

Revision of Tier 4 Criteria Pollutant Standards, Part 1: Amendments to Phase-in Schedule for Light-Duty and Medium-Duty Vehicles

Draft Regulatory Impact Analysis



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Standards, Part 1: Amendments to
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and Medium-Duty Vehicles

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Transportation Sector Impacts and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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Executive Summary

This Draft Regulatory Impact Analysis (DRIA) contains supporting documentation for the U.S. Environmental Protection Agency’s (EPA) proposed rulemaking to amend the phase-in schedule for the Tier 4 criteria pollutant standards for light-duty and medium-duty vehicles. This proposed action has the potential to impact compliance costs for the manufacturers and importers of light-duty vehicles. The DRIA also addresses requirements in Clean Air Act (CAA) section 317 and requirements under Executive Order (E.O.) 12866 to estimate the benefits and costs of major new pollution control regulations. The preamble to the *Federal Register* notice associated with this document provides the full context for the proposed rule, and it references this DRIA throughout.

Summary of Emissions Changes, Costs, Benefits, and Net Benefits

The EPA prepared an analysis of the impacts of this proposal on emissions, costs, benefits, and net benefits. Please refer to Chapter 1, Chapter 2, and Chapter 3 of this DRIA for more detailed discussion of emissions, costs, benefits, and net benefits. With respect to costs, this proposal projects a cost reduction to manufacturers of approximately \$1.66 billion to \$1.77 billion in present value terms (assuming a 7-percent or 3-percent discount rate, respectively; 2024 dollars), as shown in Table ES-1.

Table ES-1: Estimated Cost Savings (millions of dollars (2024\$))

	CY 2027	CY 2028	Present Value, 3%	Present Value, 7%	Annualized Value, 3% ^c	Annualized Value, 7% ^c
Cost Savings for PM Control	\$220	\$510	\$690	\$650	\$36	\$53
Cost Savings for NMOG+NO _x Control	\$470	\$660	\$1,070	\$1,010	\$56	\$82
Sum of Cost Savings	\$690	\$1,170	\$1,770	\$1,660	\$92	\$135

This proposed rule estimates the emissions changes that would occur from implementation of the proposed rule in model years (MYs) 2027 and 2028. The EPA estimated emissions impacts based on what the emissions would have been had the Tier 4 program phase-in schedule not been amended. Although the analysis assumes emissions would only change for MY 2027 and MY 2028 vehicles, those emission impacts would continue throughout the lifetime of the vehicles. Therefore, the EPA estimated the annual lifetime emission impacts of the MYs 2027 and 2028 vehicles through calendar year (CY) 2055.

Table ES-2 shows the estimated emissions impacts on volatile organic compounds (VOCs), oxides of nitrogen (NO_x), and particulate matter of 2.5 micrometers or less (PM_{2.5}) occurring in CYs 2027, 2028, and 2055, with positive values reflecting emission increases.

Table ES-2: Estimated Impacts on Emissions

Calendar Year	VOC Increase (short tons)	NO _x Increase (short tons)	PM _{2.5} Increase (short tons)
2027	353	389	51
2028	859	976	145
2055	92	106	27

Finally, the emissions changes described above would also be associated with impacts to air quality and human health. As discussed in section III.E of the preamble, the EPA did not monetize the health effects associated with emissions changes. The net benefits associated with this proposal are therefore the cost savings presented in Table ES-1. A qualitative description of the human health and welfare effects related to emissions changes associated with this proposal is provided in Chapter 2.3 of this DRIA.

There are likely to be sources of uncertainty in any complex analysis using estimated parameters and inputs from numerous models and assumptions. These uncertainties may impact both the baseline and the post-rule analysis, thus possibly affecting the estimated incremental impacts of the proposed rulemaking. In this analysis, the EPA considered several sources of uncertainty, both quantitatively and qualitatively, related to the costs and benefits of this action. Information on uncertainty related to costs, including estimates of battery electric vehicle (BEV) market share and variations in catalyst precious metal loading, can be found in Chapter 1 of this DRIA, including sensitivity analysis. Information on uncertainty related to benefits, including the quantification and monetization of health and welfare effects, can be found in section III.E of the preamble and Chapter 3 of this DRIA.

DRIA Chapter Summary

This document contains the following Chapters:

Chapter 1: Estimated Technology Cost Impacts

This chapter provides estimates of the impacts of the proposal on vehicle technologies and the cost of compliance.

Chapter 2: Emissions, Air Quality and Health Impacts

This chapter provides estimates of the impact of this proposal on highway vehicle emissions of criteria pollutants, criteria pollutant precursors, and selected air toxics using an updated

version of the EPA's Motor Vehicle Emission Simulator (MOVES5). The air quality impacts and health effects are also discussed in this chapter.

Chapter 3: Costs and Benefits

This chapter summarizes the results of an analysis of costs and benefits for the proposal.

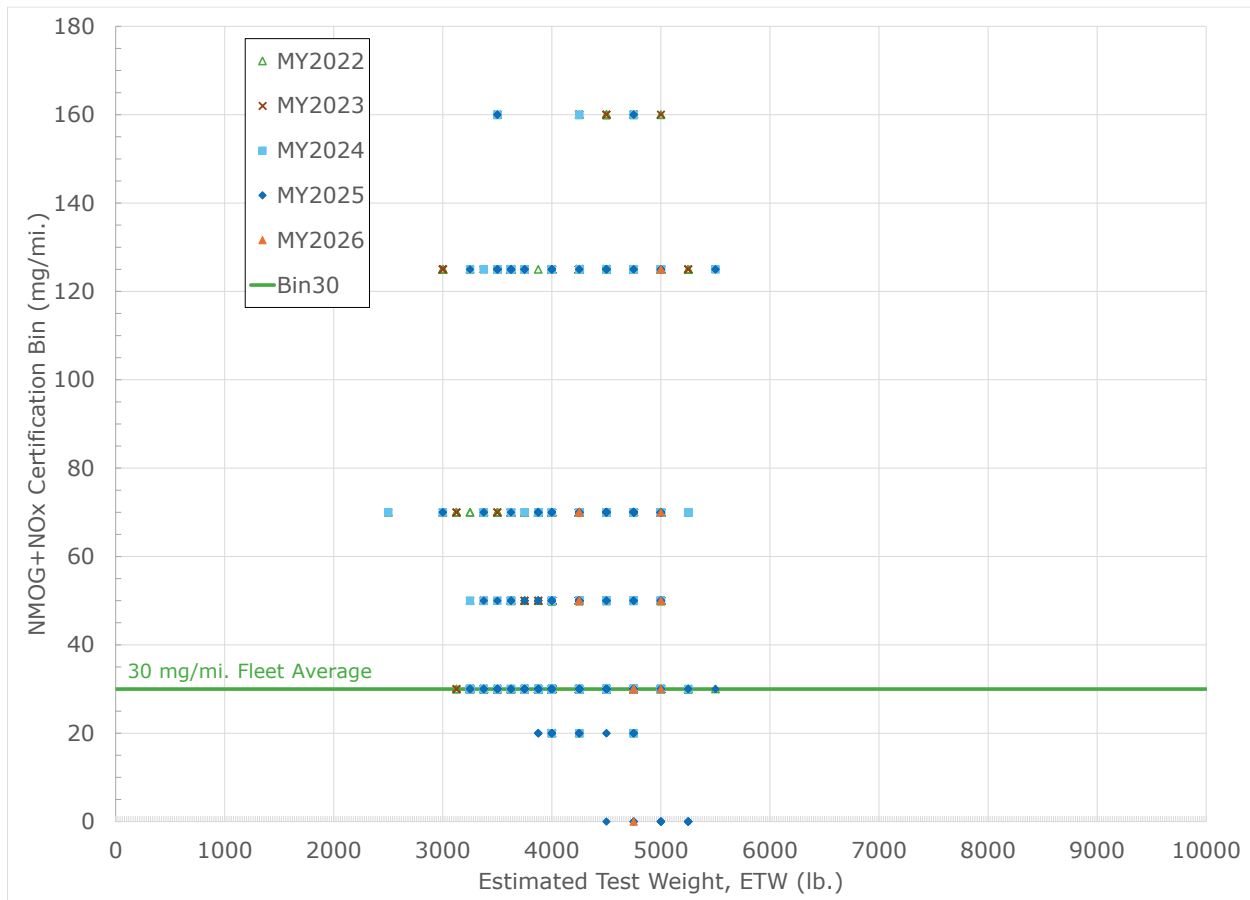
Chapter 4: Small Business Flexibilities

This chapter provides an analysis of the potential impacts of the proposal on small entities and small volume manufacturers.

Chapter 1: Estimated Technology Cost Impacts

In this DRIA, the EPA considers costs to the manufacturers, in particular, the hardware costs associated with emissions control technologies for NMOG+NO_x and PM. Because of the nature of this proposed action and its projected effects on vehicles, the EPA examines the incremental variable hardware costs associated with the various technologies. The EPA also projects changes in fixed costs as discussed later in this Chapter. The EPA assumes that certain fixed costs, such as those associated with certification, will be essentially unchanged because of this action and are not considered further.

The EPA evaluated the emissions certification levels for light-duty vehicles up to 6,000 pounds gross vehicle weight rating (GVWR) across several recent MYs. As shown in Figure 1-1, the EPA finds no correlation between a vehicle's estimated test weight (ETW, in pounds (lb.)) and the NMOG+NO_x certification bin (in milligrams/mile (mg/mile)). This result suggests that the costs for the technologies needed for Tier 4 emissions compliance could come from any vehicle within the GVWR range and not just the largest or smallest.



For the cost analysis of this proposed rule, the EPA assumed that the annual sales volume of all light-duty vehicles will be between 15 and 16 million units in both MY 2027 and MY 2028 for both the action and no-action cases.¹ This assumption is based on sales data from recent years and sales projections from the Annual Energy Outlook 2025 (AEO2025) and other groups (U.S. EIA 2025), (Alliance for Automotive Innovation 2025). For those light-duty vehicles up to 6,000 pounds, the sales volume is estimated to be about 10.2 million units, including BEVs, which is based on fleet compliance data submitted to the EPA covering MYs 2024 through 2026. Note that the EPA has assumed that sales volumes remain the same in the action and no-action cases, although if the cost savings to manufacturers resulted in lower vehicle prices the Agency would expect vehicle sales to increase.

For the analysis for this proposal, the EPA used a projected BEV market share in MYs 2027 and 2028 (U.S. EPA 2026). These values are eight percent in MY 2027 and 12 percent in MY 2028 for all light-duty vehicles. These projected BEV market shares were developed using the EPA OMEGA model. Details on the modeled projections can be found in an EPA technical memorandum (U.S. EPA 2026). These market share values are consistent with sales figures from the Alliance for Automotive Innovation and the EPA's own certification data over the last three years. This share also applies to the subset of vehicles weighing up to 6,000 pounds GVWR, as discussed in section III.A of the preamble. The EPA assumed the same number of BEVs would be sold in MYs 2027 and 2028 in the no-action and the action case for the cost and emission impact projections for this proposal. The EPA also conducted a sensitivity analysis, discussed in detail in Chapter 1.4 of this DRIA, around these central values by increasing or decreasing them by four percentage points. Thus, the full assessment considers four, eight, and 12 percent BEVs in MY 2027 and eight, 12, and 16 percent in MY 2028.

The EPA assumes the cost differences between the action and no-action cases come from changes to the emissions control technologies applied to internal combustion engine (ICE) vehicles. The EPA recognizes that multiple potential compliance pathways exist, including those that may rely more or less heavily on the use of BEVs than assumed in this proposal, and that the actual costs of the proposal may differ from what the Agency estimates here.

For the cost analysis presented in this chapter, the EPA estimated the sales-weighted fleet average emissions of NMOG+NO_x from ICE vehicles after considering the BEV market share of all light-duty vehicles up to 6,000 pounds GVWR. The EPA's assumption for the no-action case is that light-duty vehicles up to 6,000 pounds GVWR will meet the Tier 3 fleet-average standard of 30 mg/mile in MY 2026 and that manufacturers would add the technology needed to meet the Tier 4 fleet-average NMOG+NO_x standards of 25 and 23 mg/mile in MYs 2027 and 2028, respectively. The EPA also chose to exclude the potential effects of the NMOG+NO_x banking and trading program from the cost assessment for this proposal. The EPA has seen little trading of NMOG+NO_x credits between companies during the Tier 3 program, and the Agency does not have sufficient information to project how companies who have banked credits may use those credits in MYs 2027 and 2028. The EPA chose to omit potential other cost categories, such as effects on vehicle insurance costs, from this analysis because of the limited nature of this proposal. In addition, the EPA's cost analysis only looks at costs or savings in MYs 2027 and

¹ The action case represents the scenario in which the proposed changes to the regulations are implemented. The no-action case represents the 'business as usual' scenario, in which this proposal is not included.

2028 as they are the two MYs directly affected by this proposed action. However, future MYs may also be affected due manufacturers' use of the banking and trading program.

In the existing Tier 4 standards, the default Tier 4 program for heavier light-duty vehicles with GVWR between 6,001 and 8,500 pounds is that the NMOG+NO_x fleet average stays at 30 mg/mile through MY 2029 and then drops to a 15 mg/mile fleet average in MY 2030. The default Tier 4 program compliance schedule for medium-duty vehicles (MDVs), which are between 8,501 and 14,000 pounds GVWR, does not require compliance with the Tier 4 program until MY 2031. Thus, these heavier light-duty vehicles and the MDVs already have a compliance schedule that does not require meeting the Tier 4 standards in either MY 2027 or MY 2028. The EPA therefore focused the Agency's assessment of changes in costs and other impacts on those vehicles up to 6,000 lbs. GVWR.

For the tailpipe PM standards in the no-action case, light-duty vehicles up to 6,000 pounds GVWR are expected to follow the Tier 4 phase-in schedule from the 2024 LMDV Multipollutant Rule. Thus, for the cost analysis presented here, the EPA considered the costs associated with PM controls, including gasoline particulate filters (GPFs) and fuel injection systems, for that part of the new light-duty vehicle fleet.

The EPA notes the emissions control technologies considered in this proposal for MYs 2027 and 2028 are already in volume production, therefore the Agency has not performed a detailed feasibility assessment of these technologies. As discussed in the preamble for this proposal, the EPA is proposing to extend the Tier 3 program and delay the start of the Tier 4 program for two MYs due to concerns with lead time for vehicle development, not due to concerns with the ability of technologies to achieve the MY 2027 and 2028 Tier 4 standards given sufficient lead time.

In addition, the cost analysis described in this chapter for the proposed rule assumes that all vehicle models that might have been certified to the final Tier 4 standards would instead be certified to the interim Tier 4 or Tier 3 standards. The EPA is aware that some manufacturers have already certified some vehicle models to the final Tier 4 standards for MY 2027, therefore they may not realize the full level of cost savings estimated in this chapter. Thus, the cost savings estimated in this chapter represent an upper bound. The Tier 4 program uses sales to determine compliance with the per-vehicle standards and the NMOG+NO_x fleet average standards and for MYs 2027 and 2028 the Tier 4 PM standard is phased-in as a percentage of sales. The final MY2027 sales data will not be submitted to EPA until calendar year 2028. EPA may include additional information on this topic for the final rule analysis as we gather more information regarding MY 2027 certifications.

1.1 Costs Associated with the Tier 4 NMOG+NO_x Standards

There are many technology options for improving NMOG+NO_x emissions, as the EPA discussed in Chapter 3.2.5.1 of the 2024 LMDV Multipollutant Rule Regulatory Impact Analysis ("2024 LMDV RIA") (U.S. EPA 2024). Some of these technologies accelerate three-way catalyst (TWC) system warm-up during the cold start of the FTP-75 cycle, while others help reduce tailpipe emissions during operation once the exhaust aftertreatment system is warm. The modeling performed for the 2024 LMDV RIA found that vehicle electrification to be the main

compliance approach for achieving compliance with the combined GHG and Tier 4 NMOG+NO_x emissions standards. Therefore, the 2024 LMDV RIA did not model the adoption of specific NMOG+NO_x emissions control technology for ICE vehicles.

For this cost analysis, the EPA has assumed that a likely pathway for Tier 4 NMOG+NO_x emissions compliance will be adding catalyst content to the TWCs on gasoline-fueled light-duty program vehicles (U.S. EPA 2024). The application and steady improvement of TWCs for light-duty program vehicles has been the most common approach to reducing NMOG and NO_x emissions from gasoline vehicles for nearly 50 years. Improvements in TWCs were the primary technology automotive companies used to achieve the EPA Tier 2 and Tier 3 emission standards, and TWCs are one of the technologies the Agency projected could be used to comply with the Tier 4 NMOG+NO_x standards. In addition, this pathway is straightforward to assess from a cost perspective, since it relies upon adjusting the variable hardware cost associated with the TWC catalyst loading.²

In the 2024 LMDV RIA, the EPA used the formulae presented in Table 1-1 for estimating the costs associated with a TWC substrate, washcoat, and canning (U.S. EPA 2024). In addition to the 2012\$ costs presented in the LMDV RIA, the EPA also updated the parameters so that they represent 2024\$ (U.S. BLS 2025). Consistent with the EPA’s approach in the 2024 LMDV RIA and in past EPA rulemakings, the values in Table 1-1 are multiplied by a markup factor of 1.5 to represent both the indirect and direct costs to the manufacturer (Rogozhin, et al. 2010).³

Table 1-1: Direct Manufacturing Catalyst Component Costs Estimates (2012\$ and 2024\$) (U.S. EPA 2024).

Component	Cost equation (2012\$)	Cost equation (2024\$)
Catalyst substrate	$\$6.108 \times F_{\text{twc}} \times \text{Vol} + \1.955	$\$8.373 \times F_{\text{twc}} \times \text{Vol} + \2.680
Catalyst washcoat	$\$5.09 \times F_{\text{twc}} \times \text{Vol}$	$\$6.978 \times F_{\text{twc}} \times \text{Vol}$
Catalyst canning	$\$2.4432 \times F_{\text{twc}} \times \text{Vol}$	$\$3.3494 \times F_{\text{twc}} \times \text{Vol}$

Note: Vol = engine displacement and F_{twc} = TWC volume / engine displacement = 1.2
Source: SAE 2013-01-0534

Roughly 90 percent of the cost of a TWC is from the catalysts loaded into the catalyst washcoat that facilitate pollutant removal from the exhaust gas. These catalysts are the precious metals platinum (Pt), palladium (Pd), and rhodium (Rh), which are collectively known as platinum group metals (PGM). To fully estimate the catalyst costs, one must know the loadings of the three main elements in the TWC. Recent prices for these metals (Umicore 2025) are as follows:

- Pt: \$1,078.96 per troy ounce (oz.t.) or \$34.689 per gram.

² Manufacturers may determine that improved engines, controls, or other technologies may be a more cost-effective pathway to lower tailpipe emissions, which introduces a potential source of uncertainty in the cost analysis here.

³ Indirect costs include warranty, research and development, production depreciation and amortization, corporate operations (e.g., salaries, pensions, health care costs for corporate staff), OEM selling costs, dealer costs, and profit.

- Pd: \$1,058.99 per oz.t. or \$34.047 per gram.
- Rh: \$5,251.90 per oz.t. or \$168.852 per gram.

These metal prices were adjusted to 2024\$ for consistency with the rest of the cost analysis presented here. Then these values were averaged over the two years prior to retrieval—November 2, 2023, through November 2, 2025—to help smooth out fluctuations in the prices of these commodities. As with the other elements of the TWC, these catalyst costs are further multiplied by a markup factor of 1.5 to account for indirect costs at the vehicle manufacturer level.

As discussed above, the main cost increases for Tier 4 NMOG+NO_x controls for vehicles up to 6,000 pounds GVWR are assumed to be from increases in TWC catalyst loadings to meet the lower NMOG+NO_x sales-weighted fleet averages in MYs 2027 and 2028. Thus, the expected savings from the action case are from the incremental increase in PGM catalyst loading needed for Tier 4 compliance that will not be needed under this proposed action. The EPA assumed that the TWC system volume would be unchanged for a given engine displacement. The EPA also projected the change in fleet average NMOG+NO_x levels for new light-duty ICE vehicles. This projection assumed fleet-wide compliance with the applicable standards for the action and no-action cases given the BEV market share in the cost analysis. These values are shown in Table 1-2, where the analysis uses the BEV market share projections discussed earlier in this Chapter and in the preamble. The levels for ICE vehicles in the rightmost columns of Table 1-2 represent what the fleet average for the ICE vehicles needs to be so that, when averaged with the zero mg/mile levels from the market share of BEVs, the overall total meets the "action" or "no-action" regulatory standards, as shown in the second and third columns in the table.

Table 1-2: NMOG+NO_x Fleet Average Emissions for Light-Duty Vehicles up to 6,000 lb. GVWR in the Action and No-Action Cases.

Model Year	Level for Light-Duty Vehicle Fleet (including BEVs)		ICE Vehicle market share	Level for ICE Vehicles Only	
	Action Case (Tier 3) (mg/mi.)	No-Action Case (Tier 4) (mg/mi.)		Action Case (mg/mi.)	No-Action Case (mg/mi.)
2027	30	25	92%	32.6	27.2
2028	30	23	88%	34.1	26.1

The estimated fleet average NMOG+NO_x emissions levels for ICE light-duty vehicles up to 6,000 pounds are higher for the action case than for the no-action case. Thus, there is an expected incremental savings in catalyst content in TWCs across all new light-duty vehicles in each MY. For this cost analysis, sales of light-duty vehicles with ICEs are expected to be about 9.38 million vehicles in MY 2027 and 8.97 million in MY 2028.⁴ The EPA used Confidential Business Information (CBI) from eight light-duty vehicle models, all but one of which were light-duty vehicles up to 6,000 pounds GVWR. The exception was just over 6,000 pounds. The EPA determined that improving emissions performance by one Tier 3 bin, *e.g.*, Tier 3 Bin 50 to

⁴ With a ±4 percent range on the BEV market share, the range of expected sales of ICE vehicles are 8.97 million to 9.79 million in MY 2027 and 8.56 million to 9.38 million in MY 2028.

Bin 30, would require adding about 2.5 to 4.7 g of Pd or Pt per vehicle to the TWC. The PGM constituent, Rh, is assumed to stay the same. Pd and Pt are roughly interchangeable in TWC catalyst formulations, since they serve a similar function, so the cost analysis would be approximately the same using Pt costs instead of Pd costs as we have done here. Using the average value of 3.6 g of Pd increases the TWC cost by about \$175 per vehicle that improves one bin, including the indirect cost markup factor of 1.5. The lower Pd content would also make a replacement TWC cheaper, thus lowering maintenance costs over the life of the vehicle.

In MY 2027, the proposed fleet average NMOG+NO_x emissions level for ICE light-duty vehicles is 5.4 mg/mile higher in the action case than in the no-action case. The average vehicle does not need to improve one full bin, that is, 20 mg/mile. The catalyst content is therefore prorated by the average change in emissions level. For example, in MY 2027, the average incremental Pd saved per vehicle is $3.6 \text{ g} \times (5.4 \text{ mg/mile} / 20 \text{ mg/mile}) = 0.98 \text{ g Pd}$, which has a present value of \$50 per vehicle (2024\$), including markup. The CBI data suggest that the range of catalyst content reduction is 2.5 to 4.7 g Pd per bin, thus the per-vehicle catalyst savings would be \$35 to \$65, as shown in Table 1-3. The range in values in Table 1-3 reflects the range of reduction in Pd loading. Similarly, for MY 2028 the emissions level is 7.7 mg/mile higher than in the no-action case, which leads to a savings of about \$51 to \$95 per vehicle, again depending on Pd loading. For MY 2028, the average savings increases to \$73 per vehicle (2024\$) because the change is larger, *i.e.*, the incremental Pd saved is $3.6 \text{ g} \times (8.0 / 20) = 1.43 \text{ g}$. The per-vehicle cost savings estimates associated with the catalyst savings shown in Table 1-3 include undiscounted present values (in 2024\$) and discounted present values using 3-percent and 7-percent discount rates. The minimum per-vehicle values result from the lowest change in Pd used, whereas the maximum per-vehicle values result from the highest change in Pd. Here, the estimated change in Pd ranges from 0.69 g to 1.27 g in MY 2027 and from 1.00 to 1.86 g in MY 2028. For the cost analyses, though, we have used the average change in Pd, which is 0.98 g (\$50) in MY 2027 and 1.43 g (\$73) in MY 2028.

Table 1-3: Estimated 2027 Present Value of Per-Vehicle Cost Savings Associated with NMOG+NO_x Controls.

Model Year	Cost Savings, undiscounted (2024\$)	Cost Savings with 3% discount (2024\$)	Cost Savings with 7% discount (2024\$)
2027	\$35 – \$65	\$34 – \$63	\$33 – \$61
2028	\$51 – \$95	\$48 – \$90	\$45 – \$84
Overall	\$35 – \$95	\$34 – \$90	\$33 – \$84

The overall estimated savings for all new light-duty vehicles up to 6,000 pounds are shown in Table 1-4 for the central analysis case. The undiscounted present value of savings is shown along with savings reflecting a 3-percent or 7-percent discount rate. The discounted present value of the cost savings is discounted back to 2027 and uses year 2024 dollars. The projected undiscounted savings for the average incremental Pd amount of 3.6 g is \$470 million in MY 2027 and \$660 million in MY 2028 (year 2024 dollars). With a 7-percent or 3-percent discount rate, the average savings are \$440 to \$450 million in MY 2027 and \$570 to \$620 million in MY 2028 (year 2024 dollars).

Table 1-4: Estimated 2027 Present Value of Industry Cost Savings Associated with NMOG+NO_x Controls.

Model Year	ICE Vehicles ≤ 6,000 lb. GVWR	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	9.38 million	\$470	\$450	\$440
2028	8.97 million	\$660	\$620	\$570
Total	19.34 million	\$1,120	\$1,070	\$1,010

As noted above, the 2024 LMDV RIA demonstrated compliance with the Tier 4 emissions standards through vehicle electrification rather than the adoption of specific NMOG+NO_x emissions control technology for ICE vehicles. Since the cost estimates from the 2024 LMDV RIA focused on vehicle electrification, the costs of meeting the now binding NMOG+NO_x standards on final Tier 4 ICE vehicles have not been accounted for separately. This modeling limitation means that the cost savings for the NMOG+NO_x portion of this rulemaking have already been implicitly accounted for in a previous rulemaking. For this proposed rule, EPA is providing explicit estimates of the compliance cost savings from delaying NMOG+NO_x standards by using the more realistic assumption that the NMOG+NO_x standards would be met by improvements in ICE vehicle technologies. In particular, we model compliance through ICE vehicle catalyst improvements which cost less than complying through additional BEV sales.

1.2 Costs Associated with the Tier 4 PM Standards

The tailpipe PM emissions standards for Tier 4 from the 2024 LMDV Multipollutant Rule are a per-vehicle standard of 0.5 mg/mile. This standard must be met on each of three laboratory test cycles: -7°C ambient FTP-75, 25°C ambient FTP-75, and 25°C ambient US06. The PM standard is a per-vehicle requirement and not a fleet average, therefore the cost savings are directly related to the number of vehicles that need to meet the Tier 4 PM standard under the no-action case.

The Tier 4 standards are technology neutral, meaning that manufacturers may employ any technology or combination of technologies to meet the PM standard. For purposes of this cost analysis, though, the EPA has assumed that a GPF would be a cost-effective method to achieve the standard because it is a technology that is already in production and familiar to manufacturers.

The cost analysis of GPFs in Chapter 2.6.1.1.3 of the 2024 LMDV RIA (U.S. EPA 2024) used the following formula:

$$GPF = (42.269 \times Vol + 22.213) \times Markup$$

where *Vol* = the engine displacement in liters and *Markup* = the markup to include indirect costs, which was 1.5 in the 2024 LMDV RIA. To adjust the cost estimate from 2022\$ to 2024\$ (U.S. BLS 2025), the multiplicative cost factor should be 44.817 and the additive, 23.882, leading to a revised formula of

$$GPF = (44.817 \times Vol + 23.882) \times Markup$$

For example, if a vehicle had an engine displacement of 2.13 liters, which is the sales-weighted average for vehicles up to 6,000 pounds, the EPA would expect the cost to the manufacturer to be $(44.817 \times 2.13 + 23.882) \times 1.5 = \179 (2024\$). The engine displacements for these vehicles

range from 1.5 liters to 5.0 liters, which yields a GPF cost range of \$137 to \$372 per vehicle as shown in Table 1-5. This range in engine displacements represents a potential source of uncertainty in the cost savings estimates. Discounted present values are also included using the 3-percent and 7-percent discount rates.

Table 1-5: Estimated 2027 Present Value of Per-Vehicle Cost Savings Associated with PM Controls.

Model Year	Cost Savings, undiscounted (2024\$)	Cost Savings with 3% discount (2024\$)	Cost Savings with 7% discount (2024\$)
2027	\$137 – \$372	\$133 – \$361	\$128 – \$348
2028	\$137 – \$372	\$129 – \$351	\$119 – \$325
Total	\$137 – \$372	\$129 – \$361	\$119 – \$348

Currently, many manufacturers manage tailpipe PM emissions to the Tier 3 standard of 3 mg/mile by using a fuel injection system that combines a direct injection (DI) system with a port fuel injection (PFI) system. This combination allows the engine to achieve the efficiency benefits of the DI system at most operating points while mitigating engine-out PM emissions at high load by using the PFI system. There is a potential cost savings when fitting a GPF for manufacturers to simplify their fuel injection system by removing the PFI injectors. However, the EPA knows that not all manufacturers use a dual-injector approach currently, and there may be other engineering reasons to retain a dual system even with a GPF. Therefore, the cost analysis assumes no change in the number of PFI injectors and the projected net cost savings accounts for the savings associated with removing the GPF only. This assumption will tend to overstate the savings for those manufacturers who chose to remove the PFI injectors when fitting the GPF, since the PFI system cost will offset the GPF savings.

The incremental cost savings applies to each vehicle with a GVWR up to 6,000 pounds that needs to meet Tier 4 in the current phase-in schedule (*i.e.*, the no-action case) that would instead be at Tier 3 under this proposed action. The number of vehicles affected and the range of potential savings over the two MYs is shown in Table 1-6, where the savings reflect a 3-percent or 7-percent discount rate. The number of vehicles affected increases from approximately 1.22 million in MY 2027 to approximately 2.85 million in MY 2028, which are 12 percent and 28 percent of the vehicles with a GVWR up to 6,000 pounds, respectively. Note that the affected number of vehicles for PM controls is less than for NMOG+NO_x because the PM standards are per-vehicle standards while the NMOG+NO_x standards are fleet average standards. In MY 2027 under the current Tier 4 program, 20 percent of new vehicles must meet the 0.5 mg/mile PM standard, whereas a manufacturers' MY 2027 fleet must collectively meet the 25 mg/mile NMOG+NO_x standard.

The cost savings shown in Table 1-6 use the sales-weighted average engine displacement and the number of vehicles that would need GPFs in the central no-action case. The sales-weighted average engine displacement in vehicles up to 6,000 pounds GVWR is 2.13 liters, where the full range is 1.5 to 5.0 liters in these vehicles.

Table 1-6: Estimated 2027 Present Value of Industry Cost Savings Associated with PM Controls.

Model Year	Tier 4 ICE Vehicles ≤ 6,000 lb. GVWR	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	1.22 million	\$220	\$210	\$200
2028	2.85 million	\$510	\$480	\$450
Total	4.08 million	\$730	\$690	\$650

1.3 Total Costs Associated with the Proposed Rule

The combination of savings in NMOG+NO_x controls and PM controls will be substantial for manufacturers, both on a per-vehicle basis and overall. As described in Chapters 1.1 and 1.2, the per-vehicle costs for this proposed rule apply to significantly different numbers of vehicles. The market share of BEVs in the central action case is projected to be 8 percent, or about 815,000 vehicles, in MY 2027 and 12 percent, or 1.22 million vehicles, in MY 2028 (U.S. EPA 2026).

The cost savings for the two technologies apply to different numbers of vehicles. The NMOG+NO_x standards apply to all light-duty program vehicles up to 6,000 pounds GVWR because they use a sales-weighted fleet average. With the projected market share of BEVs, this means that the NMOG+NO_x controls apply to 9.38 million vehicles in MY 2027 and 8.97 million vehicles in MY 2028.

By contrast, the PM standards are a per-vehicle standard, so the costs are only incurred on those vehicles that will need a GPF to mitigate PM emissions. This means 20 percent of light-duty program vehicles up to 6,000 pounds GVWR will need to meet or exceed Tier 4 PM emissions in MY 2027, and 40 percent in MY 2028. With the projected BEV market shares in these two MYs, 1.22 million vehicles will need GPFs in MY 2027 and 2.85 million in MY 2028.

The full cost savings estimate is therefore calculated by combining the savings from NMOG+NO_x controls and PM controls. The combined savings using undiscounted values and with both discount rates are shown in Table 1-7. The middle estimates of undiscounted cost savings in the range are expected to be \$1.85 billion. The present value of cost savings is \$1.77 billion assuming a 3-percent discount rate and \$1.66 billion assuming a 7-percent discount rate (all in year 2024 dollars).

Table 1-7: Estimated 2027 Present Value of Industry Cost Savings Associated with NMOG+NO_x and PM Controls Combined.

Model Year	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	\$690	\$670	\$640
2028	\$1,170	\$1,100	\$1,020
Total	\$1,850	\$1,770	\$1,660

1.4 Sensitivity Analysis of Costs

The results presented in the preceding part of Chapter 1 are focused on the central analysis case, where the market share of BEVs is projected to be 8 percent in MY 2027 and 12 percent in MY 2028. There are two main sources of variability in the estimated cost savings are variability in the market share of BEVs sold in MYs 2027 and 2028, and variability in per-vehicle costs.

For the first point, the EPA assumed that the BEV market share might vary by four percentage points in each MY. Thus, in MY 2027, the market share could be 4 percent to 12 percent BEVs, or 408,000 to 1,220,000 BEVs sold. Likewise, in MY 2028, the market share could be 8 percent to 16 percent BEVs, or 815,000 to 1,630,000 BEVs sold. This range in BEV market share affects the number of vehicles needing more catalyst to control NMOG+NO_x emissions and the number of vehicles needing GPFs to control PM emissions.

Therefore, for the NMOG+NO_x standards, the range is 8.97 million to 9.79 million vehicles in MY 2027 and 8.56 million to 9.38 million vehicles in MY 2028 because the NMOG+NO_x standards apply to all vehicles sold. By contrast, the PM standards only apply to the portion of new vehicles sold that must comply with final Tier 4 standards, which is 815,000 to 1,630,000 vehicles in MY 2027 and 2.45 million to 3.26 million vehicles in MY 2028.

For the second point, CBI shows that the TWC catalyst loading has significant vehicle to vehicle variability within a given certification bin. The Pd loadings are a complex function of catalyst dispersion within the washcoat, other washcoat compounds that stabilize the catalyst, the geometry of the TWC system, TWC warm-up strategy, and engine-out emissions levels.

The estimated range of cost savings associated with NMOG+NO_x controls therefore includes the effects of BEV market share variability and the range of Pd loadings in light-duty program vehicles observed in the CBI. These cost savings results are shown in Table 1-8 for undiscounted present values and also values discounted by 3-percent or 7-percent.

Table 1-8: Sensitivity Analysis: Estimated 2027 Present Value Range of Industry Cost Savings Associated with NMOG+NO_x Controls.

Model Year	ICE Vehicles ≤ 6,000 lb. GVWR (million)	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	8.97–9.79	\$330 – \$610	\$320 – \$590	\$310 – \$570
2028	8.56–9.38	\$440 – \$850	\$430 – \$800	\$400 – \$740
Total	17.53–19.16	\$790 – \$1,460	\$750– \$1,390	\$710 – \$1,310

The estimated range of cost savings associated with PM controls includes the effects of BEV market share variability and light-duty program vehicle variability, including engine displacements. These cost savings results are shown in Table 1-9 for undiscounted present values and also values discounted by 3 percent or 7 percent.

Table 1-9: Sensitivity Analysis: Estimated 2027 Present Value Range of Industry Cost Savings Associated with PM Controls.

Model Year	Tier 4 ICE Vehicles ≤ 6,000 lb. GVWR (million)	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	0.82–1.63	\$150 – \$290	\$140 – \$280	\$140 – \$270
2028	2.45–3.26	\$440 – \$580	\$410 – \$550	\$380 – \$510
Total	3.26–4.89	\$580 – \$880	\$550 – \$830	\$520 – \$780

The results in Tables 1-8 and 1-9 can be combined to show the overall estimated range of cost savings to industry, as shown in Table 1-10.

Table 1-10: Sensitivity Analysis: Estimated 2027 Present Value Range of Industry Cost Savings Associated with NMOG+NO_x and PM Controls Combined.

Model Year	Cost Savings, undiscounted (millions of dollars (2024\$))	Cost Savings with 3% discount (millions of dollars (2024\$))	Cost Savings with 7% discount (millions of dollars (2024\$))
2027	\$470 – \$900	\$460 – \$870	\$440 – \$840
2028	\$900 – \$1,430	\$850 – \$1,350	\$780 – \$1,250
Total	\$1,370 – \$2,330	\$1,310 – \$2,230	\$1,230 – \$2,090

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Chapter 2: Emissions, Air Quality, and Health Impacts

The EPA estimated the impact of this proposal on highway vehicle emissions of criteria pollutants, criteria pollutant precursors, and selected air toxics by modeling national emission inventories using a regulatory version of MOVES5 (U.S. EPA 2024b). In this chapter, the EPA presents the estimated changes in the emissions inventory that would result from the proposed rule and discusses the impacts on air quality and human health.

2.1 Modeled Emissions Changes from the Proposed Rule

MOVES is an emissions modeling system that estimates air pollution emissions for criteria air pollutants and precursors, GHGs, and air toxics. MOVES covers light-, medium-, and heavy-duty onroad vehicles such as cars, trucks and buses, and other mobile sources. MOVES accounts for the phase-in of Federal emissions standards, vehicle and equipment activity, fuels, temperatures, humidity, and emission control activities such as inspection and maintenance (I/M) programs.

The version developed for this proposal, MOVES5.R3, does not contain any major algorithmic changes relative to MOVES5, making the two versions similar in terms of their modeling capabilities and outputs.

However, MOVES5.R3 incorporates several updates to vehicle population and activity based on the latest information. The EPA updated vehicle miles travelled (VMT) data for 2023 and beyond using the Federal Highway Administration's (FHWA) Highway Statistics 2023 (U.S. DOT FHWA 2023). The EPA also updated bus populations based on the School Bus Fleet Factbook (Hugget 2024) and the Federal Transit Administration's National Transit Database (U.S. DOT FTA 2024) and the Agency updated future activity projections based on the Annual Energy Outlook 2025 (AEO2025) Reference case (U.S. EIA 2025). *See* MOVES5 Vehicle Population and Activity (VPAT) technical report (U.S. EPA 2024c) for other population and activity data in MOVES5.

In addition, MOVES5.R3 includes further updates to represent the U.S. without EPA motor vehicle and engine GHG standards and relevant Inflation Reduction Act (IRA) tax credits (Public Law 117-169 2022), which were changed by the One Big Beautiful Bill Act (OBBB) (Public Law 119-21 2025) described in preamble section II.B. The EPA modeled the removal of these standards and tax credits in the no-action case by revising both the electric vehicle (EV) projections and MOVES energy consumption rates, as described below.

For the light- and medium-duty sector, the EPA used output from a run of the Agency's Optimization Model for reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) that did not contain the GHG portions of the LMDV Multipollutant Rule, the ACT rule for medium-duty EV adoption, or the IRA incentives which were ended by the OBBB. The EPA updated MOVES5.R3 to match OMEGA's projections of both EV adoption and energy consumption for light- and medium-duty vehicles. The EV fractions from OMEGA were incorporated in MOVES5.R3 via the `sampleVehiclePopulation` table in the default database. This table describes the relative default population used in MOVES based on vehicle properties such as fuel and engine technology.

In addition, to assess the impacts of LD EV penetration on emissions, the EPA performed sensitivity modeling by adjusting the EV fractions projected by OMEGA for MYs 2027 and

2028 by ±4 percent for each MOVES sourceTypeID, resulting in a High and a Low EV scenario. Changes in the shares of EV population were offset by modifying the corresponding fraction of gasoline vehicles. These adjustments were applied to passenger cars (sourceTypeID 21), light-duty passenger trucks (sourceTypeID 31), and light-duty commercial trucks (sourceTypeID 32) under 8,500 lbs GVWR.⁵ The input EV fractions used for modeling all cases are presented in Table 1 in the Appendix. The resulting weighted light-duty EV fractions for MYs 2027 and 2028 are shown in Table 2-1 for all modeled cases.

All the updates to MOVES5.R3 described above apply to both action and no-action cases for this proposal.

Table 2-1: Weighted Light-Duty EV Populations Modeled in MOVES for All Scenarios.

Modeling Scenario	Year	LD EV MYs 2027–2028 population (percent)
Low	2027	7.6
	2028	8.4
Central	2027	11.7
	2028	12.5
High	2027	15.8
	2028	16.6

2.1.1 Action Case

To model the proposed change to NMOG+NO_x standards, the EPA reverted base emission rates for passenger cars (regClassID 20) and light-duty trucks (regClassID 30) for MYs 2027 and 2028 to values corresponding to fully phased-in Tier 3 standards. These changes were applied to emission rates representing running and start emissions of total hydrocarbons (THC)⁶ and NO_x. These modifications were applied in the emissionRateByAge table for all ages and operating modes⁷ for the corresponding MYs referred above. In addition, the EPA also modified the fleetAvgAdjustment table to extend the range for Tier 3 fleet averaging conditions up through 2028.

MOVES5 models PM emissions reductions from the 2024 LMDV Multipollutant Rule with changes in the emission rates for elemental carbon (EC) PM (MOVES pollutant ID 112), and for non-EC PM (MOVES pollutant ID 118) for MYs 2027 through 2030. To model the proposed rule, the EPA replaced the MOVES5 PM emission rates for light-duty cars (regClassID 20) and

⁵ The MOVES regulatory class definition for light-duty trucks does not allow for differentiation of vehicles by GVWR. Therefore, the adjustments made to MOVES for this proposal also affect modeled emissions for heavier passenger and commercial trucks between 6,000 to 8,500 lbs. These adjustments were applied to both the no-action and action cases.

⁶ MOVES database contains emission rates for THC and models NMOG as a chained pollutant, therefore, any modifications done to represent changes in NMOG need to be applied to THC rates.

⁷ For start emission rates, these changes were applied only to rates representing "intermediate" soak periods as described in Chapter 7.2.1.4.3 of the U.S. EPA. "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. Regulatory Impact Analysis." EPA-420-R-24-004. March 2024. Available online: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=P1019VPM.pdf>.

light-duty trucks (regClassID 30) for MYs 2027 and 2028 with their respective rates from MY 2026, representing the fully phased-in Tier 3 standards. The PM rates for all MYs except 2027 and 2028 were left unchanged.

All of the datasets used to generate MOVES5.R3, the default databases for the action case, sensitivity scenarios, and the modeling outputs for each scenario are attached in a memorandum to the docket (Aldridge 2026).

2.1.2 Emission changes

The EPA performed model runs for the no-action and action cases for all years between 2027 and 2055. Table 2-2 presents absolute and relative emission changes estimated for selected pollutants and CYs. Positive values for the emission changes reflect emissions increases. Percent changes are shown relative to the no-action case for the national onroad (light-, medium-, and heavy-duty) inventory. The complete year-over-year air toxics results and more detailed description of modeling are provided in the Appendix to this chapter.

Table 2-2: Annual Increases in National Onroad Emissions for Criteria Pollutants and Air Toxics in Select CYs for the Central Scenario.

Pollutant ^A	CY 2027		CY 2028		CY 2035		CY 2045		CY 2055	
	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad
Nitrogen Oxides (NO _x)	389	<0.1	976	0.1	1031	0.2	482	0.1	106	<0.1
Particulate Matter ^B (PM _{2.5})	51	0.2	145	0.5	167	1.1	102	1.6	27	0.7
Volatile Organic Compounds (VOC)	353	<0.1	859	0.1	878	0.1	405	0.1	92	<0.1
1,3-Butadiene	2	0.1	5	0.3	5	0.5	2	0.3	<1	0.1
Acetaldehyde	5	0.1	13	0.2	13	0.3	6	0.2	1	<0.1
Benzene	16	0.1	40	0.3	41	0.5	19	0.3	4	0.1
Formaldehyde	4	0.1	9	0.2	10	0.3	5	0.2	1	<0.1
Naphthalene ^C	1	0.1	2	0.2	2	0.4	1	0.3	<1	0.1
Methane	90	0.1	212	0.1	228	0.1	111	<0.1	26	<0.1

Notes:

A. SO₂ and CO emissions do not change with this proposed rule.

B. PM_{2.5} changes only come from tailpipe emissions. Brake wear and tire wear emissions are not changing with this proposed rule.

C. Naphthalene includes changes in both particle and gas phase components.

The estimated impact of the proposed rule on VOC is equal to or less than a 0.1 percent increase in the total onroad vehicle emissions in the years presented. Increases in NO_x are equal to or less than 0.2 percent, while onroad PM_{2.5} emissions increases range between 0.2 and 1.6 percent for the years presented. The estimated impact of the proposed rule on a number of air toxics is equal to or less than a 0.5 percent increase in the total onroad vehicle emissions in the years presented. In general, the emissions impact of the proposal would be the largest during

years when these vehicles have deteriorated but still represent a significant portion of the VMT. As these vehicles age and are replaced due to fleet turnover, the emissions impact decreases and the EPA estimates changes of 0.1 percent or smaller for NO_x, VOC, and toxics and 0.7 percent for PM_{2.5} in 2055. This proposal is not expected to impact GHG emissions, with the exception of an increase in methane of 0.1 percent or smaller across the range of years modeled.

The sensitivity analysis, modeling scenarios with ±4 percent EV population, showed negligible differences in emissions increases relative to the Central scenario for NO_x and VOC, as shown in Figure 2-2. For PM_{2.5}, the sensitivity scenarios resulted in up to ±0.1 percent change across the range of years modeled relative to the Central scenario, with the Low EV scenario resulting in the highest emission increase. Detailed year-over-year results for the sensitivity cases are presented in the Appendix to this chapter.

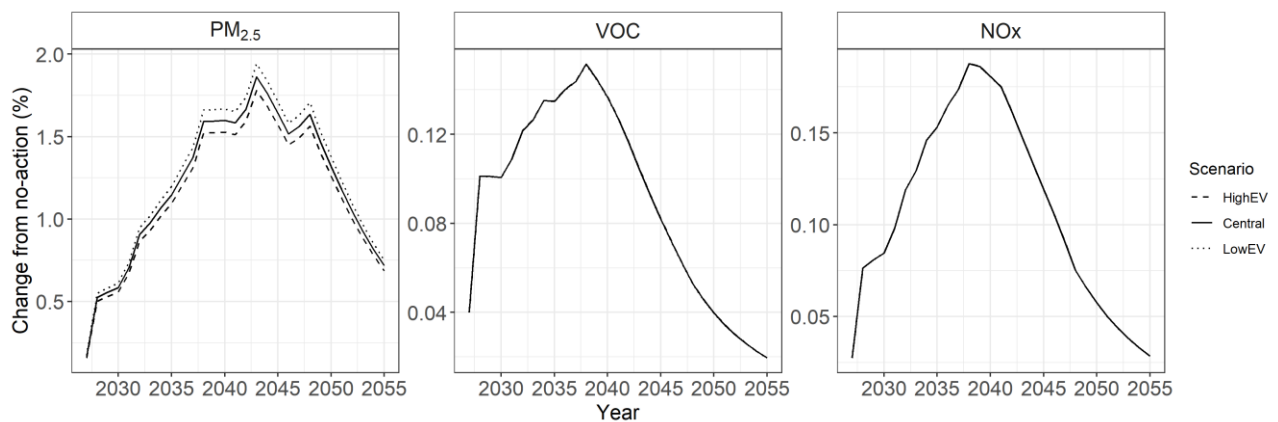


Figure 2-1 Emissions Increases from No-Action Case Across the Range of Years and Scenarios Modeled for PM_{2.5}, NO_x and VOC.

Table 2-3 presents year-over-year absolute and relative emission changes for NO_x, VOC, and tailpipe PM_{2.5} for the Central scenario. Positive values for the emission changes reflect emissions increases. Percent changes are shown relative to the no-action case for the national onroad (light-, medium-, and heavy-duty) inventory. Year-over-year results provide more insight into the period where the largest emissions impacts would be observed, depending on the pollutant. For NO_x, the largest effect (0.2 percent increase in all onroad NO_x emissions) of the proposal is observed in the 2035–2042 period. For VOC, the largest impact (0.2 percent) is observed in 2038, while PM_{2.5} shows the largest effect (1.9 percent) in 2043. The absolute emissions impact for NO_x (1058 tons) and VOC (909 tons) is the largest in 2034, while for PM_{2.5}, the largest impact (174 tons) is in 2038.

Table 2-3: Year-Over-Year Emissions Increases in NO_x, VOC, and PM_{2.5} for Central Scenario.

Year	NO _x		VOC		PM _{2.5}	
	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad
2027	389	<0.1	353	<0.1	51	0.2
2028	976	0.1	859	0.1	145	0.5
2029	932	0.1	820	0.1	139	0.6
2030	887	0.1	780	0.1	133	0.6
2031	930	0.1	813	0.1	145	0.7
2032	1018	0.1	876	0.1	169	0.9
2033	1024	0.1	882	0.1	167	1.0
2034	1058	0.1	909	0.1	170	1.1
2035	1031	0.2	878	0.1	167	1.1
2036	1019	0.2	856	0.1	168	1.3
2037	1008	0.2	851	0.1	167	1.4
2038	1022	0.2	863	0.2	174	1.6
2039	950	0.2	802	0.1	162	1.6
2040	876	0.2	739	0.1	150	1.6
2041	796	0.2	670	0.1	135	1.6
2042	710	0.2	599	0.1	131	1.7
2043	626	0.1	530	0.1	136	1.9
2044	551	0.1	464	0.1	118	1.8
2045	482	0.1	405	0.1	102	1.6
2046	421	0.1	352	0.1	88	1.5
2047	355	0.1	301	0.1	81	1.6
2048	291	0.1	256	0.1	81	1.6
2049	253	0.1	221	<0.1	69	1.5
2050	219	0.1	191	<0.1	59	1.3
2051	189	0.1	165	<0.1	50	1.2
2052	164	<0.1	143	<0.1	43	1.0
2053	143	<0.1	124	<0.1	37	0.9
2054	123	<0.1	107	<0.1	31	0.8
2055	106	<0.1	92	<0.1	27	0.7

2.2 Air Quality Impacts of the Proposed Rule

Chapter 2.1 of this DRIA presents projections of the emission reductions that would no longer occur under the proposed rule. The EPA did not conduct air quality modeling for this proposed rule, and making predictions based solely on emissions changes is extremely difficult; the atmospheric chemistry related to ambient concentrations of PM_{2.5}, ozone, and air toxics is very complex, and the emissions changes are spatially variable. Nevertheless, considering the air quality modeling conducted for recent vehicle rules and the relatively small projected increase in total on-road emissions from this proposal, overall the EPA expects relatively small changes in ambient concentrations of air pollutants from this proposal (89 FR 27842 2024) (88 FR 4296 2023).

The EPA expects that in areas close to roadways (*i.e.*, within 300–600 meters of the roadway), the increased vehicle emissions could increase ambient levels of PM_{2.5}, NO₂, and other traffic-related pollutants. Across broader geographic areas, the EPA also expects the increased vehicle emissions to contribute to ambient concentrations of ozone, PM_{2.5}, and air toxics which are

secondarily formed in the atmosphere. The EPA conducted air quality modeling for the 2024 LMDV Multipollutant Rule and expects the spatial distribution of the air quality impacts from this proposal to be similar to the spatial distribution of air quality impacts associated with the "onroad only" results from the air quality modeling analysis for that rule (89 FR 27842 2024). It is difficult to draw further conclusions about the air quality impacts of this proposed rule using the analysis from the 2024 LMDV Multipollutant Rule because the no-action cases are different, the emissions impacts are in the opposite directions, and the magnitude of the emissions impacts from the 2024 LMDV Multipollutant Rule are much larger than the emissions impacts from this proposed rule.

2.3 Health and Welfare Effects of Proposed Rule Related to Changes in Air Quality

As described in Chapter 2.1, the proposal would result in changes in emissions of pollutants that contribute to ambient concentrations of PM_{2.5}, ozone, NO₂, and air toxics. There are a broad range of health risks and welfare effects associated with exposure to these pollutants, including premature mortality, non-fatal illnesses, and other adverse effects, including ecosystem effects. This air pollution affects people nationwide and those who live or work near transportation corridors. Detailed information on the health and welfare effects associated with exposure to pollutants emitted by mobile sources and impacted by this proposed rule can be found in sections II.B–D of the 2024 LMDV Multipollutant Rule's preamble (89 FR 27842 2024) and Chapter 6 of its RIA (U.S. EPA 2024).

The EPA sometimes performs air quality modeling to conduct a full assessment of the PM_{2.5}-related and ozone-related human health benefits of the Agency's regulatory actions. As discussed in Chapter 2.2, the EPA did not conduct air quality modeling for this proposal.

Historically, the EPA estimated the monetized benefits of avoided PM_{2.5}- and ozone-related impacts, which accounted for most, if not all, of the monetized benefits of many air regulations—even when the regulation was not regulating PM_{2.5} or ozone. The Office of Management and Budget (OMB), in its annual report of the Benefits and Costs of Federal Regulations, routinely provides estimates that the monetized benefits from reducing PM_{2.5} and/or ozone exceed hundreds of millions or even billions of dollars and result in most of the monetized benefits from Federal regulations.

In previous RIAs, the EPA's approach to estimating the impacts to human health of the changes in concentrations of ozone and PM_{2.5} relied substantially on information from the Integrated Science Assessments (ISAs) for ozone and particulate matter (*e.g.*, (U.S. EPA 2020) (U.S. EPA 2019)). These documents synthesize the toxicological, clinical, and epidemiological evidence to determine whether PM and ozone are causally related to an array of adverse human health outcomes associated with either acute (*i.e.*, hours or days-long) or chronic (*i.e.*, years-long) exposure; for each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship. The ISAs reflect the EPA's most up-to-date evaluation of the strength and limitations of the available scientific evidence and clearly identify the health and welfare endpoints for which the evidence is strongest. The EPA continues to focus on these endpoints in considering how regulatory actions may impact public health and welfare. Historically, the EPA has estimated the incidence of air pollution effects for those health endpoints that the ISA classified as either causal or likely-to-be-causal and these endpoints are shown in Table 2-4. The table below omits welfare effects such as acidification and nutrient enrichment.

Table 2-4: Health Effects of Ambient Ozone and PM_{2.5}

Category	Effect	Causal/Likely-to-be-causal	More Information	
Premature mortality from exposure to PM _{2.5}	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age 65-99 or age 30-99)	✓	PM ISA	
	Infant mortality (age <1)	✓	PM ISA	
Nonfatal morbidity from exposure to PM _{2.5}	Heart attacks (age > 18)	✓	PM ISA	
	Hospital admissions—cardiovascular (ages 65-99)	✓	PM ISA	
	Emergency department visits— cardiovascular (age 0-99)	✓	PM ISA	
	Hospital admissions—respiratory (ages 0-18 and 65-99)	✓	PM ISA	
	Emergency room visits—respiratory (all ages)	✓	PM ISA	
	Cardiac arrest (ages 0-99; excludes initial hospital and/or emergency department visits)	✓	PM ISA	
	Stroke (ages 65-99)	✓	PM ISA	
	Asthma onset (ages 0-17)	✓	PM ISA	
	Asthma symptoms/exacerbation (6-17)	✓	PM ISA	
	Lung cancer (ages 30-99)	✓	PM ISA	
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	PM ISA	
	Lost work days (age 18-65)	✓	PM ISA	
	Minor restricted-activity days (age 18-65)	✓	PM ISA	
	Hospital admissions—Alzheimer’s disease (ages 65-99)	✓	PM ISA	
	Hospital admissions—Parkinson’s disease (ages 65-99)	✓	PM ISA	
	Other cardiovascular effects	✓	PM ISA	
	Other respiratory effects	✓	PM ISA	
	Other nervous system effects	✓	PM ISA	
	Cancer	✓	PM ISA	
	Reproductive and developmental effects	—	PM ISA	
	Metabolic effects	—	PM ISA	
	Mortality from exposure to ozone	Premature respiratory mortality based on short-term study estimates (0-99)	✓	Ozone ISA
		Premature respiratory mortality based on long-term study estimates (age 30-99)	✓	Ozone ISA

Category	Effect	Causal/Likely-to-be-causal	More Information
Nonfatal morbidity from exposure to ozone	Hospital admissions—respiratory (ages 0-99)	✓	Ozone ISA
	Emergency department visits—respiratory (ages 0-99)	✓	Ozone ISA
	Asthma onset (0-17)	✓	Ozone ISA
	Asthma symptoms/exacerbation (asthmatics age 2-17)	✓	Ozone ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	Ozone ISA
	Minor restricted-activity days (age 18–65)	✓	Ozone ISA
	School absence days (age 5–17)	✓	Ozone ISA
	Metabolic effects (e.g., diabetes)	✓	Ozone ISA

For regulatory analyses, the EPA estimated changes in health effects in response to modeled air quality changes for most health endpoints identified as causal or likely-to-be-causal in Table 2-4. Some endpoints were not quantified due to data availability limitations, such as for other cardiovascular/respiratory/nervous system effects. The environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) software program was used to quantify counts of premature deaths and illnesses attributable to photochemical modeled changes in annual mean PM_{2.5} and summer season average ozone. This approach to estimating health impacts involved two major steps: (1) developing spatial fields of air quality across the U.S. for the baseline and regulatory scenarios using nationwide photochemical source apportionment modeling and related analyses; and (2) using these spatial fields in BenMAP-CE to quantify selected endpoints under each scenario and each year as compared to the baseline in that year while accounting for the changes in population size, income growth, and baseline incidence and prevalence rates.

Figure 2-2 summarizes the key data inputs and modeling steps for estimating the health impacts of a regulatory impact analysis using PM_{2.5} inputs as an example.

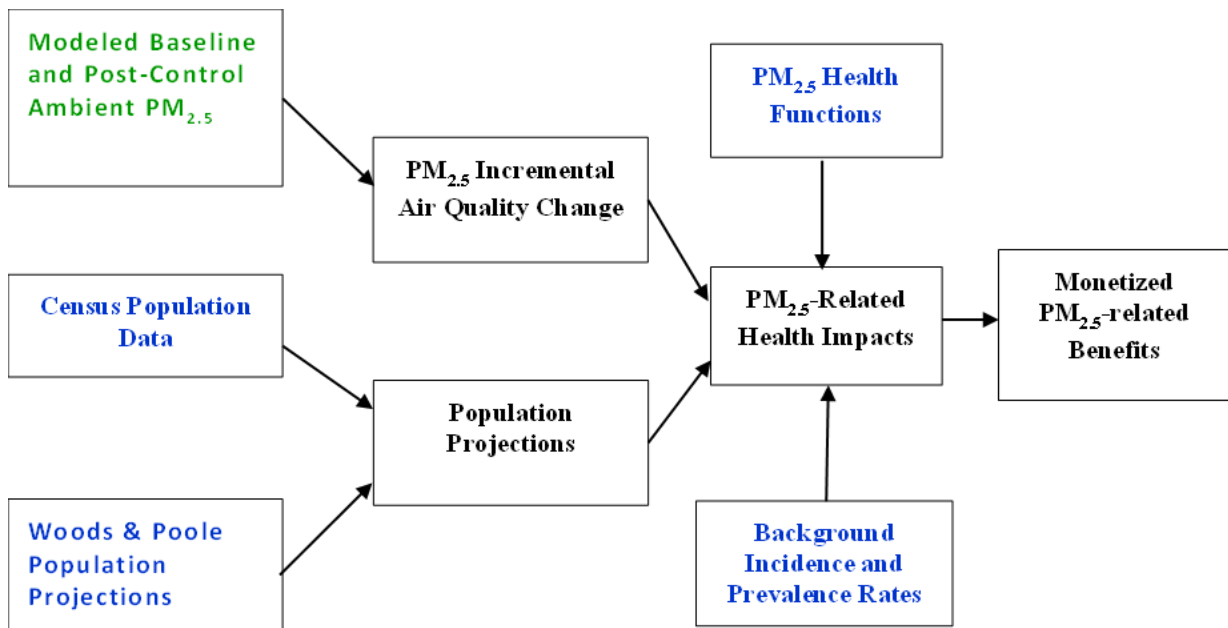


Figure 2-2: Data Inputs and Outputs for the BenMAP-CE Model Using PM_{2.5} as an Example.

As the diagram above illustrates, the approach for estimating PM_{2.5} and ozone benefits included health effect risk estimates from epidemiologic studies, population data, population growth estimates, economic data for monetizing risk reductions, and assumptions regarding the future state of the world (*e.g.*, on-the-books regulations). Each of these inputs has unique uncertainties associated with it. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. Where possible, the EPA in the past has attempted to quantitatively assess uncertainty in each input parameter. In some cases, quantitative analysis has not been possible due to lack of data, so the EPA instead characterized the sensitivity of the results to alternative plausible input parameters. And, for some inputs into the benefits analysis, such as the air quality data, the EPA lacked the data to perform either a quantitative uncertainty analysis or sensitivity analysis.

Throughout prior RIAs, the EPA acknowledged these significant uncertainties around input parameters and employed various techniques for characterizing the resulting uncertainty in estimates of regulatory impacts. For example, the EPA has estimated the fraction of avoided health effects occurring at various concentration ranges, conducted sensitivity analyses, and employed alternate concentration-response assumptions to show how much estimates could vary depending on which assumptions and inputs were used in primary estimates versus sensitivity estimates.

Chapter 6 of the EPA Health Benefits TSD, Estimating PM_{2.5}- and Ozone-Attributable Health Benefits: 2024 Update, details the Agency’s approach to characterizing uncertainty associated with the estimation of PM_{2.5} and ozone benefits in both quantitative and qualitative terms (U.S. EPA 2024a). Some of the key types of uncertainty highlighted in this chapter include:

- Statistical uncertainty around the risk estimate

- Uncertainty around low concentration exposures and the potential for thresholds
- Uncertainty in exposure estimates
- Co-pollutant confounding
- Confounding by other individual risk factors
- Effect modification
- Application of risk estimates to other locations and populations
- Uncertainties regarding at-risk populations
- Baseline incidence rate uncertainties
- Economic valuation estimate uncertainties (*e.g.*, income elasticity of willingness to pay, statistical estimates of VSL, Alzheimer’s and Parkinson’s onset lifetime costs)
- Unquantified uncertainties (*e.g.*, causality determination, estimating and assigning exposures in epidemiology studies, risk attributable to long-term and short-term exposures, shape of the concentration-response relationship)

Despite substantial investments by the EPA in approaches to characterizing uncertainties, the RIAs have still tended to focus on point estimates for PM_{2.5} and ozone-related benefits. Frequently, the EPA has utilized more than one epidemiologic study to estimate mortality impacts because these estimates drive overall benefits for a given regulatory action due to the large monetary value assigned to such impacts. Risk estimates using the top epidemiologic studies sometimes differ by a factor of two or more. Presenting multiple estimates drawn directly from the primary literature is one way to convey the prevailing uncertainty. While this leads to an estimated range of benefits, it is not a range that reflects the true uncertainties in the underlying parameters supporting each study, either for mortality or for other effects. Because of the significant impacts of environmental regulations on the U.S. economy, it is essential that the EPA has confidence in the estimated benefits of an action, and their underlying uncertainties, prior to utilizing these estimates in a regulatory context.

A 2024 Scientific Advisory Board (SAB) reviewed the EPA’s methods for estimating the health effects of PM_{2.5} and clearly and repeatedly recommended that the Agency improve the Agency’s approach to characterizing and presenting the uncertainty in estimating the health effects of PM_{2.5} (U.S. EPA 2024d). A Tier 1 SAB recommendation was that the EPA present a single probabilistic mortality estimate based on pooled risk estimates with associated uncertainty ranges rather than present multiple estimates of mortality outcomes from the epidemiologic studies. The EPA was encouraged to explore meta-analysis methods or other forms of information synthesis, and support research and development of modified methods as needed.

The OMB “2017 Report to Congress on the Benefits and Costs of Federal Regulations” (OMB 2019) listed six key assumptions underpinning PM_{2.5} health effect estimation which introduce substantial uncertainties in the health effect estimates:

- That inhalation of fine particles is causally associated with premature death at concentrations near those experienced by most Americans on a daily basis;
- That the concentration-response function for fine particles and premature mortality is approximately linear, even for concentrations below the levels established by the NAAQS;
- That all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality;
- That the forecasts for future emissions and associated air quality modeling accurately predict both the baseline (state of the world absent a rule) and the air quality impacts of the rule being analyzed;
- That BPT approaches, when used to estimate benefits, are based on regional or national-level analysis that may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors; and
- That the estimated value of mortality risk reductions is an accurate reflection of what people would be willing to pay for incremental reductions in mortality risk from air pollution exposure, and that these values are constant across the life-cycle.

To the extent that any of these assumptions are incorrect, the benefit estimates will change, though the magnitude and direction of change are not known with certainty. The EPA is interested in improving understanding in each of these six areas. The EPA understands that additional research is needed, and will begin to develop approaches that reduce these uncertainties. The EPA will seek peer review for new methods developed from this work consistent with the OMB's Peer Review Guidance (OMB 2005).

In particular, the EPA is interested in reevaluating the validity of the approach for estimating the benefits of air quality improvements relative to the National Ambient Air Quality Standards (NAAQS) for PM_{2.5} and ozone. These standards, which have been set at a level which the Administrator judges to be requisite to protect public health or welfare with an adequate margin of safety, are widely understood to represent the divide between clean air and air with an unacceptable level of pollution. Even in instances where an assumption is found to be justified based on scientific evidence, the EPA is interested in reevaluating its approach to characterizing and communicating underlying uncertainty to the public.

In the past, the EPA has explored a variety of approaches to shed light on how the estimated benefits of an action relate to the level of the NAAQS. For example, in estimating PM benefits, the EPA has employed techniques such as cutpoint analyses and Lowest Measured Level analyses, noting that the Agency is most confident in the magnitude of the risks projected at PM_{2.5} concentrations that coincide with the bulk of the observed PM_{2.5} concentrations in the epidemiological studies that are used to estimate the benefits (Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units, Section 4.4.4, p. 4-26). However, such approaches address only a few of the sources of uncertainty that influence PM-related air quality benefits.

The limitations of reduced-form approaches, such as the BPT approach, are even more pronounced than photochemical modeling/BenMAP-CE approaches due to: 1) the compounding effects of emissions reductions typically occurring across many geographic areas simultaneously, with varying proximity to population centers; 2) differing atmospheric transformation pathways for NO_x, VOCs, and secondary PM_{2.5}; and 3) region-specific photochemical and meteorological conditions. Using a national BPT estimate implicitly assumes uniform marginal health benefits for each ton of reduced emissions, an assumption not supported given heterogeneity in exposure patterns and atmospheric chemistry. As more areas achieve or maintain attainment with the NAAQS, the uncertainties associated with low-concentration health effects grow, and marginal benefits become more difficult to characterize with precision.

Therefore, it may be appropriate for the EPA to separate exposures and impacts above the level of the standard from those occurring at lower ambient concentrations. The EPA will investigate this prior to estimating these impacts in a regulatory analysis even for informational purposes.

2.3.1 Human Health Effects

The human health effects of increased emissions of directly emitted PM_{2.5}, as well as NO_x (which is a precursor to ambient PM_{2.5}), and ground-level ozone resulting from NO_x and VOC emissions, were not quantified for this rule. A qualitative description of related human health effects is provided instead.

2.3.1.1 NO_x-Related Health Effects

The Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (“NO_x ISA”) reviewed evidence from epidemiologic and laboratory studies on the health effects of exposure to NO_x, concluding that there is a causal relationship between respiratory health effects and short-term exposure to NO₂ (U.S. EPA 2016). Epidemiologic and experimental studies encompassed several endpoints, including emergency department visits and hospitalizations, respiratory symptoms, airway hyperresponsiveness, airway inflammation, and lung function. The NO_x ISA also concluded that the relationship between short-term NO₂ exposure and premature mortality was “suggestive but not sufficient to infer a causal relationship,” because it is difficult to attribute the mortality risk effects to NO₂ alone. Although the NO_x ISA stated that studies consistently reported a relationship between NO₂ exposure and mortality, the effect was generally smaller than that for other pollutants such as PM. NO_x emissions are also a precursor to PM_{2.5} and ozone and may affect human health through these additional pathways.

2.3.1.2 Ozone-Related Health Effects

Following a comprehensive review of toxicological, clinical, and epidemiological evidence, the Integrated Science Assessment for Ozone and Related Photochemical Oxidants (“Ozone ISA”) (U.S. EPA 2020) found both short-term (i.e., less than one month) and long-term (i.e., one month or longer) ozone exposure to be related to an array of adverse human health effects. For each effect, the Ozone ISA reports relationships to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship. This assessment is based on the body of scientific evidence which can include observational human studies, experimental human exposure studies, animal model studies, and mechanistic studies.

The Ozone ISA found short-term exposure to ozone to be causally related to respiratory effects, including respiratory mortality, and likely to be causally related to metabolic effects. For short-term exposure, evidence was suggestive of a causal relationship for cardiovascular and nervous system effects as well as total mortality. The Ozone ISA reported that long-term exposure to ozone is likely-to-be-causally related to respiratory effects, including respiratory mortality. Evidence on metabolic, cardiovascular, reproductive, and nervous system effects as well as total mortality was suggestive of a causal relationship with long-term ozone exposure.

When adequate data and resources are available, the EPA has generally quantified health effects which the Ozone ISA classified as causally related or likely-to-be-causally related to short- or long-term ozone exposure. Health effects classified as suggestive-of-causality or weaker have not historically been quantified. Historically quantified health effects include premature respiratory mortality, hospital admissions and emergency department visits, asthma onset and related symptoms (chest tightness, cough, shortness of breath, and wheeze), allergic rhinitis symptoms, and restricted activity days and school absences. The EPA did not quantify or monetize the disbenefits associated with changes in the incidence of the listed health effects of this rule.

2.3.1.3 PM_{2.5}-Related Health Effects

PM_{2.5} describes an array of pollutants from human and natural sources with diameters that are generally 2.5 micrometers and smaller. This includes directly emitted PM_{2.5} as well as PM_{2.5} formed through atmospheric chemical reactions of precursor pollutants, including NO_x.

Following a comprehensive review of toxicological, clinical, and epidemiological evidence, the Integrated Science Assessment for Particulate Matter (“PM ISA”) (U.S. EPA 2019) and the Supplement to the Integrated Science Assessment for Particulate Matter (“PM ISA Supplement”) (U.S. EPA 2022) found PM_{2.5} to be related to an array of adverse human health effects. For each effect, the PM ISA and PM ISA Supplement report relationships to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship. This assessment is based on the body of scientific evidence which can include observational human studies, experimental human exposure studies, animal model studies, and mechanistic studies.

The PM ISA and PM ISA Supplement found acute and chronic exposures to PM_{2.5} to be causally related to cardiovascular effects and total mortality (i.e., premature death), and respiratory effects as likely-to-be-causally related. Chronic exposures to PM_{2.5} were also determined to be likely-to-be-causally related to nervous system effects and cancer, with the latter determination based primarily on evidence from studies of lung cancer incidence as well as decades of research on the mutagenicity and carcinogenicity of PM. Evidence was suggestive of a causal relationship for reproductive and developmental effects, pregnancy and birth outcomes, and metabolic effects.

When adequate data and resources are available, the EPA has generally quantified health effects which the PM ISA and PM ISA Supplement classified as causally related or likely-to-be-causally related to PM_{2.5} exposure. Health effects classified as suggestive-of-causality or weaker have not historically been quantified. Historically quantified health effects include premature mortality, heart attacks, cardiovascular hospital admissions, cardiovascular emergency department visits, respiratory hospital admissions, respiratory emergency room visits, cardiac

arrest, stroke, asthma onset, asthma symptoms/exacerbation, lung cancer, allergic rhinitis (hay fever) symptoms, lost workdays, and minor restricted-activity days. The EPA did not quantify or monetize the disbenefits associated with changes in the incidence of the listed health effects for this rule.

2.3.2 Welfare Effects

Due to operational constraints and data limitations, most benefits analyses focus on human health effects expected to occur because of changes in primary and secondary pollutant concentrations resulting from the rulemaking. However, the benefits of reductions in emissions of air pollutants include additional effects that include, but are not limited to: effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other pollutants (42 U.S.C. §7602(h)). In this chapter, the EPA provides qualitative discussions of select welfare effects.

2.3.2.1 Ozone Welfare Effects

2.3.2.1.1 Vegetation and Ecosystem Effects

Exposure to ozone has been found to be associated with a wide array of vegetation and ecosystem effects in the published literature (U.S. EPA 2020). Sensitivity to ozone is highly variable across species, with over 66 vegetation species identified as “ozone-sensitive,” many of which occur in State and national parks and forests. These effects include those that cause damage to, or impairment of, the intended use of the plant or ecosystem. Such effects are considered adverse to public welfare and can include reduced growth and/or biomass production in sensitive trees, reduced yield and quality of crops, visible foliar injury, changes to species composition, and changes in ecosystems and associated ecosystem services (U.S. EPA 2020).

2.3.2.1.2 Animal Welfare Effects

While effects can be context- and species-specific, a large body of scientific evidence links ozone exposure to health effects in animals. When exploring environmental pathways through which environmental effects of ozone may impact animals, the Ozone ISA found a likely-to-be-causal relationship between ambient ozone concentrations and alterations of herbivore growth and reproduction (U.S. EPA 2020). In addition, many animal toxicological studies served as evidence for determining the causality of relationships between human exposure to ozone and human health effects, including respiratory and metabolic effects. The Ozone ISA states “A large body of experimental animal toxicological studies demonstrates (short- and long-term) ozone-induced changes in measures of lung function, inflammation, increased airway responsiveness, and impaired lung host defense” (U.S. EPA 2020). Additionally, animal studies report relationships between short-term ozone exposure and metabolic effects in various stocks and strains of animals across multiple laboratories (U.S. EPA 2020).

2.3.2.2 PM_{2.5} Welfare Effects

2.3.2.2.1 Visibility Effects

Reducing secondary formation of PM_{2.5} would improve levels of visibility in the U.S. because suspended particles and gases degrade visibility by scattering and absorbing light (U.S. EPA

2019). Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil. Visibility has direct significance to people's enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities. Particulate sulfate is the dominant source of regional haze in the eastern U.S. and particulate nitrate is an important contributor to light extinction in California (U.S. EPA 2019). Previous analyses such as (U.S. EPA 2012) show that visibility benefits can be a significant welfare benefit category.

2.3.2.2.2 Animal Welfare Effects

While effects can be context- and species-specific, a large body of scientific evidence links PM_{2.5} exposure to health effects in animals. The PM ISA (U.S. EPA 2019) and PM ISA Supplement (U.S. EPA 2022) evaluated exposures to PM_{2.5} and an array of health markers described in animal toxicological studies. Animal toxicological studies have found evidence that PM_{2.5} induces changes in measurements including, but not limited to, breathing patterns, airway irritation, impaired heart function, changes in blood pressure, oxidative stress, reproductive outcomes, and other outcomes. However, neither the PM ISA nor the PM ISA Supplement provide a causality determination of the causality of PM_{2.5} affecting animal health.

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Appendix to Chapter 2

This Appendix contains additional details about the emissions inventory modeling described in Chapter 2 along with more detailed year-over-year emission changes from the modeled scenarios.

MOVES runs and post-processing details

For both the action and no-action cases, national annual emissions inventories were calculated using MOVES for calendar years between 2027 and 2055. All MOVES runs were performed at the default scale, where no custom inputs were used except for the default databases. The default databases for each case were modified versions of the MOVES5 default database with the changes described in Chapter 2.1. Each MOVES run included all combinations of vehicle types, fuel types, and road types. Exhaust emissions, along with refueling, brake wear, and tire wear emissions were calculated for each State and the District of Columbia using State-level pre-aggregation and monthly temporal pre-aggregation. Evaporative emissions were calculated using national scale geographic pre-aggregation and full hourly temporal detail.

The output of these MOVES runs is a large collection of Structured Query Language (SQL) relational databases. The EPA post-processed these databases to create a single, more compressed version for each modeling case. The post-processed databases were then used for the analyses estimating the emission impacts of the proposed rule. The post-processing was done using R, an open-source programming language used primarily for data science and statistical analysis. For each modeling case, the outputs of the exhaust and evaporative emissions calculations were combined and summed over the yearID, pollutantID, processID, sourceTypeID, regClassID, fuelTypeID, and modelYearID fields. The result was a single SQL database containing annual national emissions inventory for each modeled case. Table 2A- 1 presents the light-duty EV fractions used as input in MOVES while Table 2A- 2 through Table 2A- 8 show year-over-year emissions changes for selected pollutants for the Central case, as well as sensitivity cases, relative to the no-action case.

Table 2A-1: Input LD EV Fractions Incorporated in MOVES for All Modeling Cases.

Modeling Scenario	Model Year	MOVES Regulatory Class	Vehicle Type	EV Population (Percent)
Low EV	2027	20	Cars	13.9
		30	Passenger Trucks	4.5
			Commercial Trucks	3.1
	2028	20	Cars	19.8
		30	Passenger Trucks	10.1
			Commercial Trucks	8.5
Central	2027	20	Cars	17.9
		30	Passenger Trucks	8.5
			Commercial Trucks	7.1
	2028	20	Cars	19.8
		30	Passenger Trucks	10.1
			Commercial Trucks	8.5
High EV	2027	20	Cars	21.9
		30	Passenger Trucks	12.5
			Commercial Trucks	11.1
	2028	20	Cars	23.8
		30	Passenger Trucks	14.1
			Commercial Trucks	12.5

Table 2A-2: Year-Over-Year Emissions Increases in NO_x, VOC, and PM_{2.5} for Sensitivity Cases.

Year	Low EV						High EV					
	NO _x		VOC		PM _{2.5}		NO _x		VOC		PM _{2.5}	
	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad	U.S. Tons	Percent Onroad
2027	389	<0.1	353	<0.1	53	0.2	389	<0.1	352	<0.1	48	0.2
2028	976	0.1	859	0.1	152	0.6	976	0.1	859	0.1	138	0.5
2029	932	0.1	820	0.1	146	0.6	932	0.1	820	0.1	132	0.5
2030	887	0.1	780	0.1	140	0.6	887	0.1	780	0.1	127	0.6
2031	930	0.1	813	0.1	151	0.7	930	0.1	812	0.1	138	0.7
2032	1018	0.1	876	0.1	177	0.9	1018	0.1	876	0.1	161	0.9
2033	1024	0.1	882	0.1	175	1.0	1024	0.1	882	0.1	160	0.9
2034	1058	0.1	909	0.1	178	1.1	1058	0.1	909	0.1	162	1.0
2035	1031	0.2	879	0.1	174	1.2	1031	0.2	878	0.1	159	1.1
2036	1019	0.2	857	0.1	176	1.3	1019	0.2	856	0.1	160	1.2
2037	1008	0.2	851	0.1	175	1.4	1008	0.2	851	0.1	159	1.3
2038	1022	0.2	863	0.2	183	1.7	1022	0.2	863	0.2	166	1.5
2039	950	0.2	802	0.1	170	1.7	950	0.2	802	0.1	154	1.5
2040	876	0.2	739	0.1	157	1.7	876	0.2	739	0.1	142	1.5
2041	796	0.2	670	0.1	142	1.7	796	0.2	670	0.1	129	1.5
2042	710	0.2	599	0.1	137	1.7	711	0.2	599	0.1	125	1.6
2043	626	0.1	530	0.1	142	1.9	626	0.1	530	0.1	129	1.8
2044	550	0.1	464	0.1	123	1.8	551	0.1	464	0.1	112	1.7
2045	482	0.1	405	0.1	107	1.7	482	0.1	405	0.1	97	1.6
2046	421	0.1	351	0.1	92	1.6	421	0.1	352	0.1	84	1.4
2047	355	0.1	301	0.1	85	1.6	355	0.1	301	0.1	77	1.5
2048	291	0.1	255	0.1	84	1.7	291	0.1	256	0.1	77	1.6
2049	253	0.1	221	<0.1	72	1.5	253	0.1	221	<0.1	66	1.4
2050	219	0.1	191	<0.1	62	1.4	219	0.1	191	<0.1	56	1.3
2051	189	<0.1	165	<0.1	53	1.2	190	0.1	165	<0.1	48	1.1
2052	164	<0.1	143	<0.1	45	1.1	164	<0.1	143	<0.1	41	1.0
2053	143	<0.1	124	<0.1	38	1.0	143	<0.1	124	<0.1	35	0.9
2054	123	<0.1	107	<0.1	33	0.9	123	<0.1	107	<0.1	30	0.8
2055	106	<0.1	92	<0.1	28	0.8	107	<0.1	92	<0.1	26	0.7

Table 2A-3: Year-Over-Year Emissions Increases in VOC, NO_x and PM_{2.5} for Gasoline Cars, Gasoline Trucks, and Diesel Vehicles for the Central Case.

Year	NO _x (U.S. Tons)			PM _{2.5} (U.S. Tons)			VOC (U.S. Tons)		
	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle
2027	142	244	3	22	29	<1	133	218	2
2028	344	625	6	61	84	1	314	541	4
2029	328	598	6	58	80	1	299	517	4
2030	312	569	6	56	77	1	284	492	4
2031	311	612	6	57	87	1	286	522	4
2032	317	693	7	62	107	1	295	576	5
2033	309	707	8	62	105	1	291	586	5
2034	304	746	8	64	105	1	290	613	5
2035	294	728	8	63	102	1	282	591	5
2036	288	723	8	65	102	1	275	576	5
2037	284	716	8	66	100	1	280	566	5
2038	287	728	8	72	102	1	291	566	5
2039	267	675	7	67	95	1	272	525	5
2040	245	623	7	62	87	1	250	485	4
2041	217	573	6	55	80	1	221	446	4
2042	185	520	6	52	79	1	189	406	4
2043	155	466	5	54	81	1	160	366	3
2044	127	419	4	44	73	1	132	329	3
2045	104	374	4	36	65	<1	108	294	3
2046	83	334	4	29	58	<1	87	262	2
2047	66	286	3	26	55	<1	69	230	2
2048	52	236	2	25	55	<1	56	198	2
2049	41	209	2	20	49	<1	44	176	2
2050	32	184	2	15	43	<1	35	155	1
2051	25	162	2	12	38	<1	27	137	1
2052	20	143	2	9	33	<1	21	121	1
2053	15	126	1	7	29	<1	17	107	1
2054	12	110	1	6	26	<1	13	93	1
2055	9	96	1	4	22	<1	10	82	1

Table 2A-4: Year-Over-Year Emissions Increases in VOC, NO_x and PM_{2.5} for Gasoline Cars, Gasoline Trucks, and Diesel Vehicles for the Low EV Case.

Year	NO _x (U.S. Tons)			PM _{2.5} (U.S. Tons)			VOC (U.S. Tons)		
	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle
2027	143	244	3	23	30	<1	133	218	2
2028	345	625	6	64	87	1	315	540	4
2029	329	597	6	61	84	1	300	516	4
2030	313	569	6	59	81	1	285	492	4
2031	312	612	6	60	91	1	287	522	4
2032	318	693	7	65	112	1	295	576	5
2033	310	707	7	65	110	1	291	586	5
2034	305	745	8	67	110	1	291	612	5
2035	295	728	7	67	107	1	282	591	5
2036	288	723	7	68	106	1	276	575	5
2037	285	715	7	70	105	1	281	566	5
2038	287	727	7	75	107	1	292	566	5
2039	268	675	7	70	99	1	272	525	4
2040	246	623	6	65	91	1	250	485	4
2041	217	572	6	57	84	1	221	445	4
2042	185	520	5	55	82	1	190	406	3
2043	155	466	5	56	85	1	161	366	3
2044	128	418	4	47	76	1	133	329	3
2045	104	374	4	38	68	<1	108	294	2
2046	84	334	3	31	61	<1	87	262	2
2047	67	286	3	27	58	<1	70	229	2
2048	53	236	2	26	58	<1	56	198	2
2049	41	209	2	21	51	<1	44	176	1
2050	33	184	2	16	45	<1	35	155	1
2051	25	162	2	13	40	<1	27	137	1
2052	20	143	1	10	35	<1	21	121	1
2053	16	126	1	8	31	<1	17	107	1
2054	12	110	1	6	27	<1	13	93	1
2055	9	96	1	5	23	<1	10	82	1

Table 2A-5: Year-Over-Year Emissions Increases in VOC, NO_x and PM_{2.5} for Gasoline Cars, Gasoline Trucks, and Diesel Vehicles for the High EV Case.

Year	NO _x (U.S. Tons)			PM _{2.5} (U.S. Tons)			VOC (U.S. Tons)		
	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle	Gasoline Cars	Gasoline Trucks	Diesel Vehicle
2027	143	244	3	23	30	<1	133	218	2
2028	345	625	6	64	87	1	315	540	4
2029	329	597	6	61	84	1	300	516	4
2030	313	569	6	59	81	1	285	492	4
2031	312	612	6	60	91	1	287	522	4
2032	318	693	7	65	112	1	295	576	5
2033	310	707	7	65	110	1	291	586	5
2034	305	745	8	67	110	1	291	612	5
2035	295	728	7	67	107	1	282	591	5
2036	288	723	7	68	106	1	276	575	5
2037	285	715	7	70	105	1	281	566	5
2038	287	727	7	75	107	1	292	566	5
2039	268	675	7	70	99	1	272	525	4
2040	246	623	6	65	91	1	250	485	4
2041	217	572	6	57	84	1	221	445	4
2042	185	520	5	55	82	1	190	406	3
2043	155	466	5	56	85	1	161	366	3
2044	128	418	4	47	76	1	133	329	3
2045	104	374	4	38	68	<1	108	294	2
2046	84	334	3	31	61	<1	87	262	2
2047	67	286	3	27	58	<1	70	229	2
2048	53	236	2	26	58	<1	56	198	2
2049	41	209	2	21	51	<1	44	176	1
2050	33	184	2	16	45	<1	35	155	1
2051	25	162	2	13	40	<1	27	137	1
2052	20	143	1	10	35	<1	21	121	1
2053	16	126	1	8	31	<1	17	107	1
2054	12	110	1	6	27	<1	13	93	1
2055	9	96	1	5	23	<1	10	82	1

Table 2A-6: Year-Over-Year Emissions Increases for Select Air Toxics for Central Case.

Year	1,3-Butadiene		Acetaldehyde		Benzene		Formaldehyde		Naphthalene	
	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad
2027	2	0.1	5	0.1	16	0.1	4	0.1	1	0.1
2028	5	0.3	13	0.2	40	0.3	9	0.2	2	0.2
2029	5	0.3	13	0.2	38	0.3	9	0.2	2	0.3
2030	4	0.3	12	0.2	36	0.3	9	0.2	2	0.3
2031	5	0.4	13	0.3	38	0.4	9	0.2	2	0.3
2032	5	0.4	13	0.3	41	0.4	10	0.2	2	0.4
2033	5	0.5	14	0.3	41	0.4	10	0.2	2	0.4
2034	5	0.5	14	0.3	42	0.5	10	0.3	2	0.4
2035	5	0.5	13	0.3	41	0.5	10	0.3	2	0.4
2036	5	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2037	4	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2038	4	0.6	13	0.4	40	0.5	10	0.3	2	0.6
2039	4	0.5	12	0.3	37	0.5	9	0.3	2	0.5
2040	4	0.5	11	0.3	34	0.5	8	0.3	2	0.5
2041	3	0.5	10	0.3	31	0.5	8	0.3	1	0.5
2042	3	0.4	9	0.3	28	0.4	7	0.2	1	0.5
2043	3	0.4	8	0.2	25	0.4	6	0.2	1	0.4
2044	2	0.4	7	0.2	22	0.3	5	0.2	1	0.4
2045	2	0.3	6	0.2	19	0.3	5	0.2	1	0.3
2046	2	0.3	5	0.1	16	0.3	4	0.1	1	0.3
2047	2	0.2	4	0.1	14	0.2	3	0.1	1	0.3
2048	1	0.2	4	0.1	12	0.2	3	0.1	1	0.2
2049	1	0.2	3	0.1	10	0.2	3	0.1	<1	0.2
2050	1	0.2	3	0.1	9	0.2	2	0.1	<1	0.2
2051	1	0.1	2	0.1	8	0.1	2	0.1	<1	0.2
2052	1	0.1	2	0.1	7	0.1	2	<0.1	<1	0.1
2053	1	0.1	2	<0.1	6	0.1	1	<0.1	<1	0.1
2054	1	0.1	2	<0.1	5	0.1	1	<0.1	<1	0.1
2055	<1	0.1	5	0.1	4	0.1	4	0.1	1	0.1

Table 2A-7: Year-Over-Year Emissions Increases for Select Air Toxics for Low EV Case.

Year	1,3-Butadiene		Acetaldehyde		Benzene		Formaldehyde		Naphthalene	
	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad
2027	2	0.1	5	0.1	16	0.1	4	0.1	1	0.1
2028	5	0.3	13	0.2	40	0.3	9	0.2	2	0.2
2029	5	0.3	13	0.2	38	0.3	9	0.2	2	0.3
2030	4	0.3	12	0.2	36	0.3	9	0.2	2	0.3
2031	5	0.4	13	0.3	38	0.4	9	0.2	2	0.3
2032	5	0.4	13	0.3	41	0.4	10	0.2	2	0.4
2033	5	0.5	14	0.3	41	0.4	10	0.2	2	0.4
2034	5	0.5	14	0.3	42	0.5	10	0.3	2	0.4
2035	5	0.5	13	0.3	41	0.5	10	0.3	2	0.4
2036	5	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2037	4	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2038	4	0.6	13	0.4	40	0.5	10	0.3	2	0.6
2039	4	0.5	12	0.3	37	0.5	9	0.3	2	0.5
2040	4	0.5	11	0.3	34	0.5	8	0.3	2	0.5
2041	3	0.5	10	0.3	31	0.5	8	0.3	1	0.5
2042	3	0.4	9	0.3	28	0.4	7	0.2	1	0.5
2043	3	0.4	8	0.2	25	0.4	6	0.2	1	0.4
2044	2	0.4	7	0.2	22	0.3	5	0.2	1	0.4
2045	2	0.3	6	0.2	19	0.3	5	0.2	1	0.3
2046	2	0.3	5	0.1	16	0.3	4	0.1	1	0.3
2047	2	0.2	4	0.1	14	0.2	3	0.1	1	0.3
2048	1	0.2	4	0.1	12	0.2	3	0.1	1	0.2
2049	1	0.2	3	0.1	10	0.2	3	0.1	<1	0.2
2050	1	0.2	3	0.1	9	0.2	2	0.1	<1	0.2
2051	1	0.1	2	0.1	8	0.1	2	0.1	<1	0.2
2052	1	0.1	2	0.1	7	0.1	2	<0.1	<1	0.1
2053	1	0.1	2	<0.1	6	0.1	1	<0.1	<1	0.1
2054	1	0.1	2	<0.1	5	0.1	1	<0.1	<1	0.1
2055	<1	0.1	5	0.1	4	0.1	1	<0.1	<1	0.1

Table 2A-8: Year-Over-Year Emissions Increases for Select Air Toxics for High EV Case.

Year	1,3-Butadiene		Acetaldehyde		Benzene		Formaldehyde		Naphthalene	
	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad	U.S. tons	Percent Onroad
2027	2	0.1	5	0.1	16	0.1	4	0.1	1	0.1
2028	5	0.3	13	0.2	40	0.3	9	0.2	2	0.2
2029	5	0.3	13	0.2	38	0.3	9	0.2	2	0.3
2030	4	0.3	12	0.2	36	0.3	9	0.2	2	0.3
2031	5	0.4	13	0.3	38	0.4	9	0.2	2	0.3
2032	5	0.4	13	0.3	41	0.4	10	0.2	2	0.4
2033	5	0.5	14	0.3	41	0.4	10	0.2	2	0.4
2034	5	0.5	14	0.3	42	0.5	10	0.3	2	0.4
2035	5	0.5	13	0.3	41	0.5	10	0.3	2	0.4
2036	5	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2037	4	0.5	13	0.3	40	0.5	10	0.3	2	0.5
2038	4	0.6	13	0.4	40	0.5	10	0.3	2	0.6
2039	4	0.5	12	0.3	37	0.5	9	0.3	2	0.5
2040	4	0.5	11	0.3	34	0.5	9	0.3	2	0.5
2041	3	0.5	10	0.3	31	0.5	8	0.3	1	0.5
2042	3	0.4	9	0.3	28	0.4	7	0.2	1	0.5
2043	3	0.4	8	0.2	25	0.4	6	0.2	1	0.4
2044	2	0.4	7	0.2	22	0.3	5	0.2	1	0.4
2045	2	0.3	6	0.2	19	0.3	5	0.2	1	0.3
2046	2	0.3	5	0.2	16	0.3	4	0.1	1	0.3
2047	2	0.2	4	0.1	14	0.2	4	0.1	1	0.3
2048	1	0.2	4	0.1	12	0.2	3	0.1	1	0.2
2049	1	0.2	3	0.1	10	0.2	3	0.1	<1	0.2
2050	1	0.2	3	0.1	9	0.2	2	0.1	<1	0.2
2051	1	0.1	2	0.1	8	0.1	2	0.1	<1	0.2
2052	1	0.1	2	0.1	7	0.1	2	<0.1	<1	0.1
2053	1	0.1	2	<0.1	6	0.1	1	<0.1	<1	0.1
2054	1	0.1	2	<0.1	5	0.1	1	<0.1	<1	0.1
2055	<1	0.1	1	<0.1	4	0.1	1	<0.1	<1	0.1

Chapter 3: Comparison of Benefits and Costs

This chapter summarizes the estimated cost savings and the non-monetized impacts of the proposed action. Program costs are presented in Chapter 1 of this DRIA. Cost savings are those associated with PM reduction technology that would no longer be required by this proposal. As noted in Chapter 2.3, the EPA did not quantify or monetize the health disbenefits associated with emissions increases. The net benefits associated with the proposed action are the cost savings, which are presented in year 2024 dollars.

3.1 Methods

The EPA presents cost savings using three different methods:

- 1) **CY cost savings in years 2027 and 2028**, when implementation of the proposed action will apply to MY 2027 and MY 2028 vehicles, respectively. Cost savings in these years are not discounted.
- 2) **The present value (PV) of the stream of cost savings**, which represents projected savings incurred in CYs 2027 and 2028, discounted back to 2027 and assuming end of year discounting. PVs are estimated using both a 3-percent and 7-percent discount rate.
- 3) **The equivalent annualized value (AV) of cost savings**, representing a flow of constant AVs that, had they occurred in each year from 2027 to 2055, would yield an equivalent PV to the PV described above (using either a 3-percent or 7-percent discount rate). Each AV represents a typical cost savings for each year of the analysis and is presented in year 2024 dollars.

3.2 Results

Table 3-1 presents the cost savings and non-monetized disbenefits of the proposed rule. Monetized cost savings are presented in undiscounted annual terms for CYs 2027 and 2028, in PV and AV terms.

Table 3-1: Costs and Benefits of the Proposal (millions, 2024\$).^{a,d}

	CY 2027	CY 2028	PV, 3%	PV, 7%	AV, 3% ^c	AV, 7% ^c
Cost Savings for PM Control	\$220	\$510	\$690	\$650	\$36	\$53
Cost Savings for NMOG+NO _x Control	\$470	\$660	\$1,070	\$1,010	\$56	\$82
Sum of Cost Savings	\$690	\$1,170	\$1,770	\$1,660	\$92	\$135
Non-Monetized Impacts ^b						
Impacts to human health and the environment from increased exposure to ambient PM _{2.5} , ozone, NO ₂ , air toxics, and methane (see Chapter 2.3)						

^a Totals may not sum due to rounding.

^b Several categories of costs and benefits remain unmonetized and are not reflected in the table.

^c Annualized values are based on a time horizon beginning in 2027 and ending in 2055.

^d EPA notes there are uncertainties associated with these cost savings projections. See section III.A of the preamble, and the Executive Summary and Chapter 1 of this DRIA for a discussion of uncertainties.

Chapter 4: Small Business Flexibilities

The Regulatory Flexibility Act, as amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice-and-comment rulemaking requirements under the Administrative Procedure Act or any other statute. As a part of this analysis, an agency is directed to convene a Small Business Advocacy Review Panel (SBAR Panel or ‘ Panel’), unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. During such a Panel process, the agency would gather information and recommendations from Small Entity Representatives (SERs) on how to reduce the impact of the rule on small entities. As discussed below, the EPA is certifying that this proposed rule will not have a significant economic impact on a substantial number of small entities, and thus the Agency has not conducted an SBAR Panel for this rulemaking. The following discussion provides an overview of small entities in the vehicle market. Small entities include small businesses, small organizations, and small governmental jurisdictions. For the purposes of assessing the impacts of the rule on small entities, a small entity is defined as: (1) a small business that meets the definition for business based on the Small Business Administration’s (SBA) size standards (13 CFR §121.201 2026), (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

The EPA is certifying that this proposed rule will have no significant economic impact on a substantial number of small entities (No SISNOSE). The EPA has focused the Agency’s assessment of potential small business impacts on two key aspects of the standards, including criteria pollutant NMOG+NO_x fleet average standards and PM emissions standards.

The EPA has evaluated the potential impacts on small entities (as well as small volume manufacturers) of a delay in the 2027 and 2028 criteria pollutant emissions standards, including both the NMOG+NO_x standard and the PM standard. Under the current light-duty and medium-duty vehicle program, small entities are not subject to any phase-in requirements in 2027 and 2028. The phase-in for small volume manufacturers, which produce both BEV and conventional ICE products, is 0 percent from 2027 to 2031, (thus no action is required in 2027 and 2028) and rises to 100 percent in 2032.

Many of the current small entity manufacturers produce BEVs which have no tailpipe emissions and therefore would inherently comply with the standards. These entities may have generated NMOG+NO_x emission credits in 2027 and 2028; however, since all manufacturers are exempt from the 2027 and 2028 standards, there are no disparate impacts on small entity and/or small volume manufacturers.

Chapter 4 References

13 CFR §121.201. 2026. <https://www.ecfr.gov/current/title-13/chapter-I/part-121/subpart-A/subject-group-ECFRf12a11421b08a31/section-121.201>.