Staff Report

California Air Resources Board Staff Report on the Warranty Cost Study for 2022 and Subsequent Model Year Heavy-Duty Diesel Engines

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December 2021

State of California
California Air Resources Board

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This report represents CARB staff's findings related to each goal of the study. Although members of the work group reviewed and commented on the contents of this report, ultimately this report represents CARB staff's findings, and not necessarily a group consensus.

List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ACT Research	Americas Commercial Transportation Research Co., LLC
ATA	American Trucking Associations
CARB or Board	California Air Resources Board
CBI	Confidential Business Information
CDA	Cylinder Deactivation
CE-CERT	The Bourns College of Engineering, Center for Environmental Research & Technology
CI	Confidence Intervals
CSUS	California State University, Sacramento
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
ECU	Engine Control Unit
EGR	Exhaust Gas Recirculation
EMA	Truck and Engine Manufacturers Association
EMFAC	CARB's EMission FACtor model
ERCs	Emission-Related Components
ERG	Eastern Research Group, Inc
EWIR	Emissions Warranty Information and Reporting
FET	Federal Excise Tax
FIR	Field Information Report
FTP	Federal Test Procedure
g/bhp-hr	Grams per Brake Horsepower-Hour
g/hr	Grams per Hour
GVWR	Gross Vehicle Weight Rating
HD I/M	Heavy-Duty Vehicle Inspection and Maintenance
HD OBD	Heavy-Duty On-Board Diagnostics
HDO	Heavy-Duty Otto-Cycle
HHDD	Heavy Heavy-Duty Diesel Engines >33,000 lbs. GVWR
HHDV	Heavy Heavy-Duty Vehicles >33,000 lbs. GVWR
hr	Hours
ISOR	Initial Statement of Reasons
ISR	Sacramento Institute for Social Research
lbs.	Pounds

Acronym/Abbreviation	Definition
L	Liter
LHDD	Light Heavy Duty Diesel
LLC	Low load cycle
MECA	Manufacturers of Emission Controls Association
MEMA	Motor & Equipment Manufacturers Association
MHDD	Medium Heavy Duty Diesel
MSCD	Mobile Source Control Division
mi	Miles
MIL	Malfunction Indicator Light
MY	Model Year
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
PM	Partuculate Matter
R&D	Research and Development
RMC	Ramped Modal Cycle
SCR	Selective Catalytic Reduction
SwRI	Southwest Research Insitute
TRUCRS	CARB's Truck and Bus Regulation Reporting
U.S. EPA	United States Environmental Protection Agency
US10 ERCs	ERCs meeting the current federal requirements
UL	Useful Life
yr	Years

Executive Summary

The Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments (Omnibus Regulation), approved for adoption by the California Air Resources Board (CARB or the Board) on August 27, 2020, will dramatically reduce oxides of nitrogen (NOx) emissions by comprehensively overhauling exhaust emission standards, test procedures and other emissions-related requirements for 2024 and subsequent model year (MY) California-certified heavy-duty engines. The Omnibus Regulation includes updates to the warranty requirements because the current emission warranty periods are too short compared to the long life a typical heavy-duty vehicle is driven. For example, the largest heavy-duty trucks, heavy heavy-duty vehicles (HHDV), often stay on the road for nearly 1 million miles but are currently required to be covered under warranty for only 100,000 miles/5 years/3,000 hours, and 350,000 miles/5 years starting with MY 2022.

The new Omnibus warranty requirements, for example 600,000 miles/10 years/30,000 hours for HHDV starting with MY 2031, are critical because heavy-duty vehicles are enormous contributors to mobile source air pollution. They are likely to expose communities that are near roadways, close to ports, or adjacent to warehouse distribution centers to excessive pollution if they are not emission compliant and not durable for the actual useful lives.

Information from the original equipment manufacturers (OEMs) and a survey contracted by CARB and conducted by California State University, Sacramento, confirmed that most owners purchase extended warranties already, and the warranty costs will now be shifted fairly to the OEMs. Warranty is intended to help ensure defects in materials and workmanship get fixed but is not meant to protect OEMs from having to design durable components.

During the Omnibus Regulation rulemaking process, industry stakeholders raised concerns regarding the potential cost impact of warranty requirements. In response, the Board directed CARB staff to engage with affected stakeholders to conduct a warranty cost study. The Board's purpose for conducting this study was to better understand the differences between CARB staff's estimates of warranty costs and those estimates provided by industry stakeholders. The key findings of this study are summarized below:

- **CARB's method for determining the effect of the rulemaking on all owners is appropriate for considering the statewide impact**. Although the warranty cost estimates for MY 2022 made by CARB and those presented by the Truck and Engine Manufacturers Association (EMA) differ by a factor of nine, the warranty costs "per miles covered" reasonably agree. The average incremental miles covered under warranty in CARB's estimate is small because CARB's method accounts for the fact that most vehicle owners already purchase extended warranties voluntarily. They would not be affected by the rulemaking as much as those who have minimum regulatory warranties only. On the other hand, manufacturers' estimates only consider individual customers who do not already have extended warranty.

- **CARB staff believes it is simply part of the fundamental engineering cost to design durable components and does not believe that this cost should be attributed to warranty.** The warranty is intended to cover defects in materials and workmanship which cause the failure of a warranted part to be identical in all material respects to that part as described in the vehicle or engine manufacturer's application for certification. Therefore, warranty is not intended to cover failure of parts that are not designed properly. When the lower NOx standards take effect and longer useful life and warranty requirements are phased-in for MY 2027 and 2031, EMA's warranty cost methodology projects additional repair costs due to the lower NOx standards, higher unit prices for parts due to longer useful life, and the introduction of premature new technologies with elevated failure rates. CARB staff objected to these assumptions. Although there will be some new technologies introduced to meet MY 2027/2031 requirements, such as cylinder deactivation or light-off selective catalytic reduction, nearly all emission-related components expected for meeting the Omnibus standards will be the same as the technologies used today.

- **CARB staff concluded that even if the higher warranty costs for new technologies were included, it would not have changed the staff proposal.** CARB staff's additional sensitivity analysis suggested that if the warranty costs for new technology were included, it would increase the estimate of Omnibus Regulation costs by about 11 percent. The hypothetical increase was well within the bounds of the previous CARB Staff Report sensitivity analysis. This additional sensitivity analysis was conducted in response to EMA's comments during the working group, and evaluated the potential impact of new technologies on the warranty cost.

- **Results from CARB staff's fleet owner operator survey suggest that higher initial vehicle purchase prices are likely to be passed on to the subsequent vehicle owners, which potentially reduces the cost impact that the Omnibus Regulation warranty amendments may have on first owners.** A survey of fleet owner operators and dealers was conducted to better understand the value of remaining warranties to the purchasers of used vehicles. The survey results indicate that the remaining residual warranties do in fact add value to vehicles sold in the secondary market, averaging approximately $2,000 for a 2 years/200,000 miles period of residual warranties, and $4,000 for a 4 years/400,000 miles residual period.[1]

In conclusion, the Omnibus Regulation requirements continue to be cost-effective with benefits estimated to outweigh its costs by a factor of 10 (i.e., monetized benefits of $23.4 billion vs. costs of $2.39 billion). Although CARB staff does not concur with EMA's

[1] The values of individual residual warranties should not be confused with the average incremental cost of the regulation. For example, even if the required warranty period is increased by 200,000 miles, the average incremental cost can be much less than $2,000 since many owners already buy extended warranties voluntarily.

analysis methods, CARB staff agrees that the different viewpoints led to different baseline assumptions that ultimately affected the respective warranty costing methodologies. CARB's method included in the baseline optional longer warranties purchased in order to assess the impact of the rulemaking on the entire vehicle population. However, it is understandable that individual manufacturers would consider the first point they encounter their customers, rather than the average vehicle population. Since warranty is intended to cover defects, not inadequate design, CARB's estimate did not assume higher warranty costs (per miles covered) for MY 2027/2031 and instead accounted for the engineering cost as part of new standards, certification, and new technology. The work group members agreed that future warranty cost estimates should clearly list and clarify key assumptions on the definition of what should constitute warranty cost (e.g., distinction between useful life cost vs. warranty cost) and how the incremental coverage is calculated (e.g., how years/hours/miles limits are treated) because these are major sources of the apparent differences in estimates. Also, more data on residual warranty value would be useful in any future rulemaking that lengthens warranty requirements. Based on what has been learned from this study, overall, CARB staff believes that its methodology provides reasonable and defensible estimates of the average compliance cost that affected parties will face under the Omnibus Regulation.

I. Overview

The California Air Resources Board (CARB or the Board) approved for adoption the Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments (Omnibus Regulation) at the public hearing on August 27, 2020. At that meeting, the Board further directed CARB staff to engage with affected stakeholders to conduct a warranty cost study. The Board's purpose for conducting this study was to better understand the differences between CARB staff's estimates of warranty cost and those estimates provided by industry stakeholders (reference Appendix A for the Board transcript).

Accordingly, CARB staff convened an industry stakeholder work group to analyze and study the various differences in the cost estimate methodologies used for estimating warranty costs. Industry stakeholders who participated in this study include the American Trucking Association (ATA), Cummins (the largest heavy-duty diesel engine manufacturer), the Manufacturers of Emission Controls Association (MECA), the Motor & Equipment Manufacturers Association (MEMA), and the Truck and Engine Manufacturers Association (EMA). The work group met a total of 16 times over a period of nine months. Additionally, CARB staff met individually with manufacturers (i.e., Cummins, Daimler, Paccar, and Volvo) to better understand industry's approach to warranty cost estimation practices, and any potential impacts arising from CARB's warranty requirement changes that will take effect with model year (MY) 2022.[2]

The work group established six specific goals for this study, as summarized below. In analyzing these goals, CARB staff worked collaboratively with the work group. This report represents CARB staff's findings related to each goal. Although members of the work group reviewed and commented on the contents of this report, ultimately this report represents CARB staff's findings and is not necessarily a group consensus.

Goal #1: Work collaboratively to better understand all of the assumptions made and all of the differences in the various warranty cost analysis methods

To address this goal, the work group improved the understanding of why there were large discrepancies between CARB and other's warranty cost estimates. The discrepancies stemmed from the philosophical differences in what should be the baseline and what warranty should cover. CARB's method considered all vehicle owners including those who would be affected less by the rulemaking because they were already buying longer than the

[2] In 2018, CARB approved for adoption longer emission warranty requirements for heavy-duty diesel engines that take effect with MY 2022. These amendments are known as the Step 1 warranty amendments. The Omnibus Regulation includes further lengthening of the emission warranty requirements beginning with MY 2027 that are known as the Step 2 warranty amendments.

minimum warranty. Also CARB staff assumed that the more rigorous heavy-duty engine durability demonstration program of the Omnibus Regulation would help ensure that parts are designed to be more durable. Therefore, warranty was assumed to only cover defects, as intended, rather than covering failures of parts that were not designed properly to meet lower emission standards and useful life requirements. CARB's method shifted the future repair cost to where it was intended, i.e., with Original Equipment Manufacturers (OEMs) designing emission durable components. On the other hand, EMA's analysis method focused on those who did not already have extended warranty (and who thus would be affected more by the rulemaking) and assumed higher repair costs as lower oxides of nitrogen (NOx) emission standards and useful life requirements would be phased in. When the analysis was limited to Step 1 warranty (no change in technology) and the effects of voluntary extended warranties were removed by estimating the warranty costs "per miles covered," CARB and OEM's MY 2022 warranty costs reasonably agreed as discussed below. Consequently, CARB staff concluded that its method was reasonable.

The work group discussed both Step 1 and Step 2 warranty amendments. This report focuses on evaluating per-engine costs for Heavy Heavy-Duty Diesel (HHDD) engines over 33,000 pounds (lbs.) gross vehicle weight rating (GVWR) unless otherwise noted.

Step 1 Warranty (MY 2022):

In 2018, CARB staff estimated the incremental warranty cost as the summation of the increase in emission-related repair costs and finance costs. Additionally, CARB staff estimated the rate at which parts would fail under Step 1 warranty using the then-most recent five years of the unscreened warranty claim data as reported to CARB by manufacturers in the Emission Warranty Information Reporting (EWIR) program. The baseline repair cost was estimated by multiplying the estimated failure rate and part price for each component. Other variables included projected and baseline miles covered, costs associated with linking the warranty to the on-board diagnostic system i.e., malfunction indicator light (MIL) costs, and financing costs. The procedure is summarized in equation I.1 as follows (see section IV.A.2 for more details):

$$[\Delta\, warranty\ cost] = [Baseline\ repair\ cost] \times \frac{[Projected\ miles\ covered] - [Baseline\ miles\ covered]}{[Baseline\ miles\ covered]} + [MIL\ cost] + [Finance\ cost].$$

(Equation I.1)

The incremental cost for Step 1 warranty was estimated to be $285 per HHDD engine. CARB staff described the methodology in detail in several work group meetings. The work group members suggested that staff compare CARB staff's estimated Step 1 warranty cost (i.e., $285) with the average price increase for MY 2022 products as compiled by EMA.

EMA gathered, aggregated, and averaged available cost data from OEMs for Step 1 warranty in June 2021 and provided it to staff. EMA reported that the incremental costs were approximately $3,750 for 15 liter (L) engines, $2,500 for 11-13 L engines, and $1,400 for medium heavy-duty (MHD) engines. CARB staff considered $2,500 for 11-13 L engines to be most relevant to this report; because the National Renewable Energy Laboratory (NREL), during their Omnibus Regulation cost study, received feedback from the industry that ~12-13 L engines with ~475 horsepower (hp) were more representative of HHDD engine platforms than 15 L engines (NREL, 2020).

Although the Step 1 incremental cost reported by EMA (e.g., $2,500 for 11-13 L engine) and CARB staff's estimate ($285 for HHDD) differs by a factor of nine, most of the apparent discrepancy can be explained by differing assumptions regarding the baseline and the endpoint of warranty coverages. CARB staff's analysis considers that most owners either voluntarily purchase longer warranties beyond current regulatory requirements or are gifted them during the sales negotiation process (ISR, 2017).

In its analysis, CARB staff included the miles covered under the optional longer warranties many truck owners already have into the warranty baseline because this approach more realistically reflects the actual baseline conditions before the Step 1 warranty takes effect. Also, CARB staff used CARB's EMFAC model to quantitatively determine the limiting factor of warranty requirements (miles, years, or hours) for each vehicle subcategory. But it was unclear if or how these significant miles/years/hours limiting factors were being considered in the costs estimated by OEMs. Specifically, CARB staff estimated that when the regulatory warranty requirements lengthen from 100,000 miles/5 years/3000 hours to 350,000 miles/5 years for MYs 2022-2026, the miles driven during the warranty periods would increase by only 32,100 miles as opposed to the apparent 250,000 increase of the warranty mileages (i.e., from 100,000 to 350,000 miles).

If the OEMs used the same failure rates and the repair costs as CARB but assumed a 250,000 increase in miles covered under warranty (i.e., from 100,000 to 350,000 miles), as opposed to CARB's estimate of 32,100 miles, the estimated incremental warranty costs would be $2,219 (i.e., $285 * 250,000 miles/ 32,100 miles), representing an increase of a factor of eight. During CARB staff's interviews with OEMs, one indicated that their volume-weighted average of the incremental warranty cost for MY 2022 HHDD was approximately $2,000 (excluding OEM markup or financing), indicating that on a per-mile basis, CARB and the OEM's MY 2022 warranty costs reasonably agreed.

Overall, CARB staff believes the staff's Step 1 warranty cost estimates prepared during the development of the Step 1 warranty rulemaking are still well-supported and appropriate even though at first glance they appear much lower than the prices OEMs will be charging their customers for longer warranties for MY 2022 vehicles. Staff's estimates appropriately account for the fact that many truck owners currently purchase warranty coverage much longer than the 100,000 mile minimum. In addition, staff's estimates also reasonably account

for the fact that in many cases, warranty coverage ends up truncated not by the mileage limit, but by the accompanying year limit.

Step 2 warranty (MY 2027 & MY 2031):

CARB's Step 2 warranty cost estimate is lower than the others. This is because CARB's method considers all vehicle owners including those who would be affected less by the rulemaking (i.e., those who already have extended warranty and those who will reach the operation-hour limit first). CARB's method also assumes parts will be more durable to meet the durability demonstration program requirements of the Omnibus Regulation as discussed below.

CARB staff reviewed and compared its own Step 2 warranty cost analysis methods with those of NREL, America's Commercial Transportation (ACT) Research, and EMA. A summary of warranty costs and assumptions are presented in Table I.1. The details of each methodology are described further in section IV. Table I.1 highlights the differences in the assumed warranty coverage baseline, warranty coverage endpoints, NOx standards, and the assumption regarding future repair costs, which lead to the differences in the warranty cost estimates.

Table I.1. Summary of Estimated Step 2 Warranty Costs and Assumptions

	CARB Step 2 Warranty	NREL	ACT Research	EMA
Incremental warranty cost per HHDD engine[a]	$1,104	$23,061[b]	$7,227[c]	$13,091
Time periods	From MY2022 to MY2031	From MY2018 to MY2027[d]	From MY2019 to MY2031[d]	From MY2022 to MY2031
Warranty coverage baseline	500,000 mi/5 yr (40% of owners)[e]; 350,000 mi/5 yr (60% of owners)[e]	Current warranty offered by the OEMs (not provided to CARB)[f]	250,000 mi 2 yr	350,000 mi 5 yr
Warranty coverage endpoints	600,000 mi 10 yr 30,000 hr	800,000 mi 12 yr	800,000 mi 12 yr[g]	600,000 mi 10 yr
Assumed NOx standards, gram per brake horsepower-hour (g/bhp-hr) (federal test procedure (FTP)/ramped modal cycle (RMC))	0.020 @435,000 mi 0.040 @800,000 mi	0.02 @ 1 million mi	0.02 @ 1 million mi[g]	0.020 @435,000 mi 0.040 @800,000 mi

a: Caution must be taken when comparing the different costs because of the differences in the basic assumptions such as the baseline and warranty endpoints.
b: Average-cost diesel technology package 12-13 L with CA-only volume
c: HHDD at 7% discount rate with CA-only volume
d: The baselines of NREL and ACT Research are before Step 1 warranty becomes effective (MY 2022), which overemphasizes the discrepancy between CARB and NREL/ACT Research.
e: Assumes no preference for regulatory vs. voluntary warranty
f: Each OEM chose their own 2018 baseline. It is unknown whether the baseline is CARB-warranty or OEM-provided base warranty because details are confidential.
g: CARB staff asked ACT research for clarification but did not receive a response. These numbers are based on work group members' suggestions.

Completing Goal #1 helped the work group better understand the assumptions made in the various warranty cost estimation methods. The following major factors led to the differences between estimates by CARB staff and those by the other stakeholders:

1) CARB staff and EMA have different assumptions regarding the expected part failure rates under the new emissions standards and warranty requirements.

   CARB staff assumed that a properly engineered technology package designed to be durable throughout its useful life (e.g., 800,000 miles in MY 2031) would not have more unforeseen production errors (per mile) than current parts designed to last for 435,000 miles. This is because a warranty is not intended to address part failures that are not engineered properly. Implementation of the heavy-duty engine durability demonstration program in the Omnibus Regulation is expected to help ensure that parts will be designed to be more durable. Therefore, to estimate the rate at which parts would fail under the new, longer warranties, CARB staff used the actual failure rates from manufacturers obtained from CARB's 5-year warranty claim data (EWIR) for the most recent years for which complete data had been submitted, i.e., MY 2012 (Step 1) and MY 2013 (Step 2).

   Conversely, EMA's analysis projects more failures as new technologies are introduced and NOx standards lowered. For example, EMA's analysis assumed additional warranty costs for covering new technology (resulting in a 46 percent increase in the baseline warranty cost and the incremental warranty cost), higher failure rates due to the new 0.02 g/bhp-hr NOx standard (20 percent increase), and higher failure rates of new technology compared to mature technology (additional 20 percent increase applied to new technology). EMA's analysis did not consider that the new parts would need to be designed to last to the new useful life as CARB staff's did. It is possible that some manufacturers made similar assumptions when they responded to NREL and ACT Research's surveys, although the assumptions made by each manufacturer are confidential and were not made available to CARB staff.

2) Using California State University, Sacramento (CSUS) survey data, CARB staff more accurately accounted for current warranty buying practices by fleets and owner/operators than the NREL/ACT Research/EMA's analyses, and hence CARB staff's warranty baseline is higher than in the other analyses.

   CARB staff's warranty baseline is higher than NREL, ACT Research, and EMA's because CARB staff accounted for the fact that many heavy-duty vehicle buyers already optionally buy longer emission warranties. For example, 40 percent of vehicle owners who voluntarily purchased 5 years/500,000 miles warranties would be affected less by Step 2 warranty than those who had only Step 1 warranty (5 years/350,000 miles), which lowered CARB staff's estimated incremental costs.

3) CARB staff's warranty endpoint is shorter than that used in the NREL, ACT Research, and EMA analyses because CARB staff's analysis evaluated all of the factors that could have ended the warranty period (years, hours, or miles) based on the real-world vehicle usage parameters utilized by CARB's EMFAC inventory model. On the other hand, NREL, ACT Research, and EMA's methods did not consider the impact of hour limits in Step 2 warranty (see section IV.E.2. "Analysis of alternative scenarios" for more details). In addition, NREL and ACT's warranty endpoints were 200,000 miles longer than those used by CARB staff because their studies were based on an earlier CARB staff proposal (CARB, 2019) versus the endpoints that were ultimately proposed and approved for adoption by the Board (i.e., 1,000,000 miles vs 800,000 miles).

Goal #2: Gather available data for heavy-duty vehicles to quantify the residual warranty value to the second and subsequent owners.

In this section of the study, CARB staff conducted a survey, which suggests that the remaining warranty of a used vehicle will increase its resale value.

As the regulatory warranty periods are lengthened through Step 1 and 2, it is likely that more vehicles produced under these newer warranty requirements will be later re-sold in the secondary market as used vehicles with a portion of the lengthened warranty period coverage remaining (i.e., residual warranties). To better understand the secondary market value of such residual warranties, CARB staff conducted an online survey in April 2021 as part of Goal # 2, and collected 694 responses from fleets and owner/operators and from five dealers. The survey results indicate that the remaining residual warranties do in fact add value to vehicles sold in the secondary market, averaging approximately $2,000 for a 2 years/200,000 miles period of residual warranties, and $4,000 for a 4 years/400,000 miles residual period. The survey did not evaluate the impact of different year-to-mile ratios (e.g., 6 months/200,000 miles, etc.) because it would have added complexity to the survey process. Also, approximately half of the fleet owner/operators who responded to the survey indicated that they expected to hold on to their vehicles longer as warranty periods are lengthened. These results suggest that higher initial vehicle purchase prices which offset later repair costs will likely be distributed over longer time periods or passed on with their attendant benefits to the subsequent vehicle owners to some extent, which potentially will reduce the cost impact that the Omnibus Regulation warranty amendments may have on first owners as seen in the increased value recognized by subsequent vehicle owners.

Goal #3: Gather available data on usage patterns and duty cycles from the second and subsequent owners of vehicles used in a variety of applications to assess wear characteristics.

This section of the study clarifies the emission control component suppliers' views on what kinds of additional data will be useful for them to design more durable components.

During the Omnibus regulatory development process, suppliers noted the lack of data concerning the failure rates of parts beyond current required warranty periods. CARB staff has acknowledged that data reported to CARB was only within currently required and extended warranty time periods, which were shorter than those proposed in the Omnibus Regulation. This uncertainty resulted in an inability for suppliers to accurately estimate the costs associated with extending warranties to the levels in the Omnibus Regulation. Discussions between CARB staff and supplier representatives resulted in two concepts to be explored by the warranty work group. One possible concept suggested was to conduct a survey or test program to better understand the usage/duty cycles and wear characteristics of parts on vehicles operating at periods between current regulatory useful life/warranty requirements and Omnibus requirements. To this end, CARB staff gathered available data from recent studies as discussed below. However, it was not feasible for CARB staff to collect new data within the timeframe of this warranty cost study nor to commit to conduct a long-term study. The second possible concept suggested was for CARB to facilitate information sharing between suppliers and their OEM customers, which is represented by Goal 4 and Goal 5 below. This suggestion was later canceled based on the work group's discussions of Goals #4/5.

MECA and MEMA represent the suppliers of engine and exhaust emission control components used by OEMs, and specifically requested that Goal #3 be included in the warranty study. CARB staff discussed with MECA and MEMA representatives what relevant studies would help these suppliers better understand usage and wear analysis of parts on vehicles in various applications as warranty is lengthened. Having a better understanding would help the suppliers determine where more development is needed to meet Omnibus requirements as well as more accurately estimate the costs to suppliers of extended warranty requirements. Based on the discussions, CARB staff provided the following resources to MECA and MEMA members:

- "Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles" (CE-CERT, 2017)
- CARB EMFAC Fleet Database: *https://arb.ca.gov/emfac/fleet-db*
- "Updates to Heavy-Duty Emission Deterioration in EMFAC" (ERG, 2020)
- "Heavy-Duty Vehicle Accrual Rates" (ERG, 2019)

Subsequently, although MECA and MEMA members found the information helpful, they suggested that CARB staff conduct a more detailed study to investigate the wear

characteristics of used (not failed) components and provide more details about the failures of components, such as the mileage and season of the year in which the failure occurred, oil/fuel usage, and duty cycles. There is a particular lack of data in the usage and maintenance patterns of second and third vehicle owners. While this suggestion has merit, such a study is beyond the scope of this warranty cost study.

Goal #4: Make a plan for gathering and sharing data between OEMs and suppliers as new technologies to meet MY 2024 and MY 2027 standards are rolled out.

As part of Goal #4, CARB staff attempted to understand the business relationships more comprehensively between OEMs and emission control component suppliers so as to possibly assist them in meeting the new standards. However, in CARB staff's discussions with MECA and MEMA representatives, it became clear that the structure of these OEM-supplier business relationships varied widely and that sensitivities existed with information sharing. Therefore, the group decided that there was not a clear path for CARB to intervene between OEMs and suppliers to facilitate information sharing beyond what exists today. As a result and as recommended by MECA and MEMA representatives, CARB staff subsequently decided against conducting a survey related to this goal as was originally anticipated, and no further action was taken. As part of this study, CARB staff met individually with OEMs and confirmed that some OEMs are in discussion with suppliers regarding MY 2022 warranty requirements. CARB will continue to monitor the process as the industry prepares to meet MY 2024 and MY 2027 requirements.

Goal #5: Facilitate discussions between OEMs and emission control component suppliers beyond the current 100,000-mile warranty period.

Similar to Goal #4, CARB staff initially planned to conduct a survey of OEMs and component suppliers about a broad range of issues ranging from learning about the information exchange that occurs during the development process in designing component specifications to determine how warranty claim information is shared and who pays for the cost of replaced components. However, CARB staff decided against conducting a survey at the recommendation of MECA and MEMA representatives, which was based on the same reason stated for Goal #4 above. As an alternative, CARB staff analyzed the top two to three failure modes from warranty data submitted by engine manufacturers to CARB from Field Information Reports (FIR) to provide additional information for suppliers. The claims were reported for a 5 year period, but they included claims covered by the 5 year/100,000 miles/3,000 hours warranty, base engine warranty, and paid extended warranty. For example, major failure modes of sensors are shown in Table I.2 below.

Table I.2. Common failure modes of sensors determined by examining FIRs for the 2013-2019 MYs

Components	Failure modes
NOx Sensor	1. Moisture contacting sensor element 2. Cracking due to thermal shock 3. Software Issue
PM Sensor	1. Clogged sensor tip 2. Software Issue
Ammonia Sensor	1. Sensor circuit error 2. Rusted/Corroded
Urea Quality Sensor	1. Liquid Ingress 2. Communication Error

The failure mode analysis included major components such as injectors, selective catalytic reduction (SCR) components, diesel particulate filters (DPF), exhaust gas recirculation (EGR) components, and turbochargers.

Goal #6: Review the study's results and determine the suggested next steps from the study.

Over the course of the work group study, CARB staff collected information from stakeholders related to cost estimates for warranty costs and convened 16 separate work group meetings to discuss various aspects of warranty costs. This included inviting both NREL and ACT Research to present or attend discussions on their own warranty cost analyses. Brief summaries of the activities conducted to accomplish each goal, and the suggested next steps of each goal are provided in Table I.3.

Table I.3. Summary of suggested next steps

#	Goals	Suggested next steps
1	Work collaboratively to better understand all the assumptions made and all of the differences in the various warranty cost analysis methods.	Future warranty cost estimates should clarify key assumptions on the definition of warranty cost (e.g., distinction between useful-life cost vs. warranty cost) and how incremental coverage is calculated (e.g., how years/hours/miles limits are treated) since these are major sources of the apparent discrepancies.
2	Gather available data on heavy-duty vehicles to quantify the residual warranty value to the second and subsequent owners.	As warranty periods become longer and more used vehicles are sold with residual warranties in the future, it may be helpful to collect more sales data on the value of residual warranties of actual vehicles.
3	Gather available data on usage patterns and duty cycles from the second and subsequent owners of vehicles used in a variety of applications to assess wear characteristics.	MECA and MEMA representatives suggested CARB should consider future long-term studies that collect information on: • Mileages of the vehicles studied • Location of the SCR temperatures (inlet or outlet) • Season of study, summer versus winter • Oil and fuel usage
4	Make a plan for gathering and sharing data between OEMs and suppliers as new technologies to meet MY2024 and MY2027 standards are rolled out.	None. CARB staff was advised by MECA and MEMA representatives to not conduct a survey to understand OEM-supplier relationships since their business relationships varied widely, and CARB should not interfere with their relationships.
5	Facilitate discussions between OEMs and suppliers beyond the current 100,000-mile warranty period.	Same as #4

Although CARB staff and the work group members were unable to agree on all the elements of warranty cost estimation methods, it became clear that the cost information used (e.g., EMA's aftermarket warranty price vs. CARB's repair cost) and the types of costs that should be included (e.g., distinction between research and development (R&D) cost vs. warranty cost) were significantly different. The work group members agreed that future warranty cost estimates should clearly list and clarify key assumptions on the definition of what should constitute warranty cost (e.g., distinction between useful life cost vs. warranty cost) and how the baseline incremental coverage is calculated (e.g., how years/hours/miles limits are treated) because these are major sources of the apparent differences in estimates. Also, more data on residual warranty value would be useful in any future rulemaking that lengthens warranty requirements. As useful life and warranty are increased in 2027 and 2031, it also would be beneficial for emission control parts manufacturers to have more information on

the usage patterns of vehicles as they are transferred to second or even third owners within the longer useful life.

CARB staff reviewed and analyzed multiple industry methodologies for determining warranty costs. As stated previously, the assumptions play a significant role. Fundamental differences in the interpretations of warranty coverages and costs as well as other detailed factors identified in this study explain the large discrepancy in warranty costs as estimated by CARB, ACT, EMA, and NREL.

A "waterfall" chart in Figure I.1 shows the causes of the different warranty cost estimates and the cumulative effects of major assumptions of EMA's analysis of aftermarket warranty pricing information (see section IV.D.2 and IV.E.2 for more details). The effect of each assumption is shown as a percent change compared to the previous scenario (one immediately to the left on the chart) therefore the summation does not equal 100 percent. For example, scenario #7 removes EMA's assumption of a 20 percent higher failure rate for new technologies to meet the MY 2027/2031 standards and other requirements. The overall impact of the 20 percent new technology factor is 8 percent because the new technology factor does not apply to the existing technology. The percent changes depend on the order of the scenarios and therefore should be considered as a rough guide for evaluating the impact of each assumption. The assumptions for new technology and the lower NOx standard (i.e., whether or not elevated failure rates are necessary) as well as incremental warranty coverage (i.e., warranty baseline and endpoint considering years/miles/hours) explain the majority of the differences.

EMA's assumption regarding the warranty cost of new technology resulted in the largest relative cost impact (i.e., 58 percent). CARB staff did not separately account for additional warranty costs from new technology costs for several reasons. First, although there would be some new technologies introduced to meet MY 2027/2031 requirements, such as cylinder deactivation or light-off SCR, nearly all emission-related components expected for meeting the Omnibus standards would be the same as the technologies used today. Second, CARB staff believes it is simply part of the fundamental engineering cost to design durable components and does not believe that this cost should be attributed to warranty.

However, in response to EMA's comments during the working group, CARB staff performed an additional sensitivity analysis evaluating the assumption of the warranty costs for new technology and estimated that if the warranty costs for new technology were included, it would increase the estimate of Omnibus Regulation costs by about 11 percent. The hypothetical increase was well within the bounds of the previous CARB Staff Report sensitivity analysis that incorporated the incremental warranty costs from the NREL report (CARB, 2020; see chapter IX.F). Therefore, CARB staff concluded that even if the higher warranty costs for new technologies were included, it would not have changed the staff proposal. More details of the additional analysis are shown in Appendix I.

Overall, CARB staff believes the methodology used to support the Omnibus Regulation warranty-related cost estimates is reasonable and defensible. Based on what was learned further in this study, staff continues to believe that the benefits of the Omnibus Regulation clearly outweigh its costs by a factor of 10 (i.e., monetized benefits of $23.4 billion vs. costs of $2.39 billion).

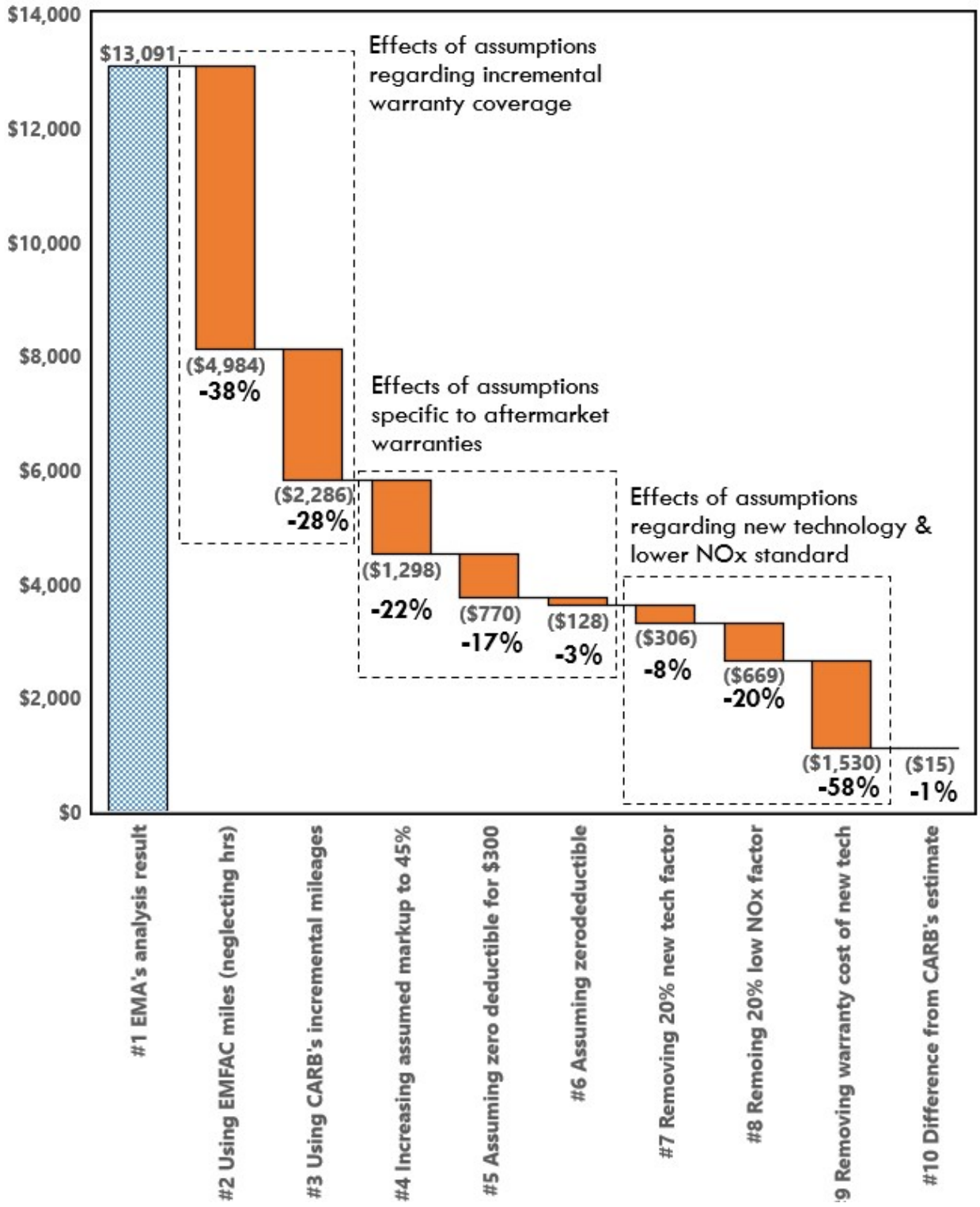

Figure I.1. Waterfall chart depicting the cumulative effects of different assumptions on EMA's warranty cost estimate based on aftermarket warranty price information. The percentage values correspond to the relative changes compared to the previous scenario.

II. Background

When CARB approved for adoption the Proposed Amendments to the Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments (Omnibus Regulation) in August 2020, they directed CARB staff to participate in a Warranty Cost Study with industry stakeholders. The Board's purpose for conducting this study was to better understand the warranty cost differences between CARB staff's estimates and those estimates provided by industry stakeholders (reference Appendix A for the Board transcript). The study, carried out from October 2020 to June 2021, focused on mitigating the industry's concerns about the uncertainties of increasing warranty costs associated with the Omnibus Regulation for heavy-duty engines/vehicles. This report presents the outcomes of the Warranty Cost Study led by CARB staff in collaboration with industry stakeholders. All members of the work group were given an opportunity to review and comment on the contents of this report. However, ultimately this report represents CARB staff's findings, and not necessarily a group consensus.

In the June 2018 board hearing, CARB staff proposed amendments to warranty requirements effective from MY 2022, which was intended as the first step of the "Two-Step" rulemaking approach (CARB, 2018), and therefore is termed as "Step 1 Warranty." In the August 2020 board hearing, the Board approved for adoption CARB staff's proposal for "Step 2 Warranty" amendments which will become effective in MY 2027 and MY 2031. This was part of the Omnibus Regulation that comprehensively overhauled a variety of requirements for heavy-duty vehicles and engines including the emission standards, useful life, and warranty periods (CARB, 2020). For simplicity, a summary of the current and amended requirements for HHDD engines/Class 8 GVWR > 33,000 pounds (lbs) are shown in Table II.1. The requirements for other weight classes and for Otto-cycle engines/vehicles are not shown but are available in the staff reports (CARB, 2018; 2020).

Table II.1. Warranty periods, useful life, and NOx standards for HHDD engines / Class 8 GVWR > 33,000 lbs.

<table>
<tr><th rowspan="2">MYs</th><th rowspan="2">Warranty (miles)</th><th rowspan="2">Useful Life (miles)</th><th colspan="3">NOx Standards</th></tr>
<tr><th>FTP/RMC (g/bhp-hr)</th><th>LLC (g/bhp-hr)</th><th>Idling (g/hr)</th></tr>
<tr><td>Current</td><td>100,000
5 years
3,000 hours</td><td rowspan="3">435,000
10 years
22,000 hours</td><td rowspan="2">0.20</td><td rowspan="2">-</td><td rowspan="2">30</td></tr>
<tr><td>2022</td><td rowspan="2">350,000
5 years</td></tr>
<tr><td>2024</td><td>0.050</td><td>0.20</td><td>10</td></tr>
<tr><td>2027</td><td>450,000
7 years
22,000 hours</td><td>600,000
11 years
30,000 hours</td><td>0.020 @ 435,000 miles
0.035 @ 600,000 miles</td><td>0.050 @ 435,000 miles
0.090 @ 600,000 miles</td><td rowspan="2">5</td></tr>
<tr><td>2031</td><td>600,000
10 years
30,000 hours</td><td>800,000
12 years
40,000 hours</td><td>0.020 @ 435,000 miles
0.040 @ 800,000 miles</td><td>0.050 @ 435,000 miles
0.100 @ 800,000 miles</td></tr>
</table>

One of the concerns raised by EMA during the Omnibus Regulation rulemaking process was the uncertainty of the increase in warranty costs in MY 2027 and 2031 when the NOx emission standards, useful life, and warranty periods become more stringent simultaneously. There were significant differences between the estimates of the warranty costs made by CARB, National Renewable Energy Laboratory (NREL), and America's Commercial Transportation (ACT) Research Co. Therefore, staff engaged with stakeholders and conducted a warranty cost study in response to the industry's concern regarding the warranty costs. The warranty cost study resulted in an analysis of three warranty cost methodologies and assumptions and provides information for the industry to assess costs for future planning purposes. The analysis shows that the discrepancies between different estimates mostly originate from different assumptions regarding the warranty coverage baseline (e.g., whether to account for voluntary extended warranties), warranty coverage endpoint (e.g., how to treat low-speed vehicles), and impact of the lower NOx standards (e.g., infant mortality). The results of the study may help the industry to better plan for complying with the Omnibus Regulation and mitigate the uncertainty that manufacturers and suppliers may have regarding the costs for the longer warranty periods under first and subsequent vehicle ownership.

III. Study Participants and Goals

CARB staff took the lead and formed a work group comprised of representatives from Cummins, MECA, and MEMA. The work group held a kick-off meeting on October 5, 2020 and agreed to hold biweekly meetings over a nine-month period and develop goals. The working group collaboratively established the following study goals, which are addressed in the subsequent chapters of this report:

1) Work collaboratively to better understand all the assumptions made and all of the differences in the various warranty cost analysis methods. (See Chapter IV below.)
2) Gather available data for heavy-duty vehicles to quantify the residual warranty value to the second and subsequent owners. (See Chapter V below.)
3) Gather available data on usage patterns and duty cycles from the second and subsequent owners of vehicles used in a variety of applications to assess wear characteristics. (See Chapter VI below.)
4) Make a plan for gathering and sharing data between original equipment manufacturers (OEMs) and emission control component suppliers as new technologies to meet MY 2024 and MY 2027 standards are rolled out. (See Chapter VII below.)
5) Facilitate discussions between OEMs and emission control component suppliers beyond the current 100,000 mile warranty period. (See Chapter VIII below.)
6) Review the results and the suggested next steps from the study. (See Chapter IX below.)

Subsequently, additional participants from EMA and ATA joined the work group. The work group met a total of 16 times over the nine-month period. This report represents CARB staff's findings related to each goal.

IV. Goal #1: Work collaboratively to better understand all the assumptions made and all of the differences in the various warranty cost analysis methods.

To address this goal, the work group improved the understanding of why there were large discrepancies between CARB's and other's warranty cost estimates. The discrepancies stem from the philosophical differences in what should be the baseline and what warranty should cover. CARB's method considered all vehicle owners including those who would be affected less by the rulemaking. Also, CARB staff assumed that the more rigorous heavy-duty engine durability demonstration program of the Omnibus Regulation would help ensure that parts will be designed to be more durable. Therefore, warranty was assumed to only cover defects, as intended, rather than covering failures of parts that were not designed properly to meet

lower emission standards and useful life requirements. CARB's method shifts the future repair cost to where it is intended, i.e., with OEMs designing emission durable components. On the other hand, EMA's analysis method focused on those who did not already have extended warranty (and who thus would be affected more by the rulemaking) and assumed higher repair costs as lower NOx emission standards and useful life requirements would be phased in. When the analysis was limited to Step 1 warranty (no change in technology) and the effects of voluntary extended warranties were removed by estimating the warranty costs "per miles covered," CARB and OEM's MY 2022 warranty costs reasonably agreed as discussed below. Therefore, CARB staff concluded that its method was reasonable.

This section describes the warranty cost estimation methods used by CARB (CARB, 2018; 2020), NREL (NREL, 2020), and ACT (EMA, 2020), as well as EMA's additional analysis presented as a part of the warranty cost study. For simplicity, the discussion in this section focuses on Heavy Heavy-Duty Vehicles (HHDV) (>33,000 lbs. GVWR) or class 8 diesel vehicles unless noted otherwise.

A. CARB's method

1. Summary of CARB's method for Step 1 and Step 2 warranties

CARB estimated the incremental warranty cost as the summation of the increase in emission-related repair costs and finance costs. The baseline repair costs were estimated using the most recent five years of the unscreened warranty claim data reported through CARB's EWIR program. To calculate the relative increase in usage because of longer years/hours/miles limitations, CARB's EMFAC model simulations were used to calculate the miles covered under warranty, which were often less than the regulatory warranty mileage because of the years or hours limitations. The relative increases in the repair costs were calculated using the increase in weighted average miles covered under warranty due to the rulemaking. The additional cost due to linking warranty to the MIL was also accounted for. Finally, the finance cost for a five-year loan with a six percent interest rate was added to calculate the incremental warranty cost. The procedure is summarized in equation IV.1 as follows:

$$[\Delta\, warranty\ cost] = [Baseline\ repair\ cost] \times \frac{[Projected\ miles\ covered] - [Baseline\ miles\ covered]}{[Baseline\ miles\ covered]} + [MIL\ cost] + [Finance\ cost].$$

(Equation IV.1)

The major assumptions of CARB's method include the following:

a. The baseline repair costs represent the average repair cost currently incurred by all relevant vehicles in California.
b. The repair cost is proportional to usage (miles or hours) in the future. The future repair cost includes the repair cost of additional emission-related components meeting the lower NOx standards due to continuous improvements in existing technology by manufacturers.
c. The average miles covered under warranty includes the coverages of optional longer warranties either as OEM-offered extended warranties or aftermarket warranties.

In 2018, CARB approved adoption of longer emission warranty requirements for heavy-duty diesel engines that will take effect with MY 2022. These amendments are known as the Step 1 warranty amendments. The Omnibus Regulation includes further lengthening of the emission warranty requirements beginning with MY 2027 that are known as the Step 2 warranty amendments. This section describes the methods used for Step 1 and Step 2 warranty amendments separately.

2. Step 1 Warranty Method

a) Baseline repair costs

CARB staff estimated the current baseline repair costs for emission-related components over a five-year period. Actual five-year warranty claim data for MY 2012 was obtained from EWIRs provided by manufacturers and shown in Table IV.A.1. CARB staff estimated repair costs for individual engines and aftertreatment components by analyzing repair shop data and having discussions with manufacturers and service providers.

Table IV.A.1. Estimated Current Warranty Repair Rates and Costs for HHDVs (2017$) (Step 1 Initial Statement of Reasons (ISOR) Appendix C Table 7)

Part	Total Claims	Claim %	Avg. Repair Cost	Weighted Avg. Repair Cost
Diesel Particulate Filter (DPF)	107	1.1%	$2,600	$28.60
DPF Doser	699	7.1%	$500	$35.50
Diesel Oxidation Catalyst (DOC)	153	1.6%	$3,800	$60.80
Exhaust Gas Recirculation (EGR) Valve	1,114	11.3%	$1,200	$135.60
EGR Cooler	1,647	16.8%	$3,100	$520.80
Injector	1,037	10.6%	$1,900	$201.40
NOx Sensor	876	8.9%	$670	$59.63
Selective Catalytic Reduction (SCR)	777	7.9%	$5,371	$424.31
Turbo	808	8.2%	$5,100	$418.20
Other Sensors	1,315	13.4%	$670	$89.78
Exhaust Manifold	87	0.9%	$850	$7.65
Fuel System	472	4.8%	$2,000	$96.00
Engine Control Module (ECM)	1,200	12.2%	$1,725	$210.45
Total:	10,292	104.8%	--	**$2,289**

b) **Baseline miles covered under warranty**

To estimate the baseline miles covered under warranty, CARB considered the current warranty purchase practice for optional warranties longer than the 100,000 mile minimum currently required. Table IV.A.2 below shows the current and future purchase practices of

longer warranties for HHDV assumed in Step 1 Warranty. The current percentages are based on the survey conducted by the Sacramento Institute for Social Research (ISR) (ISR, 2017) at CSUS under a contract with CARB. CARB staff assumed that those who currently purchase a longer warranty will continue to do so in the future. For example, 40 percent of owners who purchased a 500,000 miles warranty will continue to do so until the regulatory mileage requirement reaches 600,000 miles in MY 2031.

Table IV.A.2. Current and future warranty purchase practice for HHDV assumed in Step 1 Warranty

MYs	Regulatory requirements (% of vehicle population)	Assumed purchase of longer warranty (% of vehicle population)
Current	100,000 miles 5 years 3,000 hours (15%)	250,000 miles, 5 years (45%) 500,000 miles, 5 years (40%)
2022	350,000 miles 5 years (60%)	500,000, miles 5 years (40%)
2027	450,000 miles 7 years 22,000 hours (60%)	500,000, miles 7 years 22,000 hours (40%)
2031	600,000 miles 10 years 30,000 hours (100%)	-

A simple weighted average of the current warranty miles would result in 327,500 miles (i.e., 100,000 x 0.15 + 250,000 x 0.45 + 500,000 x 0.4). However, this value is greater than the miles covered under warranty because some vehicles would reach the years (or hours) limitation before mileage. To account for the effect of a 5-year limitation, the miles driven during the 5 year period were calculated for each vehicle category in the EMFAC model. The values for HHDV are shown in Table IV.A.3. Since most vehicles exhaust their warranties either by exceeding the mileage or year threshold, the 3,000-hour limit was assumed to be negligible and therefore excluded from Table IV.A.3.

The shaded cells in Table IV.A.3 correspond to the limiting factors (year vs. mileage) of the miles covered under warranty. The descriptions of EMFAC vehicle categories are shown in Table IV.A.4. For example, a T7 Public (Heavy-Heavy Duty Diesel Public Fleet Truck) accumulates 50,000 miles at the end of five years, and therefore the miles covered under warranty is 50,000 miles, not 100,000 miles. Over the entire EMFAC HHDV fleet, the 5-year

limitation results in the weighted average miles covered under warranty averaging to 316,010 miles. Of note, this 316,010 miles is over three times the minimum warranty mileage currently required by today's regulation (i.e., 100,000 miles) indicating vehicle owners already voluntarily purchase warranties much longer than the minimum CARB requires. The data in Table IV.A.3 are illustrated in Figure IV.A.1.

Table IV.A.3. Current miles covered under warranty for EMFAC HHDV categories (adapted from Step 1 ISOR Appendix C Table 2)

5 Years/100,000 Miles				
	Population %	5 Year Odometer Mileage	Estimated Length of Warranty	Miles Covered Under Warranty
T7 Public	48.33%	50,000	100,000	50,000
T7 SWCV	33.07%	100,000	100,000	100,000
T7 Utility	3.13%	47,000	100,000	47,000
T7 Single Construction*	15.47%	212,000	100,000	100,000
			Weighted average miles covered for 15%	74,173
5 Years/250,000 Miles				
	Population %	5 Year Odometer Mileage	Estimated Length of Warranty	Miles Covered Under Warranty
Motor Coach	2.16%	353,000	250,000	250,000
T7 Ag	0.04%	299,000	250,000	250,000
T7 Single	23.96%	212,000	250,000	212,000
T7 Single Construction*	10.36%	212,000	250,000	212,000
T7 Tractor*	50.27%	489,000	250,000	250,000
T7 Tractor Construction	13.22%	489,000	250,000	250,000
			Weighted average miles covered for 45%	236,962
5 Years/500,000 Miles				
	Population %	5 Year Odometer Mileage	Estimated Length of Warranty	Miles Covered Under Warranty
T7 CAIRP	56.35%	585,000	500,000	500,000
T7 CAIRP Construction	3.90%	585,000	500,000	500,000
T7 Other Port	1.60%	489,000	500,000	489,000
T7 POAK	5.83%	489,000	500,000	489,000
T7 POLA	13.85%	489,000	500,000	489,000
T7 Tractor*	18.48%	489,000	500,000	489,000
			Weighted average miles covered for 40%	495,628
			Weighted average	**316,010**

*Vehicle type is segregated into two warranty classes to align projected extended warranty purchases.

Table IV.A.4. EMFAC vehicle classes

EMFAC Vehicle Category	Description
T7 Ag	Heavy-Heavy Duty Diesel Agriculture Truck
T7 CAIRP	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
T7 CAIRP construction	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
T7 other port	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
T7 POAK	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
T7 POLA	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
T7 Public	Heavy-Heavy Duty Diesel Public Fleet Truck
T7 Single	Heavy-Heavy Duty Diesel Single Unit Truck
T7 single construction	Heavy-Heavy Duty Diesel Single Unit Construction Truck
T7 SWCV	Heavy-Heavy Duty Diesel Solid Waste Collection Truck
T7 tractor	Heavy-Heavy Duty Diesel Tractor Truck
T7 tractor construction	Heavy-Heavy Duty Diesel Tractor Construction Truck
T7 utility	Heavy-Heavy Duty Diesel Utility Fleet Truck
UBUS	Urban Buses
Motor Coach	Motor Coach

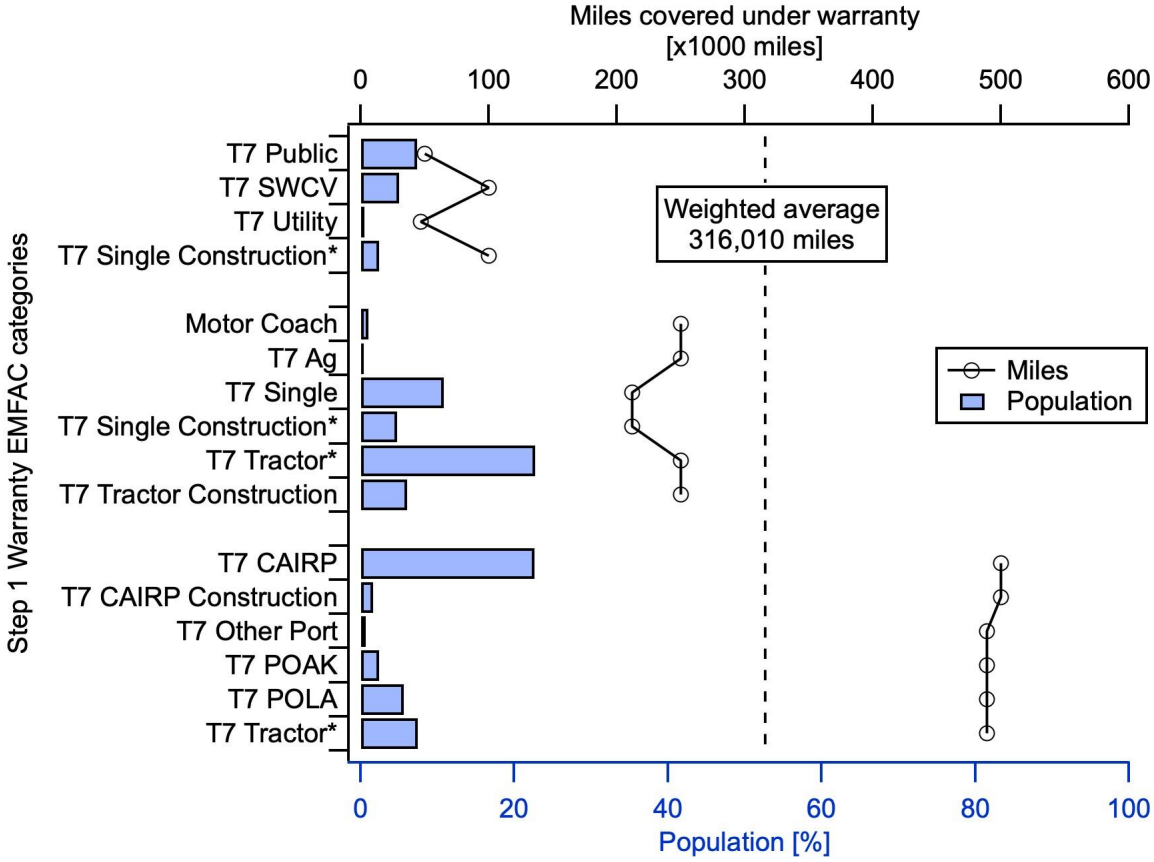

Figure IV.A.1. Illustration of the current miles covered under warranty for EMFAC HHDV categories

c) Projected miles covered under Step 1 Warranty (MY 2022)

As the regulatory warranty coverage extends in MY 2022, projected miles covered under warranty will increase. However, again, the projected miles covered under warranty will not be equal to the simple weighted average of warranty mileages. A simple weighted average would be 350,000 x 0.6 + 500,000 x 0.4 = 410,000 miles. To account for the effect of the 5-year limitation, the miles driven for 5 years were calculated for each vehicle category in the EMFAC model. The values for HHDV are shown in Table IV.A.5. The population-based weighted average after accounting for the 5-year limitation is 348,172 miles, significantly less than 410,000 miles simply calculated by the warranty miles only.

Table IV.A.5. Projected miles covered under Step 1 Warranty (MY 2022) for EMFAC HHDV categories (adapted from Step 1 ISOR Appendix C Table 14)

5 Years/350,000 Miles				
	Population %	5 Year Odometer Mileage	Estimated Length of Warranty	Miles Covered Under Warranty
T7 Public	12.08%	50,000	350,000	50,000
T7 SWCV	8.27%	100,000	350,000	100,000
T7 Utility	0.78%	47,000	350,000	47,000
T7 Single Construction	11.63%	212,000	350,000	212,000
Motor Coach	1.62%	353,000	350,000	350,000
T7 Ag	0.03%	299,000	350,000	299,000
T7 Single	17.97%	212,000	350,000	212,000
T7 Tractor*	37.68%	489,000	350,000	350,000
T7 Tractor Construction	9.92%	489,000	350,000	350,000
Weighted average miles covered for 60%				249,787
5 Years/500,000 Miles				
	Population %	5 Year Odometer Mileage	Estimated Length of Warranty	Miles Covered Under Warranty
T7 CAIRP	56.35%	585,000	500,000	500,000
T7 CAIRP Construction	3.90%	585,000	500,000	500,000
T7 Other Port	1.60%	489,000	500,000	489,000
T7 POAK	5.83%	489,000	500,000	489,000
T7 POLA	13.85%	489,000	500,000	489,000
T7 Tractor*	18.50%	489,000	500,000	489,000
Weighted average miles covered for 40%				495,750
Weighted average				**348,172**
*Vehicle type is segregated into two warranty classes to align projected extended warranty				

d) **MIL-related costs for Step 1 Warranty**

Since the Step 1 Warranty provisions enhanced and clarified the link between warranty coverage and any component that can lead to illumination of a MIL (i.e., linking on-board diagnostics (OBD) to warranty), more individual failure events will be honored under the warranty. The additional cost of components indirectly related to emission control via MIL is shown in Table IV.A.6 and is based on EWIR data which shows that claims from these additional components are all less than one percent. The increase in cost due to linking OBD to warranty is estimated to be $7.33.

Table IV.A.6. Estimated HHDV warranty repair rates and costs for additional components due to linking HD OBD to heavy-duty warranty (2017$) (Step 1 ISOR Appendix C Table 19)

Component	Avg. Repair Cost	Claim %	Weighted Avg. Repair Cost
Accelerator pedal position (sensor)	$695	0.02%	$0.16
Vehicle speed sensor	$278	0.57%	$1.58
Missing VIN - reflash ECU/ECM	$400	0.14%	$0.57
Battery voltage - wire replacement	$470	0.02%	$0.11
Battery voltage - battery replacement	$290	0.02%	$0.07
J1939/J1979 data link	$1,725	0.11%	$1.92
Thermostat	$230	0.07%	$0.16
Coolant level sensor	$245	0.05%	$0.12
Oil pressure sensor	$220	0.60%	$1.32
Crankcase pressure sensor	$148	0.78%	$1.16
Intake air heater	$715	0.02%	$0.17
Total:	-	-	**$7.33**

e) **Projected cost of Step 1 Warranty**

Based on the current average mileage (316,010 miles), baseline repair cost ($2,289), the projected average mileage in MY 2022 (348,172 miles), the projected repair cost of Step 1 Warranty was estimated to be $233. With the MIL-related cost ($7), the total repair cost was $240. Finally, additional finance costs for a five-year loan with a 6 percent interest rate were added to the repair cost. The cost of Step 1 Warranty was estimated to be $285 without markup and $413 with a 45 percent markup as shown in Table IV.A.7.

Table IV.A.7. Summary of Step 1 Warranty cost

	Baseline	**MY2022**
Mileage covered under warranty	316,010	348,172
Repair Cost	$2,289[a]	$2,522
Incremental repair cost	-	$233
Cost of additional MIL-related repairs	-	$7
Finance cost[b]	-	$45
Total Step 1 warranty cost (without markup)	-	**$285**
Total Step 1 warranty cost (with 45% markup)	-	$413

a. Repair cost estimated using 5-year data for MY2012 engines.
b. Six percent, five-year loan

3. Step 2 Warranty

CARB's Step 2 warranty cost estimate was lower than the others. This is because CARB's method considered all vehicle owners including those who would be affected less by the rulemaking (i.e., those who already had extended warranty, and those who will reach the operation-hour limit first). CARB also assumed parts would be more durable to meet the durability demonstration program requirements of the Omnibus Regulation as discussed below.

CARB staff's cost estimation method of Step 2 Warranty was analogous to that of Step 1 Warranty, with the exception that staff simplified how baseline mileage was attributed to various vehicle categories. It is important to note that Step 2 Warranty introduced additional hour requirements (22,000 hours in 2027; 30,000 hours in 2031) that further reduce the average miles covered under warranty.

a) **Baseline repair cost**

In Step 2 Warranty, the repair cost analysis was further expanded to include additional components using more current data than what was available in the Step 1 Warranty rulemaking. Additional categories allowed for a more accurate cost estimate. The total baseline repair cost increased to $2,400 as shown in Table IV.A.8. The updated repair cost is $111 more than the Step 1 Warranty's current (2017$) repair cost of $2,289.

Table IV.A.8. 2013 Model year warranty claim rates and costs for the HHDV category (2018$)
(Omnibus Regulation ISOR Appendix C-3, Table I.17)

Component	Total Claims[a]	Warranty Claims Rate	Average Repair Cost	Weighted Average Repair Cost
CATALYST	0	0.00%	$2,500	$0.00
DOC	893	8.10%	$3,800	$307.88
DPF	118	1.10%	$2,600	$27.84
Engine Control Unit (ECU)	653	5.90%	$1,725	$102.20
SCR	138	1.30%	$5,371	$67.25
DEF DOSER	1,010	9.20%	$1,178	$107.95
DPF DOSER	778	7.10%	$1,178	$83.15
EGR COOLER	1,059	9.60%	$3,100	$297.85
EGR VALVE	358	3.20%	$1,200	$38.98
FUEL INJECTOR	659	6.00%	$2,208	$132.02
TURBOCHARGER	1,082	9.80%	$5,100	$500.65
BLOWBY FILTER	0	0.00%	$150	$0.00
BOOST CONTROL VALVE	12	0.10%	$450	$0.49
CHARGE AIR COOLER	2	0.00%	$3,000	$0.54
CHARGE AIR DUCT	28	0.30%	$300	$0.76
CLAMP	8	0.10%	$50	$0.04
CRANKCASE SEPARATOR	22	0.20%	$1,029	$2.05
CYLINDER HEAD	26	0.20%	$5,000	$11.79
DEF PUMP	454	4.10%	$1,445	$59.52
DEF TANK	27	0.20%	$1,000	$2.45
ECU REPROGRAM	3,246	29.50%	$400	$117.80
ELECTRICAL HARNESS	122	1.10%	$277	$3.07
EXHAUST MANIFOLD	369	3.30%	$2,500	$83.70
EXHAUST VALVE	81	0.70%	$3,500	$25.72
FUEL LINE	6	0.10%	$1,362	$0.74
FUEL PUMP	370	3.40%	$1,624	$54.52
FUEL TANK	0	0.00%	$2,000	$0.00
GASKET	111	1.00%	$100	$1.01
IGNITION CONTROL MODULE	282	2.60%	$550	$14.07
INTAKE MANIFOLD	2	0.00%	$2,500	$0.45
NOx SENSOR	1,677	15.20%	$670	$101.94
OIL PUMP	35	0.30%	$1,293	$4.11
OIL RAIL	16	0.10%	$1,638	$2.38
OIL SEPARATOR	879	8.00%	$500	$39.87
OTHER SENSORS	3,206	29.10%	$670	$194.88
PRESS CONTROL VALVE	41	0.40%	$500	$1.86
RUBBER HOSE	25	0.20%	$250	$0.57
THROTTLE VALVE	138	1.30%	$805	$10.08
VACUUM PUMP	0	0.00%	$550	$0.00
TOTAL	**17,933**	**162.70%**	**--**	**$2,400**

[a] Note that the total claims values shown are for HHDV and urban buses. This was done to remain consistent with 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

CARB staff estimated the repair costs associated with the indirect OBD components to be $16 for HHDV.

b) **Baseline miles covered under warranty (MY 2022)**

The baseline mileage assumed the warranty purchase practice after the beginning of Step 1 Warranty in MY 2022. CARB staff simplified the assumed EMFAC vehicle population distribution in the 350,000 and 500,000-mile category. As discussed in section IV.A.2.b, CARB staff determined the current warranty purchase practice (i.e., 40 percent of HHDV have 500,000 miles warranty; 45 percent 250,000 miles; 15 percent 100,000 miles) based on CSUS survey data (ISR, 2017). In Step 1 Warranty rulemaking, CARB staff assumed that owners of vehicle subcategories that would accumulate high mileages tended to purchase longer warranties voluntarily (see section IV.A.2.b). In Step 2 Warranty rulemaking, CARB staff removed the assumption and applied the same warranty purchasing business practices for all the vehicle subcategories because data to determine who would purchase the extended coverage and who would rely on the regulatory warranty was unavailable. Therefore, for the Step 2 baseline, vehicle population percent distributions were assumed to be identical for 60 percent covered to 350,000 mile (Step 1 Warranty requirement) and for 40 percent covered to 500,000 miles voluntarily. The revised assumption was more conservative (i.e., higher cost) because 60 percent of high-mileage vehicles (e.g., T7 CAIRP) were assumed to only have regulatory warranties. This explains why the Step 2 baseline mileage (288,692 miles) is less than the projected Step 1 mileage (348,172 miles) (section IV.A.2.c).

Table IV.A.9. Estimated baseline miles covered under Step 1 Warranty (MY 2022) for EMFAC HHDV categories (adapted from Omnibus Regulation ISOR Appendix C-3 Table I.11)

60% covered to 350,000 miles				
Vehicle Subcategory	**Population %**	**5 Year Mileage**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	352,917	350,000	350,000
T7 CAIRP	13.15%	584,953	350,000	350,000
T7 CAIRP Construction	1.19%	584,953	350,000	350,000
T7 Other port	0.70%	488,987	350,000	350,000
T7 POAK	2.57%	488,987	350,000	350,000
T7 POLA	7.74%	488,987	350,000	350,000
T7 Public	11.01%	49,896	350,000	49,896
T7 Single	11.79%	211,768	350,000	211,768
T7 Single Construction	8.29%	211,768	350,000	211,768
T7 SWCV	7.18%	100,325	350,000	100,325
T7 Tractor	21.75%	488,987	350,000	350,000
T7 Tractor Construction	5.54%	488,987	350,000	350,000
T7 Utility	0.27%	46,656	350,000	46,656
UBUS	7.50%	194,564	350,000	194,564
Weighted Average Miles Covered for 60%				258,763
40% covered to 500,000 miles				
Vehicle Subcategory	**Population %**	**5 Year Mileage**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	352,917	500,000	352,917
T7 CAIRP	13.15%	584,953	500,000	500,000
T7 CAIRP Construction	1.19%	584,953	500,000	500,000
T7 Other Port	0.70%	488,987	500,000	488,987
T7 POAK	2.57%	488,987	500,000	488,987
T7 POLA	7.74%	488,987	500,000	488,987
T7 Public	11.01%	49,896	500,000	49,896
T7 Single	11.79%	211,768	500,000	211,768
T7 Single Construction	8.29%	211,768	500,000	211,768
T7 SWCV	7.18%	100,325	500,000	100,325
T7 Tractor	21.75%	488,987	500,000	488,987
T7 Tractor Construction	5.54%	488,987	500,000	488,987
T7 Utility	0.27%	46,656	500,000	46,656
UBUS	7.50%	194,564	500,000	194,564
Weighted Average Miles Covered for 40%				333,586
Overall Weighted Average Mileage Covered for HHDV				**288,692**

c) Projected miles covered under Step 2 Warranty (MY 2027 & 2031)

The projected miles covered under Step 2 Warranty were calculated in the same manner as described above. Table IV.A.10 shows the estimated miles in MY 2027-2030, and Table IV.A.11 is for MY 2031+. Step 2 Warranty introduced additional hour-limits that led to approximately 25 percent of vehicles reaching the hour-limit first both in MY 2027-2030 and MY 2031. In MY 2031, it was assumed that no vehicle owner purchased longer warranty beyond the regulatory requirements.

Table IV.A.10. Estimated miles covered under Step 2 Warranty (MY 2027-2030) for EMFAC HHDV categories (adapted from Omnibus Regulation ISOR Appendix C-3 Table I.26)

HHDV Warranty Mileage Estimates in MY 2027- 2030					
60% covered to 450,000 miles					
Vehicle Subcategory	**Population %**	**7-year mileage**	**22,000 hours equivalent miles**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	462,917	903,665	450,000	450,000
T7 CAIRP	13.15%	731,451	903,665	450,000	450,000
T7 CAIRP Construction	1.19%	731,451	378,880	450,000	378,880
T7 Other port	0.70%	615,841	232,056	450,000	232,056
T7 POAK	2.57%	615,841	232,056	450,000	232,056
T7 POLA	7.74%	615,841	232,056	450,000	232,056
T7 Public	11.01%	65,448	443,133	450,000	65,448
T7 Single	11.79%	265,329	603,795	450,000	265,329
T7 Single Construction	8.29%	265,329	378,880	450,000	265,329
T7 SWCV	7.18%	131,595	240,933	450,000	131,595
T7 Tractor	21.75%	615,841	710,426	450,000	450,000
T7 Tractor Construction	5.54%	615,841	378,880	450,000	378,880
T7 Utility	0.27%	62,208	278,715	450,000	62,208
UBUS	7.50%	270,358	221,255	450,000	221,255
				Weighted Average Miles Covered for 60%	**300,715**
40% covered to 500,000 miles					
Vehicle Subcategory	**Population %**	**7-year mileage**	**22,000 hours equivalent miles**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	462,917	903,665	500,000	462,917
T7 CAIRP	13.15%	731,451	903,665	500,000	500,000
T7 CAIRP Construction	1.19%	731,451	378,880	500,000	378,880
T7 Other Port	0.70%	615,841	232,056	500,000	232,056
T7 POAK	2.57%	615,841	232,056	500,000	232,056
T7 POLA	7.74%	615,841	232,056	500,000	232,056
T7 Public	11.01%	65,448	443,133	500,000	65,448
T7 Single	11.79%	265,329	603,795	500,000	265,329
T7 Single Construction	8.29%	265,329	378,880	500,000	265,329
T7 SWCV	7.18%	131,595	240,933	500,000	131,595
T7 Tractor	21.75%	615,841	710,426	500,000	500,000
T7 Tractor Construction	5.54%	615,841	378,880	500,000	378,880
T7 Utility	0.27%	62,208	278,715	500,000	62,208
UBUS	7.50%	270,358	221,255	500,000	221,255
				Weighted Average Miles Covered for 40%	**318,336**
Overall Weighted Average Mileage Covered for HHDV MY 2027- 2030: 307,763 miles					

Table IV.A.11. Estimated miles covered under Step 2 Warranty (MY 2031+) for EMFAC HHDV categories (adapted from Omnibus Regulation ISOR Appendix C-3 Table I.27)

HHDV Warranty Mileage Estimates in MY 2031 and subsequent 100% covered to 600,000 miles					
Vehicle Subcategory	**Population %**	**10-year mileage**	**30,000 hours equivalent miles**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	611,967	1,232,271	600,000	600,000
T7 CAIRP	13.15%	800,000	1,232,271	600,000	600,000
T7 CAIRP Construction	1.19%	800,000	516,654	600,000	516,654
T7 Other port	0.70%	765,588	316,440	600,000	316,440
T7 POAK	2.57%	765,588	316,440	600,000	316,440
T7 POLA	7.74%	765,588	316,440	600,000	316,440
T7 Public	11.01%	88,776	604,272	600,000	88,776
T7 Single	11.79%	336,079	823,356	600,000	336,079
T7 Single Construction	8.29%	336,079	516,654	600,000	336,079
T7 SWCV	7.18%	178,500	328,544	600,000	178,500
T7 Tractor	21.75%	765,588	968,762	600,000	600,000
T7 Tractor Construction	5.54%	765,588	516,654	600,000	516,654
T7 Utility	0.27%	85,536	380,066	600,000	85,536
UBUS	7.50%	393,363	301,712	600,000	301,712
Weighted Average Mileage Covered for HHDV MY 2031 and subsequent: 399,843 miles					

Figure IV.A.2 below illustrates the data provided in Table IV.A.11.

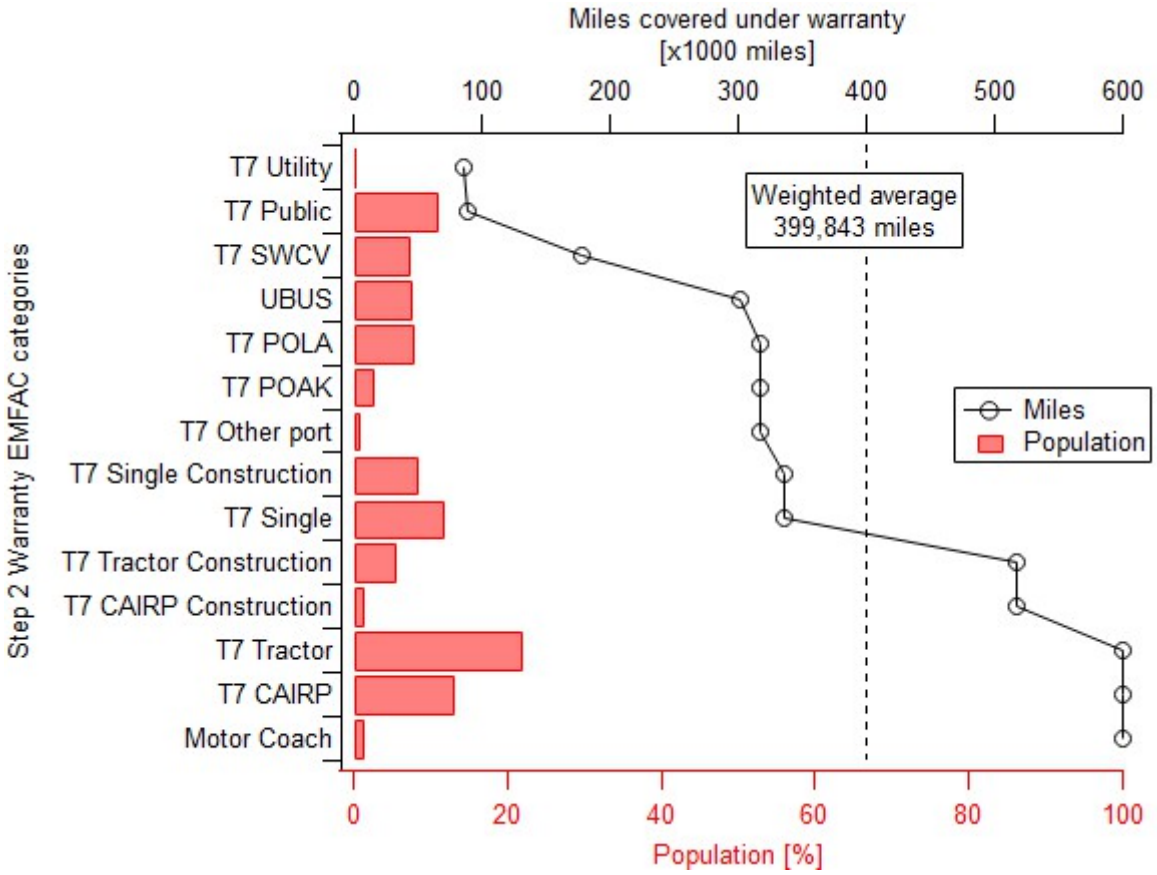

Figure IV.A.2. Illustration of the estimated miles covered under Step 2 Warranty (MY 2031+) for EMFAC HHDV categories

d) **Projected cost of Step 2 Warranty**

Finally, with the Step 2 Warranty baseline mileage (section IV.A.3.b), baseline repair cost (section IV.A.3.a), and projected mileages (section IV,A.3,c), the projected cost of Step 2 Warranty can be calculated. Table IV.A.12. summarizes the Step 2 Warranty costs, including the finance cost.

Table IV.A.12. Summary of Step 2 Warranty cost

	Baseline (MY2022)	MY2027	MY2031
Mileage	288,710[a]	307,763	399,843
Repair Cost	$2,416[b]	$2,576	$3,346
Incremental repair cost	-	$159	$771
Finance cost[c]	-	$30	$144
Total Step 2 warranty cost	-	-	**$1,104**

a. Baseline value differed from Step 1 because of different population % assumption
b. Repair cost estimated using five-year data reported for MY2013 engines
c. Six percent, five years loan on incremental repair costs

B. NREL's method

1. Summary of NREL's method

NREL estimated incremental cost (without any retail price markup) based on the survey responses from stakeholders including industry association groups, Tier 1 suppliers, and engine OEMs. NREL's Task 1 was to estimate the initial incremental costs of the technologies, while NREL's Task 2 considered the life-cycle cost assessment considering the aftertreatment technologies' effects on fuel consumption, diesel exhaust fluid (DEF) consumption, major overhaul intervals (full useful life estimates), manufacturing volume, and financial discount rates. In this report, CARB focused on the incremental warranty cost estimated in NREL's Task 1 since the life-cycle cost in Task 2 did not isolate the warranty cost.

The conditions assumed in the Task 1 second survey are summarized in Table IV.B.1. It should be noted that the useful life, warranty period, and the full useful-life NOx standard are more stringent than CARB's values because CARB staff had not finalized the proposed requirements at the time of NREL's study. As a result, the costs are significantly higher. Additionally, the details of the baseline were not specified; OEMs considered their current warranties, which varied between OEMs. The California-only production volume can result in higher warranty costs due to higher unit prices if California-specific parts with small production volumes are used. For this report, CARB focused on the 12-13 L average-cost diesel aftertreatment technology as it was the most similar to the setup implemented in Stage 3 demonstration program by the Southwest Research Institute (Sharp, 2021). The proposed average-cost diesel technology package consisted of a United States Environmental Protection Agency 2017 certification-compliant engine with a variable-geometry turbocharger, no turbo compounding, and an engine thermal management

strategy and technology for cylinder deactivation. The average-cost aftertreatment system is illustrated in Figure IV.B.1.

Table IV.B.1. Conditions assumed in NREL's warranty cost estimation (Task 1 survey 2)

MY	2027
Useful life	1,000,000 miles / 15 years
Warranty period	800,000 / 12 years
NOx standard	0.02 g/bhp-hr
Baseline cost and warranty period	Current warranty offered by the OEMs (whatever that may be)
Production volume	California only
Engine displacement volume	6-7L, 12-13L
Technology packages	Low-cost, average-cost, high-cost packages

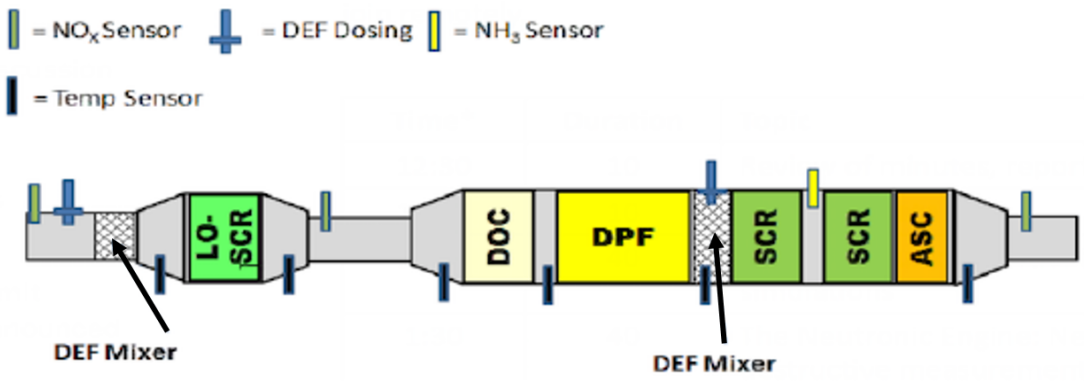

Figure IV.B.1. Schematic of proposed low- and average-cost diesel aftertreatment technology

2. Estimated cost

NREL's cost estimation for the potential average-cost 12-13 L diesel technology package is shown in Table IV.B.2. The average warranty incremental cost was $23,061, which was 21 times higher than CARB's Step 2 warranty cost ($1,104).

Table IV.B.2. Survey Responses for Potential Average-Cost Diesel Technology Package 12–13 L with Extended FUL, Extended Warranty, and California-Only Volumes (NREL report Table 18).

12–13 L	Low	Avg.	High
Cylinder Deactivation	$724	$1,176	$1,860
Other	$1,100	$1,100	$1,100
Total Engine Technology Cost	**$1,824**	**$2,276**	**$2,960**
LO-SCR	$736	$1,330	$2,450
DOC	$0	$144	$330
DPF	$0	$83	$191
SCR+ASC and DEF Dosing System	$500	$1,240	$1,892
OBD Sensors and Controllers (NO_x, NH_3, and Temp Sensors)	$476	$765	$997
Other	$300	$950	$1,600
Total Aftertreatment Technology Incremental Cost	**$2,012**	**$4,512**	**$7,460**
R&D Engineering Incremental Cost	$110	$357	$603
Certification Incremental Costs	$0	$7	$13
Warranty Incremental Costs	$7,840	$23,061[a]	$38,282
Total Indirect Incremental Costs to Manufacturer	**$7,950**	**$23,424**	**$38,898**
Total Incremental Cost Comparison	**$11,786**	**$30,212**	**$49,318**

a: CARB used this value for comparison in Table I.1.

NREL emphasized that the warranty incremental costs were based on an extremely small sample size of respondents, which may be biased high because of the OEMs' uncertainties regarding covering warranty for unfamiliar technology and much longer useful lives than today's useful lives. These warranty costs may be interpreted to represent "worst case" due to these uncertainties (NREL, 2020, page 50). While NREL did not know the method used by each OEM to determine their incremental warranty cost estimates, NREL listed the following potential reasons for the high warranty cost:

- **Failure uncertainty** – Because the OEMs will not perfectly estimate the probability of failure for their aftertreatment packages, they may charge more than needed initially to ensure they have enough capital to cover any future liabilities. This would be an amount in excess of what the vehicle owners would actually incur but would be expected to decrease over time as the failure rates on new technologies become known with more certainty.

- **Cost of capital** – The OEMs have higher costs of capital than individual vehicle owners. Thus, their cost to reserve funding to cover future warranty liabilities would be more than what a vehicle owner would realize in lifetime repair costs on average.
- **Soft costs** – The OEMs may have embedded additional "soft" costs into the cost estimate for the extended full useful life and extended warranty to account for costs associated with warranty administration (tracking warranty data, contacting vehicle owners, processing payments), legal liability (increased legal staffing in the event of fraud), and potentially others.
- **Customer relationships** – Some manufacturers may reduce the price of the aftertreatment package with extended warranty for some customers with long-standing relationships or high volumes of purchases. These discounts may then be offset with the "typical" MSRP aftertreatment price, which may be reflected as marketing-decision price distortions inflating the values reported to NREL's survey.

C. ACT Research's method

1. Summary of ACT Research's method

ACT Research (ACT) obtained industry input primarily consisting of confidential business information (CBI), and therefore specific technology solutions were not disclosed to CARB. Table IV.C.1 summarizes the conditions assumed in ACT's warranty cost estimation. Although the ACT report did not explicitly specify the warranty periods and NOx standard, the input from the work group indicated that they were 12 years /800,000 miles and 0.02 g/bhp-hr, which is significantly more stringent than CARB's 2031+ MY warranty requirements (see Table II.1). The mismatch resulted because their study was based on an earlier CARB staff proposal (CARB, 2019) versus the endpoints that were ultimately proposed and approved for adoption by the Board.

Table IV.C.1. Conditions assumed in ACT's warranty cost estimation

MY	2027 and 2031
Baseline warranty periods	2 years / 250,000 miles
Production volume	Nationwide and California only
Discount rate	2%, 3%, 7%, and Weighted Average Cost of Capital 10%

2. Estimated cost

Table IV.C.2 and Table IV.C.3 summarize the estimated incremental indirect cost to meet MY 2027 and MY 2031 standards assuming a 7 percent discount rate with California and national volumes, respectively. The costs for "Warranty on new technology" and "Warranty Step 2" combined were $7,227 for California-only production, which was 7 times higher than CARB's Step 2 warranty cost ($1,104).

Table IV.C.2. Summary of ACT's incremental indirect costs for HHDD at 7% discount rate (California volume)

Indirect Cost to Manufacturers	MY2027 from MY2018 baseline	MY2031 from MY2027 baseline	Sum
Research and development costs	$26,029	$169	$26,198
Warranty on new technology	$1,713	$0	$1,713
Warranty Step 2	$2,562	$2,952	$5,514
Useful life extension	$7,622	$6,947	$14,569
Compliance program costs	$2,023	$0	$2,023

Table IV.C.3. Summary of ACT's incremental indirect costs for HHDD at 7% discount rate (National volume)

Indirect Cost to Manufacturers	MY2027 from MY2018 baseline	MY2031 from MY2027 baseline	Sum
Research and development costs	$1,900	$9	$1,909
Warranty on new technology	$1,506	$0	$1,506
Warranty Step 2	$2,258	$2,663	$4,921
Useful life extension	$6,445	$5,524	$11,969
Compliance program costs	$125	$0	$125

D. EMA's analysis

1. Aggregated incremental costs of Step 1 warranty

As part of Goal #1, CARB staff described the cost estimation methodology used for Step 1 warranty in detail in several work group meetings. The work group members suggested that staff compare CARB staff's estimated Step 1 warranty cost (i.e., $285) with the average price increase for MY 2022 products as compiled by EMA. EMA gathered, aggregated, and averaged the available cost data of Step 1 warranty (email dated June 18, 2021) and reported that the incremental costs were approximately $3,750 for larger 15 L engines, $2,500 for 11-13 L engines, and $1,400 for medium heavy-duty (MHD) engines. The estimated average cost increases did not include OEM mark-ups or Federal Excise Tax (FET) impacts. CARB staff considered $2,500 for 11-13 L engines to be most relevant to this report because the warranty cost estimation by the National Renewable Energy Laboratory (NREL) for 12-13 L with approximately 475 horsepower (hp) was the representative HHDD engine platform (NREL, 2020). NREL stated that although they initially planned to survey costs for 12 L and 15 L engines for the HHDD category, industry requested NREL to consolidate engine platforms to make the burden of calculating incremental costs for surveys manageable. Industry agreed that 12-13 L represented the HHDD category based on the current trends of increased power density.

The difference between the Step 1 incremental cost reported by EMA (e.g., $2,500 for 11-13 L engine) and CARB's estimate ($285 for HHDV) is mostly due to the different assumptions regarding the incremental warranty coverage. As shown in Table IV.A.2, CARB considers that most owners voluntarily purchase longer warranties beyond the current regulatory requirements. Also, CARB used the EMFAC model to quantitatively determine the limiting factor of warranty requirements (miles, years, or hours) for each vehicle subcategory. Therefore, CARB estimated that when the regulatory warranty requirements extend from 100,000 miles/5 year/3000 hours to 350,000 miles/5 year for MY 2022-2023, the miles driven during the warranty periods will only increase by 32,100 miles (see section IV.A.2 for more details), as opposed to the apparent 250,000 miles that would increase from 100,000 to 350,000 miles.

Hypothetically speaking, if the OEMs used the same failure rates and the repair costs as CARB but assumed a 250,000 increase in miles covered under warranty (i.e., from 100,000 to 350,000 miles), as opposed to CARB's estimate of 32,100 miles, the estimated incremental warranty costs would be $2,219 (i.e., $285 * 250,000 miles/ 32,100 miles), an increase of a factor of eight. During CARB staff's interviews with OEMs, one indicated that their volume-weighted average of the incremental warranty cost for MY 2022 HHDD was approximately $2,000 (this price did not include OEM markup or financing), which indicated that on a per-mile basis, CARB and the OEM's MY 2022 warranty costs were in reasonable agreement. The

apparent cost difference can be attributed to whether extended warranties purchased voluntarily should be included in the baseline. CARB staff believes it was reasonable to include them because it represented the status quo before the rulemaking. Furthermore, title 13, California Code of Regulation, section 2036(c) requires emission warranties to be no less than the basic mechanical warranty that the manufacturer provides (with or without additional charge) to the purchaser of the engine. Therefore, the extended basic mechanical warranties should be considered as the regulatory baseline.

2. EMA's analysis of aftermarket warranty price information

EMA carried out an alternative cost estimation of Step 2 warranty based on their analysis of confidential price information from a third-party aftermarket warranty provider. EMA used two different baselines: one using the OEM-offered base warranty (5 years / 250,000 miles) as the baseline and another using Step 1 Warranty (5 years / 350,000 miles) as the baseline. EMA assumed that the warranty endpoint was 10 years / 600,000 miles, neglecting the 30,000-hour limit. This section uses the latter analysis. However, CARB's Step 2 Warranty cost estimate included a 30,000-hour limit. To protect the confidentiality of the aftermarket warranty information, the details of specific warranty plans were removed. The major assumptions of EMA's calculation process are summarized below:

- The baseline is the Step 1 Warranty: 5 years / 350,000 miles.
- To calculate the incremental warranty cost between 5 years / 350,000 miles and 10 years / 600,000 miles, the cost for warranty for an additional 5 years and additional 250,000 miles needed to be estimated. EMA used confidential aftermarket warranty pricing information (including deductible costs) to calculate the incremental warranty cost. Since an exact match was not available in the available aftermarket warranty plans, EMA used the warranty price for 50 percent of 2 years /200,000 miles plan + 50 percent of 3 years / 300,000 miles plan, assuming mileage is the limiting factor determining the price.
- EMA made assumptions that aftermarket warranty prices would be marked up 20 percent for profit and vehicle owners pay deductible fees for a certain number of repairs. The incremental warranty cost was estimated to be $5,340.
- The lower NOx standards were assumed to lead to a 20 percent increase in repair cost because (1) the tighter control limits and OBD strategies drive higher OBD MIL-on frequency, (2) there are additional failures due to components that indirectly contribute to MIL-on, and (3) unit cost increases due to longer useful life.
- EMA assumed that the cost of the current emission-related components (ERCs) meeting the current federal requirements (US10 ERCs) was $10,000. The new ERCs for meeting MY 2027 standards was estimated to cost $4,580 (i.e., 46 percent of US10 ERCs cost) based on an on-going study contracted by EMA.

- When the new ERCs were included in the warranty coverage, the costs for the baseline warranty and the additional warranty both increased by 46 percent, assuming linearity between component costs and repair costs.
- New technology was assumed to experience 20 percent higher fail rates in the early years of production. For example, if a mature component has a 3 percent fail rate, the product will have a 3.6 percent fail rate in early years.

Using these assumptions, EMA calculated the incremental warranty cost in terms of the current technology package meeting the future lower NOx standard (US10, low NOx) and the new technology:

$$[\Delta\, warranty\ cost] = [\Delta\, warranty\ cost]_{US10,lowNOx} + [\Delta\, warranty\ cost]_{New}.$$

(Equation IV.2)

The incremental warranty cost for the current technology was affected by the assumed 20 percent low NOx factor:

$$[\Delta\, warranty\ cost]_{US10,lowNOx} = [Baseline\ warranty\ cost] * 0.2 + [\Delta\, warranty\ cost]_{US10} * 1.2,$$

(Equation IV.3)

whereas the incremental warranty cost for the new technology was assumed to be 46 percent of US10 warranty costs with the assumed 20 percent new technology factor:

$$[\Delta\, warranty\ cost]_{New} = ([Baseline\ warranty\ cost] + [\Delta\, warranty\ cost]_{US10}) * 0.46 * 1.2.$$

(Equation IV.4)

Using the equations above, EMA estimated the incremental warranty cost for the existing technology and the new technology would be $7,408 and $5,683, respectively, totaling $13,091, which is 12 times higher than CARB's Step 2 warranty cost estimate.

E. CARB's analysis of the difference between CARB and NREL/ACT Research/EMA's estimates

1. Major causes of the discrepancy

CARB staff evaluated the three warranty cost estimation methods provided by NREL, ACT Research, and EMA, and conducted a comparison and analysis of assumptions and costs. CARB staff believes that CARB's method is reasonable and defensible and has identified the following key areas where CARB and NREL/ACT Research/EMA have differing viewpoints.

a) **Should optional warranties be included in the baseline?**

To estimate the overall cost impact of the rulemaking, CARB's baseline warranty considered those owner/operators and fleets who voluntarily purchased optional warranties (e.g., 5 years / 500,000 miles) longer than the regulatory warranties since they would not be directly impacted by the rulemaking. ACT Research's cost estimate, on the other hand, considered 5 years / 250,000 miles as the baseline for the entire vehicle population. CARB's higher baseline correctly leads to the lower incremental costs. CARB's approach more accurately represents the average baseline in the entire state and therefore is more appropriate for the rulemaking.

b) **How should warranty periods be quantified?**

Since warranty coverage may be limited by years, hours, or miles, a challenge arose when comparing the coverage of two warranty periods with different ratios of years: hours: miles, especially when there was no hour limit in one case (e.g., MY 2022 vs. MY 2031). CARB's approach was to estimate the miles driven over each of the year- and hour-limitations to find the miles covered under warranty. For example, the regulatory warranty period in MY 2022 is 5 years / 350,000 miles and MY 2031 warranty period is 10 years / 600,000 miles / 30,000 hours. In terms of years alone, the warranty period increases by a factor of 2 (= 10/5) and in terms of miles a factor of 1.7 (= 600,000/350,000). However, when the hour limit is also considered using EMFAC simulations, the relative increase in coverage from MY 2022 to MY 2031 in terms of miles covered under warranty is only a factor of 1.4 (=399,843/288,692). CARB's small relative increase in warranty coverage contributed to its low-cost estimate. CARB's approach is the most transparent in terms of how years, miles, and hours are considered in quantifying the warranty coverage.

c) **What is the cost of current warranties?**

CARB staff estimated the baseline repair costs for individual engine and aftertreatment components by analyzing repair shop data and by having discussions with manufacturers and service providers and then considering the finance costs for a 5-year and 6 percent loan to the repair costs. EMA used aftermarket warranty prices as the basis for estimating the incremental warranty cost for the current ERCs up to 10 years / 600,000 miles. No details

regarding cost estimation methods were available in the NREL and ACT reports as they were CBI.

CARB staff thinks its approach is reasonable given the unique circumstances of aftermarket warranties. For instance, aftermarket warranty providers may need to obtain parts from OEMs. Also, their customers may be disproportionately high-mileage drivers who accumulate mileages well over the current full useful life and expect frequent failures (because such drivers would be those who would most likely choose to buy an aftermarket warranty). Also, there is no basis for the 20 percent markup assumed in EMA's analysis of the aftermarket warranty price.

d) **Will the lower NOx standards and new technology increase warranty costs?**

EMA's analysis assumed that the lower NOx standards would lead to an approximately 20 percent increase in warranty cost and the introduction of new technology will lead to a 46 percent increase in the baseline and incremental warranty cost because of additional components covered under warranty. Also, the new technology was assumed to have a 20 percent higher failure rate in the early years. In ACT's analysis, the new technology was estimated to contribute to 24 percent of the overall incremental cost in California-only production.

CARB assumed that the additional costs for meeting the low NOx standards and durability will be accounted for in the R&D cost, not warranty cost, since the intent of warranty provisions is to protect the consumer from unforeseen production errors (e.g., a batch of improperly tempered steel, defective computer memory, bad solder joints, improper installation, etc.). CARB assumed that any potential increase in costs due to the lower NOx standard and new technology such as higher unit prices of emission-related components will be offset by gradual improvement in existing technology (e.g., early detection of failures by OBD), which was not accounted for in NREL/ACT Research/EMA's cost estimation. CARB staff believes that the comprehensive requirements of the Omnibus Regulation, including a more robust durability demonstration program, will ensure components will be designed to be more durable even under the lower NOx standard.

In addition, in response to EMA's comments on the draft report (Appendix G), CARB staff performed an additional sensitivity analysis evaluating the assumption of the warranty costs for new technology and estimated that if the warranty costs for new technology were included, it would increase the estimate of Omnibus Regulation costs by about 11 percent. The hypothetical increase is well within the bounds of the previous CARB Staff Report sensitivity analysis that incorporated the incremental warranty costs from the NREL report (CARB, 2020; see chapter IX.F). Therefore, staff concludes that even if higher warranty cost estimates due to new technologies were included, it would not have changed the staff proposal. More details of the additional analysis are shown in Appendix I.

2. Analysis of alternative scenarios

To better understand how each of the different assumptions made by CARB and EMA contributed to the warranty cost discrepancy, alternative scenarios were considered as summarized in Table IV.E.1. and Figure IV.E.1. For reference, scenario #1 is EMA's analysis based on aftermarket warranty pricing and #10 is CARB's Step 2 warranty incremental cost. The ratio of EMA's analysis to CARB's Step 2 is 11.9. The percentage change depends on the order of the scenarios and therefore should be considered as a rough guide only for evaluating the impact of each assumption. The waterfall chart shows that the assumptions regarding new technology and lower NOx standards (scenario #7, 8, and 9) have the biggest relative effect on the difference between CARB and EMA's estimates.

Table IV.E.1. Incremental costs of alternative scenarios applied to EMA's warranty cost calculation method

#	Scenarios	Incremental cost	Difference from previous scenario	Relative decrease from previous scenario
1	***EMA's analysis based on aftermarket warranty pricing***	$13,091	-	-
2	After using EMFAC-based incremental mileage without considering hour limit	$8,107	-$4,984	-38.1%
3	After using EMFAC-based incremental mileage considering hour limit (i.e., same incremental mileage as CARB)	$5,820	-$2,286	-28.2%
4	After increasing assumed markup of aftermarket warranty from 20% to 45%	$4,522	-$1,298	-22.3%
5	After assuming zero deductible for $300	$3,752	-$770	-17.0%
6	After assuming zero deductible	$3,624	-$128	-3.4%
7	After removing 20% elevated failure rate for new technology	$3,318	-$306	-8.4%
8	After removing 20% elevated failure rate at 0.02 g/bhp-hr NOx standard	$2,649	-$669	-20.2%
9	After removing additional warranty cost for new technology	$1,119	-$1,530	-57.8%
10	***CARB Step 2 Warranty (MY 2027 & 2031)***	$1,104	-$15	-1.3%

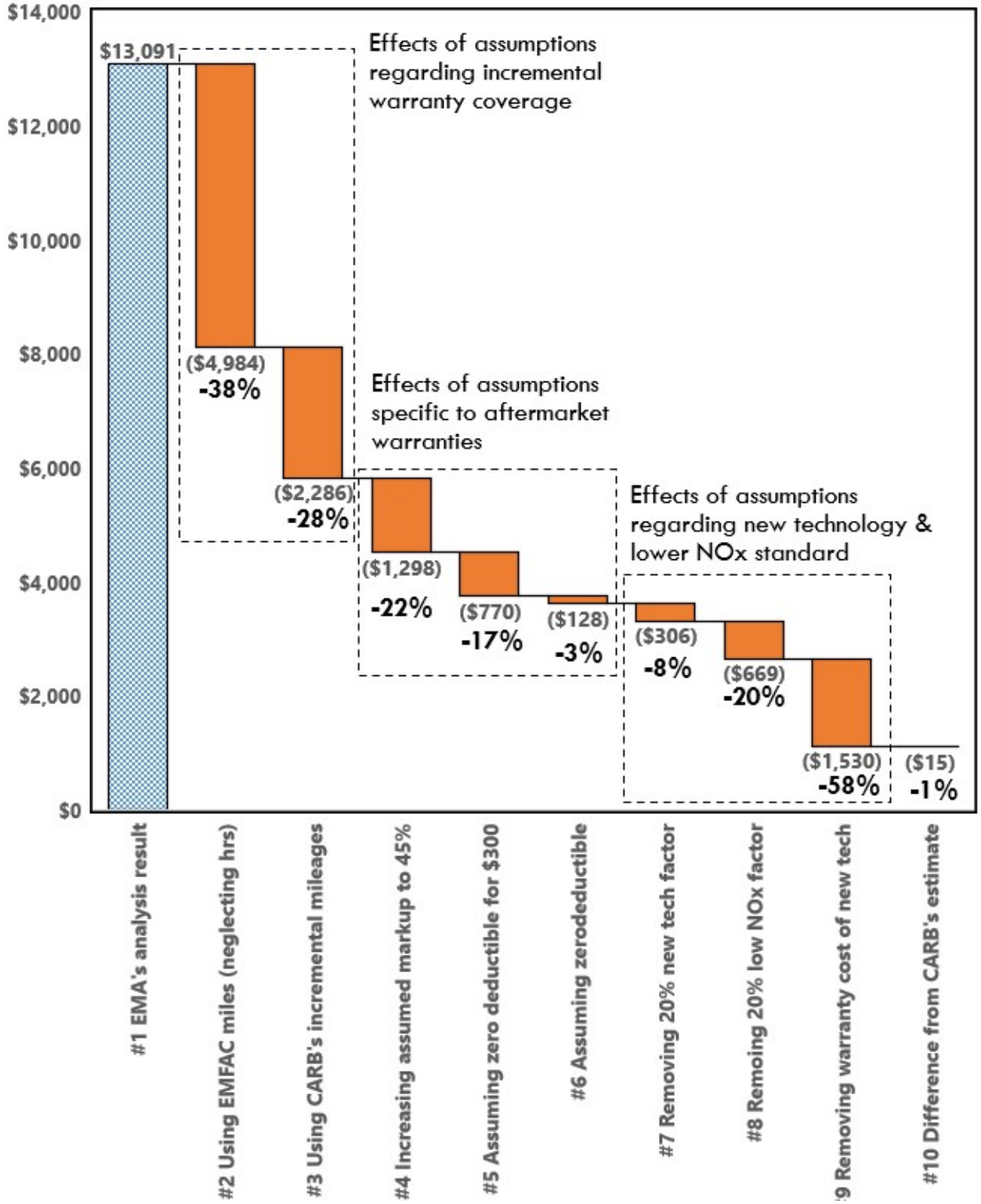

Figure IV.E.1. Effects of different assumptions on EMA's warranty cost estimates. The x-axis label corresponds to scenarios in Table IV.E.1.

Effects of assumptions regarding incremental warranty coverage (scenarios #2 and 3):

These calculations highlight the impact of accounting for the extended warranties purchased voluntarily. Scenario #2 implements CARB's calculation method of incremental miles covered under warranty using EMFAC simulations. The baseline scenario assumes that 40 percent of owners purchase 5 years / 500,000 miles warranty and 60 percent have Step 1 warranty (5 years / 350,000 miles). The average miles covered under warranty in this baseline is 288,692 miles (see section IV.A.3.b). The warranty end-point of scenario #2 assumes 10 years/600,000 miles neglecting a 30,000-hour limit consistent with EMA's assumption (section IV.D.2). To evaluate the effects of neglecting the hour limit, CARB staff estimated the average miles covered under warranty in MY 2031 without the hour limit in Table IV.E.2 shown below. The weighted average miles covered under warranty without the hour limit is 443,508 miles, in contrast to 399,843 miles that account for an hour limit (section IV.A.3.c). This means that in scenario #2 with a 10 year / 600,000 miles warranty, the average incremental miles covered under Step 2 warranty is 154,816 miles (i.e., 443,508 – 288,692 miles), as opposed to the apparent increase of 250,000 miles in warranty mileages (from 350,000 to 600,000 miles). Therefore, the warranty cost of scenario #1 ($13,091) is decreased to $13,091 * (154,816/250,000) = $8,107 in scenario #8.

In scenario #3 with 10 years / 600,000 miles / 30,000 hours warranty, the average incremental coverage decreases to 111,151 miles (i.e., 399,843 – 288,692 miles). As a result, the warranty cost is further decreased to $8,107 * (111,151/154,816) = $5,820.

Table IV.E.2. Hypothetical miles covered under Step 2 Warranty (MY 2031+) for EMFAC HHDV categories without 30,000-hour limitation. The shaded cells correspond to the factor determining the miles covered under warranty for each vehicle subcategory.

HHDV Warranty Mileage Estimates in MY 2031 and subsequent					
100% covered to 600,000 miles What if no hour limit?					
Vehicle Subcategory	**Population %**	**10-year mileage**	**30,000 hours equivalent miles**	**Warranty Mileage**	**Miles Covered Under Warranty**
Motor Coach	1.31%	611,967	1,232,271	600,000	600,000
T7 CAIRP	13.15%	800,000	1,232,271	600,000	600,000
T7 CAIRP Construction	1.19%	800,000	516,654	600,000	600,000
T7 Other port	0.70%	765,588	316,440	600,000	600,000
T7 POAK	2.57%	765,588	316,440	600,000	600,000
T7 POLA	7.74%	765,588	316,440	600,000	600,000
T7 Public	11.01%	88,776	604,272	600,000	88,776
T7 Single	11.79%	336,079	823,356	600,000	336,079
T7 Single Construction	8.29%	336,079	516,654	600,000	336,079
T7 SWCV	7.18%	178,500	328,544	600,000	178,500
T7 Tractor	21.75%	765,588	968,762	600,000	600,000
T7 Tractor Construction	5.54%	765,588	516,654	600,000	600,000
T7 Utility	0.27%	85,536	380,066	600,000	85,536
UBUS	7.50%	393,363	301,712	600,000	393,363
Weighted Average Mileage Covered for HHDV MY 2031 and subsequent: 443,508 miles					

Effects of assumptions specific to aftermarket warranties (scenarios #4, 5, 6):

The aftermarket warranty price provided to EMA contained an unknown amount of markup values in addition to labor and parts. EMA assumed that the markup value was 20 percent. In Step 1 Warranty, CARB staff considered up to 45 percent markup. To evaluate the sensitivity of the cost estimate on the unknown markup value, scenario #4 considered the impact of assuming 45 percent markup. Scenario #4 contains deductible costs for each repair. Scenario #5 assumes zero deductible for $300 based on the information provided by J.D. Power Valuation service (Appendix C). Scenario #6 assumes no deductible fee since CARB's method did not consider a deductible cost.

Effects of assumptions regarding new technology and lower NOx (scenarios #7, 8, 9):

As discussed in section IV.E.1.d, CARB staff disagrees with EMA and assumes that the engineering costs for meeting the lower NOx standard and durability requirements will be accounted for in the R&D costs, and gradual improvements in existing technology cancel out

the potential increases in warranty costs of new technology. Therefore, CARB's warranty cost estimate does not include additional warranty costs associated with new technology and 0.02 g/bhp-hr NOx standard.

Also, the additional sensitivity analysis of the warranty costs for new technologies in Appendix I shows that even if higher warranty costs for the new technologies were incorporated, the Omnibus Regulation would continue to be cost-effective, and thus it would not have changed the staff proposal.

F. Conclusion of Goal #1: "Work collaboratively to better understand all of the assumptions made and all of the differences in the various warranty cost analysis methods"

During work group meetings, CARB and industry stakeholders engaged collaboratively to better understand all the assumptions made in CARB's method and multiple methods from NREL/ACT Research/EMA. In some cases, due to CBI, information was not available.

The previous section IV.E.2. identified the key assumptions that led to the discrepancies between CARB and EMA's analyses. The top three contributors to the discrepancies were found to be the following (Effects of all major factors are summarized in Figure IV.E.1):

- Assumed warranty costs for new technology (scenario #3);
- Use of EMFAC-based incremental mileage (including hour limit) (scenario #8,9); and
- Assumed elevated failure rates at 0.02 g/bhp-hr NOx standard (scenario #4).

Although CARB staff does not concur with EMA's methods, CARB staff agrees that the different viewpoints lead to different baseline assumptions that ultimately affect the respective warranty costing methodologies. CARB's method included optional longer warranties in the baseline to assess the impact of the rulemaking on the entire vehicle population. However, it is understandable that individual OEMs would consider the first point they encounter their customers, rather than the average vehicle population and overall cost shifts between operating and capital, which may have led to OEM's higher costs reported to NREL and ACT Research. The differences in major assumptions between CARB, NREL, ACT Research, and EMA are summarized in Table IV.E.3.

Table IV.E.3. Summary of Estimated Warranty Costs and Assumptions

	CARB Step 2 Warranty	NREL	ACT Research	EMA
Incremental warranty cost per HHDD engine[a]	$1,104	$23,061[b]	$7,227[c]	$13,091
Time periods	From MY2022 to MY2031	From MY2018 to MY2027[d]	From MY2019 to MY2031[d]	From MY2022 to MY2031
Warranty coverage baseline	500,000 mi/5 yr (40% of owners);[e] 350,000 mi/5 yr (60% of owners)[e]	Current warranty offered by the OEMs (not provided to CARB)[f]	250,000 mi 2 yr	350,000 mi 5 yr
Warranty coverage endpoints	600,000 mi 10 yr 30,000 hr	800,000 mi 12 yr	800,000 mi 12 yr[g]	600,000 mi 10 yr
Assumed NOx standards, g/bhp-hr FTP/RMC	0.020 @435,000 mi 0.040 @800,000 mi	0.02 @ 1 million mi	0.02 @ 1 million mi[g]	0.020 @435,000 mi 0.040 @800,000 mi

a: Caution must be taken when comparing the different costs because of the differences in the basic assumptions such as the baseline and warranty end-points.
b: Average-cost diesel technology package 12-13 L with CA-only volume
c: HHDD at 7% discount rate with CA-only volume
d: The baselines of NREL and ACT Research are before Step 1 warranty becomes effective (MY 2022), which overemphasizes the discrepancy between CARB and NREL/ACT Research.
e: Assumes no preference for regulatory vs. voluntary warranty
f: Each OEM chose their own 2018 baseline. It is unknown whether the baseline was CARB-warranty or OEM-provided base warranty because details are confidential.
g: CARB staff asked ACT research for clarification but did not receive a response. These numbers were based on work group members' suggestions.

In conclusion, major reasons why CARB's warranty costs are lower than industry's include the following:

- CARB's method includes the optional longer warranties in the baseline which reduces the cost impact of the rulemaking. CARB staff believes it is critical to include the optional longer warranties in the baseline to calculate the statewide cost impact of the rulemaking.

- CARB's method uses the EMFAC model to identify the factor that limits the warranty period (years, hours, miles) whereas NREL/ACT Research/EMA did not consider hours. CARB's method is the most transparent in terms of how years, hours, and miles are considered in determining the warranty coverages.

- CARB's method assumes the repair costs per miles covered under warranty stay the same after introduction of lower NOx standards and new technologies because a future technology package must be designed to be durable through its useful life, and the R&D cost is counted as useful life cost. CARB staff believes this assumption is consistent with warranty's intent to cover only the defects, not failures of components that are not designed to be durable.

V. Goal #2: Gather available data for heavy-duty vehicles to quantify the residual warranty value to the second and subsequent owners.

As the regulatory warranty periods are lengthened through Step 1 and 2, it is likely that more vehicles produced under these newer warranty requirements will be later re-sold in the secondary market as used vehicles with a portion of the lengthened warranty period coverage remaining (i.e., residual warranties). To better understand the secondary market value of such residual warranties, an on-line survey was collected from heavy-duty vehicle owner/operators and dealers. The survey results showed that the residual emission warranties add significant resale values to used vehicles.

A. Methods

CARB staff drafted a survey, which was then provided to all work group members to review. Comments were provided by EMA, Cummins, and ATA. CARB staff then did a survey pre-test of several fleets to get preliminary feedback. Where questions were ambiguous, CARB revised the survey. A set of survey questions were finalized (Appendix D) and implemented via a SurveyMonkey® questionnaire. CARB staff sent out emails to 59,424 owner/operators and 41 dealers. CARB staff obtained the email addresses of owner/operators from CARB's Truck and Bus Regulation Reporting (TRUCRS) database and dealers. 1,295 raw responses were acquired. After screening responses that spent less than 1 minute and answered only one question, the total screened responses were 699. Five dealerships responded. While there is higher uncertainty in the dealership estimated residual warranty values than from the owner/operator responses, these dealer responses provide an important view into sellers' understanding and attitudes regarding residual warranty value.

B. Survey Results

The following figures characterize the owner/operators who responded to the survey based on their fleet size (Figure V.B.1), vehicle weight class (Figure V.B.2), fuel type (Figure V.B.3), fleet service type (Figure V.B.4), vehicle age (Figure V.B.5), how emission control-related maintenance is handled (Figure V.B.6), how emission-related warranty repairs are handled (Figure V.B.7), and whether they purchase vehicles new or used (Figure V.B.8). The x-axes of the following plots generally represent the percentage of survey responses. For example, responses from single vehicle owner/operators and 50+ vehicle fleet weigh equally.

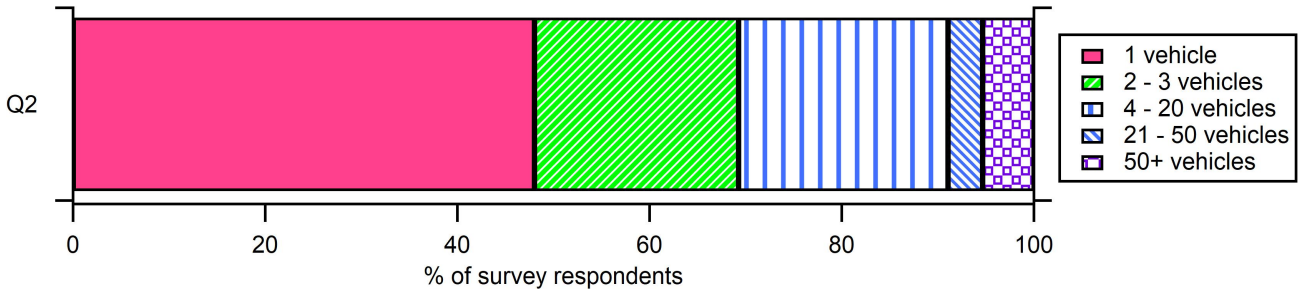

Figure V.B.1. How many heavy-duty vehicles (gross vehicle weight rating > 14,000 pounds) are in your fleet? (Question #2)

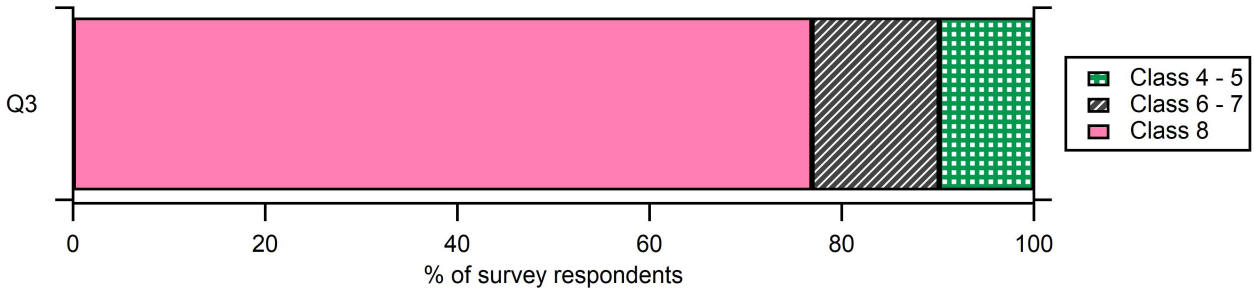

Figure V.B.2. What weight class are your vehicles (i.e., what gross vehicle weight rating (GVWR))? (e.g., do you have 100 percent class 8 or a mixture of classes, indicate the percent below with the total adding to 100) (Question #3)

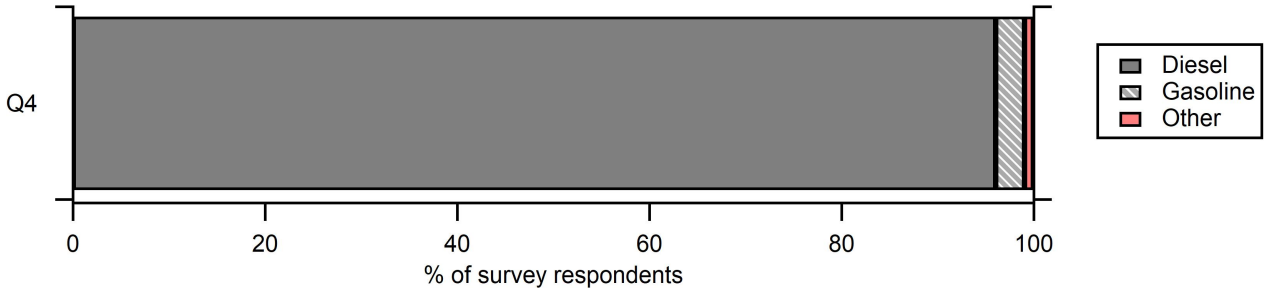

Figure V.B.3. What truck fuel types are used in your fleet? Indicate the percent below with the total adding to 100. (Question #4)

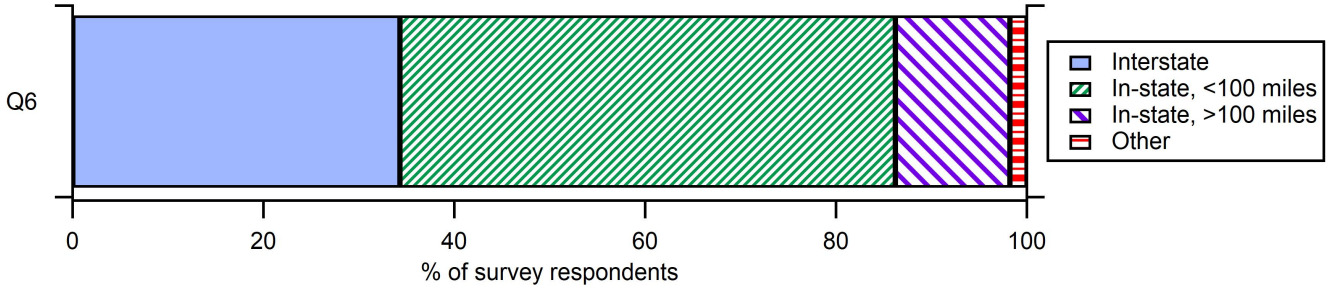

Figure V.B.4. List the approximate percentage of your fleet by service type(s). The percent below should add to 100. (Question #6)

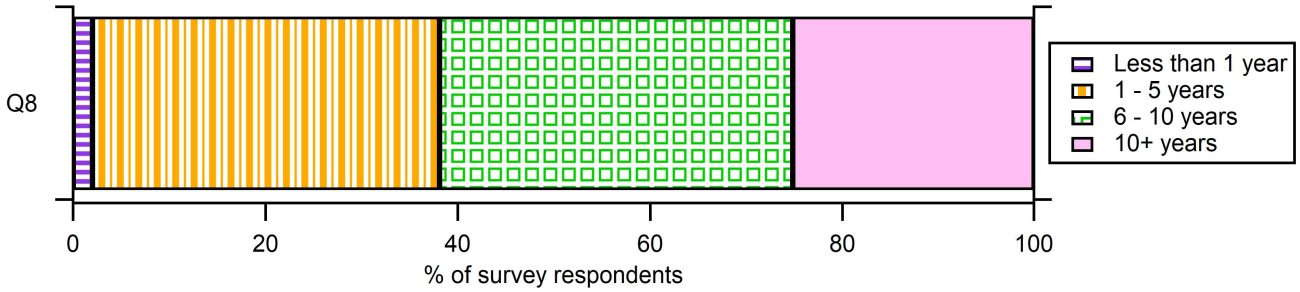

Figure V.B.5. What is the average age of heavy-duty vehicles in your fleet? (Question #8)

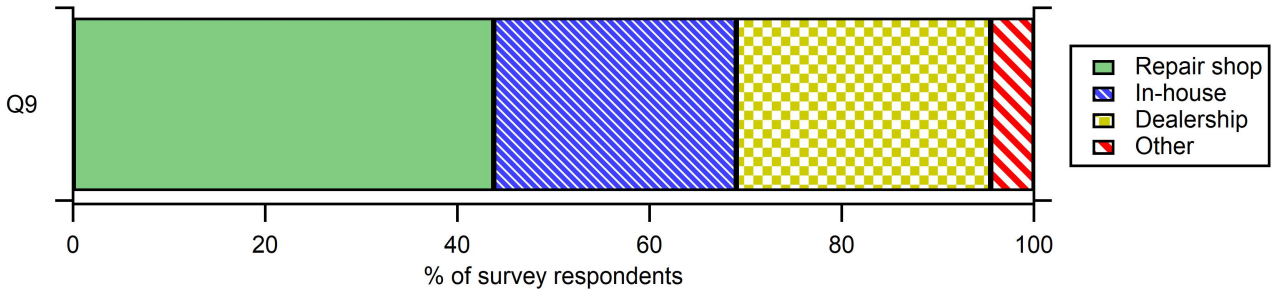

Figure V.B.6. How do you typically handle emission control-related (EGR valves, turbochargers, NOx sensors, SCRs, DPFs) maintenance (e.g., adjustments, cleanings, replacements)? Choose as many as applicable. (Question 9)

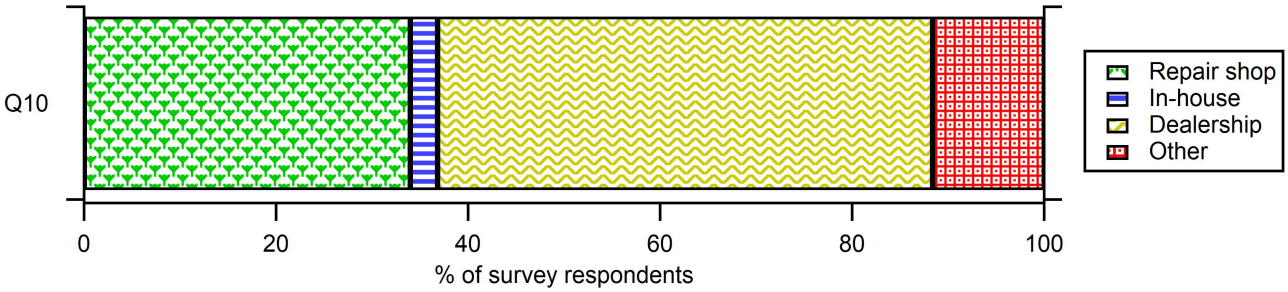

Figure V.B.7. How do you handle emission-related warranty repairs? (Question 10)

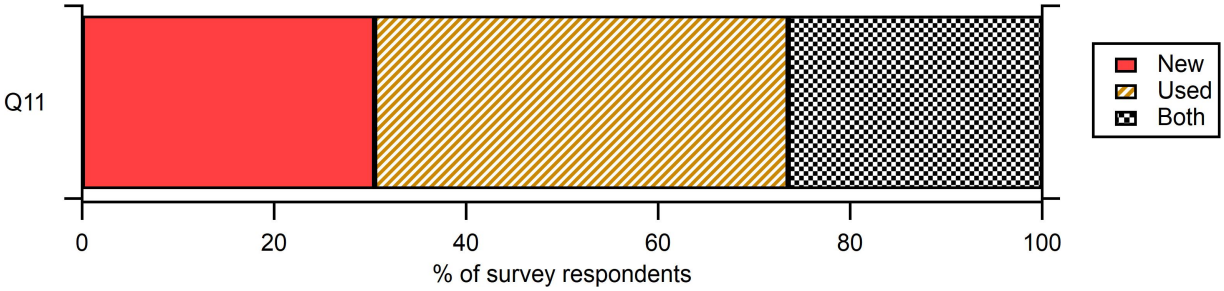

Figure V.B.8. Do you typically buy your vehicles new or used? (Question 11)

To better understand the value of residual warranties from sellers' and buyers' perspectives, the following figures compare responses from those who typically purchase vehicles new, used, or both (new and used). Figure V.B.9 shows that most used vehicle owners are either unsure about the warranty or do not have warranties ("Not Applicable").

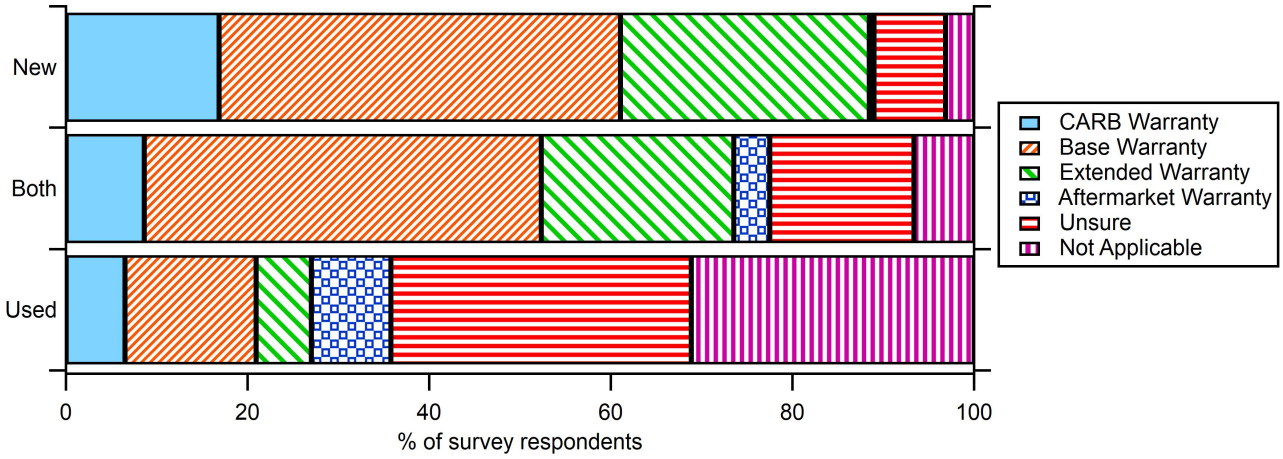

Figure V.B.9. What is your typical warranty type? (Question #12, #19, and #31)

Figure V.B.10 shows that for most owner/operators, cost of repairs and dependability determine how long they keep their vehicles. A small number of respondents indicated that they have set numbers of years/miles for retiring the vehicles from their fleet. Approximately half of respondents expect to hold on to their vehicles longer because of CARB's longer emission warranty periods (see Figure V.B.11). More than half of respondents sell their vehicles through private sales (see Figure V.B.12).

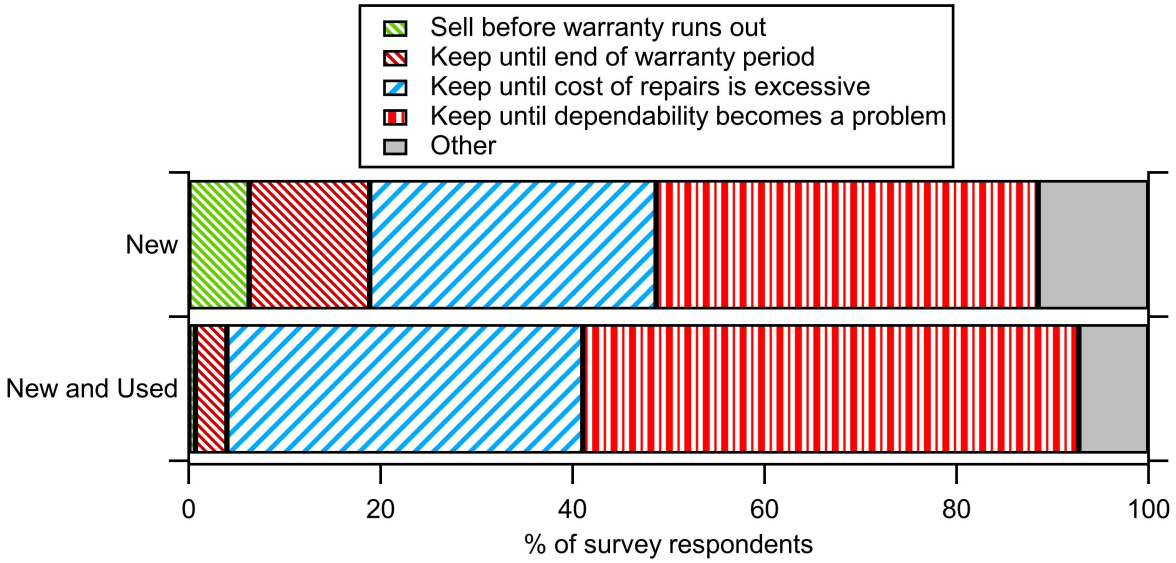

Figure V.B.10. How long do you typically keep your vehicles? (Question #13 and #32)

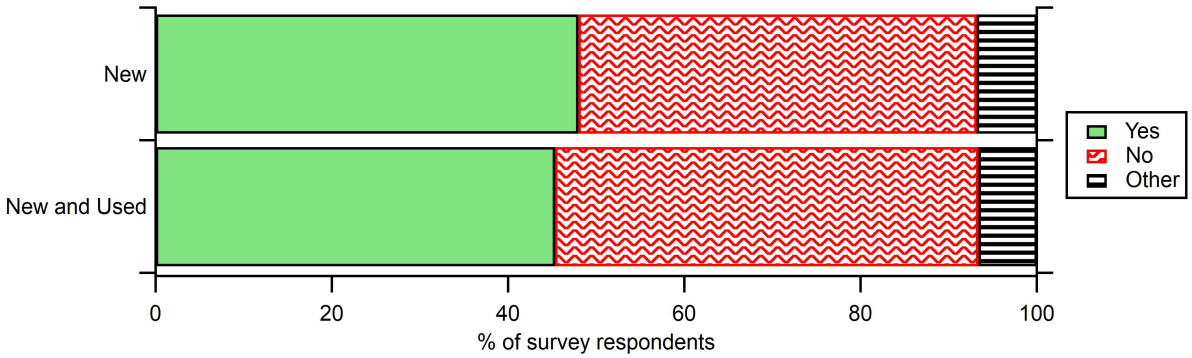

Figure V.B.11. Do you expect this practice will change because of CARB's longer emissions warranty periods? In other words, will a longer emissions-related component warranty (assuming all other warranties remain the same) cause you to hold on to the vehicles longer? (Question #15 and #34)

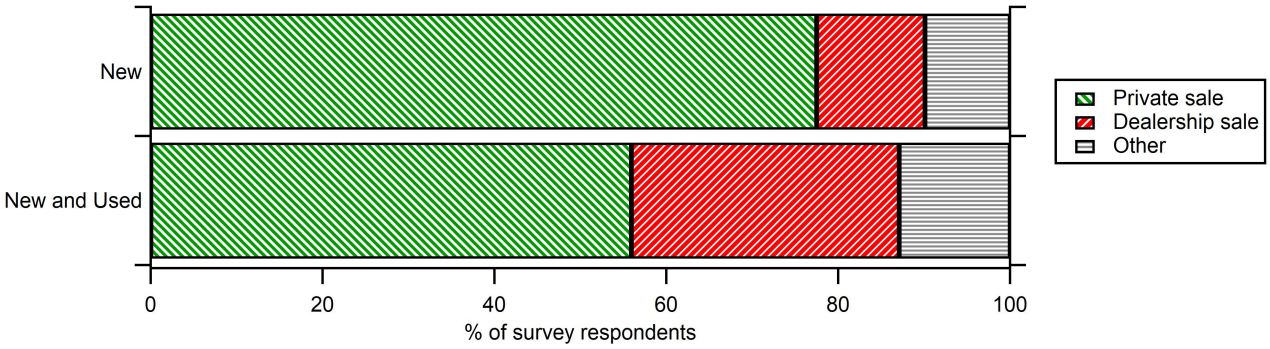

Figure V.B.12. Where do you sell your vehicles? (Question #16 and #35)

To obtain the estimated values of the residual warranties from those who typically purchase vehicles new, used, or both (new and used), as well as from dealers, a similar set of questions was created with slightly different wording. For example, Question #17 is for new vehicle purchasers:

> ***Question #17 for new vehicle purchasers:***
> Hypothetically speaking, if you are selling a class 8 vehicle with 2 years/200,000 miles of remaining emission-related component warranty that covers everything related to the malfunction indicator light (MIL), how much more would you expect to get for a vehicle with the remaining emission warranty compared to one without it (the same production year, mileage, planned future use)? Please consider the vehicle class and fuel type that best represents your fleet.

a. $0 - 999
b. $1,000 – 1,999
c. $2,000 – 2,999
d. $3,000 – 4,999
e. More than $5,000 (please specify)

For used vehicle purchasers, the question was rephrased to ask how much of a higher price they would be willing to pay using the same multiple choices. The survey did not evaluate the impact of different year-to-mile ratios (e.g., 6 months/200,000 miles, etc.) because it would have added complexity to the survey process. When analyzing the results, the mid-point values (e.g., $2,500 for $2,000 – 2,999) were taken and the 95 percent confidence intervals (CI) were calculated as

$$CI = \bar{x} \pm t \times \frac{s}{\sqrt{n}}, \qquad \text{(Equation V.5)}$$

Where $\bar{x}$ is the mean, *t* is the corresponding *t*-value (two-tailed, significance level 0.05), *s* is the standard deviation, and *n* is the sample number.

Figure V.B.13 summarizes the estimated values of residual warranties. The responses were grouped into new vehicle purchasers (those who sell used vehicles), used vehicle purchasers (those who buy used vehicles), new and used vehicle purchasers (as sellers), and new and used vehicle purchasers (as buyers). Responses from five dealers are also included for completeness, but the small sample number leads to the large error bars. The results in Figure V.B.13 indicate that the residual warranties have significant values, approximately 1 cent/mile, generally within a factor of two. Also, it was found that the sellers tend to value residual warranty more than buyers do.

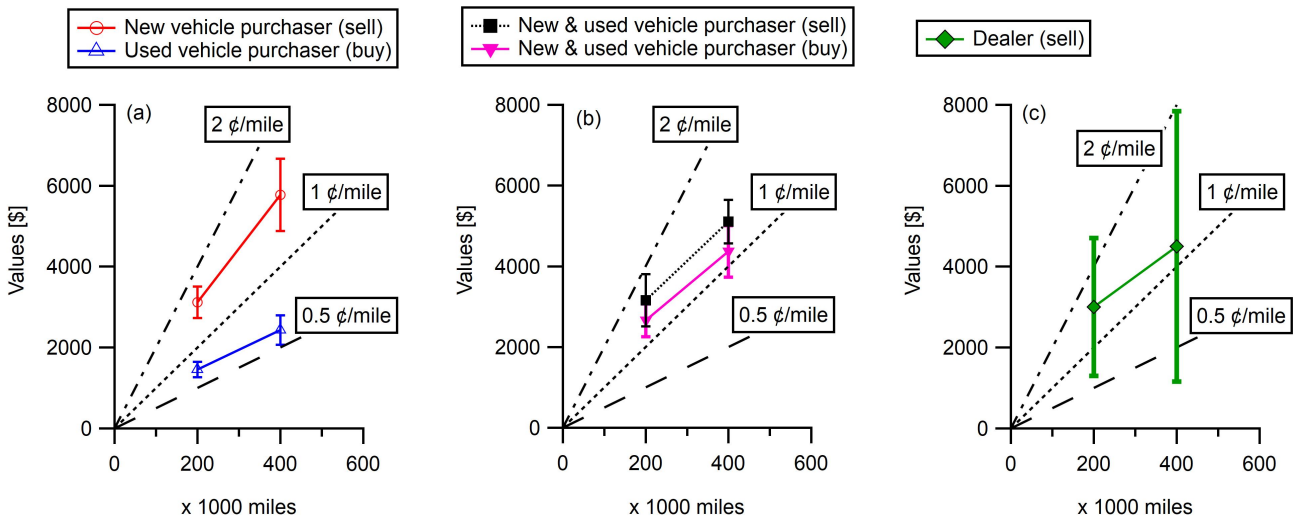

Figure V.B.13. The expected values of residual warranties as a function of remaining warranty mileages: (a) New vehicle purchasers and used vehicle purchasers, (b) New and used vehicle purchasers as sellers and as buyers, and (c) Dealers (Question #17, #18, #21, #22, #29, #30, #36, and #37).

C. Conclusion of Goal #2

The survey results collected from 694 fleets and owner/operators indicate that residual warranties have significant value, approximately 1 cent/mile. Those who sell used vehicles tend to put higher price values on the residual warranties than those who buy the used vehicles. Approximately half of the respondents expect to hold on to vehicles longer as CARB extends warranty periods. These results suggest that higher initial vehicle purchase prices are likely to be passed on to the subsequent vehicle owners, which potentially reduces the cost impact that the Omnibus Regulation warranty amendments may have on first owners.

VI. Goal #3: Gather available data on usage patterns and duty cycles from the second and subsequent owners of vehicles used in a variety of applications to assess wear characteristics.

MECA and MEMA represent the suppliers of emission control components used by OEMs, and specifically requested that Goal #3 be included in the warranty study. MECA and MEMA representatives requested that CARB staff identify and provide references to previous studies relevant to Goal #3. The following references were provided to MECA and MEMA:

- "Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles" by the Bourns College of Engineering, Center for Environmental Research & Technology (CE-CERT) (CE-CERT, 2017)
- CARB EMFAC Fleet Database: *https://arb.ca.gov/emfac/fleet-db*
- "Updates to Heavy-Duty Emission Deterioration in EMFAC" by Eastern Research Group, Inc (ERG) (ERG, 2020)
- "Heavy-Duty Vehicle Accrual Rates" (ERG, 2019)

MECA and MEMA members found the references helpful in longer life design of aftertreatment. Engine component suppliers indicated that further studies are needed to understand wear characteristics of used (not failed parts) parts such as injectors, turbos, and EGR coolers. Catalyst suppliers indicated that in future studies for EMFAC model updates, it would be useful to collect the following:

- Mileages of the vehicles studied;
- Location of the SCR temperatures (inlet or outlet);
- Season of study, summer versus winter; and
- Oil and fuel usage.

MECA and MEMA members wished to have information on what failed, when did it fail, what was the duty cycle during its life, mileage at the time of failure, and OBD information at the time of failure and would like to explore obtaining this data via CARB warranty reporting. They also wanted to have the parts for post-mortem analysis.

Staff concluded that there is variation in the post-mortem failure data and analysis that their members receive. While some members are privy to this information, smaller suppliers are not. Although additional requirements for submitting failure-related information may benefit some part suppliers, CARB is currently not storing this information. In addition, it would take up to five years for data to become available, and therefore it is unlikely that part suppliers

could quickly and comprehensively obtain relevant information. To provide more immediate information to part suppliers, CARB staff offered to analyze and provide common failure modes reported to CARB through FIRs. The result is summarized in section VIII (Goal #5).

VII. Goal #4: Make a plan for gathering and sharing data between OEMs and suppliers as new technologies to meet MY 2024 and MY 2027 standards are rolled out.

To achieve Goal #4, CARB staff drafted a survey that covered a broad range of issues ranging from the information exchange between OEMs and suppliers that occurs during the development process in designing specifications for components including questions on how information is shared with regards to warranty claims and who pays for the cost of replaced components. However, upon discussion with MECA representatives, CARB staff was advised not to conduct the survey. Developing specifications for components that last the full useful life and agreeing to responsibility with regards to warranty is tied to individual business agreements between suppliers and their customers that depends on many different factors. Every OEM handles it differently so a supplier that provides components to different OEMs may have very different arrangements based on their business relationship. Each OEM will likely have different warranty arrangements with each supplier based on the value of the component that is being supplied, the relative size of the business and other factors as well. Because of the diversity of these business arrangements, MECA representatives thought it would be difficult to make a conclusion from a potential OEM-supplier survey. As a result, a survey was not executed. Therefore, CARB staff concluded that Goal #4 was not feasible to achieve as part of this study. To assist part suppliers in improving the durability of their parts, CARB staff offered to summarize common failure modes as discussed in section VIII (Goal #5). As part of this study, CARB staff met individually with OEMs and confirmed that some of the OEMs are in discussion with suppliers regarding MY 2022 warranty requirements. CARB will continue to monitor the process as the industry prepares to meet MY 2024 and MY 2027 requirements.

VIII. Goal #5: Facilitate discussions between OEMs and emission control component suppliers beyond the current 100,000-mile warranty period.

As noted above regarding Goal #4, MECA representatives advised CARB not to conduct the OEM-supplier survey to achieve Goal #5. Without meaningful data, discussion was very limited.

To provide alternative information useful to suppliers however, CARB staff analyzed the top 3 failure modes for critical emission control components based on FIRs for the 2013-2019 MYs. Light Heavy-Duty Diesel (LHDD), Medium Heavy-Duty Diesel (MHDD), and HHDD engine families were included in the study. The failures of these components occurred within the 5 year/100,000-mile emissions warranty, base engine warranty, or paid extended warranty periods. The top three failure modes were not necessarily ranked in order of most common occurrence. They were based on how frequently engine families experienced a failure mode for a particular emissions control component so that the rankings would not be skewed by engine families with large populations. Conducting an analysis in this manner better represents how parts are failing in the field across many engine families as the results are not weighted by the size of the population of each engine family. For these reasons, this study can be considered more of an engine family-based survey than a quantitative analysis of the highest-ranking failure mode for a particular emissions control component.

It is important to note that manufacturers have different designs for components. Even if manufacturers used the same design for a component from the same supplier, calibrations may be different, and they may be used for different applications which would impact how they could potentially fail. There may even be variability in components used for engines in the same engine family if an improved version of a component is introduced as a replacement part and not equipped on all engines.

Table VIII.1 Common failure modes for critical emission control components determined by examining FIRs for the 2013-2019 MYs

Components	Failure modes
Injector	1. Physical damage due to corrosion 2. Wearing of needle control valve 3. Electrical Issue
SCR	1. Catalyst is deactivated in the presence of water during low to high temperature cycling 2. Software Issue
DEF Pump	1. Particle contamination damaging pumping membrane 2. Software Issue
DEF Dosing Valve	1. Software Issue 2. Clogged Injector 3. Leaking Doser
DPF	1. Excessive soot load leading to cracking 2. Filter Clogged 3. Software Issue
Aftertreatment Hydrocarbon Injector	1. Clogged Injector
EGR Valve	1. Valve sticking due to contamination 2. Software issue
EGR Cooler	1. Cleaning is necessary 2. Thermal fatigue 3. Assembly issues
Fuel Pump	1. Control valve sticking 2. Contaminated fuel
Computer	1. OBD/Software issue 2. Hardware replacement
Turbocharger	1. Cycle fatigue 2. Coolant leak 3. Sector shaft/gear binding
NOx Sensor	1. Moisture contacting sensor element 2. Cracking due to thermal shock 3. Software Issue
PM Sensor	1. Clogged sensor tip 2. Software Issue
Ammonia Sensor	1. Sensor circuit error 2. Rusted/Corroded
Urea Quality Sensor	1. Liquid Ingress 2. Communication Error

IX. Goal #6: Review the results and the suggested next steps from the study.

This chapter summarizes the findings related to each of the first five goals.

Goal #1: Work collaboratively to better understand all the assumptions made and all of the differences in the various warranty cost analysis methods.

Over a nine-month period, the working group met 16 times to work collaboratively and better understand the assumptions in the warranty cost analysis methods. The outcomes of Goal #1 clarified the reasons for the discrepancies between CARB and NREL/ACT Research/EMA's warranty costs. Two major factors are identified:

1) CARB and EMA have different interpretations of the meaning of warranty costs.
   - CARB assumes that a properly engineered technology package should be durable through its useful life. CARB assumes warranty costs cover unforeseen failures of properly engineered parts.
   - EMA expects more failures as new technologies are introduced and NOx standards tightened. It is possible that some manufacturers made similar assumptions when they responded to NREL and ACT Research's surveys although the assumptions made by each manufacturer are confidential.
2) CARB and NREL/ACT Research/EMA have different baselines and incremental warranty coverages
   - CARB's warranty baseline is higher than NREL/ACT Research/EMA because CARB accounts for optional 5 years / 500,000 miles warranties that 40 percent of the vehicle population are expected to have for MY 2022.
   - CARB's warranty endpoint is lower than NREL/ACT Research/EMA because CARB uses the EMFAC model to account for the limiting factors such as years, hours, or miles and the vehicle population.

Because of these fundamental differences in the interpretation of warranty coverages and costs, direct comparison of the warranty costs resulted in a large discrepancy by an order of magnitude.

> ***Suggested Next Step:*** Although CARB and the work group members were not able to agree on which methods should be used generally to estimate warranty cost, it was suggested that future warranty cost estimates clarify key assumptions on the definition of warranty cost (e.g., distinction between useful life cost vs. warranty cost) and how incremental coverage is calculated (e.g., how years/hours/miles limits are treated, etc.) because these assumptions are major sources of the apparent discrepancies.

Goal #2: Gather available data on heavy-duty vehicles to quantify the residual warranty value to the second and subsequent owners.

CARB surveyed and collected responses from 694 fleets and owner/operators as discussed in section V (Goal #2). Results indicate that fleets and owner/operators expect approximately 1 cent/mile (within a factor of two) value in residual warranties. For example, when a used vehicle with 2 years/200,000 miles of remaining emission-related warranty is sold, the owner expects to receive approximately $2,000 as a result of this residual warranty. Also, survey results indicated that approximately half of the fleets/owner/operators expected to hold on to their vehicles longer as CARB extends the warranty periods. These results suggest that higher initial purchase prices are likely to be distributed over longer time periods or passed on to the subsequent owners to some extent, which lessens the impact of the potential price increase.

Suggested Next Step: As warranty periods become longer and more used vehicles are sold with residual warranties in the future, it may be helpful to collect more sales data on the value of residual warranties of actual vehicles in the secondary market.

Goal #3: Gather available data on usage patterns and duty cycles from the second and subsequent owners of vehicles used in a variety of applications to assess wear characteristics.

CARB staff provided MECA and MEMA members useful references for longer-life design of emission-related components.

Suggested Next Step: MECA and MEMA representatives suggested CARB to consider future long-term studies that collect information on:

- Mileages of the vehicles studied;
- Location of the SCR temperatures (inlet or outlet);
- Season of study, summer versus winter; and
- Oil and fuel usage.

Goal #4: Make a plan for gathering and sharing data between OEMs and suppliers as new technologies to meet MY 2024 and MY 2027 standards are rolled out.

In discussions with supplier representatives, CARB staff was advised that OEM-supplier business relationships vary widely and that particular sensitivities exist when it comes to information sharing. Therefore, the group decided that there was not a clear path for CARB to intervene between OEMs and suppliers to facilitate information sharing more than what exists today.

Suggested Next Step: None

Goal #5: Facilitate discussions between OEMs and suppliers beyond the current 100,000-mile warranty period.

As in Goal #4, the group decided that there was not a clear path for CARB to intervene between OEMs and suppliers to facilitate information sharing more than what exists today. To provide alternative useful information to suppliers, CARB staff analyzed available FIRs to determine the top two to three failure modes of critical emission control components. Supplier representatives noted that data generated in Goal 3 is necessary to better understand the failure mechanisms and rates that lead to the top failure modes CARB reports from its summary of warranty data.

Suggested Next Step: None

X. References

(CARB, 2018) Staff Report: Initial Statement of Reasons for Proposed 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=2.14983222.1608313504.1619533513-1362703053.1594203696*

(CARB, 2019) 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, April 18, 2019, *https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdlownox/white_paper_04182019a.pdf*

(CARB, 2020) Staff Report: Initial Statement of Reasons for Proposed Rulemaking, "Public Hearing to Consider the Proposed Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments: Proposed Amendments to the Exhaust Emissions Standards and Test Procedures for 2024 and Subsequent Model Year Heavy-Duty Engines and Vehicles, Heavy-Duty on-Board Diagnostic System Requirements, Heavy-Duty in-Use Testing Program, Emissions Warranty Period and Useful Life Requirements, Emissions Warranty Information and Reporting Requirements, and Corrective Action Procedures, in-Use Emissions Data Reporting Requirements, and Phase 2 Heavy-Duty Greenhouse Gas Regulations, and Powertrain Test Procedures," (Heavy-Duty Omnibus), California Air Resources Board, June 23, 2020. *https://ww3.arb.ca.gov/regact/2020/hdomnibuslownox/isor.pdf*

(CE-CERT, 2017) Collection of Activity Data from on-Road Heavy-Duty Diesel Vehicles, Carb Final Report, Arb Agreement No. 13-301, May 2017, *https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/13-301.pdf*

(EMA, 2020) Comments of the Truck and Engine Manufacturers Association, August 13, 2020. *https://www.arb.ca.gov/lists/com-attach/8-hdomnibus2020-1jACGvmafqDgElXk.pdf*

(ERG, 2019) Heavy-Duty Vehicle Accrual Rates, Carb Final Report, Erg No. 3982. 01. 001, June 14, 2019, *https://ww2.arb.ca.gov/sites/default/files/2021-01/erg_finalreport_hdv_accruals_20190614.pdf*

(ERG, 2020) Updates to Heavy-Duty Emission Deterioration in Emfac, Carb Agreement No. 17aqp006, Report Version 3, July 21, 2020, *https://ww2.arb.ca.gov/sites/default/files/2021-02/carb_hd%20emfac_det_rates_v3_20200721.pdf*

(ISR, 2017) Survey and Analysis of Heavy-Duty Vehicle Warranties in California | 15msc009, Institute for Social Research, California State University, Sacramento, December 2017. *https://ww3.arb.ca.gov/regact/2018/hdwarranty18/apph.pdf*

(NREL, 2020) On-Road Heavy-Duty Low-Nox Technology Cost Study, National Renewable Energy Laboratory, May 2020. *https://www.nrel.gov/docs/fy20osti/76571.pdf*

(Sharp, C., 2021) Further Development and Validation of Technologies to Lower Oxides of Nitrogen Emissions from Heavy-Duty Vehicles. Low Nox Demonstration Program - Stage 3, *https://www.arb.ca.gov/lists/com-attach/79-hdomnibus2020-Uj4AaQB2Aj8FbAhw.pdf*

XI. Appendix

A. Excerpt of the August 27, 2020 board hearing transcript regarding the warranty cost study

The entire transcript is available at *https://ww3.arb.ca.gov/board/mt/2020/mt082720.pdf*

<Mobile Source Control Division (MSCD) Assistant Division Chief Carter>

From page 294 line 24 to page 295 line 25:

> MSCD ASSISTANT DIVISION CHIEF CARTER: Okay. Well, thank you very much. I appreciate that. So I think one of the other issues that was brought up by industry, Cummins in particular, and I think MECA and others, was the warranty implications after 2027, and what the costs associated with those would be.
>
> We're pretty confident in our cost estimates and what we believe is doable in our estimates, that kind of a thing. But on the other hand, we also recognize just the unknown from the industry and from the manufacturers. And So they suggested -- a couple people suggested that perhaps we engage in some sort of a cost study -- a deeper dive cost study. And this would give the information -- more information for the industry to assess what those costs would be. It would also help the industry plan for the warranty costs and warranty associated with it, that kind of a thing.
>
> And from the staff's perspective, we're perfectly open to some sort of a joint study, cooperative study in the next year or so, so we can do a deeper dive. We will learn from it and so will the industry. So just from the staff's perspective, we're certainly fine with that.
>
> We're not -- just to make it clear, there was also a suggestion of delaying the warranty requirements. We're not in favor of that at all. But again, we are certainly in favor of doing some sort of a cost study, joint study with them.

<Vice Chair Berg>:

From page 311 line 14 to page 312 line 4:

> I am concerned with the time frame for 2027 with new technology and a big bump up in warranty. And so I'm supportive of the industry and staff suggestion to undergo a cost study, which would include understanding that interaction between parts manufacturers and the people that put all the parts together to create systems. These are all parts of a warranty issue. But I really want to know that both industry and staff are going to go into that study with an open mind to the outcome. And if it shows that we were -- had it right, then industry is going to get behind it. But staff if it shows that we missed the mark that we're going to come back and do something about it.

> So I think it's only wise to go into such a study if all parties are truly committed to going through that process and honoring the outcome.

<Chair Nichols>

From page 338 line 23 to line 25:

> Sandy raised the warranty study. I think that sounds like that's in the works or will be in the works when this rule passes and we'll accomplish what we needed to accomplish.

B. Excerpt of the email from EMA regarding the warranty cost data from OEMs for Step 1 warranty

Sent: Friday, June 18, 2021 12:31 PM
Subject: Aggregated Average Costs of CARB's First-Step Extended Warranties

As a follow-up to our last call, and based on the available data EMA has gathered, aggregated, and averaged, the cost of CARB's first-step extended warranty will be approximately $3,750 for larger 15L engines, and approximately $2,500 for 11-13 L engines. The cost increase for MHD engines will be approximately $1,400. Please note that these average cost increases do not include OEM mark-ups or FET impacts.

C. Warranty values estimated by J.D. Power Valuation Services

WARRANTY VALUES

Level 1	**48 mo./400,000 miles**	**$6400**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 2	**36 mo./1,000,000 miles**	**$5500**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 3	**36 mo./300,000 miles**	**$5000**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 4	**24 mo./200,000-250,000 miles**	**$3750**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 5	**24 mo./200,000-250,000 miles**	**$3400**

Coverage of internal and external engine components and accessories and transmission.

Level 6	**24 mo./200,000-250,000 miles**	**$2850**

Coverage of internal and external engine components and accessories.

Level 7	**12 mo./100,000-125,000 miles**	**$2500**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 8	**12 mo./100,000-125,000 miles**	**$2100**

Coverage of internal and external engine components and accessories and transmission.

Level 9	**12 mo./100,000-125,000 miles**	**$1750**

Coverage of internal and external engine components and accessories.

Level 10	**6 mo./50,000 miles**	**$1250**

Full driveline coverage (engine, transmission, rear axles), including internal and external engine components and accessories.

Level 11	**6 mo./50,000 miles**	**$1000**

Coverage of internal and external engine components and accessories and transmission.

Level 12	**6 mo./50,000 miles**	**$ 750**

Coverage of internal and external engine components and accessories.

For all warranty levels:

Add	$0 Deductible	**$ 300**
Add	DPF Coverage	**$ 750**
Add	EGR Valve Coverage	**$ 500**
Add	Free Towing Included	**$ 500**
Ded	Without Electronic Engine Controller Coverage	**$ 750**
Ded	Without Turbocharger Coverage	**$ 1000**

For warranty transfers, values may be pro-rated proportionally to the time/mileage remaining in the warranty.

It is at the user's discretion to arrive at a value for other packages not mentioned on this page. Be sure to obtain all available documentation to assist in the appraisal.

D. Residual warranty survey questions

Business category:

1) Please choose your business

- Fleet owner or Owner operator
- Vehicle Dealership

Fleet and Owner/Operators Questions:

2) How many heavy-duty vehicles (gross vehicle weight rating > 14,000 pounds) are in your fleet?

- 1
- 2-3
- 4-20
- 21-50
- 50+

3) What weight class are your vehicles (i.e., what gross vehicle weight rating (GVWR))? (e.g., do you have 100% class 8 or a mixture of classes, indicate the percent below with the total adding to 100)

- GVWR greater than 33,000 lbs (Class 8): _____
- GVWR 19,501 to 33,000 lbs (Class 6 and 7):_____
- GVWR 14,000 to 19,500 lbs (Class 4 and 5):_____

4) What truck fuel types are used in your fleet? Indicate the percent below with the total adding to 100.

- Diesel: _____
- Natural Gas (CNG or LNG): _____
- Gasoline: _____
- Other: _____

5) If "Other", please identify.

6) List the approximate percentage of your fleet by service type(s)? The percent below should add to 100.

- In-state operation & delivery within 100-mile radius from the fleet base
- In-state operation & delivery greater than 100-mile radius from the fleet base
- Interstate operation
- Other (please describe) _____

7) If "Other", please identify.

8) What is the average age of heavy-duty vehicles in your fleet?

- Less than 1 year
- 1-5 years
- 6-10 years
- More than 10 years

9) How do you typically handle emission control-related (EGR valves, turbochargers, NOx sensors, SCRs, DPFs) maintenance (e.g., adjustments, cleanings, replacements)? Choose as many as applicable.

- Do maintenance in-house
- Do maintenance at a repair shop
- Do maintenance at the dealership
- Other (please describe) _____

10) How do you handle emission-related warranty repairs?

- Take vehicles to a repair shop
- Take vehicles to the dealer
- Fleet authorized to do in-house warranty work
- Other (please describe) _____

11) Do you typically buy your vehicles new or used?

- Both (→ Go to question #12-20)
- New (→ Go to question #12-17)
- Used (→ Go to question #18-20)

For new vehicle purchasers:

12) What is your typical warranty type?

- CARB warranty (5 years / 100,000 miles)
- Base warranty provided by the manufacturer/dealer (Example: 2 years / 250,000 miles)
- Extended warranty provided by the manufacturer/dealer
- Aftermarket warranty provided by a third party
- Unsure
- Not applicable (please specify)

13) How long do you typically keep your vehicles?

- Sell before warranty runs out
- Keep until end of warranty period
- Keep until cost of repairs is excessive
- Keep until dependability becomes a problem
- Other (please specify)

14) If you answered, "Sell before warranty runs out", do you typically cash in the remaining warranty (i.e., get a pro-rated refund for the amount of the unused warranty) on the vehicles prior to selling them back to the dealer?

- Yes
- No
- Other (please describe)

15) Do you expect this practice will change because of CARB's longer emissions warranty periods? In other words, will a longer emissions-related component warranty (assuming all other warranties remain the same) cause you to hold on to the vehicles longer?

- Yes
- No
- Other (please specify)

16) Where do you sell your vehicles?

- Private sale e.g., online, word-of-mouth, etc.…
- Dealership sale
- Other list:

17) Hypothetically speaking, if you are selling a class 8 vehicle with 2 years/200,000 miles of remaining emission-related component warranty that covers everything related to the malfunction indicator light (MIL), how much more would you expect to get for a vehicle with the remaining emission warranty compared to one without it (the same production year, mileage, planned future use)? Please consider the vehicle class and fuel type that best represents your fleet.

- $0 - 999
- $1,000 – 1,999
- $2,000 – 2,999
- $3,000 – 4,999
- More than $5,000 (please specify)

18) Same as above (hypothetically speaking) but with 4 years/400,000 miles.

- $0 - 999
- $1,000 – 1,999
- $2,000 – 2,999
- $3,000 – 4,999
- $5,000 – 6,999
- $7,000 – 8,999
- More than $9,000 (please specify): $ _____

For used vehicle purchasers:

19) What is your typical warranty type?

- CARB warranty (5 years / 100,000 miles)
- Base warranty provided by the manufacturer/dealer (Example: 2 years / 250,000 miles)
- Extended warranty provided by the manufacturer/dealer
- Aftermarket warranty provided by a third party
- Unsure
- Not applicable (please specify)

20) Where do you buy used vehicles from?

- Private sales (e.g., online or vehicle sales publications)
- Dealership sales

- Vehicle auction sales
- Other : _____

21) Hypothetically speaking, if you are buying a used class 8 vehicle with 2 years/200,000 miles of remaining emission-related component warranty that covers everything related to the malfunction indicator light (MIL), how much of a higher price would you be willing to pay for the vehicle compared to one without it (the same production year, mileage, planned future use)? Please consider the vehicle class and fuel type that best represents your fleet/truck.

- $0 - 999
- $1,000 – 1,999
- $2,000 – 2,999
- $3,000 – 4,999
- More than $5,000 (please specify): $ _____

22) Same as above (hypothetically speaking) but with 4 years/400,000 miles

- $0 - 999
- $1,000 – 1,999
- $2,000 – 2,999
- $3,000 – 4,999
- $5,000 – 6,999
- $7,000 – 8,999
- More than $9,000 (please specify): $ _____

23) Do you typically purchase a longer warranty (offered by the manufacturer or a third-party provider)?

- Yes (go to "Longer Warranty Questions" section)
- No

DEALERSHIP QUESTIONS:

24) Please list the estimated percent of your vehicle sales by the Gross Vehicle Weight Ratings (GVWR) for class 4 through class 8 vehicle. Indicate the percent below with the total adding to 100.

- Greater than 33,000 lbs (Class 8): _____
- 19,501 to 33,000 lbs (Class 6 and 7): _____

- 14,000 to 19,500 lbs (Class 4 and 5): _____

25) Based on your customer experience, how long does the typical fleet keep their vehicles before replacing them?

- Sell before warranty runs out (If yes, go to 2-1)
- Keep until end of warranty period
- Keep until cost of repairs are excessive
- Keep until dependability becomes a problem
- Other (please specify): _____

26) If you answered, "Sell before warranty runs out", do they typically cash in the remaining warranty on the vehicles prior to selling them back to the dealer?

- Yes
- No
- Other (please describe)

27) After fleets start purchasing new vehicles having CARB's longer emissions warranties, do you expect fleets will operate the vehicles for a longer period before selling them?

- Yes
- No
- If your answer is "No" please briefly explain:_____

28) Do you typically offer vehicles for sale that have remaining extended warranties that can then transfer to the new owner?

- Yes
- No
- If your answer is "No" please briefly explain:_____

29) Hypothetically speaking, if you are selling two identical class 8 tractors that are the same production year, the same mileage, planned future use, but one has a remaining "manufacturer's emissions" warranty of **200,000 miles/2 years**, how much higher selling price would the vehicle with the warranty command compared to the one without?

- $0 - 999
- $1,000 – 1,999

- $2,000 – 2,999
- $3,000 – 4,999
- More than $5,000 (please specify): $_____

30) Same as above (hypothetically speaking) but **400,000 miles/4 years**

- $0 - 999
- $1,000 – 1,999
- $2,000 – 2,999
- $3,000 – 4,999
- $5,000 – 6,999
- $7,000 – 8,999
- More than $9,000 (please specify): $ _____

#31 – 40: FLEET – For new & used vehicle purchasers.

E. Cummins' testimony from the August 27, 2020 board hearing

The entire transcript is available at *https://ww3.arb.ca.gov/board/mt/2020/mt082720.pdf*

From page 277 line 22 to page 279 line 19:

> MS. KENNEDY: Okay. Thank you. Chairwoman Nichols and members of the Board, thank you for the opportunity to provide comments today. My name is Melina Kennedy and I'm the Vice President of Product Compliance and Regulatory Affairs at Cummins. As a global power leader, Cummins is investing significantly in technologies, ranging from cleaner and more efficient diesel and natural gas, hybrids, battery electric, and fuel-cell electric powertrains, as well as hydrogen technologies.
>
> We understand the unique air quality issues California faces and we too are committed to improving the environment, while also delivering for our customers. To enable mutual success in these goals, we are recommending changes to the Heavy-Duty Omnibus Regulation outlined in detail in our written comments.
>
> Cummins has participated in industry discussions with CARB to explore the possibility of voluntary emission-wide NOx reductions. Despite good faith efforts by many, an agreement could not be reached, and as such Cummins plans to work toward meeting the proposed 2024. 0.05 gram NOx standard, which, at this point in time, will be extremely challenging.
>
> To eliminate regulatory uncertainty, we believe the 0.1 gram 50-state option in the proposal could be removed. Second, the incredibly short lead time for 2024 demands much more screen-lined pre-certification requirements for anyone to deliver on time.
>
> CARB's proposed durability and deterioration factor testing far exceed the time available in the manufacturer's product development schedule and should be revised.
>
> Third, we ask CARB not to finalize the proposed changes to emissions warranty reporting, corrective actions, warranty periods and useful life periods. Changing those requirements at the same time as introducing new technology will increase prices further and likely impact the adoption of those technologies in the market.
>
> We ask the Board to instead direct staff to conduct a comprehensive study to assess the cost and market implications of these potential changes and compare those to the impacts of other alternatives that achieve the same objectives.
>
> Cummins is committing to work with CARB to that end. We thank you for your time and your work, and this is just a summary of some of our suggested changes.
>
> Thank you.

F. ATA's comment on the draft report

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August 13, 2021

California Air Resources Board
1001 I Street
Sacramento CA 95812

RE: **DRAFT Warranty cost study final report_072321 CLEAN**

Dear CARB staff and interested parties:

Thank you for the opportunity to review the draft document titled "DRAFT Warranty cost study final report_072321 CLEAN." ATA appreciates the time and effort involved in attempting to better understand the significant differences among the estimates contained in the various warranty cost studies. As noted in the report, "CARB staff and the work group members were unable to agree on all the elements of warranty cost estimation methods" (p. ES-11). Given the continuing disagreement over methodology and findings, ATA requests that CARB note this in the disclaimer (p. iv) and include stakeholder reviews as part of the final report. This will help to ensure industry concerns are documented and reflected in the final document.

With regard to the document itself, ATA offers the following observations and comments.

1. Beginning with CARB's 2018 rulemaking to extend the emission warranties of heavy-duty diesel trucks (Step 1), ATA has contended that CARB is underestimating the costs associated with extended warranties. One key assumptions is, "CARB staff's analysis considers that most owners either voluntarily purchase longer warranties beyond current regulatory requirements or are gifted them during the sales negotiation process (ISR, 2017)" (p. ES-3). As a result, CARB staff assumes that these "voluntarily purchased" or "gifted" warranties have zero financial cost and are essentially a free commodity. ATA disagrees with this assertion and notes when our members voluntarily purchase extended warranties, real dollars are spent and this transaction needs to be accounted for as part of the warranty analysis. Additionally, "gifted" warranties represent a cost to the manufacturer and should be similarly accounted for.

2. The document states, "Using CSUS survey data, CARB staff more accurately accounted for current warranty buying practices by fleets and owner/operators than the NREL/ACT Research/EMA's analyses and hence CARB staff's warranty baseline is higher than in the other analyses." (p. ES-7). Table III.A.2 indicates CARB staff assumes 85% of HDDVs are currently purchased with warranties that are longer than the regulatory requirements (p. 7).

   According to the CSUS survey,

   > Only a small percentage (24%) of owner/operators report having an extended warranty that provides protection beyond the mandatory coverage; however, for those that have an extended warranty, 84 percent report that it covers both parts and labor, with a wide

> variance of the number of additional miles covered (see Figures 12, 13, and 14). The majority of these extended warranties (60%) cost anywhere from $1,000 to $5,000 (see Figure 15). (CSUS, p. 9)

How CARB staff arrived at its assumption based on the survey findings is unclear. Further, the survey indicates only 12% of those who reported having an extended warranty received it for "free", likely a manufacturer-provided extended warranty (CSUS, p. 10). These survey results are inconsistent with the presented analysis.

3. CARB states, "The survey results indicated that the remaining residual warranties do in fact add value to vehicles sold in the secondary market, averaging approximately $2,000 for a 2 years/200,000 miles period of residual warranties, and $4,000 for a 4 years/400,000 miles residual period." (p. ES-8). Contrasting this statement with CARB's incremental cost estimate for Step 1 warranty of $285 per HHDD engine (p. ES-2) highlights the inconsistency of CARB's initial cost estimate.

4. The CARB staff analysis appears to continue to assume that manufacturers will choose to distribute costs evenly across product lines (FSOR, p. 19). This assumption has proven to be incorrect by the recent manufacturer surcharge notices that have been issued for Step 1. As indicated in these notices and CARB's own rulemaking, the extended warranty requirements only affect commercial vehicles registered for use in California. In addition, three additional "CARB Opt in" states are subject to these requirements. These surcharges, which are consistent with the manufacturers supplied cost estimates, are being applied to a subset of vehicles purchases rather than across product lines. Additionally, the mandatory, as opposed to voluntary, application of these extended warranties is subjecting these added warranty costs to the 12% federal excise tax.

While a substantial amount of time and effort has been spent analyzing the CARB staff assumptions and projections and receiving industry input, unfortunately, we do not believe this process has brought us any closer to agreeing on the additional cost impacts of mandatory extended warranties. The industry's experience with the Step 1 warranty is just playing out and truck buyers are experiencing higher costs when purchasing affected vehicles. These impacts are not adequately reflected in the analysis and, as a result, dilute the baseline being used for the prospective analysis.

We remain deeply concerned about the additional costs associated with the Step 1 and upcoming Step 2 warranties and will continue to evaluate their impacts on truck purchases going forward.

Sincerely,

Michael Tunnell
Director, Energy and Environmental Affairs
American Trucking Associations

G. EMA's comment on the draft report

APPENDIX to California Air Resources Board (CARB) Staff Report on the Warranty Cost Study for 2022 and Subsequent Model Year Heavy-Duty Diesel Engines – EMA Remarks

The Truck and Engine Manufacturers Association ("EMA") represents the industry regulated under, and therefore most impacted by, the Omnibus Low NOx Rules. For that reason, and early on, EMA submitted a proposal to CARB Staff to co-fund a supplemental, independent, and rigorous reanalysis of the warranty-related costs that are likely to result from the implementation of the Omnibus regulations. Unfortunately, CARB Staff rejected that collaborative proposal, and instead elected to convene a Working Group to comment on the warranty-cost review that CARB Staff itself elected to undertake.

EMA participated in that Working Group, and has made a good faith effort to bring objective information and real warranty-cost data to the process. For its part, however, CARB Staff made it very clear from the outset that no changes would be made to the 2027 and 2031 model year emissions warranty requirements, no matter how significant any new warranty-cost information might be, or how the relevant cost-benefit ratios might change. As a result, and despite more than nine months of additional inputs and cost data, nowhere in this Report has Staff made any adjustments to any of the cost assumptions set forth in Staff's original Initial Statement of Reasons (ISOR) for the Omnibus Rule.

The Final Staff Report, as written, describes the various inputs submitted through the Working Group process, including inputs from EMA, and then offers Staff's defense of the original assumptions and significantly understated warranty costs set forth in the ISOR. In that regard, Staff made no revisions whatsoever to account for any of the new information that was submitted over the nine-month Working Group process. Consequently, the Report's conclusions do not actually reflect the consensus and results of a collaborative work group effort; they simply amount to Staff's rearticulation of the methods and warranty-cost assertions contained in the ISOR. Because of that non-collaborative outcome, EMA has requested to have these summary remarks included as an Appendix to the Report, to be sure that the actual cost data from the impacted industry are available to all stakeholders.

We are also providing the warranty cost estimates newly prepared by Ricardo PLC, an independent consulting group with a great deal of experience studying the cost impacts of emissions regulations. Significantly, Ricardo's estimates are for more in line with those of ACT Research and NREL, and project warranty costs more than an order of magnitude higher than CARB's.[3] More specifically, Ricardo estimates the incremental costs from CARB's 2031 warranty requirements for heavy heavy-duty diesel engines to be $16,268. EMA has provided the full Ricardo report to CARB Staff along with these comments.

[3] Both CARB and EPA were requested by EMA to be direct contributors to and co-funders of the Ricardo study to promote transparency and full consideration of all viewpoints, data, and information from the Agencies. Both EPA and CARB declined. EMA provided Ricardo with all relevant CARB rulemaking documents.

As noted, Staff's Report includes a number of explanations regarding why the warranty-cost projections made by researchers outside of CARB differ from Staff's, but does not provide an adequate explanation or justification as to *why* CARB Staff continue to hold to those original positions. Thus, many of CARB's methods and assumptions remain unjustified, especially in the face of the new information submitted to Staff. More specifically, EMA continues to have strong objections to many of the underlying assumptions that CARB has made in its warranty-cost assessment, including the following:

1. CARB does not report the full range of costs that the purchasers of heavy-duty trucks will be expected to bear as a result of the new emissions warranty requirements, including those that will be forced upon truck buyers that do not currently purchase extended warranties.

2. CARB assumes that the warranty costs associated with the $4,800 of new additional emissions-control hardware and componentry that will be needed to comply with the new Omnibus low-NOx emission standards will be *zero,* and summarily dismisses the historical precedent that those new emissions-control components likely will experience elevated failure rates during the first years of deployment.

3. CARB further assumes that none of the other significant requirements of the Omnibus Regulations -- including the new extremely stringent emission standards, the new extended Useful Life requirements, the new in-use testing protocols and standards, the new low-load certification requirements, and the new OBD provisions -- will have any significant impact on warranty costs.

None of those assumptions is reasonable, and they all are belied by the additional data and commentary that CARB Staff received from the regulated industry through the Working Group process. The net result is that Staff's assumptions regarding future warranty-related costs remain unreasonable and understated by an order of magnitude, as explained in further detail below.

CARB's methodology is based on the assumption that the unscreened warranty claims rates that have pertained over the most recent five-year period will be fully predictive of the warranty claims rates that will pertain to the new engines, aftertreatment systems, components and close-coupled packaging that will be required to comply with CARB's 2024 and 2027 model year standards over the significantly extended useful life and emissions warranty periods. (See, e.g., Report, pp. ES-1 and ES-5.) That assumption is not supported by the warranty-claims increases that have followed the initial implementation years of every prior rulemaking of this type, and does not comport with manufacturing practices and supplemental product improvements that are learned about and implemented after new stringent standards take effect. Moreover, CARB's assumption makes no separate accommodations for the increased componentry and complexity of the close-coupled multi-element aftertreatment systems that the new Omnibus standards will dictate. That is simply not reasonable. The multiple new requirements under the Omnibus Regulations are very different from what pertains today, with multiple new and different things that can go wrong, and with fundamentally different consequences if they do. It is for those reasons that EMA assumed a 20% higher emissions warranty claims rate during the initial

years after the phase-in of CARB's 2024 and 2027 model year standards. CARB's complete disregard of that reality is, again, unreasonable.

CARB's methodology appears to use nationwide production volumes (not California-only production volumes) to dilute the per-vehicle/engine costs of CARB's extended emission warranty requirements. (See Report, pp. 20, 32-33.) That too is not reasonable. CARB's own regulations make clear (see, e.g. CCR Title 13, section 2035) that CARB's extended emissions warranty program will apply only to CARB-certified and California-registered vehicles up through the 2027 model year. CARB's analysis is fundamentally flawed in this regard.

Using nationwide production numbers, CARB assumes that the "Step 1" warranty costs will only amount to $285 per engine. (See Report, ES-1.) That assumption is belied by the actual cost numbers that OEMs have reported to CARB for the Step 1 warranties that they are providing for the 2022 MY pursuant to CARB's regulations (for example, manufacturers of 11-13L engines are currently charging, on average, approximately $2,500 for the extended "Step 1" warranty). CARB's disagreement with those actual, reported and publicly announced cost increases does not detract from the fact that the increased costs that OEMs have reported are **real** costs being passed on to **real** vehicle/engine purchasers starting with **real** product orders that are being processed now. CARB's continued assertion of assumed Step 1 cost increases in the face of countervailing actual cost information is manifestly unreasonable. The actual current cost data conclusively prove that CARB's warranty-cost assumptions are understated by an order of magnitude.

CARB's assumed emissions warranty baseline is **not** the current standard **regulatory** emissions warranty, but rather a hypothetical "average" **extended** warranty that various fleet operators might have elected to buy in the past. That is not a fair baseline to assess the impacts of moving from one **regulated** baseline to another. A hypothetical fleet operator's past calculus of whether to pay more in today's market for more miles of warranty coverage is not germane to an assessment of the actual baseline cost differential of moving the regulated emissions warranty requirements from one range of mileage/years to a much greater range of mileage/years in the future. That change in regulatory baselines has an ascertainable cost increase. Whether fleet operators have shown a past willingness to take on a portion of that cost increase does not reduce the overall ascertainable cost increase of changing the regulatory requirements; it simply reveals that the market likely will be inelastic enough to accommodate a portion of those costs without changing vehicle-purchasing decisions. CARB's use of that marginal inelasticity in demand to discount the actual cost impact of its extended warranty regulations is simply not justified or reasonable.

CARB's warranty-cost rationale is internally inconsistent. On the one hand, CARB assumes that an extended warranty of approximately 200,000 miles (moving from a regulated warranty of 100,000 miles to an extended regulated warranty of 350,000 miles) will only result in a cost increase of $285 per engine. Yet at the same time, CARB asserts that a residual emissions warranty of 200,000 miles would increase the resale value of a truck by $2,000. (See Report, ES-6.) This implies that a used vehicle purchaser is willing to pay nearly ten-times more than the actual cost of the residual warranty at issue. That does not add-up. One of CARB's numbers is off by a factor of ten. The relevant and established

facts at issue reveal it to be CARB's inherently unreasonable $285 number, which, again, is understated by an order of magnitude.

EMA developed an additional approach to compare CARB's understated cost estimates against the more objective analyses of ACT Research, and now Ricardo. Before discussing that additional approach, it bears noting that Ricardo's methodology and cost estimates are based on the most exhaustive review of public data sources, estimation methods, industry input, and expert analysis conducted to date. Notwithstanding the rigor of Ricardo's study (which, again, is being submitted with these comments), EMA also undertook an additional approach of fact-checking CARB's unreasonable assumptions by using aftermarket warranty costs as a tool to estimate the costs that can reasonably be expected as a result of CARB's extended warranty requirements, based on *real, current business experience*. (CARB inaccurately refers to this supplemental analysis based on aftermarket warranty pricing as the "EMA estimate.")

CARB's review of the EMA analysis based on aftermarket warranty pricing is a clear example of CARB's effort to discount and dismiss new information, rather than incorporate it into reasonable and necessary adjustments to Staff's original cost projections. More specifically, CARB Staff present a "waterfall" breakdown of EMA's aftermarket-based analysis in Section III.E. of the Report, including Staff's rationalization for each progressive segment of their analysis, in Figure III.E.1, reproduced here:

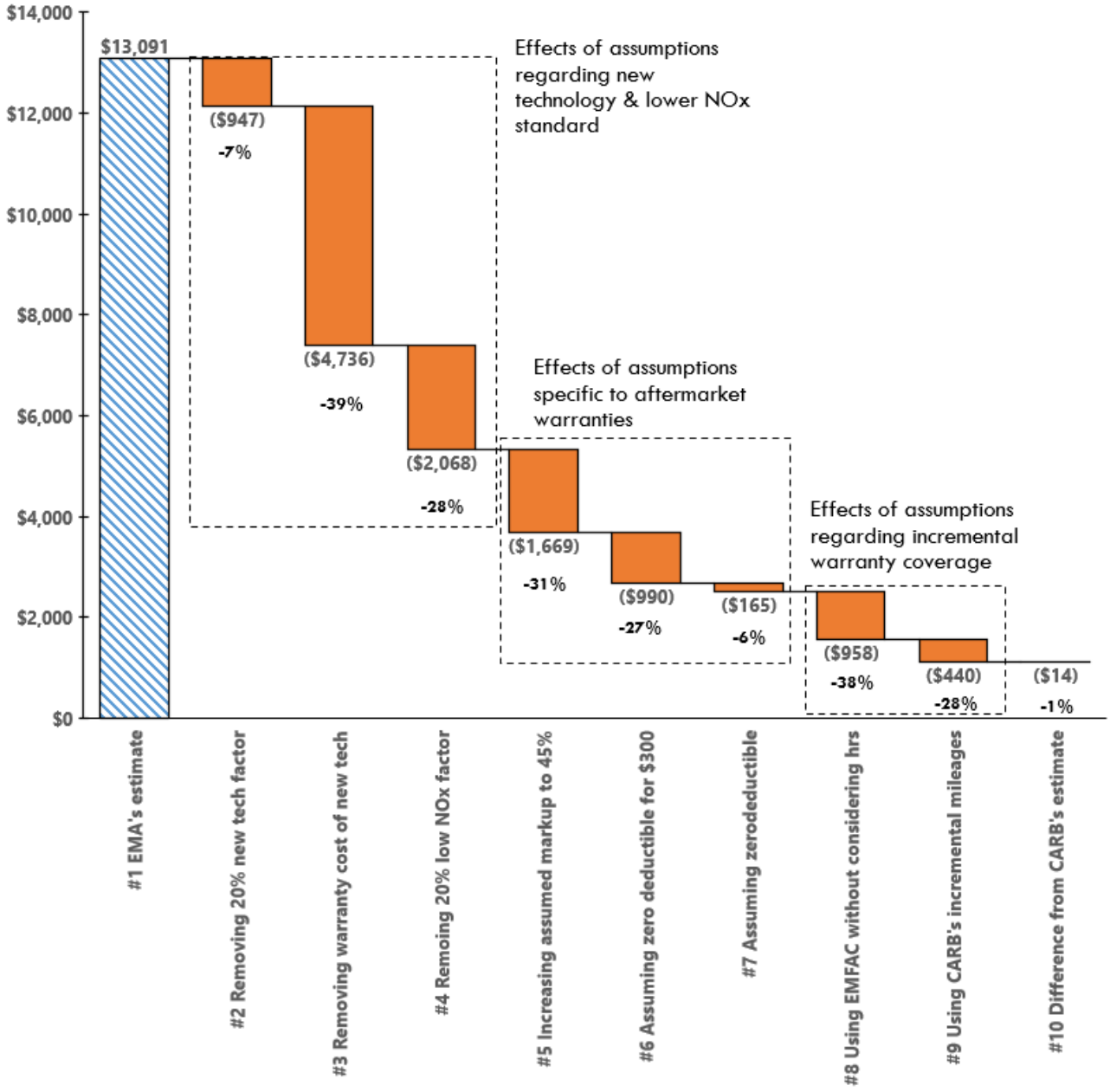

Figure III.E.1. Effects of different assumptions on EMA's warranty cost estimates. The x-axis label corresponds to scenarios in Table III.E.1.

There are multiple flaws with each of CARB's rationalizations in the figure above (CARB Staff's full explanations can be found on pages 28-31 of the Report). The counter-points below track the flow of CARB's "waterfall" in the figure above:

1) EMA's "estimate" (it is really an aftermarket-based analysis, as noted above) was put forward as a rationality check using the real-world aftermarket costs for extended warranties as a means for comparison with CARB's assumption-based estimates that are more than an order of magnitude lower. EMA did not establish the aftermarket warranty prices that show

the order-of-magnitude difference with CARB's numbers. Thus, it is a misnomer to refer to the $13,091 number as "EMA's estimate." It is a cost number derived from publicly available aftermarket warranty price information.

2) CARB chooses to ignore the historical precedent that major new emission-control technologies deployed on an accelerated regulatory timeline will experience elevated failure rates in the first few years after introduction.

3) The most egregious of the assumptions that CARB makes is that adding 50% more emissions-control componentry (on a cost basis), including close-coupled SCR and Cylinder Deactivation -- technologies never before applied above Class 3 vehicles and engines – will have absolutely no impact on the emissions warranty costs experienced on a heavy-duty truck. It should be noted that CARB is dismissing *all* of the warranty costs associated with those multiple new components from the first mile of operation. If the assumption instead is that the *combined* warranty costs from both existing and new technologies will not increase above today's levels, then that would mean that the warranty costs associated with existing components (most of them in production for one to two decades or more) would suddenly decrease by almost 50%, effective with the first introduction of Omnibus-compliant engines. Such an assumption is patently unreasonable.

4) CARB assumes that the replacement costs for existing emissions-related components will not increase despite their having to be re-designed to meet CARB's extended Useful Life requirements, despite the fact that OBD systems will illuminate the MIL more frequently when operating to ensure tailpipe emissions control to 10% of today's levels, and despite the fact that CARB's new warranty coverage will pertain to "*anything that illuminates the MIL."* That cannot be and is not reasonable.

5) EMA made a projection that the companies that offer aftermarket warranties will look to make a marginal profit of approximately 20%. CARB rejected EMA's projection and claims that the profit margin should be assumed to be 45%, based on an article[4] that CARB found regarding the operation of third-party repair centers -- a completely different business and business model from aftermarket warranty providers. CARB's extrapolation from that one largely irrelevant article, as part of Staff's transparent maneuver to discount the underlying "real" costs of the extended warranties at issue, is emblematic of Staff's overall approach in preparing its Report.

6) CARB dismisses one of the revenue sources for the aftermarket warranty business balance sheet.

7) Same as #6.

[4] https://www.fullbay.com/blog/heavy-truck-shop-parts-pricing/

8) While the new warranty limitations based on hours are a reasonable basis for considering the expiration of the extended emissions warranties, CARB makes no attempt to characterize separately the warranty costs of trucks that operate "on the clock" versus those that operate "on the odometer."

9) One of the most serious faults with CARB's economic assessment is its complete failure to reflect the likely cost impacts on the most heavily impacted truck buyers in California. CARB's attempt to assess the "average customer experience" is not a full assessment of the real-world cost impacts at issue.

10) CARB concludes its waterfall breakdown of the additional aftermarket-based warranty cost assessment that EMA provided by stating, "As a result, the warranty cost is further decreased to … $1,118, which agrees with CARB's estimate ($1,104) within 2 percent." The reality is that this purported "alignment" is observed only after applying the unreasonable cascade of assumptions that CARB has devised, as described above, which means that there is no actual alignment whatsoever. Moreover, CARB's efforts to defend its significantly under-estimated cost projections would mean that the purchasers of aftermarket warranties are consistently and repeatedly making extremely foolish business investments. EMA is confident that the trucking industry in California and elsewhere has a far better understanding of the real costs and benefits of doing business than does CARB.

As one more reality check of CARB's warranty-cost assessment, it should be noted that CARB applies its $0.01 (one cent) per-mile warranty cost estimate to each and every truck, regardless of application. More specifically, CARB applies this same estimate across all heavy heavy-duty engines and vehicles, including applications such as "T7 Utility" vehicles, which CARB assumes to have a 10-year accumulated mileage of 85,536 miles. CARB's estimation methodology would predict that the *total (from day 1)* emissions warranty costs encountered by that vehicle application *over a 10-year warranty period* would be approximately $855 – just $185 more than the cost to replace a single NOx sensor. Unreasonable outcomes such as this clearly illustrate the complete lack of rigor in CARB's cost-estimation process.

In sum, CARB's Report of its supplemental warranty cost assessment has disregarded the key input from engine and vehicle manufactures – input that includes the actual costs of Step 1 warranties -- in order to try to justify the extended warranty requirements of CARB's Omnibus Low-NOx Regulations. The calculation methods that CARB has utilized completely gloss over the real costs that will be incurred by the most heavily-impacted truck buyers. Consequently, while CARB's Report, in the end, attempts to ignore the Working Group process that Staff set up, it does not and cannot change what stakeholders have known about CARB's warranty cost estimates from the outset – they were and remain understated by an order of magnitude.

H. CARB staff's response to stakeholder comments on the draft report

(a) Comments from ATA

(a).1. Comment: … As a result, CARB staff assumes that these "voluntarily purchased" or "gifted" warranties have zero financial cost and are essentially a free commodity. ATA disagrees with this assertion and notes when our members voluntarily purchase extended warranties, real dollars are spent and this transaction needs to be accounted for as part of the warranty analysis. Additionally, "gifted" warranties represent a cost to the manufacturer and should be similarly accounted for.

Response: CARB staff does not assume voluntary warranties have zero financial cost. They are considered as the baseline cost. This report shows the incremental cost per new engine as a result of the rulemaking.

13 CCR 2036(c)(4)(A) equates emissions warranty with the base warranty period provided by the manufacturer with or without additional costs:

> (4)(A) In the case of diesel-powered heavy-duty vehicles greater than 14,000 pounds GVWR which are equipped with 2021 and prior model year motor vehicle engines, and motor vehicle engines used in such vehicles, a period of use of five years, 100,000 miles, or 3000 hours of operations, whichever first occurs. However, in no case may this period be less than the basic mechanical warranty that the manufacturer provides (with or without additional charge) to the purchaser of the engine. Extended warranties on select parts do not extend the emissions warranty requirements for the entire engine but only for those parts. In cases where responsibility for an extended warranty is shared between the owner and the manufacturer, the emissions warranty shall also be shared in the same manner as specified in the warranty agreement.

(a).2. Comment: According to the CSUS survey,

> Only a small percentage (24 percent) of owner/operators report having an extended warranty that provides protection beyond the mandatory coverage; however, for those that have an extended warranty, 84 percent report that it covers both parts and labor, with a wide variance of the number of additional miles covered (see Figures 12, 13, and 14). The majority of these extended warranties (60 percent) cost anywhere from $1,000 to $5,000 (see Figure 15). (CSUS, p. 9)

How CARB staff arrived at its assumption based on the survey findings is unclear. Further, the survey indicates only 12 percent of those who reported having an extended warranty received it for "free", likely a manufacturer-provided extended warranty (CSUS, p. 10). These survey results are inconsistent with the presented analysis.

Response: The 24 percent value includes used vehicles without extended warranties or with expired extended warranties and is not directly applicable to our baseline for new vehicles. CARB determined the warranty purchase practices based on the combination of the CSUS survey data (screened only for new vehicles) and CBI from OEMs. In a letter to CARB dated August 1, 2017, EMA estimated that 50 percent of new Heavy Heavy-Duty truck purchases include 5 year/500,000 mile extended warranties (CARB Staff Report Reference #59 - EMA, 2017). CARB elected to use 40 percent to be more conservative. The cost of the extended warranty is part of the baseline cost.

(a).3. Comment: CARB states, "The survey results indicated that the remaining residual warranties do in fact add value to vehicles sold in the secondary market, averaging approximately $2,000 for a 2 years/200,000 miles period of residual warranties, and $4,000 for a 4 years/400,000 miles residual period." (p. ES-8). Contrasting this statement with CARB's incremental cost estimate for Step 1 warranty of $285 per HHDD engine (p. ES-2) highlights the inconsistency of CARB's initial cost estimate.

Response: These numbers are conceptually different quantities. The former represents an increase in resale value based on remaining warranty, whereas the latter is the averaged incremental cost for Step 1 warranties after factoring in that 85 percent of new heavy-duty trucks are historically covered by extended warranties purchased separately or provided without additional cost. 13 CCR 2036(c)(4)(A) equates emissions warranty with the base warranty period provided by the manufacturer with or without additional costs. Therefore, CARB staff did not believe it appropriate to include the costs of current de facto warranty periods for the same coverage in Step 1.

(a).4. Comment: The CARB staff analysis appears to continue to assume that manufacturers will choose to distribute costs evenly across product lines (FSOR, p. 19). This assumption has proven to be incorrect by the recent manufacturer surcharge notices that have been issued for Step 1.

Response: Pg. 4 indicates that CARB's method does not assume even costs across product lines. It is based on all the unscreened warranty claim data for the recent five years. If a certain product line has higher claim rates, it is reflected in the average claim rates. Staff estimated average repair costs for individual engine and aftertreatment components by analyzing repair shop data and through discussions with manufacturers and service providers. We cannot predict the behavior of every manufacturer.

(a).5. Comment: … As indicated in these notices and CARB's own rulemaking, the extended warranty requirements only affect commercial vehicles registered for use in California. In addition, three additional "CARB Opt in" states are subject to these requirements. These surcharges, which are consistent with the manufacturers supplied cost estimates, are being applied to a subset of vehicles purchases rather than across product lines. Additionally, the mandatory, as opposed to voluntary, application of these extended warranties is subjecting these added warranty costs to the 12 percent federal excise tax.

Response: California emissions warranty coverage would be expanded to California-certified vehicles with California-certified engines, even if they are registered outside California, beginning with the 2027 MY. CARB's estimate does not include the federal excise tax.

(b) Comments from EMA

(b).1. Comment: … CARB Staff made it very clear from the outset that no changes would be made to the 2027 and 2031 model year emissions warranty requirements, no matter how significant any new warranty-cost information might be, or how the relevant cost-benefit ratios might change.

Response: CARB staff disagree with the comment. The Board directed staff to convene the work group to get a better understanding of the different cost methodologies not to change the warranty requirements.

CARB staff believe the methodology used to support the Omnibus Regulation warranty-related cost estimates is reasonable and defensible, and based on what was learned further in this study, we do not believe changes to those estimates are needed.

(b).2. Comment: … Staff made no revisions whatsoever to account for any of the new information that was submitted over the nine-month Working Group process. Consequently, the Report's conclusions do not actually reflect the consensus and results of a collaborative work group effort; they simply amount to Staff's rearticulation of the methods and warranty-cost assertions contained in the ISOR.

Response: Again, the purpose for conducting this study was to better understand the differences between CARB staff's estimates of warranty cost and those provided by industry stakeholders. CARB staff listened to stakeholder concerns. One action was the analysis of the warranty cost of new technologies. In response to the EMA's comments, CARB staff performed an additional sensitivity analysis evaluating the assumption of the warranty costs for new technology and estimated that if the warranty costs for new technology were included, it would increase the estimate of Omnibus regulatory costs by about 11 percent. The hypothetical increase was well within the bound of the previous CARB Staff Report sensitivity analysis that incorporated the incremental warranty costs from the NREL report (CARB, 2020; see chapter IX.F). Therefore, staff concluded that even if higher warranty cost estimates due to new technologies were included, it would not have changed the staff proposal. More details of the additional analysis are shown in Appendix I.

CARB staff will include the EMA's summary remarks as an Appendix to the report as requested.

(b).3. Comment: We are also providing the warranty cost estimates newly prepared by Ricardo PLC, an independent consulting group with a great deal of experience studying the cost impacts of emissions regulations.[…] EMA has provided the full Ricardo report to CARB Staff along with these comments.

Response: EMA did not provide CARB staff with the full Ricardo report but instead provided Ricardo's slide deck summarizing the report. Detailed analysis of Ricardo's method is beyond the scope of this study as it was shared to CARB staff beyond the scheduled 9-month period and after this draft Heavy-Duty Warranty Cost Study Report was completed.

It appears that Ricardo's method is based on confidential incremental cost information provided by OEMs, and therefore details of warranty cost estimation methods are unknown.

(b).4. Comment: … EMA continues to have strong objections to many of the underlying assumptions that CARB has made in its warranty-cost assessment, including the following:

1. CARB does not report the full range of costs that the purchasers of heavy-duty trucks will be expected to bear […].
2. CARB assumes that the warranty costs associated with the $4,800 of new additional emissions-control hardware and componentry that will be needed to comply with the new Omnibus low-NOx emission standards will be zero, and summarily dismisses the historical precedent that those new emissions-control components likely will experience elevated failure rates during the first years of deployment.
3. CARB further assumes that none of the other significant requirements of the Omnibus Regulations […] will have any significant impact on warranty costs.

Response: Detailed responses are discussed in the report. A properly engineered technology package designed to be durable throughout its useful life should not have more unforeseen production errors (per mile) than current packages designed to last for 435,000 miles. The emissions defects warranty requirements are not meant to compensate for improper engineering on the part of the manufacturer, but rather to protect the consumer (and air quality) from incorrect installations or material defects leading to premature failure. The occurrence of such defects is not expected to occur at higher rates than for current production vehicles because of CARB's amendments.

Regarding the second point on the warranty cost of new technologies, refer to comment (b).2.

(b).5. Comment: CARB's methodology is based on the assumption that the unscreened warranty claims rates that have pertained over the most recent five-year period will be fully predictive of the warranty claims rates that will pertain to the new engines, aftertreatment systems, components and close-coupled packaging that will be

required to comply with CARB's 2024 and 2027 model year standards over the significantly extended useful life and emissions warranty periods. […] That assumption is not supported by the warranty-claims increases that have followed the initial implementation years of every prior rulemaking of this type, and does not comport with manufacturing practices and supplemental product improvements that are learned about and implemented after new stringent standards take effect.

Response: CARB staff extrapolated the most recent five-year data starting from 2013 MY to Step 2 warranty because most emission-related components expected for meeting the Omnibus standards would be similar to the existing technology that's currently on engines now. Some changes, such as heated dosing, are new, but CARB staff considers these changes to be evolutionary not revolutionary. Additionally, we expect that parts are less likely to fail because of continued improvement since 2013.

(b).6. Comment: Moreover, CARB's assumption makes no separate accommodations for the increased componentry and complexity of the close-coupled multi-element aftertreatment systems that the new Omnibus standards will dictate. That is simply not reasonable. The multiple new requirements under the Omnibus Regulations are very different from what pertains today, with multiple new and different things that can go wrong, and with fundamentally different consequences if they do. It is for those reasons that EMA assumed a 20 percent higher emissions warranty claims rate during the initial years after the phase-in of CARB's 2024 and 2027 model year standards. CARB's complete disregard of that reality is, again, unreasonable.

Response: Similarly, this is addressed in pg. 27-28 of this report. A properly engineered technology package designed to be durable throughout the longer useful life would not require higher defect warranty claim rates. Research & development cost for engineering should not be part of the defects warranty cost. Manufacturers may petition the Executive Officer to relax maintenance intervals should durability issues arise during the demonstration testing required for certification.

(b).7. Comment: CARB's methodology appears to use nationwide production volumes (not California-only production volumes) to dilute the per-vehicle/engine costs of CARB's extended emission warranty requirements. (See Report, pp. 20, 32-33.) That too is not reasonable. CARB's own regulations make clear (see, e.g., CCR Title 13, section 2035) that CARB's extended emissions warranty program will apply only to CARB-certified and California-registered vehicles up through the 2027 model year. CARB's analysis is fundamentally flawed in this regard.

Response: CARB's methodology uses CA-only production volume to calculate the statewide cost (see ISOR page IX-24).

Page 20 of the draft report states that "The California-only production volume can result in higher

warranty costs due to higher unit prices if California-specific parts with small production volumes are used." Page 32-33 shows the table comparing CARB/NREL/ACT/EMA's methodology with footnotes for NREL/ACT that their estimates use CA-only volume, whereas CARB's column did not have the same footnote. EMA may have misinterpreted these to conclude CARB uses nationwide production volume.

CARB's methodology is based on the extrapolation of historical repair data. Although CA-only
production volume may contribute to higher unit prices, as stated in page 27, CARB's method assumed that potential increase in unit prices of emission-related components will be offset by gradual improvement in existing technology (e.g., early detection of failures by OBD).

(b).8. Comment: …CARB assumes that the "Step 1" warranty costs will only amount to $285 per engine. (See Report, ES-1.) That assumption is belied by the actual cost numbers that OEMs have reported to CARB for the Step 1 warranties that they are providing for the 2022 MY pursuant to CARB's regulations (for example, manufacturers of 11-13 L engines are currently charging, on average, approximately $2,500 for the extended "Step 1" warranty).

Response: As described in the report, although the details of OEMs' estimation methods are unknown, most of the difference between $285 and $2,500 may be explained by the different baselines and treatment of the miles covered under warranty. In CARB's method, miles covered under warranty increase only by 32,100 miles for Step 1 warranty, whereas OEMs may be budgeting assuming 250,000 miles increase in coverage (going from 100,000 to 350,000 miles).

(b).9. Comment: CARB's assumed emissions warranty baseline is not the current standard regulatory emissions warranty, but rather a hypothetical "average" extended warranty that various fleet operators might have elected to buy in the past. That is not a fair baseline to assess the impacts of moving from one regulated baseline to another. A hypothetical fleet operator's past calculus of whether to pay more in today's market for more miles of warranty coverage is not germane to an assessment of the actual baseline cost differential of moving the regulated emissions warranty requirements from one range of mileage/years to a much greater range of mileage/years in the future. […]

Response: CARB staff believe it is reasonable to include voluntary longer warranties to the baseline because those fleet operators who elected to purchase longer warranties in the past will experience less cost increase as a result of the rulemaking. Furthermore, 13 CCR 2036(c)(4)(A) equates emissions warranty with the base warranty period provided by the manufacturer with or without additional costs. Therefore, CARB did not believe it appropriate to include the costs of current de facto warranty periods for the same coverage in Step 1. The cost of the status quo is clearly not part of the incremental cost.

(b).10. Comment: CARB's warranty-cost rationale is internally inconsistent. On the one hand, CARB assumes that an extended warranty of approximately 200,000 miles (moving from a regulated warranty of 100,000 miles to an extended regulated warranty of 350,000 miles) will only result in a cost increase of $285 per engine. Yet at the same time, CARB asserts that a residual emissions warranty of 200,000 miles would increase the resale value of a truck by $2,000. (See Report, ES-6.) This implies that a used vehicle purchaser is willing to pay nearly ten-times more than the actual cost of the residual warranty at issue. That does not add-up. One of CARB's numbers is off by a factor of ten. The relevant and established facts at issue reveal it to be CARB's inherently unreasonable $285 number, which, again, is understated by an order of magnitude.

Response: Those two numbers are conceptually different. $285 is the average incremental cost accounting for those who voluntarily purchase longer warranties or who are gifted them in extended base packages or through negotiations. CARB staff estimated that the increase in miles covered under warranty in Step 1 is only 32,100 miles. $2,000 is an individual cost (not an average of the entire vehicles). On a per-mile basis, those two numbers are both approximately 1 cent/mile.

(b).11. Comment: EMA developed an additional approach to compare CARB's understated cost estimates against the more objective analyses of ACT Research, and now Ricardo. Before discussing that additional approach, it bears noting that Ricardo's methodology and cost estimates are based on the most exhaustive review of public data sources, estimation methods, industry input, and expert analysis conducted to date. Notwithstanding the rigor of Ricardo's study (which, again, is being submitted with these comments), EMA also undertook an additional approach of fact-checking CARB's unreasonable assumptions by using aftermarket warranty costs as a tool to estimate the costs that can reasonably be expected as a result of CARB's extended warranty requirements, based on real, current business experience. (CARB inaccurately refers to this supplemental analysis based on aftermarket warranty pricing as the "EMA estimate.")

Response: CARB staff has edited the report language from "EMA estimate" to "EMA's analysis using aftermarket warranty pricing". EMA did not provide the actual report to CARB staff but rather Ricardo's slide deck summarizing the report. Detailed analysis of Ricardo's method is beyond the scope of this study as it was shared to CARB staff beyond the scheduled 9-month period after this report had been drafted.

(b).12. Comment: 1) … Thus, it is a misnomer to refer to the $13,091 number as "EMA's estimate." It is a cost number derived from publicly available aftermarket warranty price information.

Response: CARB staff has changed "EMA estimate" to "EMA's analysis using aftermarket warranty pricing".

(b).13. Comment: 2) CARB chooses to ignore the historical precedent that major new emission-control technologies deployed on an accelerated regulatory timeline will experience elevated failure rates in the first few years after introduction.

Response: CARB staff did not include elevated failure rates because most emission-related components expected to meet the Omnibus standards would be similar to the existing technology that's currently on engines now. Some changes, such as heated dosing, are new, but CARB staff does not consider such changes as revolutionary. Additionally, we expect that parts are less likely to fail because of continued improvement in technology. Manufacturers should be aware of durability challenges regarding their products with respect to a change in standards prior to certification and apply for relaxed maintenance intervals for new technology durability issues rather than rely on the warranty provisions for this purpose. CARB staff also addressed EMA's concern in (b).2.

Also, the Omnibus ISOR performed a sensitivity analysis showing that the overall cost-effectiveness would still be reasonable even when much higher warranty costs (using NREL's survey) were incorporated.

(b).14. Comment: 3) The most egregious of the assumptions that CARB makes is that adding 50% more emissions-control componentry (on a cost basis), including close-coupled SCR and Cylinder Deactivation -- technologies never before applied above Class 3 vehicles and engines – will have absolutely no impact on the emissions warranty costs experienced on a heavy-duty truck. It should be noted that CARB is dismissing all of the warranty costs associated with those multiple new components from the first mile of operation. If the assumption instead is that the combined warranty costs from both existing and new technologies will not increase above today's levels, then that would mean that the warranty costs associated with existing components (most of them in production for one to two decades or more) would suddenly decrease by almost 50%, effective with the first introduction of Omnibus-compliant engines. Such an assumption is patently unreasonable.

Response: These points are discussed in pg. 27-28 of the draft report. A properly engineered technology package designed to be durable throughout its useful life should not have more unforeseen production errors (per mile) than current packages designed to last for 435,000 miles. Research & development cost for engineering should not be part of the defects warranty cost. Manufacturers should be aware of durability challenges prior to certification and apply for relaxed maintenance intervals for new technologies rather than rely on the warranty provisions for this purpose.

As described in the response to comment (b).2, an additional analysis on the potential impact of the warranty costs for new technologies is shown in Appendix I.

(b).15. Comment: 4) CARB assumes that the replacement costs for existing emissions-related components will not increase despite their having to be re-designed to meet CARB's

extended Useful Life requirements, despite the fact that OBD systems will illuminate the MIL more frequently when operating to ensure tailpipe emissions control to 10% of today's levels, and despite the fact that CARB's new warranty coverage will pertain to "anything that illuminates the MIL." That cannot be and is not reasonable.

Response: Refer to the response to comment (b).14. MIL-related cost is included in CARB's estimate.

(b).16. Comment: 5) EMA made a projection that the companies that offer aftermarket warranties will look to make a marginal profit of approximately 20%. CARB rejected EMA's projection and claims that the profit margin should be assumed to be 45%, based on an article that CARB found regarding the operation of third-party repair centers -- a completely different business and business model from aftermarket warranty providers. CARB's extrapolation from that one largely irrelevant article, as part of Staff's transparent maneuver to discount the underlying "real" costs of the extended warranties at issue, is emblematic of Staff's overall approach in preparing its Report.

Response: Since the actual profit margin used by the aftermarket provider is unknown, the intent here is to understand the sensitivity of EMA's cost analysis on the assumed profit margin of 20 percent. CARB's reference to the Fullbay article in the Step 1 staff report does not maintain that the warranty costs should be increased by 45 percent, but uses this figure to project the possible upward range of warranty costs assuming manufacturers increase the costs of warranty packages for profit margin.

(b).17. Comment: 6) CARB dismisses one of the revenue sources for the aftermarket warranty business balance sheet.

Response: The intent here is to understand the sensitivity of EMA's cost analysis on the assumed deductible costs. CARB staff used information provided by J.D. Power ($0 deductible for $300) for evaluating this scenario.

(b).18. Comment: 7) Same as #6.

Response: Again, the intent here is to understand the sensitivity of EMA's cost analysis on the assumed deductible costs.

(b).19. Comment: 8) While the new warranty limitations based on hours are a reasonable basis for considering the expiration of the extended emissions warranties, CARB makes no attempt to characterize separately the warranty costs of trucks that operate "on the clock" versus those that operate "on the odometer."

Response: CARB's method estimates the warranty cost of average vehicles in order to evaluate the total statewide costs and benefits of the rulemaking.

(b).20. Comment: 9) One of the most serious faults with CARB's economic assessment is its complete failure to reflect the likely cost impacts on the most heavily impacted truck buyers in California. CARB's attempt to assess the "average customer experience" is not a full assessment of the real-world cost impacts at issue.

Response: As discussed in the response to comment (b).19, CARB's method aims at estimating the total statewide costs and benefits of the rulemaking. Therefore, estimation of individual cost impacts for different truck buyers is beyond the scope of the analysis.

Since CARB's estimates of the warranty costs are for the average vehicles, the individual incremental costs can be above or below the average. However, caution must be taken when applying CARB's method to individual vehicle categories. CARB's method assumes a linear relationship between the "average" repair cost under the warranty periods and the "average" miles covered under warranty. The same incremental mileage value (e.g., 100,000 miles) has different cost impacts for high-mileage (i.e., high average speed) vehicles and low-mileage (i.e., low average speed) vehicles.

To calculate the "individual" incremental cost for each vehicle category, one would need an "individual" repair cost for each vehicle category (which was not available to CARB staff) and "individual" miles covered under warranty (which is available from the EMFAC model).

For example, in Step 1 warranty, the average miles covered under warranty increases from 316,010 miles to 348,172 miles, which is only a 10 percent increase (section III.A.2). However, the miles covered under warranty of a "T7 Single Construction" vehicle with only the current regulatory warranty (5 years/100,000 miles) would increase from 100,000 miles to 212,000 miles in MY 2022, which means that their repair costs would increase by a factor of 2.12 as a result of Step 1 warranty. Since the repair cost information specific to "T7 Single Construction" vehicle at the end of 5 year/100,000 miles is not available, absolute values of the individual cost impact cannot be quantified using CARB's method intended for the average vehicles.

(b).21. Comment: 10) CARB concludes its waterfall breakdown of the additional aftermarket-based warranty cost assessment that EMA provided by stating, "As a result, the warranty cost is further decreased to … $1,118, which agrees with CARB's estimate ($1,104) within 2 percent." The reality is that this purported "alignment" is observed only after applying the unreasonable cascade of assumptions that CARB has devised, as described above, which means that there is no actual alignment whatsoever.

Response: Again, the intent of the waterfall breakdown is to better understand how each of the different assumptions made by CARB and EMA contributes to the warranty cost discrepancy.

(b).22. Comment: Moreover, CARB's efforts to defend its significantly under-estimated cost projections would mean that the purchasers of aftermarket warranties are consistently and repeatedly making extremely foolish business investments. EMA is confident that the trucking industry in California and elsewhere has a far better understanding of the real costs and benefits of doing business than does CARB.

Response: CARB staff think our approach is reasonable given the unique circumstances of aftermarket warranties. For instance, aftermarket warranty providers may need to obtain parts from OEMs. Also, their customers may be disproportionately high-mileage drivers who accumulate mileages well over the current full useful life and expect frequent failures (because such drivers would be those who would be most likely to choose to buy an aftermarket warranty).

(b).23. Comment: As one more reality check of CARB's warranty-cost assessment, it should be noted that CARB applies its $0.01 (one cent) per-mile warranty cost estimate to each and every truck, regardless of application. More specifically, CARB applies this same estimate across all heavy heavy-duty engines and vehicles, including applications such as "T7 Utility" vehicles, which CARB assumes to have a 10-year accumulated mileage of 85,536 miles. CARB's estimation methodology would predict that the total (from day 1) emissions warranty costs encountered by that vehicle application over a 10-year warranty period would be approximately $855 – just $185 more than the cost to replace a single NOx sensor. Unreasonable outcomes such as this clearly illustrate the complete lack of rigor in CARB's cost-estimation process.

Response: This statement is incorrect. $0.01 per mile is an approximate average incremental cost calculated "after" considering different usage patterns of different vehicle subcategories in EMFAC. Using "T7 Utility" as an example, its baseline miles covered under warranty in MY 2022 is 46,656 miles and its endpoint miles covered under warranty in MY 2031 is 85,536 miles, which means their repair cost increase by a factor of 1.8 (i.e., 85,536/46,656).

(c) Comment from MEMA

(c).1. Comment: Given there is a learning curve when new technologies and/or new emission standards are phased-in, it is possible for more failures to result initially. CARB's warranty data from 2010 technology has shown that this is a transient phenomenon that declines to a stable level of failure rates after 2-3 years as the technology matures.

Response: Refer to the response to comment (b).13.

I. CARB staff's analysis of warranty costs for new technologies

As described in section IV.A (CARB's method in the Omnibus Regulation), CARB staff estimated the costs of Step 2 warranty by extrapolating the most recent five-year repair data into MY 2027/2031 conditions assuming a linear relationship between the average repair costs and the average miles covered under warranty.

Although there will be some new technologies introduced to meet MY 2027/2031 requirements, such as cylinder deactivation or light-off SCR, the technology changes are expected to be evolutionary rather than revolutionary and nearly all emission-related components expected for meeting the Omnibus standards would be the same as the technologies used today (DPF and SCR). CARB's methodology assumes there will be no net addition of repair costs per mile when those new technologies will be introduced because nearly all emission-related components expected for meeting the Omnibus standards would be the same as the existing technology that is currently on engines now, and because existing components will be less likely to fail because of continued improvement since 2013.

Through the work group meetings, EMA expressed their concern regarding this assumption for new technologies (see EMA's comments in section XI.G). In response to the comment, CARB staff performed an additional sensitivity analysis to determine the potential increase in cost if additional warranty costs for new technologies were accounted for.

1. Per-vehicle cost impact

In CARB's method, the baseline repair cost was calculated using the repair cost (including parts and labor) and unscreened warranty claim rate of each emission-related component. In this analysis of the warranty costs for new technologies, CARB staff used the incremental technology costs based on NREL's survey (CARB, 2020; Appendix C-3). The labor cost information was obtained through Step 1 warranty rulemaking (CARB, 2018; references #39 and #81). The unscreened warranty claim rates are taken from the five-year EWIR data for MY 2013 shown in Table IV.A.8 when relevant data are available, otherwise the average warranty claim rate of Table IV.A.8 (i.e., 4.2 percent) was used. As shown in Table XI.1, if the repair costs for the new technologies were included, it would increase the baseline repair cost by $445 from $2,416 (see section IV.A.3.(a)), i.e., 18.4 percent increase. In other words, if the repair costs for new technologies were included without changing the warranty periods, the repair costs would increase by 18.4 percent.

Table XI.1 Estimated incremental technology costs, labor costs, unscreened warranty claim rates, and repair costs per HHDD engine meeting MY 2027 and 2031 requirements

Technologies	Adjusted incremental cost based on NREL survey[a]	Assumed labor	Assumed warranty claim rate	Weighted average repair cost
Cylinder Deactivation	$1,097	$400[b]	4.2%[c]	$62
Other: Engine technology	$932	$400[b]	4.2%[c]	$56
Light-off SCR	$1,256	$300	1.3%[d]	$20
DOC	$125	$0	8.1%[e]	$10
DPF	$38	$0	1.1%[e]	$0
SCR + ASC and DEF Dosing System	$1,079	$300	5.3%[f]	$72
OBD Sensors and Controllers (NOx, NH3, and Temp Sensors)	$611	$200	22.2%[g]	$180
Other: Aftertreatment technology	$667	$400[b]	4.2%[c]	$45
Total	$5,803	-	-	**$445**

a. Adjustment is done by interpolating NREL's survey results for 435,000 miles and 1,000,000 miles at 800,000 miles.
b. Assumed average labor cost (based on data readily available to staff) when relevant data is not available.
c. When relevant warranty claim rate data is not available, the average value for the entire 2013 MY warranty claim rates was used.
d. Assuming same failure rate as 2013 MY SCR
e. Based on 2013 MY data
f. Average of 2013 MY SCR and DEF doser data
g. Average of 2013 MY NOx sensor and other sensors

The next step is to account for the longer warranty periods of Step 2 warranty. The average miles covered under warranty for HHDD engines in MY 2022 and MY 2031 are 288,710 miles and 399,843, respectively. Using the ratio of the miles covered under warranty, the hypothetical repair cost that includes new technologies is estimated to be $3,963 (i.e., $2,861 * 399,843/288,710). Since the baseline repair cost is $2,416, the incremental repair cost is $1,547 (i.e., $3,963-$2,416). By accounting for the finance cost (6 percent, five-year loan), the resulting warranty cost would be $1,836 as shown in Table XI.2. Figure XI.1. graphically represents the same procedure for estimating the incremental repair costs.

Table XI.2 Estimated impact of new technologies on warranty cost per HHDD engine in MY 2031

	Baseline miles covered under warranty in MY 2022	Baseline repair cost in MY 2022	Estimated miles covered under warranty beginning MY 2031	Estimated repair cost beginning MY 2031	Incremental repair cost beginning MY 2031	Finance cost (6%, 5-year loan)	Capital cost increase per vehicle beginning MY 2031
Omnibus ISOR	288,710	$2,416	399,843	$3,346	$930	$174	$1,104
New technology sensitivity analysis	288,710	$2,861	399,843	$3,963	$1,547	$289	$1,836

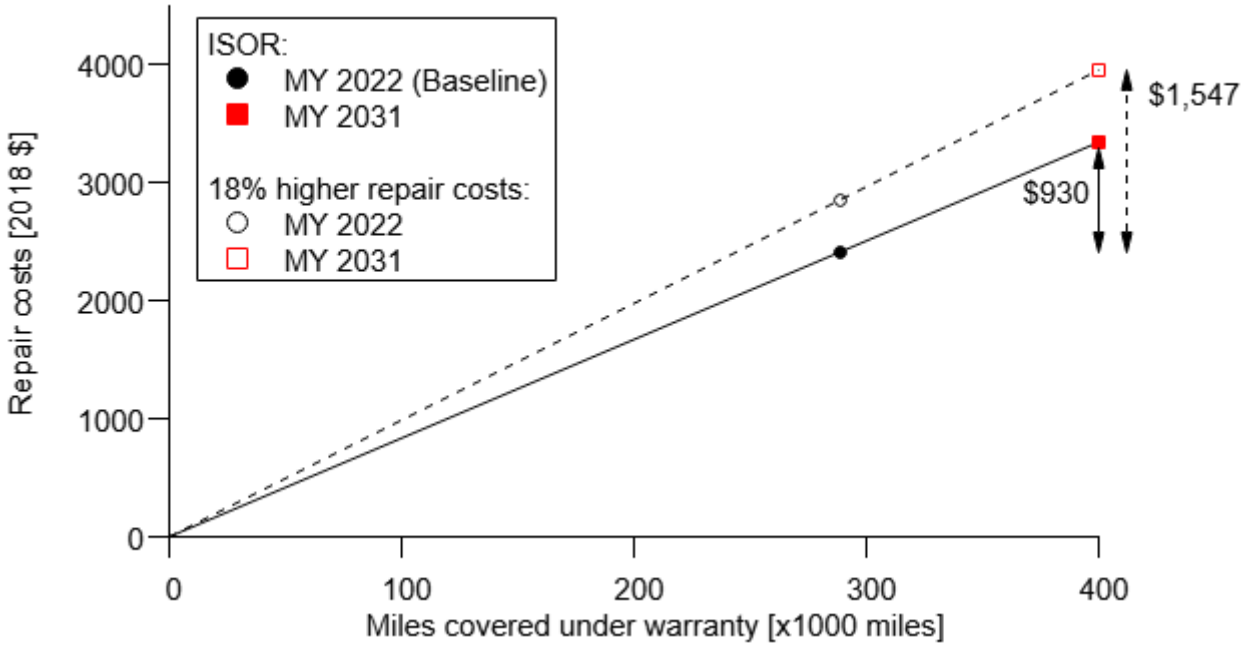

Figure XI.1 Estimated impact of new technologies on repair cost per HHDD engine in MY 2031

2. Statewide cost impact

To evaluate the potential impact of including the warranty costs for new technologies on the overall cost effectiveness of the Omnibus Regulation, for simplicity, the repair costs for all heavy-duty engines (HHDD, MHDD, LHDD, and HDO) are assumed to increase by 18.4 percent from MY 2027. Table XI.3 shows that if the warranty costs for new technologies were

included (i.e., 18.4 percent higher repair costs per mile), it would increase the total cost of warranty (i.e., parts, labor, and finance costs) by 54 percent and the total cost of the Omnibus Regulation by 11 percent. Since the increased repair costs reflected on the purchase price would eventually be recouped as cost savings, the total savings of the Omnibus Regulation would increase by 49 percent. The total NOx benefit would stay the same. As a result, the cost effectiveness ($ per pound of NOx reduction) would increase by five percent.

Table XI.3 Estimated impact of the warranty costs of new technologies on Omnibus Regulation's cost-effectiveness

Scenario	Total Cost of Warranty	Total Cost of Regulation	Total Savings of the Regulation	Total NOx Benefits [Tons]	Cost Effectiveness $/Ton	Cost Effectiveness $/lbs
ISOR	$933,280,923	$4,494,764,136	$650,574,767	352,797	10,896	5.45
Increasing repair costs by 18%	$1,435,433,020	$4,996,916,234	$970,336,830	352,797	11,413	5.71
Difference	$502,152,098	$502,152,098	$319,762,063	-	517	0.26

CARB staff compared the analysis result with the sensitivity analysis in the CARB staff report examining the impact of higher assumed warranty cost (CARB, 2020; Chapter IX.F). The CARB staff report sensitivity analysis showed that if the incremental warranty costs reported to the NREL survey were incorporated, it would have increased the cost effectiveness [$/lbs] by 26 percent (i.e., 6.88/5.45), which would still be reasonable when compared to those of recent CARB rulemakings. Since the five-percent increase is well within the bound of the previous CARB staff report sensitivity analysis (+26 percent), staff concluded higher warranty cost estimates due to new technologies would not have changed the staff proposal.

J. EMA's additional analysis "Projecting Extended Regulated ERC Warranty from Actual Extended Warranty Experience"

This analysis was presented to the work group by EMA staff on September 27, 2021. CARB staff was not provided the data it was based on and has not verified the analysis method.