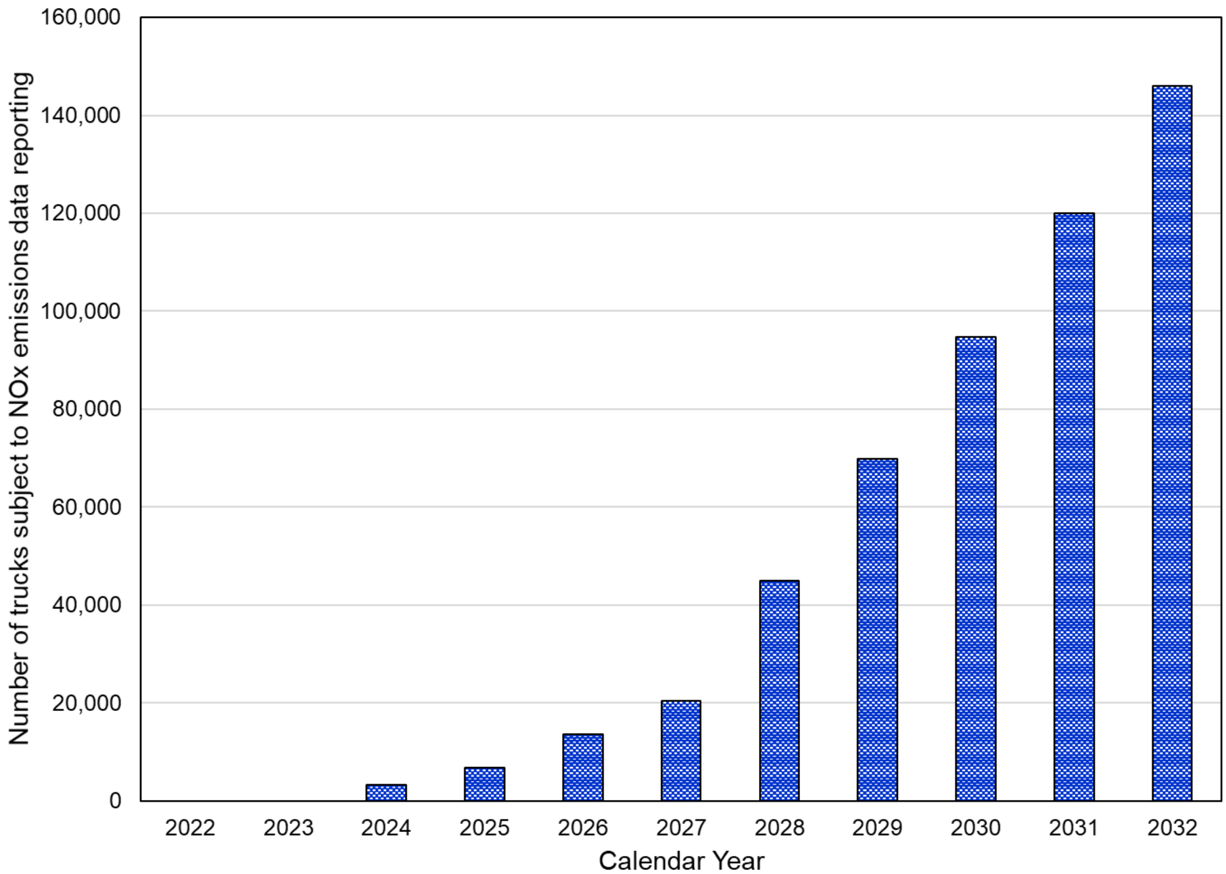
- Labor costs
- Data transfer costs via telematics
- Database licensing cost
- Data storage costs

In developing the in-use NOx emissions data reporting costs, staff made the conservative (i.e., highest cost) assumption that at the end of the 2032 calendar year, all of the on-road heavy-duty diesel trucks sold from the 2024 through 2032 calendar years in California remain at or below their applicable useful life. Except for calendar year 2024, staff also assumed that all on-road heavy-duty diesel engines produced in a specific model year were sold in the following calendar year, i.e., all 2025 model year on-road heavy-duty engines were sold in the 2026 calendar year. In calendar year 2024, the first in-use NOx emissions data report deadline, staff assumed that half of 2024 model year HHDD engines were sold in the 2024 calendar year.

Figure C-1 shows the estimated number of on-road heavy-duty diesel trucks that could be subject to in-use NOx emissions data reporting in the 2022-2032 calendar year timeframe based on the aforementioned assumption. In reality, the slope of the line should be less steep because some of the trucks would probably reach their full useful lives before the 2032 calendar year and would hence no longer be subject to monitoring requirements.

In Figure C-1, staff made the assumption that all HHDD engine manufacturers would start implementing in-use NOx emissions data reporting for all of the engines sold in California starting with the 2024 model year. Although this is an optional certification pathway in the Proposed Regulation, stakeholder feedback suggests that this pathway would be chosen by all HHDD engine manufacturers because the only other compliance pathway would require HHDD engine manufacturers to age the engine on which they are conducting durability testing for a period of two years starting with the 2024 model year, instead of the typical one-year program. Engine manufacturers have told CARB staff that the additional one-year aging period would have a negative impact on the product development cycle (i.e., could delay certification beyond when they hope to sell engines). Hence, staff assumed that all HHDD engine manufacturers would instead use the option to submit in-use NOx emissions data starting with the 2024 model year.

Figure C-1. Estimated Number of On-Road Heavy-Duty Diesel Trucks Subject to In-Use NOx Emissions Data Reporting



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The methods for estimating the costs are described in detail below.

Labor Costs

The labor costs for in-use NOx emissions data reporting can further be separated into two components:

- Upfront programming and database development costs – This is a one-time expense to set up the data collection system that would automatically transfer the required data set from each on-road heavy-duty diesel truck via telematics and store it in a centralized database. The proposed amendments would require the manufacturers to provide the required data set for each on-road heavy-duty diesel engine that was originally sold in the California market once per calendar year until the end of useful life is reached.

  Staff estimates that a total of 1,000 hours of programming costs for a junior engineer ($70/hour) for each of the eight on-road heavy-duty diesel engine manufacturers would be required. The hours will be required to set up the database to store the collected in-use NOx emissions data, and to set up the program which would collect the in-use NOx emissions data every year until the vehicle reaches its useful life period. This is a one-time expense that is included in the 2023 calendar year costs for HHDD engines (5 manufacturers), and the 2026 calendar year for all other manufacturers (3 additional manufacturers).

- Annual reporting costs – Once the programming for collection and reporting of the in-use NOx emissions data is completed, additional labor would be required each calendar year to prepare and submit the reports electronically to CARB. Staff estimates a total of 100 hours for a junior engineer ($70/hour) would be required for each report starting with the 2024 calendar year. After collecting the data each calendar year, manufacturers must compile all vehicle data into an annual report, and submit annual reports to CARB. The required hours cover the cost of annual reporting.

Data Transfer Costs Via Telematics

In order to prepare the annual in-use NOx emissions data reports for individual on-road heavy-duty diesel trucks originally sold in California, the required data must first be transferred from the truck to a centralized database. Staff used an average cost[86] of $30 per truck for each time that the data are submitted via telematics (one telematic transaction fee of $30 per calendar year for each on-road heavy-duty diesel truck that needs to submit a report).

Staff believes that the $30 estimate is a conservative (high) overestimation of the actual costs for telematics services. This cost corresponds to one full month of telematics subscription. A one-time per calendar year transaction fee would most likely be an order

[86] (GPS Insight, 2019) "What is the Cost of Telematics?" GPS Insight, accessed September 2019. https://www.gpsinsight.com/blog/what-is-the-cost-of-telematics/

of magnitude less costly, but at this time, staff does not have access to more detailed telematics pricing for a one-time per calendar year transaction.

Database Licensing Costs

In order to prepare the in-use NOx emissions data reports, the data set submitted via telematics must be stored in a centralized database for each heavy-duty diesel manufacturer. Staff used a one-time upfront cost of $100,000 for procurement of the database license[87] per manufacturer which includes software update and support. The database must be set up prior to the reporting period so that it would be ready for data collection in the subsequent calendar year.

Staff assumed that each on-road heavy-duty diesel manufacturer would procure one database license exclusively for in-use NOx emissions data reporting. This is an overestimation, as staff believes that on-road heavy-duty diesel engine manufacturers already procure database licenses for other internal applications. Under the proposed amendments, HHDD manufacturers would need to procure the database in the 2023 calendar year for 2024 model year engine reporting, while the remaining LHDD and MHDD manufacturers would have to procure the database in the 2026 calendar year for 2027 model year engine reporting.

Data Storage Costs

The data submitted through telematics from each operating truck must also be stored in a centralized data storage facility. Based on the number of parameters required, staff believes that one dataset from one truck should be less than 5 kilobytes in size (this is a conservative estimate and the actual dataset is more likely less than 2 kilobytes in size).

The cost of data storage varies widely depending on whether it is stored in a localized data storage facility or in cloud services. For this cost analysis, staff used an average cost of $0.026 per gigabyte per month[88] to estimate the data storage costs. Staff also assumed that after a NOx emissions data report is submitted for each truck, the manufacturer only needs to keep the dataset in cloud storage temporarily, and the dataset can be either deleted or overwritten by a new dataset for the next report. The annual data storage costs per truck are calculated using the following equation:

$$Data\ storage\ costs\ for\ each\ truck\ per\ calendar\ year = \frac{5\ kilobytes}{truck} \times \frac{1\ gigabyte}{1 \times 10^{6}\ kilobyte} \times \frac{\$0.026}{gigabyte.month} \times \frac{12\ months}{1\ year}$$

Based on these assumptions, the estimated incremental cost of NOx sensor reporting is shown in Table C-41.

[87] (Oracle, 2019) Oracle Technology Global Price List, Oracle, August 12, 2019. https://www.oracle.com/assets/technology-price-list-070617.pdf
[88] (Google, 2019) Google Cloud Storage Pricing, Google, accessed September 2019. https://cloud.google.com/storage/pricing

Table C-41. Estimated Incremental Costs Relative to the 2018 Model Year Baseline for Proposed In-Use NOx Emissions Data Reporting (2018$)

Calendar Year	Total NOx Emissions Data Reporting Costs
2022	$0
2023	$850,000
2024	$136,677
2025	$238,354
2026	$953,185
2027	$670,505
2028	$1,405,584
2029	$2,149,887
2030	$2,897,829
2031	$3,655,978
2032	$4,435,295
Total	**$17,393,294**

j. Powertrain Certification Test Procedure for Heavy-Duty Hybrid Vehicles

As described above, 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 to criteria pollutants emission standards. The proposed amendments would give manufacturers of heavy-duty 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 experience, 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 will be more convenient and more effective for manufacturers, as it is more comprehensively harmonized with its federal counterpart optional procedures.

Overall, staff anticipates that the powertrain test procedure amendments would not increase costs or savings on manufacturers or the cost of vehicles certified for sale in California. This is because 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, as the cost and savings are too negligible to be compelling.

k. Heavy-Duty Vehicle GHG Tractor APU Certification Amendments

Staff expects that the proposed APU amendments would not result in a cost increase to APUs that would be used in 2024 and later model tractors. Existing California APU certification requirements, reporting, and processes remain unchanged. The addition of 40 CFR 1039.699 in the California APU certification procedures would allow harmonization with the federal certification requirements. Thus, no additional cost to APUs is projected.

l. Technical Amendments and Clean-up Items

All of the proposed Phase 2 amendments are either minor clarifications to ensure the functionality of the regulation or alignments with already proposed or adopted national standards. The California specific proposed amendments do not affect the stringency of the emission standards or the testing standards of the already adopted CA Phase 2 program. Because of this, staff considers all of these Phase 2 amendments as no-cost changes.

m. Total Costs

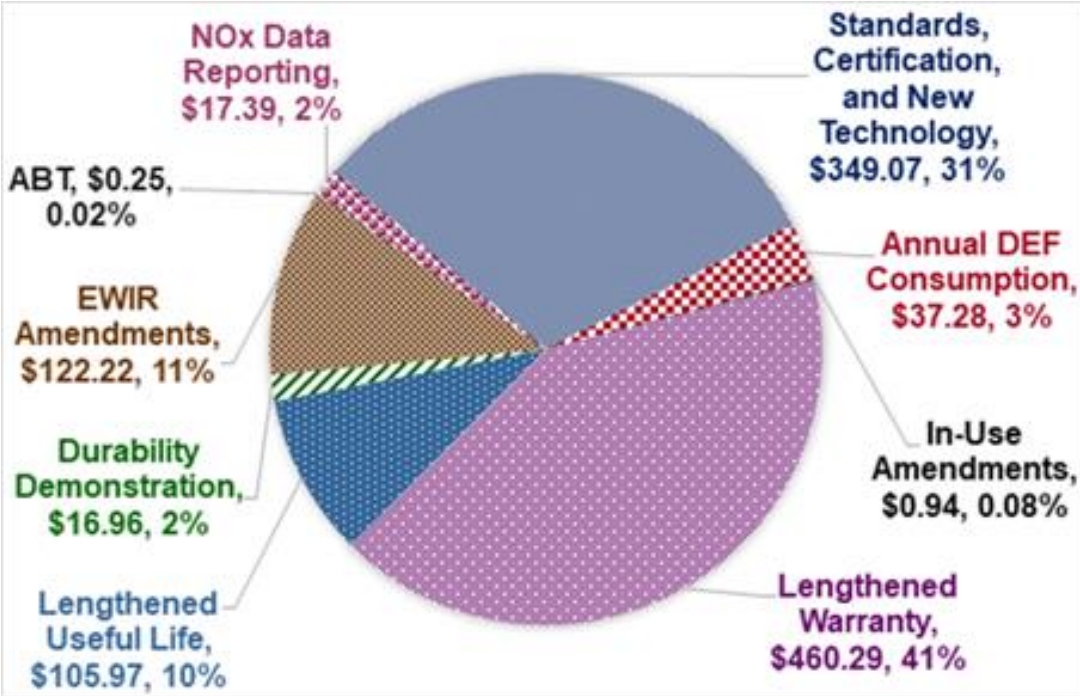
The Proposed Regulation would require newly sold combustion engines used in vehicles rated at 10,000 pounds GVWR or greater to be certified to lowered emission standards, in-use requirements, warranty, and useful life amendments. The total incremental increased costs of the Proposed Regulation, including certification testing, in-use testing, hardware, research and development, warranty, useful life, ABT, DEF consumption, NOx sensor data tracking, EWIR changes, and reporting costs associated with them are summarized in Table C-42. The Proposed Regulation is expected to cost $17.52 million in the first year and $1.11 billion from 2022 through 2032. Although the projected costs from the Proposed Regulation are significant (over $1 billion), it is worth noting that the valuation of the estimated total statewide health benefits from the program are nearly three times higher, at $3.15 billion.

A visual representation of the cost share of the Proposed Regulation elements are presented in Figure C-2. As noted in Figure C-2, the largest costs stem from Standards, Certification, and New Technology and Lengthened Warranty.

Table C-42. Total Estimated Direct Incremental Costs Relative to the Baseline for the Proposed Regulation for Calendar Years 2022 through 2032 (Millions 2018$)

Calendar Year	Standards, Certification, and New Technology	Annual DEF Consumption	In-Use Amendments	Lengthened Warranty	Lengthened Useful Life	Durability Demonstration	EWIR Amendments	ABT	NOx Data Reporting	Total Costs
2022	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$17.52	$0.00	$0.00	$17.52
2023	$1.73	$0.00	$0.00	$0.00	$0.00	$8.72	$18.43	$0.00	$0.85	$29.73
2024	$1.94	$0.00	$0.10	$0.00	$0.00	$0.00	$18.73	$0.10	$0.14	$21.02
2025	$34.07	$0.94	$0.10	$0.00	$0.00	$0.00	$19.47	$0.02	$0.24	$54.84
2026	$35.73	$1.89	$0.10	$0.00	$0.00	$8.24	$19.57	$0.02	$0.95	$66.50
2027	$29.48	$2.84	$0.10	$75.73	$17.32	$0.00	$4.68	$0.02	$0.67	$130.86
2028	$58.22	$4.01	$0.10	$75.53	$17.32	$0.00	$4.69	$0.02	$1.41	$161.30
2029	$48.24	$5.16	$0.10	$76.20	$17.54	$0.00	$4.71	$0.02	$2.15	$154.13
2030	$46.95	$6.32	$0.10	$76.20	$17.61	$0.00	$4.72	$0.02	$2.90	$154.81
2031	$46.33	$7.47	$0.10	$77.23	$17.84	$0.00	$4.78	$0.02	$3.66	$157.43
2032	$46.37	$8.64	$0.10	$79.40	$18.34	$0.00	$4.92	$0.02	$4.44	$162.23
Total	**$349.07**	**$37.28**	**$0.94**	**$460.29**	**$105.97**	**$16.96**	**$122.22**	**$0.25**	**$17.39**	**$1,110.39**

Figure C-2. Relative Share of Costs for the Proposed Regulation



The estimated incremental cost per truck by truck class for the 2025 and 2028 model years is shown in Table C-43. This is calculated by taking the total incremental costs by engine class and dividing by the total population of vehicles in that engine class. These are used to illustrate the anticipated increase in vehicle costs within the 2024 to 2026 model years and the 2027 and subsequent model years, respectively.

Table C-43. Estimated Incremental Cost Per Truck by Truck Class for 2025 and 2028 for the Proposed Regulation (2018$)

Truck Class	2025 Model Year Total Incremental Costs	2028 Model Year Total Incremental Costs
HHDD	$2,140	$6,228
MHDD	$1,981	$6,744
LHDD	$1,664	$4,845
HDO	$674	$1,580
MDDE-3	$1,580	$3,441
MDOE-3	$602	$744
New Sales Population Weighted Average	**$1,772**	**$5,520**

2. Direct Costs on Typical Businesses

Medium- and heavy-duty engine/vehicle manufacturers would be the regulated entities under the Proposed Regulation. Because all these manufacturers are located outside of California, CARB staff assumed the direct costs imposed on these manufacturers would be passed on from manufacturers through higher vehicle prices to California vehicle fleets that purchase the low NOx-certified vehicles and engines. Typical businesses are defined here to be California fleets within the trucking industry with four or more heavy-duty vehicles.

Tables C-44 and C-45 shows the estimated incremental increase in cost of ownership over the lifetime of the vehicle depending on truck class for a vehicle purchased in 2025 and 2028, respectively. The incremental increase in lifetime cost of ownership could range from $602 to $8,237 per vehicle depending on truck class and year purchased. A new sales population weighted average increase in incremental cost is approximately $2,404 and $6,276 for purchases in 2025 and 2028, respectively.

Table C-44. Example – Proposed Regulation Cost for Purchasing a New Vehicle in 2025 (2018$)[89]

Truck Class	Additional Upfront New Vehicle Cost (2018$)	Additional Cost of Incremental DEF Consumption over the Vehicle Lifetime (2018$/yr)	Total Incremental Lifetime Cost (2018$)
HHDD	$2,140	$1,674	$3,814
MHDD	$1,981	$386	$2,367
LHDD	$1,664	$262	$1,926
HDO	$674	$0	$674
MDDE-3	$1,580	$353	$1,933
MDOE-3	$602	$0	$602
New Sales Population Weighted Average	**$1,772**	**$632**	**$2,404**

[89] The costs shown in Table C-44 are for an assumed total vehicle lifetime of 18 years. Note that the example costs shown in Table C-44 would be partially offset by the savings discussed above in section B.2.

Table C-45. Example – Proposed Regulation Cost for Purchasing a New Vehicle in 2028 (2018$)[90]

Truck Class	Additional Upfront New Vehicle Cost (2018$)	Additional Cost of Incremental DEF Consumption over the Vehicle Lifetime (2018$/yr)	Total Incremental Lifetime Cost (2018$)
HHDD	$6,228	$2,009	$8,237
MHDD	$6,744	$464	$7,208
LHDD	$4,845	$314	$5,159
HDO	$1,580	$0	$1,580
MDDE-3	$3,441	$424	$3,865
MDOE-3	$744	$0	$744
New Sales Population Weighted Average	**$5,520**	**$756**	**$6,276**

As an example, a typical business that buys 20 new MHDD vehicles in 2025, would see a total increase in costs of about $47,800 over the lifetime compared to the baseline. If the business were to instead purchase 20 new MHDD vehicles in 2028, then they could expect to see an increase in cost of ownership of about $144,700 over the lifetime compared to the baseline.

To show the net cost impacts of the regulation, the data from Tables B-2, B-3, C-44, and C-45 were combined for their respective purchase periods. Table C-46 shows the net lifetime cost impacts of a single vehicle purchased in the 2024 to 2026 time period, by service class. Net impacts could range from a savings of $173 for MHDD to a cost of $3,294 for HHDD compared to the baseline. Table C-47 shows the net lifetime cost impacts of a single vehicle bought in 2027 or later by service class. Net impacts could range from a cost of $373 for a HDO to a cost of $5,247 for a HHDD compared to the baseline.

[90] The costs shown in Table C-44 are for an assumed total vehicle lifetime of 18 years. Note that the example costs shown in Table C-45 would be partially offset by the savings discussed above in section B.2.

Table C-46. Net Cost Impact of a Vehicle Purchased from 2024 to 2026 under the Proposed Regulation[91]

Truck Class	Lifetime Costs	Lifetime Savings	Lifetime Net Impact
HHDD	$3,814	$520	$3,294
MHDD	$2,367	$2,540	-$173
LHDD	$1,926	$545	$1,381
HDO	$674	$620	$54
MDDE-3	$1,933	$0	$1,933
MDOE-3	$602	$0	$602
New Sales Population Weighted Average	**$2,404**	**$1,279**	**$1,125**

Table C-47: Net Cost Impact of a Vehicle Purchased in 2027 or Later under the Proposed Regulation

Truck Class	Lifetime Costs	Lifetime Savings	Lifetime Net Impact
HHDD	$8,237	$2,990	$5,247
MHDD	$7,208	$5,065	$2,143
LHDD	$5,159	$2,110	$3,049
HDO	$1,580	$1,207	$373
MDDE-3	$3,865	$873	$2,992
MDOE-3	$744	$153	$591
New Sales Population Weighted Average	**$6,276**	**$3,345**	**$2,930**

As shown in the examples above, for a typical business that buys 20 new MHDD vehicles in 2025, the owner would see a net savings of $3,460 over the vehicles' lifetime compared to the baseline. If the business were to instead purchase 20 new MHDD vehicles in 2028, then the owner would see a net cost of $42,860 over the vehicles' lifetime compared to the baseline.

[91] Lifetime savings for MDDE-3 and MDOE-3 are $0 because there were no warranty claims for these classes in model year 2013 and hence no projected savings related to the EWIR amendments. For MHDD for model years 2024 to 2026, savings related to the EWIR amendments are projected to be great enough to offset projected costs of the Proposed Regulation and hence lifetime net cost impact is negative.

3. Direct Costs on Small Businesses

Based on California DMV 2017 registration data, small businesses, identified as fleets of three or fewer heavy-duty vehicles, represent 54 percent of the affected vehicle population due to the Proposed Regulation.

The final compliance date for the Truck and Bus Regulation is January 1st, 2023. As of this date, heavy-duty vehicle owners are required to fully turn over their fleet to 2010 standard compliant engines. Small business fleets throughout California will be likely, in 2023, to have recently come into full compliance 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 meet the Truck and Bus Regulation, they are expected to be unlikely to turn over their engines to the proposed 2024 or 2027 and subsequent model year Proposed Regulation compliant engines within the 11-year analysis for this SRIA. Although small business purchases of heavy-duty trucks may be less likely to occur within the analysis period, some such purchases will still occur, and an example of costs for a small business fleet is provided based on engine technology purchased in 2025 or 2028.

As an example, the lifetime incremental increase in cost to a small business for a single vehicle purchased in 2025 or 2028 depending on truck class can be seen in in Tables C-44 and C-45, respectively. For a vehicle purchased in 2025, a small business could expect to spend an additional $602 to $3,814 over the vehicle's lifetime compared to the baseline. For a vehicle purchased in 2028, a small business could expect to spend an additional $744 to $8,237 over the vehicle's lifetime compared to the baseline.

As an example, a small fleet that buys one HHDD model year 2024 vehicle would have a net cost $3,294 over the lifetime of the vehicle as a result of the proposed amendments, as shown in Table C-46. As another example, a small fleet purchasing one HHDD in 2027 would expect to have a net cost of $5,247 over the lifetime of the vehicle as a result of the proposed amendments, as shown in Table C-47. Compared to the costs small businesses will likely have recently faced to comply with the Truck and Bus Regulation (i.e., the cost to purchase one or more used or new trucks earlier than under the normal course of business, each for $50,000-$100,000 per truck), any costs due to the Proposed Regulation would be relatively insignificant.

4. Direct Costs on Individuals

There are no direct costs on individuals as a result of this Proposed Regulation. Individuals may see health benefits as described in section B.4.a. due to the displacement of engines at the current emission levels to the Proposed Regulation engines providing statewide, regional, and local emission benefits. Staff estimates that manufacturers and fleets will see increased costs as a result of this rule and will likely pass the costs through to individuals in the state. Individuals may see macroeconomic indirect and induced benefits and costs; these costs are discussed further in section E.

D. FISCAL IMPACTS

1. Local Government

a. Local Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Regulation would increase the cost of each heavy-duty truck and engine sold in the state in 2024 and subsequent model years by about 2.5 to 6 percent. The Proposed Regulation 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%.[92] Overall, local sales tax revenue may increase less than the direct increase from vehicle sales if overall business spending does not increase.

b. Local Government Fleet Costs

The local government fleet is estimated to make up 10.7 percent of California's total fleet.[93] The same proportion of the total costs outlined in Table C-42 are assumed to pass through to local government, for new government fleet purchases.

c. Fiscal Impact on Local Government

Table D-1 shows the estimated fiscal impact to local governments due to the Proposed Regulation relative to baseline conditions. The fiscal impact on local government in 2022 would be a cost of $1.73 million; and the ongoing fiscal impact on local government would range from $1.73 to $15.97 million in cost within the proposed regulation's lifetime of 11 years.

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[92] (CARB, 2019c) Spreadsheet for California City and County Sales and Use Tax Rates, California Air Resources Board, July 2019, obtained from the California Department of Tax and Fee Administration website at http://cdtfa.ca.gov/taxes-and-fees/sales-use-tax-rates.htm

[93] (CARB, 2018b) Staff Report: Initial Statement of Reasons for the for Rulemaking: "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles" (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf?_ga=2.169925923.2011115175.1568077425-1788626826.1465349672

Table D-1. Fiscal Impacts on Local Government (Millions 2018$)

Calendar Year	Local Government Fleet Costs	Local District Sales Tax Revenue	Fiscal Impact
2022	$1.87	-$0.15	$1.73
2023	$3.18	-$0.25	$2.93
2024	$2.25	-$0.18	$2.07
2025	$5.87	-$0.47	$5.40
2026	$7.12	-$0.57	$6.55
2027	$14.00	-$1.12	$12.89
2028	$17.26	-$1.38	$15.88
2029	$16.49	-$1.31	$15.18
2030	$16.56	-$1.32	$15.24
2031	$16.85	-$1.34	$15.50
2032	$17.36	-$1.38	$15.97
Total	**$118.81**	**-$9.47**	**$109.34**

* Totals may vary due to rounding.
** Negative values indicate revenue to local governments.

2. State Government

a. CARB Staffing and Resources

The Proposed Regulation would have a small impact on staffing resources. The Proposed Regulation is expected to require a total of eight positions, as summarized below:

- Two additional Air Resources Engineers would be required to review certification applications using new strategies and technologies, as well as manage and review the new standardized extended durability testing.
- EWIR amendments are forecasting increased claims and recall. In order to address these future concerns, two Air Pollution Specialists are required to fulfill the duties.
- Two additional Air Resources Engineers would be required to coordinate test plans with manufacturers, implement new procedures, and verify submitted test data with the amended HDIUT program.
- Finally, another two Air Resources Engineers are required to handle the NOx sensor data submissions and certify the additional OBD certification requirements associated with the newer technologies expected in low NOx engines.

b. State Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Regulation would result in the sale of more expensive (higher upfront cost) trucks as well as increased DEF consumption in those trucks in California which would result in higher sales taxes collected by the state government. The entire population of new California-sold trucks and DEF consumption over the entire state were used for this analysis. California sales tax at 7.25 percent was used in this analysis.[94] Overall, state sales tax revenue may increase less than the direct increase from vehicle sales if overall business spending does not increase.

As discussed further above in section B.1.a., although it is possible the Proposed Regulation 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 this SRIA, for the reasons outlined in section B.1.a., 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.

c. State Fleet Costs

The state government fleet is estimated to make up 3.3 percent of California's fleet.[95] A proportionate amount of the total costs outlined in Table C-42 are assumed to pass through to the state government.

d. Fiscal Impacts on State Government

Table D-2 shows the estimated fiscal impacts to the state government due to the Proposed Regulation relative to baseline conditions. The fiscal impact on state government in 2022 would be an additional $1.00 million in revenues; and the ongoing fiscal impact on state government would range from an additional $1.00 to $7.81 million in revenue per year within the considered regulations' period of analysis.

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[94] (CARB, 2019c) Spreadsheet for California City and County Sales and Use Tax Rates, California Air Resources Board, July 2019, obtained from the California Department of Tax and Fee Administration website at http://cdtfa.ca.gov/taxes-and-fees/sales-use-tax-rates.htm

[95] (CARB, 2018b) Staff Report: Initial Statement of Reasons for the for Rulemaking: "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-Road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines With Gross Vehicle Weight Ratings Greater Than 14,000 Pounds and Heavy-Duty Diesel Engines In Such Vehicles" (Step 1 Warranty), California Air Resources Board, May, 8, 2018. https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf?_ga=2.169925923.2011115175.1568077425-1788626826.1465349672

Table D-2. Summary of Fiscal Impacts to State Government (Millions 2018$)

Calendar Year	CARB Staffing	State Government Fleet Costs	State Sales Tax Revenue	Fiscal Impact
2022	$0	$0.27	-$1.27	-$1.00
2023	$0	$0.45	-$2.16	-$1.70
2024	$1.13	$0.32	-$1.52	-$0.07
2025	$1.13	$0.83	-$3.98	-$2.02
2026	$1.13	$1.01	-$4.82	-$2.68
2027	$1.49	$1.99	-$9.49	-$6.01
2028	$1.49	$2.45	-$11.69	-$7.76
2029	$1.49	$2.34	-$11.17	-$7.35
2030	$1.49	$2.35	-$11.22	-$7.39
2031	$1.49	$2.39	-$11.41	-$7.54
2032	$1.49	$2.46	-$11.76	-$7.81
Total	**$12.31**	**$16.86**	**-$80.50**	**-$51.34**

* Totals may vary due to rounding.
** Negative values indicate revenue to state government.

E. MACROECONOMIC IMPACTS

1. Methods for Determining Economic Impacts

This section describes the estimated total impact of the Proposed Regulation on the California economy. The Proposed Regulation would result in changes in expenditures by businesses in order to comply with its requirements. These changes in expenditures would affect employment, output, and investment in business sectors, classified by the North American Industry Classification System (NAICS) that supply goods and services in support of the trucking industry.

These impacts lead to additional induced effects, like changes in personal income that affect consumer expenditures across other spending categories. The incremental total economic impacts of the Proposed Regulation are simulated relative to the baseline scenario using the cost data and assumptions described in section C. The analysis focuses on the incremental changes in major macroeconomic indicators from 2022 to 2032 including employment, output growth, and gross state product (GSP). The years of the analysis were chosen to frame the simulation of the Proposed Regulation through 12 months post full implementation 2028 to 2032, the final year of analysis.

Regional Economic Models, Inc. (REMI) Policy Insight Plus Version 2.2.8 is used to estimate the macroeconomic impacts of the Proposed Regulation 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.[96] REMI Policy Insight Plus provides year-by-year estimates of the total impacts of the Proposed Regulation, pursuant to the requirements of SB 617 and the California Department of Finance.[97,98] 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.

2. Inputs of the Assessment

The estimated economic impact of the Proposed Regulation incorporates modeling assumptions based on relevant data. This section provides a summary of the assumptions and inputs used to determine the suite of policy variables that best reflect the macroeconomic impacts of the Proposed Regulation. The direct costs estimated in

[96] For further information and model documentation see: https://www.remi.com/model/pi/

[97] (CLI, 2019b) SB-617 State government: financial and administrative accountability (Calderon; Chapter 496, Statutes of 2011), California Legislative Information, accessed November 2019. http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB617

[98] (DGS, 2019) State Administrative Manual, 6600: Standardized Regulatory Impact Assessment For Major Regulations - Order of Adoption, California Department of General Services, accessed November 2019. https://www.dgsapps.dgs.ca.gov/documents/sam/SamPrint/new/sam_master/sam_master_File/chap6000/6600.pdf

section C and the non-mortality health benefits estimated in Section B are translated into REMI policy variables and used as inputs for the macroeconomic analysis.[99]

The Proposed Regulation would impost direct costs on manufacturers who would be required to produce engines and vehicles compliant with the Proposed Regulation, as described above in section C. While these costs are directly incurred by manufacturers, those manufacturers are not located in California. Staff assumes that manufacturers wanting to remain profitable would pass these costs on to their customers in the form of increased prices of vehicles.

Because this analysis focuses on the impacts to the California economy, it is concerned with the impact of the Proposed Regulation on California trucking fleets (i.e., changes to their production costs and exogenous final demand due to the regulation). In addition to the cost from increased vehicle prices, this analysis includes other costs on California fleets, including additional DEF consumption and maintenance costs. Additionally, this analysis includes savings for fleets beginning in 2032 from the warranty and useful life amendments within the Proposed Regulation.

In addition to impacts on California businesses, the consumption changes due to requirements affecting vehicle price, DEF, and activities would change the amount of revenue generated in state and local taxes. The total change in taxes paid by businesses in the truck transportation industry are modeled as a revenue for the state and local governments.

Costs and savings incurred by both manufacturers and fleets would result in corresponding changes in final demand for industries supplying those particular goods or services as shown in Table E-1. As the direct costs and savings on vehicle manufacturers are incurred out-of-state, production cost changes for the supply chain cannot be directly modeled as a change in final production costs in California. In order to account for this, staff estimates the increased production costs would be passed on to California businesses, primarily fleets based in California. All other changes in demand are included in this analysis.

The required changes to testing methods and techniques are represented as a change in final demand for Vehicle Manufacturing (3361). The EWIR amendments of the Proposed Regulation would induce final demand changes to the Vehicle Manufacturing (3361) and Motor Vehicle Parts Manufacturing (3363) Industries. The engine and vehicle maintenance are assumed to be supplied by businesses in the Vehicle Repair and Maintenance Industry (8111). The new demand for labor to manage the ABT credits is presented as an adjustment to the demand for Office Administrative Services (5611) Industry. The increased demand for DEF fluid is assumed to be incurred by the Basic Chemical Manufacturing (3259) Industry. The change in demand for telematics reporting is assumed to be supplied by the Other Measuring and Controlling Devices (3345) Industry.

[99] Refer to Section G: Macroeconomic Appendix for a full list of REMI inputs for this analysis.

Table E-1. Sources of Changes in Production Cost and Final Demand by Industry

Source of Cost or Savings	Industry with changes in Production costs (NAICS)	Industries with Changes in Final Demand (NAICS)
New Technology & Testing	Truck Transportation (484)	*Recurring cost:* Vehicle Manufacturing (3361)
Corrective Warranty Action		*Recurring cost:* Vehicle Manufacturing (3361) 25%
		Recurring cost: Motor Vehicle Parts Manufacturing (3363) 75%
Warranty & Useful Life		*Recurring cost:* Vehicle Repair and Maintenance (8111)
ABT Credits Accounting		*Recurring cost:* Basic Chemical Manufacturing (3259)
DEF Fluid		*Recurring cost:* Other Measuring and Controlling Devices Manufacturing (3345)
Reporting and Telematics		*Recurring savings:* Hospitals (622)
Healthcare Savings		*State & Local Government Spending*

In addition to these changes in production costs and final demand for businesses, there would also be economic impacts as a result of the fiscal effects, primarily from changes in sales tax revenue, as described in section D. The corresponding change in government revenue is modeled as a change in state and local government spending, assuming this revenue increase is not offset elsewhere. The person-years requested are included in the model as state employees.

The health benefits resulting from the emission reductions of the Proposed Regulation reduce healthcare costs for individuals on average. This reduction in healthcare cost is modeled as a decrease in spending for Hospitals (622), with a reallocation of this spending towards other goods and increased savings.

3. Assumptions and Limitations of the Model

In accordance with the rest of the analysis, the REMI model assumes minimal redirection of purchasing activity from California to other states resulting from the Proposed Regulation. As discussed above in section B.1.a., because the Proposed Regulation would increase new vehicle purchase prices, it is possible it could encourage California fleets 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.

Due to the relatively small percent increase in projected vehicle price; the uncertainty regarding the extent to which California standards would diverge from federal standards; the regulations governing the purchase, registration and operation of vehicles in California;

and the fact that fleet purchase decisions are influenced by numerous factors staff did not attempt to quantify any such changes in fleet purchase behavior in this SRIA.

Other assumptions applied to the analysis can be found in section C.1. Savings due to the warranty and useful life amendments start accumulating in the 2032 calendar year (the sixth year after 2027) because the savings generated in the first five years after 2027 are due to the Step 1 warranty amendments. The ABT credits would not be significantly utilized, beyond manufacturers accounting for them. All other assumptions from section C.1. are applied in this analysis. The Proposed Regulation was modeled with the assumption that all manufacturers would act according to market incentives and not purposefully boycott the California market.

4. Results of the Assessment

The results from the REMI model provide estimates of the impact of the Proposed Regulation on the California economy. These results represent the annual incremental change from the implementation of the Proposed Regulation relative to the baseline scenario. The California economy is forecasted to grow through 2032. 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 Regulation. The results are reported here in tables for every year from 2022 through 2032.

a. California Employment Impacts

Table E-2 presents the impact of the Proposed Regulation total employment in California across all industries. The employment impacts represent the net change in employment, which consist of positive impacts for some industries and negative impacts for others. The Proposed Regulation is estimated to result in a slightly negative job growth from about 2022 to 2032. These changes in employment represent less than 0.01 percent of baseline California employment.

Across the California economy, the REMI simulation shows job losses over the years of analysis. While the decline is mostly steady, it jumps in 2028, the first year post full implementation of the Proposed Regulation and appears to follow the same steady decline in job growth. As the Truck Transportation Industry is a central and deeply interconnected industry in the economy, staff analyzed the impacts on job growth in the industries selected for the model (Table E-3). In most cases, impacts on job growth appear to intensify in 2028 and stabilize or decline though 2032, the last year of analysis.

Table E-2. Total California Employment Impacts of the Proposed Regulation

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
California Employment	24,692,221	24,884,804	25,076,190	25,265,740	25,454,430	25,643,764	25,831,677	26,018,401	26,204,400	26,389,408	26,572,580
% Change	-0.00%	-0.00%	-0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
Change in Total Jobs	-452.250	-735.921	-618.034	-1406.280	-1751.540	-1566.649	-2286.432	-2138.101	-2145.729	-2149.798	-1810.234

The total employment impacts shown above are net changes at the industry level. Table E-3 shows the changes in employment by industries that are directly impacted by the Proposed Regulation. As the requirements of the Proposed Regulation are implemented, the industries experiencing reductions in production costs or increases in final demand would see an increase in employment growth. This analysis includes the Truck Transportation (484), Automotive Repair and Maintenance (8111), and manufacturing sectors and upstream industries. The largest decrease in employment results from the Truck Transportation Industry (484), which is estimated to realize an increase in production costs. The Automotive Repair and Maintenance Industry (8111) realizes gains in employment, mostly due to increased demand because of longer Useful Life and Warranty timeframes and Corrective Warranty Action. Motor Vehicle Parts Manufacturing (3363) and Motor Vehicle Manufacturing (3361) show some employment gains due to Corrective Warranty Action and the new testing requirements.

The Truck Transportation Industry (484) is an industry that interacts with many other industries during its typical operations. This industry has systemic connections to the majority of other industries in the economy. These connections contain varying degrees of strength, durability and vulnerability to new economic conditions. Full consideration of the employment impacts of the Proposed Regulation would require an analysis of those indirectly affected industries. Table E-4 presents the REMI simulation's findings on the employment impacts of industries connected with the Truck Transportation Industry.

Table E-3. Job Impacts Due to the Proposed Regulation by Primary Industries

		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Truck Transportation (484)	% Change	-0.04%	-0.07%	-0.05%	-0.12%	-0.15%	-0.28%	-0.34%	-0.32%	-0.32%	-0.32%	-0.18%
	Change in Jobs	-94.89	-158.26	-110.70	-284.79	-340.83	-655.96	-799.47	-751.86	-743.36	-743.66	-414.52
Automotive Repair and Maintenance (8111)	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	+0.42%	+0.41%	+0.42%	+0.41%	+0.41%	+0.42%
	Change in Jobs	-3.82	-5.56	-3.91	-10.56	-12.06	+895.93	+882.80	+888.32	+883.24	+889.69	+913.83
Motor Vehicle Parts Manufacturing (3363)	% Change	+0.01%	+0.02%	+0.01%	+0.06%	+0.07%	+0.04%	+0.08%	+0.06%	+0.06%	+0.06%	+0.06%
	Change in Jobs	+3.88	+4.02	+3.91	+4.14	+4.04	+2.54	+2.43	+2.17	+1.97	+1.85	+2.47
Motor Vehicle Manufacturing (3361)	% Change	0.01%	0.02%	0.01%	0.06%	0.07%	0.04%	0.08%	0.07%	0.06%	0.06%	0.06%
	Change in Jobs	+0.70	+2.61	+1.02	+6.79	+8.38	+4.67	+9.43	+7.42	+6.98	+6.71	+6.75
Chemical Product Manufacturing (325199)	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change in Jobs	-0.04	-0.07	-0.07	-0.13	-0.17	-0.24	-0.34	-0.36	-0.38	-0.39	-0.36
Other Measuring and Controlling Devices Manufacturing (3345)	% Change	0.00%	+0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	+0.00%	+0.00%	+0.00%
	Change in Jobs	-0.24	+0.35	-0.20	-0.44	-0.01	-0.62	-0.63	-0.24	+0.13	+0.50	+1.36

b. California Business Impacts

Gross output is used as a measure for business impacts because it represents an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output growth is the sum of output in each private industry and state and local government as it contributes to California's GSP, and is affected by production cost and demand changes. As production cost increases or demand decreases, output is expected to contract, but as production costs decline or demand increases, industry would likely experience output growth.

The REMI analysis of the Proposed Regulation projects a decrease in statewide output growth of $67 million in 2022 and a decrease of approximately $376 million in 2032 as shown in Table E-4. The trend in output changes is illustrated by major sector in Table E-4. There are negative impacts on output for Office Administrative Services, and Other Measuring and Controlling Devices. Meanwhile, the Proposed Regulation shows positive impacts on Automotive Repair and Maintenance, Motor Vehicle Manufacturing, Motor Vehicle Parts Manufacturing, and Chemical Product Manufacturing. The negative output impact on the Truck Transportation Industry is primarily driven by increased passed-on production costs, while the positive output growth on the Automotive Repair and Maintenance Industry is driven by increased demand due to the Proposed Regulation.

Table E-4. Change in California Output Growth by Industry Due to the Proposed Regulation

Year of Anticipated Impacts		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
California Economy	Output (2018M$)	4123.95	4188.207	4256.524	4327.932	4395.837	4471.491	4548.992	4630.578	4715.911	4805.755	4900.336
	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change in output (2018M$)	-66.74	-110.03	-95.38	-215.38	-271.66	-312.46	-434.04	-422.08	-432.39	-442.19	-376.91
State & Local Government	% Change	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.03%
	Change in output (2018M$)	-4.234	-6.122	-9.586	-14.882	-23.65	-28.863	-32.779	-35.109	-36.449	-38.474	-106.999
Truck Transportation (484)	% change	-0.04%	-0.07%	-0.05%	-0.12%	-0.15%	-0.28%	-0.34%	-0.33%	-0.32%	-0.32%	-0.18%
	Change in output (2018M$)	-15.169	-25.683	-18.312	-47.565	-57.764	-112.563	-139.402	-133.507	-134.351	-136.803	-78.538
Automotive Repair and Maintenance (8111)	% change	0.00%	0.00%	0.00%	-0.01%	-0.01%	0.43%	0.42%	0.42%	0.42%	0.42%	0.43%
	Change in output (2018M$)	-0.354	-0.52	-0.374	-0.997	-1.149	82.969	82.42	83.572	83.713	84.928	87.846
Motor Vehicle Parts Manufacturing (3363)	% change	0.03%	0.03%	0.03%	0.03%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
	Change in output (2018M$)	1.986	2.081	2.054	2.203	2.173	1.392	1.346	1.213	1.119	1.062	1.429
Vehicle Manufacturing (3361)	% change	0.01%	0.02%	0.01%	0.06%	0.07%	0.04%	0.08%	0.06%	0.06%	0.06%	0.06%
	Change in output (2018M$)	0.671	2.534	0.998	6.68	8.308	4.682	9.504	7.554	7.182	6.967	7.085
Chemical Product Manufacturing (325199)	% change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change in output (2018M$)	-0.157	-0.297	-0.304	-0.6	-0.797	-1.147	-1.618	-1.773	-1.925	-2.052	-1.927
Other Measuring and Controlling Devices Manufacturing (33451)	% change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Change in output (2018M$)	-0.148	0.201	-0.135	-0.301	-0.038	-0.464	-0.504	-0.259	-0.008	0.262	0.937

c. *Impacts on Investments in California*

Private domestic investment consists of purchases of residential and nonresidential structures and of equipment and software by private businesses and nonprofit institutions. It is used as a proxy for impacts on investments in California because it provides an indicator of the future productive capacity of the economy.

The relative changes to growth in private investment for the Proposed Regulation are shown in Table E-5 and show a decrease of private investment of about $10 million in 2022, $73 million in 2028 and $41 million in 2032, or less than 0.03 percent of baseline investment.

d. *Impacts on Individuals in California*

The Proposed Regulation would impose no direct costs on individuals in California. However, the costs incurred by affected businesses and the public sector would ripple through the economy and affect individuals.

One measure of this impact is the change in real personal income. Table E-6 shows annual change in real personal income across all individuals in California. Total personal income growth decreases by approximately $38 million in 2022 and $262 million in 2032 as a result of the Proposed Regulation, representing about 0.01 percent of the baseline. Per capita personal income growth decreases by approximately $53 in 2022 and decreases by $78 in 2032.

Table E-5. Change in Gross Domestic Private Investment Growth Due to the Proposed Regulation

Year of Change	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Private Investment (2018M$)	370.880	376.058	380.450	384.617	388.911	392.855	398.275	404.609	411.663	419.213	426.877
% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.01%
Change (2018M$)	-10.219	-19.651	-18.962	-35.767	-46.451	-55.988	-73.352	-72.005	-68.129	-63.123	-41.154

Table E-6. Change in Personal Income Growth Due to the Proposed Regulation

Year of Change	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Personal Income (2018M$)	2,107.685	2,197.791	2,290.623	2,387.326	2,485.146	2,588.343	2,696.241	2,799.083	2,906.347	3,018.36	3,135.246
% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
Change (2018M$)	-37.81	-65.617	-61.428	-136.411	-179.918	-181.423	-261.86	-259.217	-268.159	-276.439	-262.334
Personal Income per capita (2018M$)	52.69	54.94	57.27	59.68	62.13	64.71	67.41	69.98	72.66	75.46	78.38

e. Impacts on Gross State Product

GSP is the market value of all goods and services produced in California and is one of the primary indicators used to gauge the health of an economy. GSP is one of the variables output by the REMI model, which was utilized to analyze the Proposed Regulation's impact on California's economy. Under the Proposed Regulation, GSP growth is anticipated to decrease by approximately $39 million in 2022 and decrease by $221 million in 2032 as shown in Table E-7. These changes do not exceed 0.01 percent of baseline GSP.

f. Creation or Elimination of Businesses

Although the REMI model cannot directly estimate the creation or elimination of businesses, or changes in jobs and output for the California economy described above, it can be used to understand some potential impacts. The trend of increasing production costs for the truck transportation industry has the potential to result in a contraction or decrease in business in this industry if sustained over time. On the other hand, the projected increase in demand for automotive repair and services, motor vehicle parts manufacturing, and vehicle manufacturing resulting from the Proposed Regulation has the potential to result in an increase in growth for businesses in those industries if maintained for a long duration.

Table E-7. Change in Gross State Product Due to the Proposed Regulation

Year of Change	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GSP (2018M$)	2,531,212	2,571,338	2,614,399	2,660,087	2,704,363	2,752,897	2,802,018	2,852,720	2,904,650	2,958,070	3,012,828
% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
Change (2018M$)	-39.296	-64.399	-56.056	-127.061	-160.358	-175.719	-246.72	-238.32	-243.573	-248.362	-221.856

g. Incentives for Innovation

The Proposed Regulation contains several elements that encourage innovation. The warranty, useful life, and EWIR 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 engines 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 Regulation.

The proposed low load cycle and more rigorous durability testing, and the option to transmit the REAL 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 amendments would support improved emission control technology performance while at the same time encourage innovation by manufacturers to meet the more stringent standards.

h. Competitive Advantage or Disadvantage

As described above, the Proposed Regulation would impose new emissions requirements on heavy-duty engine manufacturers. These manufacturers are headquartered and produce engines entirely outside of California for a national and international market. The costs for meeting the Proposed Regulation would increase costs to California fleets through an increase in new heavy-duty vehicle prices to truck buyers. The expected percent increases in vehicle cost range between two and five percent as discussed in section C.1.m and would be partially offset by savings starting in 2032 as discussed in section B.2.b.

Because U.S. EPA is concurrently working on a proposal to lower federal emission standards for the same engines affected by the Proposed Regulation, the U.S. EPA's Cleaner Trucks Initiative, it is not certain how much stricter the California standards will likely be compared to the federal standards. It is also not clear how the model year applicability would line up between the two programs. However, due to federal lead time requirements, it seems certain that California standards would be stricter than the federal standards for the model years 2024 through 2026.

That means that at least for some model years, California would have slightly higher truck prices (potentially two to five percent higher) than in other states. This difference in California truck prices could affect heavy-duty truck fleets and heavy-duty truck dealers.

For heavy-duty truck fleets, in years when California standards are stricter than federal, fleets that buy trucks predominantly in California could be at a small competitive disadvantage versus fleets that buy trucks elsewhere. California fleets may react by trying to minimize the competitive disadvantage by holding onto old trucks slightly longer, purchasing used trucks, or purchasing out-of-state trucks. However, staff believes the impact of the regulation would be mitigated by several factors. First, used trucks and engines must comply with CARB's Truck and Bus Regulation to legally operate and be registered with the California DMV.[100] The Truck and Bus regulatory requirements, which are designed to reduce NOx and PM emissions, will mean it is illegal to register many older used trucks in California. Second, purchases of new out-of-state trucks are forbidden as well. Vehicles with less than 7,500 miles on the odometer are considered new and may not legally be purchased by California fleets for operation in California or registered with California DMV.[101] Any new vehicle submitted for California registration will be required to comply with California emissions regulations.

Under the Proposed Regulation, it is likely that there would be some financial incentive for fleets to purchase new vehicles outside of California and bring them in for registration when they no longer qualify as a "new vehicle" (i.e., after they have over 7,500 miles on the odometer). How strong the financial incentive is for the fleets depends on the location of the fleet's headquarters, shipping fees, the inconvenience of accumulating the necessary 7,500 miles for a vehicle to no longer be considered "new," and whether the prices of heavy-duty vehicles and engines in neighboring states significantly differ in response to the change of vehicle and engine prices in California. Finally, some companies that operate trucking fleets may choose to relocate outside of California in order to avoid the regulatory costs, in instances that would be logistically and financially feasible for them.

In addition to fleets, the Proposed Regulation would impact California truck dealers as well. Because of the impact on fleets described above, overall new heavy-duty vehicle sales in California may decrease slightly versus what they would have been without the Proposed Regulation and sales outside California may increase slightly. Hence, California truck dealers could be at a small competitive disadvantage versus out-of-state dealers. However, as noted above, out-of-state sales by California fleets would be somewhat limited both by the California Truck and Bus Regulation and by the ban on bringing new vehicles in from out-of-state. In addition, any competitive disadvantage for California dealers would only exist to the extent California standards are stricter than federal standards. It is not certain how much stricter the California standards would be compared to the federal standards, nor for precisely which model years California standards would be different.

[100] (CARB, 2019t) "CARB Truck Rule Compliance Required for DMV Registration," California Air Resources Board, accessed November 2019. https://ww3.arb.ca.gov/msprog/truckstop/pdfs/sb1_faqeng.pdf
[101] Health and Safety Code 43146
https://california.public.law/codes/ca_health_and_safety_code_section_43156

Overall, although the REMI analysis above gives staff a general understanding of the expected impacts of the Proposed Regulation 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 empirical research that 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[102,103] that the estimates are highly uncertain, and that these responses may change markedly in the span of only several years due to the dynamics of industry, and modern global economics.

5. Summary and Agency Interpretation of the Assessment Results

The results of the macroeconomic analysis of the Proposed Regulation are summarized in Table E-8. As analyzed here, CARB estimates the Proposed Regulation is unlikely to have a significant impact on the California economy. From the perspective of the California economy, the change in the growth of jobs, state GSP, and output is projected to not exceed 0.02 percent of the baseline. The Proposed Regulation shows some decreases in growth in the Truck Transportation Industry, mostly due to increased passed-on production costs from vehicle and engine manufacturers. This analysis also shows a negative impact estimated for state and local government output. The Proposed Regulation results in increased growth in the Automotive Repair and Maintenance Industry in California, as well as less dramatic growth in the Motor Vehicle Manufacturing and Motor Vehicle Parts Manufacturing Industries.

[102] (Askin et al., 2015) "The Heavy-Duty Vehicle Future in the United States: A Parametric Analysis of Technology and Policy Tradeoffs," Amanda C. Askin et al., Energy Policy, Science Direct, 2015. https://www.sciencedirect.com/science/article/pii/S0301421515000683

[103] (Greene, 2001) "TAFV Alternative Fuels and Vehicles Choice Model Documentation," David L. Greene, Oak Ridge National Laboratory, July 2001.

Table E-8. Summary of Macroeconomic Impacts of the Proposed Regulation

	Year of Change	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
GSP	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	-39.296	-64.399	-56.056	-127.061	-160.358	-175.719	-246.72	-238.32	-243.573	-248.362
Personal Income	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	-37.81	-65.617	-61.428	-136.411	-179.918	-181.423	-261.86	-259.217	-268.159	-276.439
Employment	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change in Jobs	-452.25	-735.921	-618.034	-1406.28	-1751.54	-1566.65	-2286.43	-2138.1	-2145.73	-2149.8
Output	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	-0.067	-0.11	-0.095	-0.215	-0.272	-0.312	-0.434	-0.422	-0.432	-0.442
Private Investment	% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%
	Change (2018M$)	-10.219	-19.651	-18.962	-35.767	-46.451	-55.988	-73.352	-72.005	-68.129	-63.123

F. ALTERNATIVES

Pursuant to Senate Bill 617,[104] and HSC sections 11346.2, 11346.3, 11346.5, 11346.9, 11347.3, 11349.1, 13401, 13402, 13403, 13404, 13405, 13406, 13407, 11342.548, 11346.36, and 11349.1.5, CARB staff solicited alternatives for the Proposed Regulation during workgroups, public workshops, and individual meetings with industry. CARB staff encouraged public input on alternative approaches that may yield the same or greater benefits compared to staff's Proposed Regulation or may achieve the goals at a lower cost.

1. Alternative 1

Alternative 1 was proposed by the South Coast Air Quality Management District 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 Model Year Medium-Duty and Heavy-Duty Diesel Engines."[105] Under this alternative, the same Proposed Regulation elements would be implemented on an earlier timeline than the schedule outlined in staff's proposal.

The amendments to the NTE procedure of the HDIUT program would be shifted one year earlier to 2021 model year engines. This alternative would also 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 Regulation, from 2024 to 2022 model year engines. The amendments to the standards on the FTP, RMC-SET, and LLC to 0.02 g/bhp-hr 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 F-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.

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[104] Senate Bill 617, Calderon. State government: financial and administrative accountability. October 6, 2011. http://dof.ca.gov/Forecasting/Economics/Major_Regulations/SB_617_Rulemaking_Documents/documents/Section%202000%20ISOR%201%20sb_617_bill_20111006_chaptered.pdf

[105] (SCAQMD, 2019) Letter to CARB regarding "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 Model Year Medium-Duty and Heavy-Duty Diesel Engines," South Coast Air Quality Management District, May 24, 2019.

Table F-1. Summary and Timeline of Alternative 1

	Standards, Test Procedures, and Elements	Units	Baseline (B)	Model Year 2021	Model Year 2022	Model Year 2024	Model Year 2027
1)	FTP/RMC-SET	g/bhp-hr	0.2	Baseline	0.05	0.02	0.02
2)	LLC	g/bhp-hr	---	Baseline	0.05	0.02	0.02
3)	Idling	g/hr	30	Baseline	10	1	1
4)	HDIUT						
	Method		Current NTE	Mod NTE	MAW - Mod Euro VI-D	MAW - Mod Euro VI-E	MAW - Mod Euro VI-E
	In-Use Threshold	g NOx/bhp-hr	0.45	0.45	0.075	0.03	0.03
5)	DDP		(35-50)% × UL	Baseline	Baseline	100% UL aging	100% UL aging
6)	UL (HHD/MHD/LHD/Otto)	10^3×miles	435/185/110/110	Baseline	Baseline	Baseline	850/450/350/250
7)	Warranty (HHD/MHD/LHD/Otto)	10^3×miles	350/150/110/50	Baseline	Baseline	Baseline	800/360/280/200
8)	EWIR	---	EWIR	Mod EWIR	Mod EWIR	Mod EWIR	Mod EWIR

Note: Each row highlights the baseline and implementation conditions of each of the elements in the proposed amendments by year.

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.

a. Costs

The total costs of Alternative 1 were assessed using the same baseline conditions used for the Proposed Regulation. The annual costs for the elements of Alternative 1 are presented in Table F-2. Costs begin in 2022 at $28.34 million. The overall cost of Alternative 1 is approximately $1.237 billion over the 11 years of the analysis period, 2022 through 2032. Thus, the cost of this alternative is estimated at $126 million more than the Proposed Regulation, an 11 percent increase in cost in the period of analysis.

Table F-2. Annual Summary of Costs Associated with Alternative 1 (Millions 2018$)

Calendar Year	Standards, Certification, and New Technology	Annual DEF Consumption	In-Use Amendments	Lengthened Warranty	Lengthened Useful Life	Durability Demonstration	EWIR Amendments	ABT	NOx Data Reporting	Total Costs
2022	$1.99	$0.00	$0.10	$0.00	$0.00	$8.72	$17.52	$0.00	$0.00	$28.34
2023	$33.40	$0.92	$0.10	$0.00	$0.00	$0.00	$18.43	$0.00	$0.85	$53.70
2024	$33.38	$1.89	$0.10	$0.00	$0.00	$8.24	$18.73	$0.10	$0.14	$62.58
2025	$57.19	$2.82	$0.10	$0.00	$0.00	$0.00	$19.47	$0.02	$0.24	$79.84
2026	$57.51	$3.77	$0.10	$0.00	$0.00	$0.00	$19.57	$0.02	$0.95	$81.91
2027	$48.23	$4.72	$0.10	$75.73	$17.32	$0.00	$4.68	$0.02	$0.67	$151.49
2028	$46.91	$5.89	$0.10	$75.53	$17.32	$0.00	$4.69	$0.02	$1.41	$151.87
2029	$45.99	$7.05	$0.10	$76.20	$17.54	$0.00	$4.71	$0.02	$2.15	$153.76
2030	$44.75	$8.20	$0.10	$76.20	$17.61	$0.00	$4.72	$0.02	$2.90	$154.50
2031	$44.19	$9.35	$0.10	$77.23	$17.84	$0.00	$4.78	$0.02	$3.66	$157.18
2032	$44.27	$10.52	$0.10	$79.40	$18.34	$0.00	$4.92	$0.02	$4.44	$162.01
Total	$457.81	$55.13	$1.14	$460.29	$105.97	$16.96	$122.22	$0.25	$17.39	$1,237.18

b. Benefits

The benefits for Alternative 1 are presented in Table F-3. The accelerated implementation schedule would provide additional NOx benefits compared to the Proposed Regulation. The valuation of the health benefits resulting from Alternative 1 is presented in Table F-4. Table F-5 indicates the change in growth of economic indicators for Alternative 1 relative to the baseline, larger than both the Proposed Regulation and Alternative 2.

Table F-3. NOx Benefits with Alternative 1

Calendar Year	Statewide NOx Benefits (tons per day)
2022	0.4
2023	2.4
2024	5.2
2025	8.3
2026	11.8
2027	15.3
2028	18.6
2029	22.1
2030	25.2
2031	28.4
2032	31.5

Table F-4. Valuation of Statewide Health Benefits for Alternative 1

Outcome	Avoided Incidents	Valuation (Millions 2018$)
Avoided Premature Mortality	496	$4,675.95
Avoided Cardiovascular Hospitalizations	70	$3.98
Avoided Acute Respiratory Hospitalizations	84	$4.14
Avoided Emergency Room Visits	238	$0.19
Total	**889**	**$4,684.26**

Table F-5: Change in Growth of Economic Indicators for Alternative 1 Relative to Baseline

		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GSP	% Change	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%
	Change (2018M$)	-177.375	-314.595	-397.743	-494.761	-530.243	-634.833	-645.328	-661.242	-665.944	-673.814	-629.677
Income	% Change	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%
	Change (2018M$)	-152.53	-282.49	-370.9	-470.12	-514.43	-623.57	-645.01	-664.43	-670.34	-677.96	-625.21
Employment	% Change	-0.01%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%
	Change (2018M$)	-1717.68	-2936.78	-3619.76	-4382.63	-4557.96	-5497.9	-5427.48	-5418.65	-5312.03	-5239.33	-4664.37
Output	% Change	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.03%	-0.03%	-0.03%	-0.02%	-0.02%	-0.02%
	Change (2018M$)	-324.05	-577.36	-726.33	-903.52	-962.92	-1127.3	-1143.88	-1169.61	-1176.85	-1190.62	-1122.28
Private Investment	% Change	-0.02%	-0.03%	-0.04%	-0.05%	-0.05%	-0.06%	-0.05%	-0.05%	-0.05%	-0.04%	-0.04%
	Change (2018M$)	-57.42	-114.6	-150.83	-182.65	-190.95	-216.23	-214.13	-204.93	-191.02	-178.08	-152.48

c. Economic Impacts

Alternative 1 would impose the same standards as the Proposed Regulation but on an accelerated schedule compared to the Proposed Regulation. The accelerated schedule of producing low NOx engines, early compared to the Proposed Regulation, would increase the total number of low NOx engines to be sold in the 2022 through 2032 time period. This would result in an overall increase of 11.4 percent in cost over the time period of analysis compared to the Proposed Regulation. The cost would be increased in Alternative 1 primarily due to the accelerated timeframe compared to the Proposed Regulation. Table F-5 shows the impact on select macroeconomic indicators in the economy. The analysis of Alternative 1 shows that the major macroeconomic indicators would decrease from 2022 to 2032. The major macroeconomic indicators show a greater decrease by Alternative 1 compared with Alternative 2's results during the period of analysis. However, the Private Investment indicator stays in a similar range between both Alternatives. Overall, Alternative 1 would have greater impacts to the Californian economy than the impacts of Alternative 2 and the Proposed Regulation.

d. Cost-Effectiveness

Cost-effectiveness is defined as the cost to achieve a ton of emission reductions. In the case of Alternative 1, the total cost from 2022 through 2032 would be greater than the Proposed Regulation and would achieve greater emission reductions. Alternative 1 is expected to achieve 44,155 tons of NOx reductions over the 11 years from 2022 through 2032 at a cost of $1.237 billion. The Proposed Regulation is expected to achieve 28,617 tons of NOx reductions over the 11 years from 2022 through 2032 at the cost of $1.110 billion. Alternative 1 would be 28 percent more cost-effective compared to the Proposed Regulation. However, as described further below, because staff does not believe Alternative 1 is technically feasible, staff rejected it.

e. Reason for Rejecting

Although Alternative 1 would achieve greater NOx reductions sooner, the accelerated program 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 Regulation provides manufacturers with necessary lead time for engineering development for the changes required in 2024[106] 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.

[106] (CARB, 2019b) 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 Model Year Medium-Duty and Heavy-Duty Diesel Engines," California Air Resources Board, April 18, 2019.

2. Alternative 2

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 Regulation. Alternative 2 would be less stringent and achieve less emission reductions than the Proposed Regulation 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.[107] 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 model year engines. EMA's proposal also stated an approximate 50 percent reduction in the real-world in-use NOx standard for 2027 and subsequent model years. Staff interpreted this statement to reduce the standards on the FTP, RMC-SET, and in-use HDIUT threshold by half of the current emission rates for 2027 and subsequent model year engines. A summary of Alternative 2 is presented in Table F-6.

[107] (EMA, 2019) Letter to CARB regarding "A Representative Nationwide Alternative to CARB's Proposed Omnibus Low-NOx Rulemaking," Truck and Engine Manufacturers Association, July 11, 2019.

Table F-6. Summary and Timeline of Alternative 2, EMA Alternative

	Standards, Test Procedures, and Elements	Units	Baseline (B)	Model Year 2024	Model Year 2027
1)	FTP/RMC-SET	g/bhp-hr	0.2	0.15	0.1
2)	LLC	g/bhp-hr	---	0.7	0.7
3)	Idling	g/hr	30	Baseline	Baseline
4)	HDIUT				
	Method		Current NTE	EMA modified NTE	EMA modified NTE
	In-Use Threshold	g NOx/bhp-hr	0.45	0.22	0.22
5)	DDP		(35-50)% × UL	Baseline	Baseline
6)	UL (HHD/MHD/LHD/Otto)	10^3×miles	435/185/110/110	Baseline	Baseline
7)	Warranty (HHD/MHD/LHD/Otto)	10^3×miles	350/150/110/50	Baseline	Baseline
8)	EWIR	---	EWIR	Baseline	Baseline

Note: Each row highlights the baseline and implementation conditions of each of the elements in the proposed amendments by year.

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.

a. Costs

The total costs of Alternative 2 were assessed using the same baseline conditions used for the Proposed Regulation and Alternative 1. The yearly costs for the elements of Alternative 2 are presented in Table F-7. Staff estimates recalibration alone will be sufficient to meet Alternative 2 emission standards. The incremental costs for 2024 to 2026 model year engines only consider research and development costs for recalibration and no hardware changes. The incremental technology cost to meet the 2027 and subsequent model year engine standards for Alternative 2 assumes the same technology, research and development costs estimated in the Proposed Regulation for 2024 to 2026 model year engines. The cost of DEF fluid uses the same cost data and assumptions utilized in the analyses for Alternative 1 and the Proposed Regulation. Alternative 2 does not make changes to the current in-use HDIUT program, warranty duration, useful life duration, durability demonstration program, EWIR, ABT program, or require NOx data reporting, and the presented costs in Table F-7 reflect this. The overall cost of Alternative 2 is approximately $182 million over the 11 years of the regulation, 2022 through 2032. The Proposed Regulation is expected to have 28,617 tons of NOx reductions over the 11 years from 2022 through 2032 at the cost of $1.110 billion. Alternative 2 is estimated to be $927 million less than the Proposed Regulation, an 84 percent decrease in cost during the period of analysis.

Table F-7. Summary of Costs Associated with Alternative 2 (Millions 2018$)

Calendar Year	Standards, Certification, and New Technology	Annual DEF Consumption	Total Costs
2022	$0.00	$0.00	$0.00
2023	$0.00	$0.00	$0.00
2024	$0.40	$0.00	$0.40
2025	$4.59	$0.31	$4.91
2026	$4.62	$0.63	$5.25
2027	$6.18	$0.95	$7.13
2028	$32.84	$1.60	$34.43
2029	$28.60	$2.24	$30.83
2030	$29.66	$2.88	$32.54
2031	$29.51	$3.52	$33.04
2032	$29.79	$4.17	$33.96
Total	**$166.19**	**$16.30**	**$182.49**

b. Benefits

The benefits for Alternative 2 are presented in Table F-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. The statewide health benefits of Alternative 2 are presented in Table F-9. Table F-10 indicates the change in growth of economic indicators for Alternative 2 relative to the baseline.

Table F-8. NOx Benefits with Alternative 2

Calendar Year	Statewide NOx Benefits (tons per day)
2022	0.00
2023	0.00
2024	0.2
2025	1.2
2026	2.8
2027	4.7
2028	7.5
2029	10.9
2030	14.3
2031	17.8
2032	21.3

Table F-9. Valuation of Statewide Health Benefits for Alternative 2[108]

Outcome	Avoided Incidents	Valuation (Million 2018$)
Avoided Premature Mortality	254	$2,395.10
Avoided Cardiovascular Hospitalizations	37	$2.07
Avoided Acute Respiratory Hospitalizations	44	$2.15
Avoided Emergency Room Visits	122	$0.10
Total	**456**	**$2,399.42**

[108] Note that the table assumes Alternative 2 could be fully enforced, which as discussed below, because it involves engines certified and sold outside California, is doubtful.

Table F-10: Change in Growth of Economic Indicators for Alternative 2 Relative to Baseline

		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GSP	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0.46	0.44	-1.03	-17	-59.82	-155	-347.92	-360.59	-381.39	-398.2	-406.03
Income	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0.44	0.47	-0.69	-14.13	-52.14	-146.26	-333.52	-375.06	-415.58	-451.19	-475.26
Employment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0	0	-0.01	-0.15	-0.52	-1.5	-3.14	-3.17	-3.27	-3.33	-3.32
Output	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0.72	0.68	-2.14	-32.82	-113.39	-264.71	-634.52	-645.2	-679.84	-706.41	-720.26
Private Investment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%
	Change (2018M$)	0.08	0.09	-0.37	-5.43	-19.34	-53.51	-119.06	-135.05	-137.81	-132.99	-124.69

c. Economic Impacts

Alternative 2 would implement less stringent requirements in 2024 and 2027 compared to the Proposed Regulation. The total cost of Alternative 2 ($182 million) would be 84 percent less than the Proposed Regulation ($1,110 million) over the years between 2022 and 2032. Table F-10 shows the impact on select macroeconomic indicators in the economy. The analysis of Alternative 2 shows that the major macroeconomic indicators would increase until the year of 2024. By 2032, the major macroeconomic indicators show less of a decrease by Alternative 2 compared with Alternative 1's results. However, the Private Investment indicator shows similar results between both Alternatives. Overall, Alternative 1 would have greater impacts to the Californian economy than the impacts of Alternative 2.

d. Cost-Effectiveness

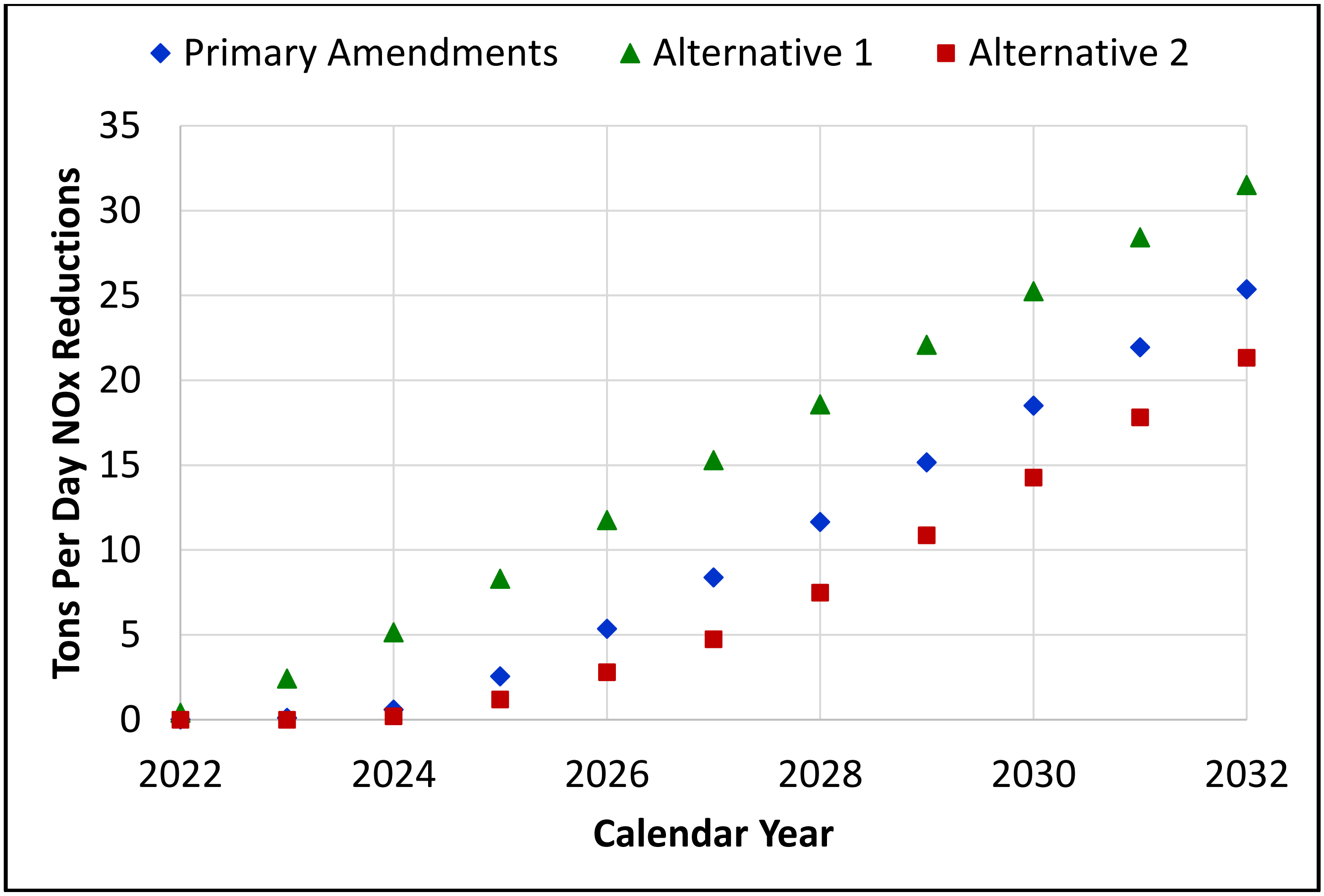
Cost-effectiveness is defined as the cost to achieve a ton of emission reductions. In the case of Alternative 2, the total cost from 2022 through 2032 is less than the cost of the Proposed Regulation and would achieve fewer NOx reductions. Alternative 2 is expected to achieve 21,056 tons of NOx reductions over the 11 years from 2022 through 2032 at the cost of $182 million. The Proposed Regulation is expected to achieve 28,617 tons of NOx reductions over the same time period at a cost of $1.073 billion. Alternative 2 is a more cost-effective alternative compared to the Proposed Regulation, but for the reasons discussed below, it was rejected.

e. Reason for Rejecting

Although Alternative 2 would be more cost-effective than the Proposed Regulation, it was rejected for not achieving the NOx emission reductions needed to achieve California's air quality goals. Alternative 2 provides less health benefits for Californians, and EMA's proposal to include reductions from a voluntary national standard for out-of-state trucks operating in California could not be enforced by California.

Comparing the yearly tons per day NOx reductions, the Proposed Regulation would achieve greater reductions every year between 2022 through 2032, as shown in Figure F-1. Overall, the Proposed Regulation is expected to reduce 7,561 more tons of NOx than Alternative 2. With regard to health benefits, even if EMA's proposal could be fully enforced (which is doubtful), Alternative 2 is predicted to save 24 percent fewer lives compared to the Proposed Regulation, 254 premature deaths avoided compared to the 334 deaths avoided, respectively.

Figure F-1. NOx Reductions for the Proposed Regulation and the Alternatives (tons per day)



California does not have the authority over engines sold outside of California. To ensure engines outside of California meet the proposed Alternative 2 standards, the engine manufacturers would need to develop a legally binding agreement. The enforceability of such an agreement is unclear. It is also unclear if U.S. EPA could enforce a voluntary national program agreement without a new rulemaking.

Thus, for all the reasons described above, Alternative 2 was rejected.

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66. (U.S. EPA, 2016) "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2," Regulatory Impact Analysis, United States Environmental Protection Agency, EPA-420-R-16-900, August 2016. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF

H. HEALTH MODELING METHODOLOGY APPENDIX

To estimate the change in health outcomes from changes in emissions due to the proposed amendments, CARB uses the incidents-per-ton (IPT) methodology.[109,110] This methodology quantifies the health benefits of primary and secondary PM2.5 reductions due to regulatory controls. Primary PM2.5 is emitted directly from the source, for example, the black particles in diesel exhaust. Secondary PM2.5 is formed in the atmosphere as a result of chemical reactions. NOx emissions are converted by atmospheric processes to secondary ammonium nitrate PM2.5. Therefore, NOx emission reductions from the proposed amendments will result in a reduction in PM2.5 exposure.

This methodology is similar to the methodology developed by the U.S. EPA for health benefit estimations,[111] but uses California air basin specific relationships between emissions and air quality. The basis of the IPT methodology is the approximately linear relationship which holds between changes in emissions and estimated changes in health outcomes. Therefore, health outcomes are approximately proportional to emissions, and changes in health outcomes from the proposed amendments can be estimated by multiplying changes in emissions by a reference incidence factor, known as the IPT factor.

IPT factors were derived for a reference scenario by identifying the health incidence associated with a PM2.5 source in an air basin, and dividing by the emissions of that PM2.5 source, as in the following equation. This reference scenario is based on 2014 through 2016 average data used in IPT factor development, and is not the same as the regulatory baseline. Separate IPT factors were developed for each health endpoint, air basin, and for primary PM2.5 and NOx emissions.

$$IPT\ Factor = \frac{Reference\ Incidence\ (\#\ cases)}{Reference\ Emissions\ (tons)}$$

A change in health outcomes from the proposed amendments can then be calculated by multiplying the emission change in a given year by the IPT Factor. Since the total incidence of health outcomes is also proportional to population, the change in health outcomes are additionally scaled by the ratio of the population in a given year to the

[109] (CARB, 2019d) CARB's Methodology for Estimating the Health Effects of Air Pollution, California Air Resources Board, accessed September 2019. https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution

[110] (CARB, 2010b) "Appendix J: Health Impacts and Benefits and Methodology," to Staff Report: Initial Statement of Reasons, Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles, California Air Resources Board, November 9, 2010, accessed September 2019. https://ww3.arb.ca.gov/regact/2010/truckbus10/truckbus10.htm and https://www.arb.ca.gov/regact/2010/truckbus10/correctedappj.pdf

[111] (Fann et al., 2012) "Characterizing the PM2.5-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S.," Neal Fann, Kirk R. Baker & Charles M. Fulcher, Environment International, Volume 49, November 15, 2012, pages 141-151, ISSN 0160-4120. http://dx.doi.org/10.1016/j.envint.2012.08.017

population in the reference year, which is the 2014 through 2016 average. The equation used to estimate health outcomes is:

$$Health\ Outcome_Y = [Emission\ Change_Y(tons)] * \left[IPT\ Factor\ (\frac{incidents}{ton})\right] * \left[\frac{Population_Y}{Population_R}\right]$$

where, Y is a given year for which the proposed amendments lead to a change in PM2.5 emissions, and R is the reference case. The change in health outcomes is calculated for each health endpoint, air basin, year, and for both primary PM2.5 and NOx emissions. A further description of the methodology, assumptions, and uncertainty follows.

IPT Factors

A detailed description of the methodology used to calculate premature mortality from PM2.5 has been published, and is similar to that used to determine IPT factors.[112] IPT factors for other health endpoints are calculated using similar methodology. Calculating IPT factors requires reference incidence rates, population data, ambient concentrations of PM2.5, and a concentration-response function (CRF) relating changes in PM2.5 exposure to changes in health incidence.[113] The underlying analysis was performed at the census tract level, then aggregated to air basin and statewide results.

Reference incidence rates are the number of cases of death or illness in the exposed population. Incidence rates vary according to age; for instance, an older person is more likely to die or be hospitalized because of heart disease or stroke than a child or young adult. Age-specific incidence rates were taken from the Centers for Disease Control and Prevention Wonder database.[114] The CARB methodology divides the population into five-year age brackets up to ages 80-84, and an 85+ age bracket. Thus, this analysis reflects differences in vulnerability between different age groups.

Population exposure to PM2.5 was estimated from monitored or modeled concentrations of PM2.5. Consistent with U.S. EPA practice, CARB uses the software program BenMap, which uses input exposure data and CRF to calculate estimated mortality.

Following recent U.S. EPA practice, CRFs for death from heart disease and stroke are taken from a study by Krewski et al.,[115] for hospital admissions for heart and lung disease

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[112] (CARB, 2010a) "Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency Methodology," California Air Resources Board, August 31, 2010. https://ww3.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf

[113] (CARB, 2010a) "Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency Methodology," California Air Resources Board, August 31, 2010. https://ww3.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf

[114] (CDC, 2019) Wonder Database, Centers for Disease Control and Prevention, accessed September 2019. https://wonder.cdc.gov

[115] (Krewski et al., 2009) Research Report: Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality, Daniel Krewski et al., Health Effects Institute, Number 140, May 2009. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf

from a study by Bell et al.,[116] and for asthma emergency room visits from a study by Ito et al.[117] Change in cardiopulmonary mortality were not quantified when the concentrations were below 5.8 µg/m^3, because the Krewski et al. study did not examine impacts below that concentration.

The IPT factors were originally developed for use with on-road diesel PM emissions, but are also applied to PM from portable diesel equipment. This assumes that the emission patterns for PM from portable diesel equipment are similar to those for PM from on-road diesel vehicles. That is, a ton of PM2.5 emitted from portable equipment is expected to result in the same PM2.5 exposure and health effects as a ton of PM2.5 emitted from on-road diesel vehicles.

Population Scaling

Population was estimated by taking 2010 Census data for total population by age bracket and projecting to 2026 using total county population projections from the California Department of Finance (DOF). This accounts for overall population growth in a county but does not reflect shifts in the spatial distribution of the population such as new housing developments built on previously undeveloped land.

Uncertainty

This health benefit analysis relies on multiple data sources and assumptions that contain significant inherent uncertainty. The reference case used to develop IPT factors reconstructs ambient concentrations of both primary PM2.5 and secondary ammonium nitrate formed in the atmosphere from NOx emissions to estimate population exposure. These datasets were constructed from California's ambient monitoring networks, which have limited spatial and temporal coverage. Atmospheric concentrations of PM vary dramatically both spatially and temporally depending on the emission behavior of local sources, the local meteorological conditions, and topographical features. Extrapolating atmospheric concentrations between air quality monitors adds uncertainty to the underlying methodology.

CRFs are also used to develop IPT factors, and are based on the best available scientific literature, but are difficult to measure and contain inherent uncertainty. These CRFs do not have sufficient detail to account for all sensitive populations, specifically populations with low socioeconomic status.

Another important source of uncertainty are projected emission inventories under the baseline and proposed amendments. Projecting emission inventories relies on CARB expert judgment of likely future equipment technology changes and business behavior both in the absence of (i.e., baseline) and presence of the proposed amendments. CARB

[116] (Bell et al., 2008) Seasonal and Regional Short-term Effects of Fine Particles on Hospital Admissions in 202 US Counties, 1999–2005, Michelle L. Bell et al., Am J Epidemiol, 2008, Dec 1; 168(11): 1301–1310. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2732959/

[117] (Ito et al., 2007) Characterization of PM2.5, gaseous pollutants, and meteorological interactions in the context of time-series health effects models, Kazuhiko Ito et al., J Expo Sci Environ Epidemiol, Vol. 17 Suppl 2: S45-60. http://www.nature.com/jes/journal/v17/n2s/full/7500627a.html

worked closely with stakeholders to identify the likely response from business both with and without the proposed amendments. Still, unforeseen events could occur that dramatically change future emissions. In addition, the spatial distribution of future emission reductions as a result of the proposed amendments contributes high uncertainty. Health outcomes at the air basin level are presented in this analysis, but represent higher uncertainty than the statewide analysis. It is not possible to accurately constrain the error in projected emission inventories due to lack of information about future conditions.

Some of the uncertainty described above is accounted for in the health outcome calculation, as represented by the 95 percent confidence intervals. Importantly, error associated with projected emission inventories is not included in these confidence intervals. The error associated with the projected emission inventories could contribute significant additional error.

A full explanation of the methodology is available at:

Estimating Health Benefits Associated with Reductions in PM and NOx Emissions: Detailed Description

(https://ww2.arb.ca.gov/sites/default/files/2019-08/Estimating%20the%20Health%20Benefits%20Associated%20with%20Reductions%20in%20PM%20and%20NOX%20Emissions%20-%20Detailed%20Description.pdf)

I. MACROECONOMIC APPENDIX

Table I-1 REMI Inputs for the Proposed Regulation (Million 2016$)

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Production Costs	Truck Transportation	18.75	30.91	22.34	57,44	68.13	19.1	36.69	67.45	56.8	55.4	54.83
Exogenous Final Demand	Automotive Repair and Maintenance	-	-	-	-	-	99.59	99.38	100.322	100.3	101.74	101.6
Exogenous Final Demand	Motor Vehicle Parts Manufacturing	14.06	14.79	15.03	15.62	15.7	3.75	3.76	3.78	3.78	3.78	3.8
Exogenous Final Demand	Chemical Manufacturing	-	-	0.001	1.0	2.017	3.04	4.28	5.52	6.76	7.99	9.24
Exogenous Final Demand	Measuring and Controlling Devices Manufacturing	-	0.841	0.135	0.235	0.943	0.66	1.39	2.12	2.86	3.61	4.39
Consumer Spending	Hospitals	-	-	-	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Government Spending	State	(2.03)	(1.47)	(3.84)	(4.61)	(8.75)	(10.83)	(10.27)	(10.25)	(9.92)	(10.65)	(71.70)
Government Spending	Local	(0.24)	(0.17)	(0.45)	(0.54)	(1.03)	(1.27)	(1.21)	(1.21)	(1.22)	(1.25)	(8.44)
Government Employment (jobs)	State	2.0	2.0	2.0	2.0	2.0	2.0	8.0	8.0	8.0	8.0	8.0

Table I-2 REMI Inputs for the Alternative 1 (Million 2016$)

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Production Costs	Truck Transportation	16.71	41.99	50.96	68.21	68.66	60.43	58.92	58.09	56.83	56.41	57.12
Exogenous Final Demand	Automotive Repair and Maintenance	0.00	0.00	0.00	0.00	0.00	94.07	93.77	94.59	94.55	95.83	98.53
Exogenous Final Demand	Motor Vehicle Parts Manufacturing	15.40	18.40	18.58	20.61	20.95	26.04	25.75	26.19	26.41	26.93	28.80
Exogenous Final Demand	Chemical Manufacturing	0.00	0.93	1.90	2.84	3.80	4.77	5.94	7.11	8.28	9.44	10.62
Exogenous Final Demand	Measuring and Controlling Devices Manufacturing	0.00	0.91	0.15	0.26	1.02	0.72	1.50	2.30	3.10	3.91	4.75
Exogenous Final Demand	Basic Chemical Manufacturing	-	-	0.1	0.1	0.2	0.4	0.5	0.6	0.8	0.9	1.1
Exogenous Final Demand	Hospitals	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Exogenous Final Demand	State	2.06	1.49	3.99	4.46	8.67	10.68	10.15	9.99	10.00	10.00	2.06
Exogenous Final Demand	Local	0.26	0.19	0.46	0.56	1.29	1.25	1.23	1.18	1.25	1.25	0.26
Industry Sales	State	2.0	2.0	2.0	2.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

Table I-3 REMI Inputs for the Alternative 2 (Million 2016$)

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Production Costs	Truck Transportation	0.00	0.00	0.43	4.92	15.63	15.61	69.21	58.69	59.18	58.69	59.36
Exogenous Final Demand	Automotive Repair and Maintenance	0.00	0.00	0.00	0.00	0.00	93.21	92.92	93.73	93.70	94.96	97.63
Exogenous Final Demand	Motor Vehicle Parts Manufacturing	0.00	0.00	0.00	0.00	0.00	26.04	25.75	26.19	26.41	26.93	28.80
Exogenous Final Demand	Chemical Manufacturing	0.00	0.00	0.00	0.31	0.63	0.96	2.14	3.30	4.47	5.64	6.81
Exogenous Final Demand	Measuring and Controlling Devices Manufacturing	0.00	0.00	0.00	0.00	0.91	0.15	0.26	1.02	0.72	1.50	2.30
Exogenous Final Demand	Basic Chemical Manufacturing	-	-	3.6	8.2	13.4	18.8	24.6	30.6	36.7	43.4	49.8
Consumer Spending	Hospitals	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Government Spending	State	(1.43)	(1.34)	(2.58)	(4.28)	(8.14)	(10.34)	(1.43)	(1.34)	(2.58)	(4.28)	(8.14)
Government Spending	Local	(0.14)	(0.13)	(0.24)	(0.23)	(0.71)	(1.14)	(0.14)	(0.13)	(0.24)	(0.23)	(0.71)
Government Employment (jobs)	State	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0