



ZERO EMISSION
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Summary of Final EPA Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles (Phase 3)

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Action: Final Rule

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Link: Pre-publication [rule here](#)

Key Links:

- [EPA Final Rule Landing Page](#)
- [EPA Final Rule Fact Sheet](#)
- [Final Regulatory Impact Analysis](#) (March 2024)
- [ZETA comments on proposed rule](#) (June 2023)

Introduction

The final rule sets stronger standards to reduce greenhouse gas emissions from heavy-duty (HD) vehicles beginning in model year (MY) 2027. The new standards will be applicable to HD vocational vehicles (such as delivery trucks, refuse haulers, public utility trucks, transit, shuttle, school buses, etc.) and tractors (such as day cabs and sleeper cabs on tractor-trailer trucks).

The final “Phase 3” standards build on EPA’s Heavy-Duty Phase 2 program from 2016 and maintain that program’s flexible structure, which is designed to reflect the diverse nature of the heavy-duty vehicle industry. The standards are technology-neutral and performance-based, allowing each manufacturer to choose what set of emissions control technologies is best suited for them and the needs of their customers.

This final rule will produce \$13 billion in annualized net benefits through the year 2055. EPA estimates approximately \$10 billion in annualized climate benefits and up to \$300 million in annualized benefits from reduced emissions of fine particulate matter (PM_{2.5}). Under the Phase 3 program, the heavy-duty industry will see annualized savings of \$3.5 billion compared to annualized costs of about \$1.1 billion. After accounting for the vehicle purchase tax credits provided under the Inflation Reduction Act, the typical buyer of new clean technology heavy-duty vehicles will recoup any costs in two to five years.

The following document summarizes the effects of the rule on BEV and ZEV fleet penetration, emissions, economic, and other targets. The document also compares the final rule with the comments ZETA submitted in response to EPA’s proposed rule in June 2023.

NOTE: All page numbers refer to the number at the bottom of the page of the .pdf file, not the page number in Adobe Acrobat.

Next Steps

EPA's rulemaking will likely face a variety of challenges from states, Congress, and interest groups. Following EPA's publication, the Clean Freight Coalition's director issued [a statement](#) in opposition, arguing that the rule "will require the adoption of zero-emissions commercial vehicles at a pace that isn't possible due to the limits of today's technology." Other groups, like MEMA, The Vehicle Suppliers Association, [welcomed](#) the rule.

Following final publication, ZETA also anticipates legal challenges from states. It's possible that the arguments will be similar to those brought in [Texas v. EPA](#). ZETA will continue to monitor relevant legislation and legal action and alert its members of any relevant developments.

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Summary of Key Provisions & Comparison to ZETA Comments

Topline Targets

When compared to the existing Phase 2 standards,

- Phase 3 standards begin in MY 2027 with a stringency increase of:
 - 13% for medium heavy-duty vocational vehicle standards;
 - 17% for light heavy-duty vocational vehicle standards.
- Phase 3 day cab tractor standards begin in MY 2028 with a stringency increase of 8% over Phase 2 standards
- Heavy-duty (HD) vocational standards begin in MY 2029 with a 13% increase over Phase 2
- Sleeper cab tractor standards begin in MY 2030 with a 6% increase over Phase 2.

Each vehicle category then increases in stringency each year, through MY 2032, at which time compared to the Phase 2 program the light heavy-duty vocational standards are a 60% increase in stringency of the CO₂ standard, the medium heavy-duty vocational vehicle standards are a 40% increase, the day cab standards are a 40% increase, the heavy-duty vocational standards are a 30% increase, and the sleeper cab standards are a 25% increase in the stringency of the standards.

EPA updated its reference scenario between the proposal and this final rule to include California's ACT program implementation in California and in the states that have adopted the ACT rule under CAA section 177, thus increasing the amount of ZEV technology in its projection of the United States without the final standards in place. Likewise, EPA improved its projections of the rate of expected ZEV adoption across vehicle categories for the reference scenario, the result of which in the modeled compliance pathway was increased projected adoption in the light heavy-duty vocational vehicle subcategory and decreased adoption in other subcategories compared to the reference scenario in the proposal.

Credit Multipliers *(p.41)*

ZETA comments: ZETA supported the proposed accelerated phaseout of HDEV credit multipliers by MY 2027.

Result: In the final rule, EPA stated that it is retaining the advanced technology vehicle credit multipliers for PHEV, BEV, and FCEV technologies through MY 2027, consistent with the previously promulgated HD GHG Phase 2 program. In order to ensure meaningful vehicle GHG emission reductions under the Phase 3 program, EPA is limiting the period over which manufacturers can use the multiplier portion of credits earned from advanced technologies. EPA requested separate comments on certain

additional transitional flexibilities to assist manufacturers in the implementation of Phase 3 in recognition that the final HD GHG Phase 3 standards will require meaningful investments from manufacturers to reduce GHG emissions.

HD GHG Averaging, Banking, and Trading (ABT) Program (p.482)

EPA further stated that it is retaining and did not reopen the general structure of the Averaging, Banking and Trading (ABT) program, which allows manufacturers further flexibility in meeting standards using averaging provisions. The existing regulatory scheme does not require each vehicle to meet the standards individually and instead allows manufacturers to meet the standards on average within each weight class of their fleet. EPA justified this decision by arguing that the program will continue to help provide additional flexibility in compliance for manufacturers to make necessary technological improvements and reduce the overall cost of the program, without compromising overall environmental objectives.

However, EPA is revising three components of the program, with the intention that limitations placed on credits generated from Phase 2 advanced technology credit multipliers and the transitional allowance of credit transfers across averaging sets finalized in this rule are be entirely separate and severable from the Phase 3 emissions standards and other varied components of this rule:

- The applicable production volume for use in calculating ABT credits;
- How manufacturers can use credit multipliers for advanced technologies; and
- Credit transfers across averaging sets.

EPA argues that the severability component is essential in the case that a process of judicial review were to invalidate any one of these elements of the final rule. In that case, EPA intends for the remainder of this action to remain effective, and has designed the program to function even if one part of the rule is set aside. For example, if a reviewing court were to invalidate the transitional allowance of credit transfers across averaging sets, the other components of the rule, including the Phase 3 GHG standards (which are not predicated on these transitional flexibilities), remain fully operable.

Applicable Production Volume (p.487)

ZETA Comment: ZETA urged EPA to finalize standards consistent with California's Advanced Clean Truck (ACT) regulation through MY2032.

Result: In response to commenters (like ZETA) who suggested EPA adjust the stringency of Phase 3 to include nationwide adoption rates similar to ACT, the final rule notes that EPA developed the final rule stringency through a balanced and measured approach, based on consideration and balancing of the statutory and other relevant factors, including technical feasibility, costs, and lead time.

To address the interaction between the existing definition of U.S.-directed production volume and the California Advanced Clean Truck (ACT) regulation for HD vehicles, **EPA is revising the definition of “U.S.-directed production volume” by removing any exclusions (e.g. vehicles certified to different state emission standards) from the definition. The change will take effect in MY 2024 to minimize the uncertainties related to how ACT will be implemented.**

Advanced Technology Credit Multipliers (p.494)

In the final rule, EPA states that it is **retaining the existing Phase 2 flexibility that allows manufacturers to continue to earn advanced technology credit multipliers for PHEV and BEV technologies through model year 2027.** In other words, the final rule will not provide for an earlier phase out (one year early) of multipliers for PHEVs and BEVs, and manufacturers may continue to generate credits that include credit multipliers for PHEV, BEV, and FCEV technologies through MY 2027 as was adopted in Phase 2. To address the concern of reduced Phase 3 stringency raised in comments, **EPA is finalizing a provision that places certain restrictions on and specifies the circumstances when credits from multipliers may be used in model years 2027 through 2029 and eliminates the availability of credit multipliers for use in model years 2030 and later.**

In MYs 2027 through 2029, manufacturers can continue to use multiplier credits to meet the Phase 3 standards; however, multiplier credits can only be applied toward Phase 3 compliance after available base credits are used. By prioritizing the use of base credits, EPA argues that the final rule reduces the potential for multiplier credits to erode the emission benefits of the Phase 3 program, in particular in MYs beyond 2029. Further, any unused multiplier credits would expire in MY 2030.

Transitional Flexibility Allowing Credit Exchange (p.507)

The current rules provide three averaging sets for HD vehicles: Light HDV, Medium HDV, and Heavy HDV. The provision that limits credit exchanges to within averaging sets is unique to the heavy-duty rules—on the light-duty vehicle side, credits can flow freely among all vehicle types.

In the final rule, EPA states that it is **finalizing an interim provision allowing credits to be used across HD vehicle averaging sets during the MY 2027 through MY 2032 period.** More specifically, during model years 2027 through 2032, manufacturers can transfer credits generated from heavy-duty vehicles in MYs 2027-2032 between all heavy-duty vehicle averaging sets. **There is no cap on credits transferred between**

averaging sets in the final interim flexibility. However, this provision is subject to several limitations:

- EPA is not extending the interim flexibility to include credits generated from MY 2026 and earlier vehicles;
- Credits can only be used in a one-way transfer;
- Medium-duty credits may be used for demonstrating compliance only for Light HDV or Medium HDV averaging sets.

Further, 40 CFR part 8-certified credits transferred under this flexibility would no longer be available for the part 86 ABT program to aid in manufacturers meeting the requirements for medium-duty vehicles. Likewise, vehicles defined as Medium-duty Passenger Vehicles in 40 CFR part 86, subpart S, are over 8,500 pounds GVWR but are subject to the standards that apply for light trucks and are therefore not eligible to generate credits for this transitional flexibility

Battery Durability Monitoring *(p.513)*

In the final rule, **EPA is finalizing a requirement that manufacturers provide a customer-facing battery state-of-health (SOH) monitor for all heavy-duty BEVs and PHEVs.** The new 40 CFR 1037.115(f) requires manufacturers to install a customer-accessible SOH monitor which estimates, monitors, and communicates the vehicle's state of certified energy (SOCE); specifically, manufacturers would implement onboard algorithms to estimate the current state of health of the battery, in terms of the state of its usable battery energy (UBE) expressed as a percentage of the original UBE when the vehicle was new.

At this time, **EPA is not finalizing a specific procedure for determining UBE, nor is EPA requiring pack level testing for the determination of UBE in BEV vehicles. The final rule instead requires manufacturers to develop and get EPA approval of their own test procedure for determining UBE that meets the criteria that is described in this section.**

PHEV manufacturers would select the most representative vehicle configuration to determine UBE for the powertrain family. In addition to this test procedure, the final rule allows manufacturers to develop and get EPA approval of their own test procedures for determining UBE for PHEV. EPA is finalizing this option since some manufacturers may use the same battery pack for their BEV and PHEV products, and using the same procedure will reduce testing burden and variability in the determination of UBE.

While manufacturers can determine their own test procedure, **EPA does set four specific criteria for such a test procedure** to ensure it produces accurate results that are representative of in-use operation. These are:

1. The test procedure must measure UBE by discharging the battery at a constant power that is representative of the vehicle cruising on the highway.
2. The test must be complete when the battery is not able to maintain the target power.
3. The battery energy measurements must meet the requirements defined in 40 CFR 1036.545(a)(10).
4. The SOH monitor must be able to determine the UBE within +/- 5% of the result of the test procedure.

Since a vehicle state-of-certified-range (SOCR) monitor is not likely to provide useful information to the driver, **EPA is not finalizing a requirement for a SOCR monitor at this time.**

Warranty Requirements (p. 528)

ZETA Comments: ZETA supported EPA's proposed warranty requirements but cautioned that designating the electric battery and powertrain as "emissions control equipment" under the Clean Air Act could subject these components to additional regulatory requirements and rules.

Result: In consideration of the comments and that BEV, PHEV, and FCEV are playing an increasing role in manufacturers' compliance strategies, **EPA is identifying the high-voltage battery and the powertrain components that depend on it (including fuel-cell stack, electric motors, and inverters), as "emission-related components" in HD vehicles.** As such, **EPA is finalizing new warranty requirements for MY 2027 and later BEV and FCEV batteries and associated emission-related electric powertrain components** (but there are no new battery warranty requirements for PHEVs).

EPA is finalizing its proposal to remove the sentence stating that the emission-related warranty does not need to cover components whose failure would not increase a vehicle's emissions of any regulated pollutant, and replacing this sentence with "and any other components whose failure would increase a vehicle's CO₂ emissions" to the existing sentence that states the emission-related warranty covers components included in the application for certification.

Furthermore, EPA is clarifying two key points related to the new definition: First, that the RESS (also known as the high-voltage battery) and associated electric powertrain components in the vehicle's application for certification are covered under the emission-related warranty. Second, EPA is finalizing text in 40 CFR 1037.205(b) stating that "For any vehicle using RESS (such as hybrid vehicles, FCEV, and BEV), describe in detail all components needed to charge the system, store energy, and transmit power to move the vehicle."

The current warranty requirements already provide the framework for manufacturers to define the specific failures that are covered under warranty. EPA is finalizing as proposed a requirement that components enabling ZEV to have a zero CO₂ grams per mile from the tailpipe be covered by the existing regulations' emissions warranty periods of 5 years or 50,000 miles for Light HDV and 5 years or 100,000 miles for Medium HDV and Heavy HDV.

EPA anticipates that most if not all manufacturers would include the averaging of credits generated by BEVs and FCEVs as part of their compliance strategies for the final standards. Thus, emission credits would be calculated assuming the battery sufficiently maintains its performance for the full useful life of the vehicle.

Regulatory Impact Analysis (RIA)

Estimated Adoption Rates

The tables below map projected ZEV adoption rates across various vehicle classes. From 2027 to 2032, EPA estimates that:

- LHD vocational vehicles will increase from 18.4% to 61.2% of fleets
 - Without the standards: 10.1% to 30.1%
 - “LHD” typically refers to vehicle classes 2b and 3
- MHD vocational vehicles will increase from 13.5% to 40.7% of fleets
 - Without the standards: 6.9% to 20.5%
 - “MHD” typically refers to vehicle classes 4, 5, 6
- HHD vocational vehicles will increase from 4.6% to 25.7% of fleets
 - Without the standards: 4.6% to 13.6%
 - “HHD” typically refers to vehicle classes 7 and 8.

*Separately, please note that “ZEV” refers to **both** BEV and FCEV vehicles. See tables below for BEV-only data.*

Table 4-9 National heavy-duty ZEV adoption in the control case for the final standards

Model Year	LHD Vocational	MHD Vocational	HHD Vocational ^a	Short-Haul Tractors	Long-Haul Tractors ^b
2027	18.4%	13.5%	4.6%	5.3%	0.4%
2028	23.6%	16.7%	9.4%	8.4%	0.7%
2029	28.8%	20.0%	11.9%	11.9%	1.3%
2030	34.0%	23.2%	14.5%	16.3%	6.2%
2031	47.5%	32.0%	20.1%	27.7%	12.5%
2032	61.2%	40.7%	25.7%	39.9%	25.0%

^a For HHD vocational vehicles, we are not finalizing revisions to MY 2027 standards. ZEV adoption for these vehicles in this model year was set to be equal to the reference case.

^b For sleeper cab tractors, which are represented by long-haul tractors (source type 62) in MOVES, we did not propose and are not finalizing revisions to MY 2027 standards or new standards for MYs 2028 or 2029. ZEV adoption for this source type in these model years was set to be equal to the reference case.

Table 4-8 National heavy-duty ZEV adoption in the reference case

Model Year^A	LHD Vocational	MHD Vocational	HHD Vocational	Short-Haul Tractors	Long-Haul Tractors
2024	3.2%	2.2%	1.1%	1.0%	0.0%
2025	5.4%	3.7%	2.4%	2.2%	0.0%
2026	6.4%	4.4%	2.8%	3.2%	0.0%
2027	10.1%	6.9%	4.6%	4.7%	0.4%
2028	15.2%	10.4%	6.9%	6.1%	0.7%
2029	20.2%	13.8%	9.2%	7.4%	1.3%
2030	25.2%	17.2%	11.4%	8.7%	1.9%
2031	27.6%	18.9%	12.5%	9.3%	3.7%
2032	30.1%	20.5%	13.6%	10.4%	4.7%
2033	33.1%	22.6%	14.9%	10.5%	4.8%
2034	36.2%	24.9%	16.2%	10.8%	4.9%
2035	39.5%	27.2%	17.5%	11.0%	5.0%
...
2055	52.0%	37.3%	20.3%	15.1%	7.2%

^A The ZEV adoption rates for model years 2036 through 2054 increase linearly between the adoption rates in model years 2035 and 2055. Appendix B to this RIA presents the adoption rates for each model year from 2024 through 2055.

Note: “Control Case” in this instance models the effect of the final standards. The first table is found on p.574 of the RIA. The “reference case” refers to a scenario without the rule. The second table is found on p.572 of the RIA.

Appendix B to the RIA (beginning on p. 827) contains a more detailed breakdown of the national ZEV adoption rates in the reference and control cases by model year, source type, regulatory class, and ZEV technology. Summarized versions of the tables are included below.

Projected <i>national</i> BEV sales percentages under the final standards*			
Vehicle Class and Type**	In 2027	In 2055	Percentage Point Δ
Class 4-5			
School buses	20.0%	66.7%	+47%
Transit buses	20.0%	66.7%	+47%
Other Buses	20.0%	66.7%	+47%
single-unit short-haul trucks	20.0%	66.7%	+47%
single-unit long-haul trucks	20.0%	66.7%	+47%
Class 6-7			
School buses	20.0%	70.0%	+50%
Transit buses	10.0%	37.6%	+28%
Other (Intercity) buses***	14.0%	37.6%	+24%
refuse trucks	20.0%	39.0%	+19%
single-unit short-haul trucks	12.3%	37.3%	+25%
single-unit long-haul trucks	14.0%	39.0%	+25%
Combination short-haul trucks	7.0%	21.4%	+14%
Combination long-haul trucks	0.4%	15.8%	+15%
Class 8			
School buses	5.6%	39.0%	+33%
Other (Intercity) buses	6.0%	13.7%	+8%
refuse trucks	3.5%	39.0%	+36%
single-unit short-haul trucks	4.1%	27.9%	+24%
single-unit long-haul trucks	4.1%	39.0%	+35%
Combination short-haul trucks	4.5%	43.5%	+39%
Combination long-haul trucks	0.4%	15.8%	+15%
Urban Buses***			
Urban buses	6.0%	39.0%	+33%

*National sales are averaged between BEV sales percentages in ACT and non-ACT states.

**EPA projects BEV sales using its modelling system, MOVES. In MOVES, each vehicle class and subtype is assigned a code, detailed below. In the RIA, SourceTypeID 61 and 62 vehicles are

referred to as single-unit short-/long-haul trucks (respectively), the same as SourceType ID 52/53 vehicles; to eliminate confusion, this analysis renames them combination short-/long-haul trucks per EPA’s [own definitions](#). Long haul trucks perform trips longer than 200 miles.

Vehicle Class Description	MOVES Code referenced in the RIA
Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs)	RegClass ID 42
Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs)	RegClass ID 46
Class 8a and 8b Trucks (GVWR > 33,000 lbs)	RegClass ID 47
Urban Bus (see CFR Sec 86.091_2)	RegClass ID 48
Vehicle Type Description	MOVES Code referenced in the RIA
Intercity Bus	sourceTypeID 41
Transit Bus	sourceTypeID 42
School Bus	sourceTypeID 43
Refuse Truck	SourceTypeID 51
Single Unit Short-haul Truck	SourceTypeID 52
Single Unit Long-haul Truck	SourceTypeID 53
Combination Short-haul Truck	SourceTypeID 61
Combination Long-haul Truck	SourceTypeID 62

***Urban buses have their own regulatory definition & therefore have an independent regulatory class. Per the [definition](#)— “Urban bus means a heavy heavy-duty diesel-powered passenger-carrying vehicle with a load capacity of fifteen or more passengers and intended primarily for intra-city operation, i.e., within the confines of a city or greater metropolitan area. Urban bus operation is characterized by short rides and frequent stops.” By contrast, transit buses are defined in the Federal Transit Administration’s National Transit Database (NTD), which states that they are buses owned by a public transit organization for the primary purpose of transporting passengers on fixed routes and schedules. According to FHWA, school buses are defined as vehicles designed to carry more than ten passengers, used to transport K-12 students between their home and school. Intercity buses are, as defined by the Bureau of Transportation Statistics, “interstate motor carrier of passengers with an average annual gross revenue of at least one million dollars,” but MOVES also considers any bus that cannot be categorized as either a transit or school bus to be an intercity bus.

Projected BEV sales percentages under the final standards in ACT States			
Vehicle Class and Type	In 2027	In 2055	Percentage Point Δ
Class 4-5			
School buses	25.6%	91.9%	+66%
Transit buses	25.6%	91.9%	+66%
Other Buses	25.6%	91.9%	+66%
single-unit short-haul trucks	25.6%	91.9%	+66%
single-unit long-haul trucks	25.6%	91.9%	+66%
Class 6-7			
School buses	20.0%	70.0%	+50%
Transit buses	19.2%	69.0%	+50%
Other Buses	19.2%	69.0%	+50%
refuse trucks	20.0%	69.0%	+49%
single-unit short-haul trucks	19.2%	69.0%	+50%
single-unit long-haul trucks	19.2%	69.0%	+50%
Combination Short-haul Truck	21.4%	35.4%	+14%
Combination Long-haul Truck	2.0%	15.8%	+14%
Class 8			
School buses	12.8%	46.0%	+33%
Other buses	12.8%	25.6%	+13%
refuse trucks	12.8%	46.0%	+33%
single-unit short-haul trucks	12.8%	46.0%	+33%
single-unit long-haul trucks	12.8%	46.0%	+33%
Combination short-haul trucks	21.4%	45.5%	+24%
Combination long-haul trucks	2.0%	15.8%	+14%
Urban Buses			
Urban buses	12.8%	46.0%	+33%

Projected BEV sales percentages under the final standards in Non-ACT States

Vehicle Class and Type	In 2027	In 2055	Percentage Point Δ
Class 4-5			
School buses	17.3%	54.4%	+37%
Transit buses	16.1%	49.1%	+33%
Other Buses	16.1%	49.1%	+33%
single-unit short-haul trucks	18.2%	58.7%	+41%
single-unit long-haul trucks	5.1%	38.6%	+34%
Class 6-7			
School buses	20.0%	70.0%	+50%
Transit buses	7.5%	29.0%	+22%
Other Buses	12.6%	29.0%	+16%
refuse trucks	20.0%	29.8%	+10%
single-unit short-haul trucks	10.5%	29.0%	+19%
single-unit long-haul trucks	12.6%	31.1%	+19%
Combination short-haul trucks	4.3%	18.9%	+15%
Combination long-haul trucks	0.2%	15.8%	+16%
Class 8			
School buses	1.2%	34.9%	+34%
Other buses	1.2%	5.4%	+4%
refuse trucks	1.2%	37.3%	+36%
single-unit short-haul trucks	1.2%	21.8%	+21%
single-unit long-haul trucks	1.2%	21.8%	+21%
Combination short-haul trucks	2.1%	43.2%	+41%
Combination long-haul trucks	0.2%	15.8%	+16%
Urban Buses			
urban buses	1.2%	34.1%	+33%

Estimated Economic Impacts

EPA estimates that for calendar years 2027 through 2055 and at an annualized 2% discount rate, costs to manufacturers will result in a cost savings of \$0.19 billion dollars before considering the IRA battery tax credits. With those battery tax credits (estimated at \$0.063 billion), the cost to manufacturers of compliance with the program will result in a cost savings of \$0.25 billion. Further, EPA estimates that the MY 2032 fleet average per-(vocational) vehicle cost to manufacturers by regulatory group will range from a cost savings of between \$700 and \$3,000 per vehicle.

EPA estimates that the annualized value of monetized net benefits to society at a 2% discount rate will be approximately \$13 billion through the year 2055, roughly 12 times the cost in vehicle technology and associated electric vehicle supply equipment (EVSE) combined. Regarding social costs, EPA estimates that the cost of vehicle technology (not including the vehicle or battery tax credits) and EVSE at depots will be approximately \$1.1 billion. **The HD industry will save approximately \$3.5 billion in operating costs (e.g., savings that come from less liquid fuel used, lower maintenance and repair costs for ZEV technologies as compared to ICE technologies, etc.).**

Finally, the benefits due to reductions in energy security externalities caused by U.S. petroleum consumption and imports will be approximately \$0.45 billion under the program. For vocational vehicle ZEVs, the incremental upfront costs (after the tax credits) are recovered through operational savings such that payback occurs between two and four years on average.

Table ES-9: MY 2032 Estimated Average Per-Vehicle Purchaser Upfront Cost and Annual Savings Difference Between BEV/FCEV and ICE Technologies for the Program (2022\$)^{a, b, c}

Regulatory Group	Upfront Incremental Vehicle Cost Difference (Including Tax Credits)	Upfront EVSE ^d Costs on Average (Including Tax Credits)	Total Incremental Upfront Costs on Average Including Taxes and Tax Credits	Annual Incremental Operating Costs on Average	Payback Period (year) on Average
Light Heavy-Duty Vocational Vehicles	-\$10,300	\$11,700	\$1,500	-\$3,700	2
Medium Heavy-Duty Vocational Vehicles	-\$5,600	\$15,300	\$9,700	-\$5,100	3
Heavy Heavy-Duty Vocational Vehicles	-\$11,700	\$46,200	\$34,500	-\$10,500	4
Short-Haul (Day Cab) Tractors	-\$1,500	\$5,900	\$4,400	-\$5,500	2
Long-Haul (Sleeper Cab) Tractors	\$22,400	\$0	\$22,400	-\$8,300	5

^a Undiscounted dollars.

^b Values rounded to the nearest \$100 for values above \$100, and nearest \$10 for values below \$100.

^c The average costs and payback periods represent the sales weighted average across the regulatory group, for example the first row represents the average across all LHD vocational vehicles.

^d Electric Vehicle Supply Equipment.

Note: This table is found on p.55 of the final rule.

Estimated Emission Impacts From the Final Standards (p.645, p.657)

Downstream Emissions Impacts

In 2055, EPA estimates that the final standards will reduce downstream emissions of CO₂ from heavy-duty vehicles by 20%, methane by 12%, and nitrous oxide by 20%, resulting in a reduction of 20% for total CO₂ equivalent emissions from heavy-duty vehicles. Most of the GHG emission reductions are from CO₂, which represents approximately 96% of all heavy-duty GHG emission reductions from the final standards.

Table 4-16 Annual downstream heavy-duty GHG emission reductions from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	100-year GWP	CY 2035 Reductions		CY 2045 Reductions		CY 2055 Reductions	
		Million Metric Tons	Percent	Million Metric Tons	Percent	Million Metric Tons	Percent
Carbon Dioxide (CO ₂)	1	32.5	9%	66.3	19%	70.0	20%
Methane (CH ₄)	28	0.002	3%	0.006	10%	0.009	12%
Nitrous Oxide (N ₂ O)	265	0.005	9%	0.01	19%	0.01	20%
CO ₂ Equivalent (CO ₂ e)	---	33.8	9%	69.1	19%	73.0	20%

Note: This table is available on p.487 of the RIA).

Table 4-17 Annual downstream heavy-duty criteria pollutant and air toxic emission reductions from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	CY 2035 Reductions		CY 2045 Reductions		CY 2055 Reductions	
	U.S. Tons	Percent	U.S. Tons	Percent	U.S. Tons	Percent
Nitrogen Oxides (NO _x)	10,801	3%	47,027	16%	54,268	20%
Particulate Matter (PM _{2.5}) ^A	126	2%	302	5%	331	5%
Volatile Organic Compounds (VOC)	3,014	6%	6,426	17%	7,242	20%
Sulfur Dioxide (SO ₂)	126	9%	256	19%	270	20%
Carbon Monoxide (CO)	49,273	6%	117,155	17%	131,014	19%
1,3-Butadiene	7	11%	14	27%	14	27%
Acetaldehyde	62	6%	138	17%	160	17%
Benzene	38	8%	80	22%	82	25%
Formaldehyde	41	4%	100	14%	126	15%
Naphthalene ^B	3	5%	6	22%	6	23%

^A PM_{2.5} estimates include both exhaust and non-exhaust emissions, but all modeled reductions come from exhaust emissions. Relative exhaust PM_{2.5} reductions are similar to other criteria pollutants with reductions of 3% in 2035, 18% in 2045, and 21% in 2055.

^B Naphthalene includes both gas and particle phase emissions.

Note: This table is available on p.487 of the RIA.

Additional Analysis

EPA expects initial emissions reductions to be small but increase year-over-year as the final standards come into effect and more ICE vehicles are displaced by ZEVs. Further,

while EPA projects that all major pollutants will decrease over time, EPA also notes increases in methane emissions due to increasing numbers of compressed natural gas (CNG)-fuelled HDVs. While the agency projects there is CNG growth in the future anyway, EPA also projects that this growth will be moderated by ZEVs displacing CNG—a move that would result in significant reductions in methane emissions overall.

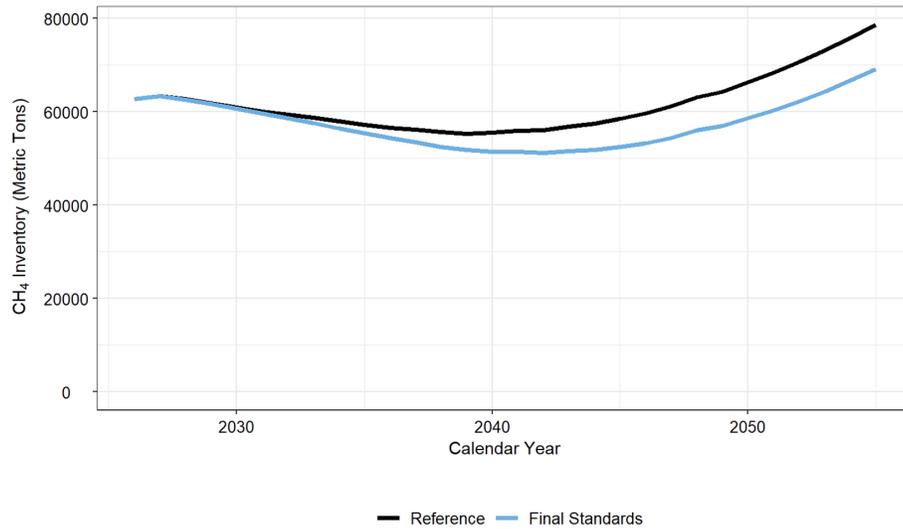


Figure 4-4 Yearly downstream CH₄ inventory for the reference case and final standards from 2027 through 2055

Note: This table is found on p.591 of the RIA.

While HD ZEVs displace vehicles of all fuel types and vehicle types, **the largest increase in HD ZEV adoption relative to the reference case occurs for diesel tractors and heavy heavy-duty vehicles**. Similarly, EPA projects only modest methane emission reductions from displacement of gasoline and diesel vehicles with ZEVs (most methane reductions will come from displacing CNG vehicles, specifically buses and HHD trucks).

Emissions from Electricity Generation

Table 4-21 Annual GHG emission increases from EGUs from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	100-year GWP	Additional EGU Emissions (MMT)		
		CY 2035	CY 2045	CY 2055
Carbon Dioxide (CO ₂)	1	29.3	14.5	12.9
Methane (CH ₄)	28	0.00186	0.00033	0.00026
Nitrous Oxide (N ₂ O)	265	0.00026	0.00004	0.00003
CO ₂ Equivalent (CO ₂ e)	---	29.4	14.5	12.9

Table 4-22 Annual criteria pollutant emission increases from EGUs from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	Increase in EGU Emissions (U.S. Tons)		
	CY 2035	CY 2045	CY 2055
Nitrogen Oxides (NO _x)	9,719	1,588	1,520
Primary PM _{2.5}	1,418	596	513
Volatile Organic Compounds (VOC)	467	347	196
Sulfur Dioxide (SO ₂)	11,726	648	69

Note: This table is available on p.606 of the RIA.

EPA notes that an increased reliance on ZEV vehicles as a result of the rule will increase emissions resulting from electricity generation. **In 2055, EPA estimates that the final standards will increase electricity generation unit (EGU) emissions of CO₂ by 12.9 million metric tons, compared to 29.3 million metric tons in 2035. There are similar trends for all other pollutants.**

However, EPA notes that EGU impacts decrease over time because of changes in the projected power generation mix (the expectation that electricity generation uses less fossil fuels over time) and estimates decreased refinery emissions. Through the 2030s and 2040s, a substantial increase in the use of renewable energy sources is expected to take place in the national power generation mix, driven in part by the IRA. This is expected to lead to decreases in EGU emissions at a national level, including a decrease in EGU emissions attributable to HD ZEVs and the final standards.

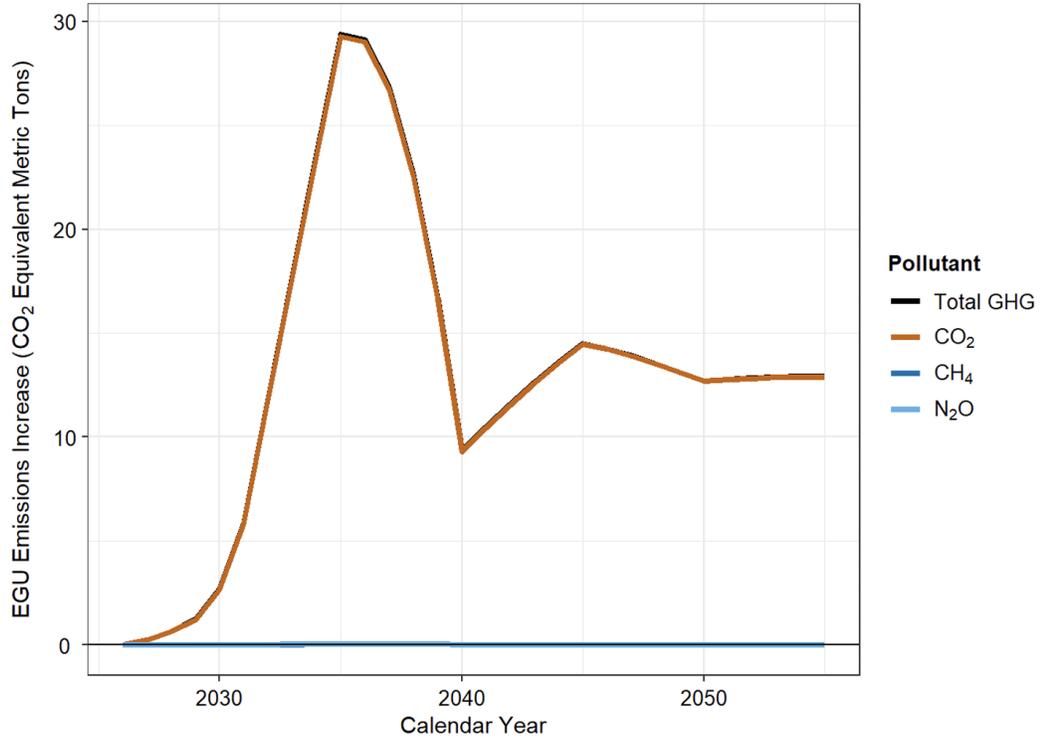


Figure 4-15 Yearly GHG emissions increase from EGUs from the final standards from 2027 through 2055

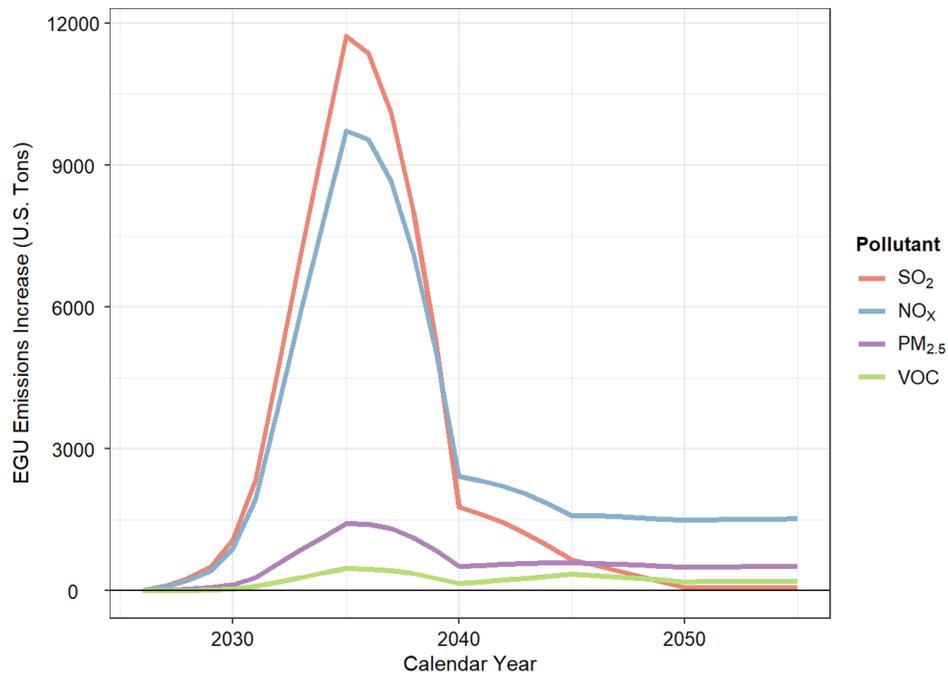


Figure 4-16 Yearly criteria pollutant emissions increase from EGUs from the final standards from 2027 through 2055

Note: These tables are available on p.610 and p.611 of the RIA.

Net Emissions Impacts (p.617, RIA)

In 2055, EPA estimates the final standards will result in a net decrease of 61 million metric tons of GHG emissions. The agency also estimates net decreases in emissions of NO_x, VOC, and SO₂ in 2055. However, EPA estimates a net increase in PM_{2.5} emissions.

In general, net emission impacts are determined by the interaction of two effects. First, HD ZEV adoption increases over time, thus reducing downstream and refinery emissions. Second, the increase in EGU emissions declines over time as the electricity grid becomes cleaner due to EGU regulations and the future power generation mix changes, in part driven by the IRA. These effects can balance differently for different pollutants.

Downstream emissions are a more significant source of GHG, NO_x, and VOC emissions, so net reductions grow over time. However, EGUs are a more significant source of SO₂ emissions (largely driven by coal combustion) and PM_{2.5} emissions (largely driven by coal and natural gas combustion). EPA estimates a **net increase in SO₂ emissions in 2035 and 2045, a net reduction of SO₂ emissions beginning in 2048, and a net decrease in 2055 as coal is phased out of the electricity sector. Natural gas remains an important fuel for electricity generation, which is why EPA estimates a net increase in PM_{2.5} in all years.** However, consistent with the trends for other pollutants, the magnitude of the PM_{2.5} emission increases diminish over time.

Table 4-30 Annual net impacts^A on GHG emissions from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	GWP	Calendar Year	Emission Impact (MMT)			
			Downstream	EGU	Refinery	Net
Carbon Dioxide (CO ₂)	1	2035	-32.5	29.3	-0.3	-3.5
		2045	-66.3	14.5	-0.6	-52.4
		2055	-70.0	12.9	-0.7	-57.8
Methane (CH ₄)	28	2035	-0.002	0.002	0.000	0.000
		2045	-0.006	0.000	0.000	-0.006
		2055	-0.010	0.000	0.000	-0.009
Nitrous Oxide (N ₂ O)	265	2035	-0.005	0.000	0.000	-0.005
		2045	-0.010	0.000	0.000	-0.010
		2055	-0.010	0.000	0.000	-0.010
CO ₂ Equivalent (CO ₂ e)	---	2035	-33.8	29.4	-0.3	-4.7
		2045	-69.1	14.5	-0.7	-55.2
		2055	-73.0	12.9	-0.7	-60.8

^A We present emissions reductions as negative numbers and emission increases as positive numbers.

Table 4-31 Annual net impacts^A on criteria pollutant emissions from the final standards in calendar years (CYs) 2035, 2045, and 2055

Pollutant	Calendar Year	Emission Impact (U.S. Tons)			
		Downstream	EGU	Refinery	Net
Nitrogen Oxides (NO _x)	2035	-10,801	9,719	-148	-1,230
	2045	-47,027	1,588	-288	-45,728
	2055	-54,268	1,520	-304	-53,051
Particulate Matter (PM _{2.5})	2035	-126	1,418	-34	1,258
	2045	-302	596	-66	227
	2055	-331	513	-70	113
Volatile Organic Compounds (VOC)	2035	-3,014	467	-112	-2,659
	2045	-6,426	347	-216	-6,295
	2055	-7,242	196	-226	-7,272
Sulfur Dioxide (SO ₂)	2035	-126	11,726	-46	11,554
	2045	-256	648	-89	304
	2055	-270	69	-94	-295

Note: Both tables above are found on p.617 of the RIA.

Estimated Sales Impacts (p.751)

EPA finds that both pre-buy (when a purchaser pulls ahead a planned future purchase to make the purchase before implementation of an EPA regulation in anticipation that a future vehicle may have a higher upfront or operational cost, or have reduced reliability) and low-buy (when a vehicle that would have been purchased after the implementation of a regulation is either not purchased at all, or the purchase is delayed) are unlikely to occur in a significant manner as a result of the rule. **With respect to possible purchaser anxiety over being unable to purchase an ICE vehicle after promulgation of the regulation, EPA notes that these final standards do not mandate the production or purchase of any particular vehicle, or the use of any**

particular technology in such vehicles. In addition, the phasing-in of the standards will allow ample time for purchasers to make decisions about their vehicle of choice, and the potential compliance pathway modeled for this rule reflects that the majority of vehicles will remain ICE vehicles, even in MY 2032.

Separately, EPA notes that the risks of both pre- and low-buy can be mitigated with additional education about the benefits of ZEV ownership and maintenance (e.g. reduced operational costs, decreased exposure to exhaust emissions and engine noise and smoother acceleration).

Table 1-4 AEO 2023 Sales Projections in Thousands by Weight Class and Energy Use from 2023 - 2050

Weight Class	Heavy-duty Vehicle Sales (thousands)											
	Class 3				Class 4 – 6				Class 7 and 8			
Year	2023	2030	2040	2050	2023	2030	2040	2050	2023	2030	2040	2050
Diesel	142.57	166.84	195.80	227.60	111.86	121.07	131.93	139.16	277.07	268.67	257.36	238.36
Gasoline	106.85	118.57	134.13	153.52	70.74	74.62	79.84	83.55	1.47	1.37	1.30	1.20
Propane	0.28	0.32	0.59	1.23	0.19	0.24	0.49	0.78	0.17	0.16	0.15	0.14
Compressed Natural Gas	0.00	0.00	0.00	0.00	0.08	0.03	0.01	0.00	4.04	2.91	4.46	6.90
Flex Fuel	11.86	11.59	13.88	15.73	3.56	6.93	13.42	15.09	0.00	0.00	0.00	0.00
Battery Electric	0.00	0.00	0.00	0.00	0.06	0.02	0.01	0.00	0.04	0.02	0.00	0.00
Diesel Hybrid	0.32	0.41	0.96	1.84	0.00	0.25	0.41	0.72	0.00	0.13	0.19	0.35
Gasoline Hybrid	0.33	0.39	1.02	2.04	0.00	0.22	0.49	1.00	0.00	0.26	0.35	0.54
Fuel Cell	0.00	0.00	0.00	0.00	0.00	0.43	0.73	1.35	0.00	0.43	0.53	0.82

Other Impacts

Electricity Demand

When accounting for the increase from all vehicles (light-duty and heavy-duty), EPA finds the portion of demand attributable to the entire heavy-duty vehicle sector (including ACT) increases by only 2.6% between 2024 and 2027. State-by-state results show similar small percentages of increased demand; most of the demand comes from the states which have adopted ACT.

In 2027, the Phase 3 rule is projected to increase transportation sector electricity demand by a modest 0.67%; that is, of the national demand for electricity posed by the transportation sector, less than 1% is attributable to the Phase 3 rule in 2027. In 2032, this rule is projected to increase transportation sector electricity demand to 9.27%.

Furthermore, since this demand is only that attributable to the transportation sector, the demand as a percentage of total demand on a utility would be less, since it would be a fraction of all other sources of demand. Thus, in 2030 and 2035 (the years EPA modeled

for this analysis), increases in the demand for the modeled compliance pathway are only 0.41% and 2.59%.

Electric vehicle charging associated with the Action case (light- and medium-duty combined with heavy-duty) is expected to require 4% of the total electricity generated in 2030, which is slightly more than the increase in total U.S. electricity end-use consumption between 2021 and 2022. This is also roughly equal to the combined latest U.S. annual electricity consumption estimates for data centers and cryptocurrency mining operations.

Charging Infrastructure

Given the relatively low demand, ability to prioritize initial public charging deployment in discrete freight corridors, the extra lead time afforded for HDV applications projected to utilize public charging under the modeled potential compliance pathway, and the amount of public and private investment, EPA projects that the necessary public charging corresponding to the potential compliance pathway will be available within the lead time afforded by the HD Phase 3 final standards.

Associated Costs of Grid Buildout

A -3% increase in distribution system build out correlates to a small increase in manufacturing output so concerns regarding supply chain timing and cost are minimal. The total costs are modest both in and of themselves, as a percentage of grid investment even without considering mitigation strategies, and in terms of effect on electricity rates for users. EPA thus believes that the costs associated with distribution grid buildout attributable to the Phase 3 rule are reasonable.

Grid Reliability

Given that this rule is being developed concurrently with the multipollutant emissions standards for light-duty passenger cars and light trucks and for Class 2b and 3 vehicles, EPA analyzed the impacts of these two rules (the “Vehicle Rules”) on the grid together. **EPA does not expect that the Vehicle Rules and proposed Power Sector Rules will adversely affect resource adequacy and expects that the rules will not inhibit the industry from its responsibility to maintain a grid capable of meeting demand without disruption.**