February 12, 2024

Submitted by email: a-and-r-docket@epa.gov

Attention: Docket ID No. EPA-HQ-OAR-2022-0985

Re.: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles, Notice of Proposed Rulemaking, 88 Fed. Reg. 25926 (April 27, 2023)

Environmental Defense Fund (EDF) respectfully submits supplemental comments on Environmental Protection Agency's (EPA) Proposed Rule, Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles, 88 Fed. Reg. 25926 (April 27, 2023) ("Proposal" or "Proposed Standards").

Executive Summary

Since the close of the comment period, EDF has evaluated alternative technology pathways for manufacturers to meet the Proposed Standards, different from those presented by EPA.[1] Our analysis concludes that EPA's proposed standards for most vehicle categories can be met without any zero emission vehicles (ZEVs) and all can be met with ZEV levels well below those that will otherwise result from heavy-duty (HD) ZEV sales in states that have already adopted California's Advanced Clean Truck (ACT) program.

EPA has always set performance-based, heavy-duty vehicle greenhouse gas (GHG) standards that manufacturers can meet with a range of emissions-improving technologies. The Proposed Standards are no exception. EDF has performed a detailed analysis, set forth below, assessing additional viable pathways to achieve compliance through fuller reliance on internal combustion engine vehicle (ICEV) emission controls, strong hybrids, and plug-in hybrid electric vehicles (PHEVs) with low levels of ZEV sales.

[1] EDF submitted a series of similar alternative pathways analyses and comments to the docket for EPA's proposed Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 88 Fed. Reg. 29184 (May 5, 2023). See Docket ID Nos. EPA-HQ-OAR-2022-0985-0451 and EPA-HQ-OAR-2022-0985-5118.

Our analysis concludes that EPA's Proposed Standards for most classes of vehicles can be met without any ZEV sales at all, and all classes of vehicles can meet the standards with ZEV levels well below those that will otherwise result from heavy-duty (HD) ZEV sales in ACT states in model year (MY) 2032, the first year of Phase 3's highest stringency. While the analysis was only for MY2032, the same conclusions are expected to apply to earlier years with lower stringencies. The technologies relied on in this analysis have already been demonstrated and/or are commercially available. Thus, our analysis demonstrates the flexibility afforded to manufacturers to reduce emissions using a mix of technologies with no or substantially lesser reliance on ZEV sales as compared to what was shown in EPA's Proposal. Figures ES-1 and ES-2 below show the multiple scenarios modeled in this analysis demonstrating a small sampling of the compliance pathways manufacturers can use to meet the Proposed Standards.

Figure ES-1: Possible Compliance Pathways for EPA's Proposed 2032 Vocational Vehicle Standards

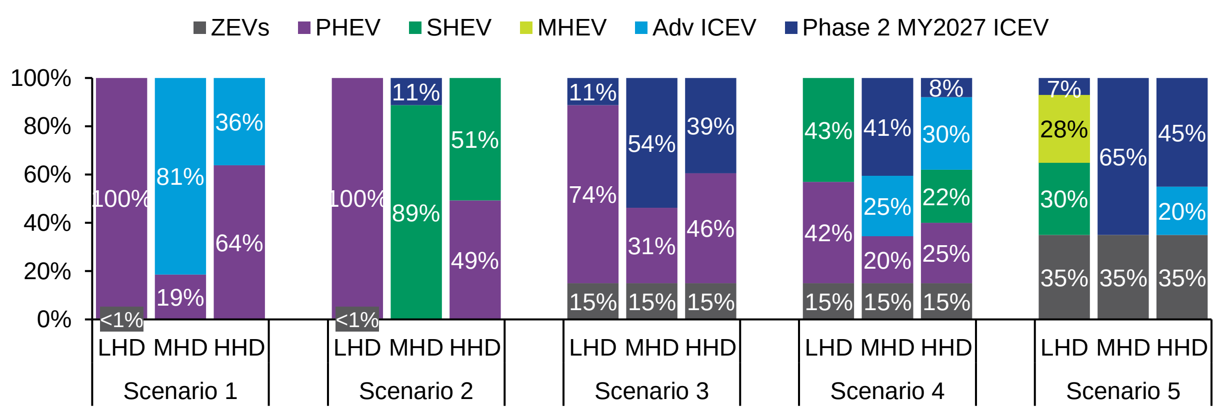
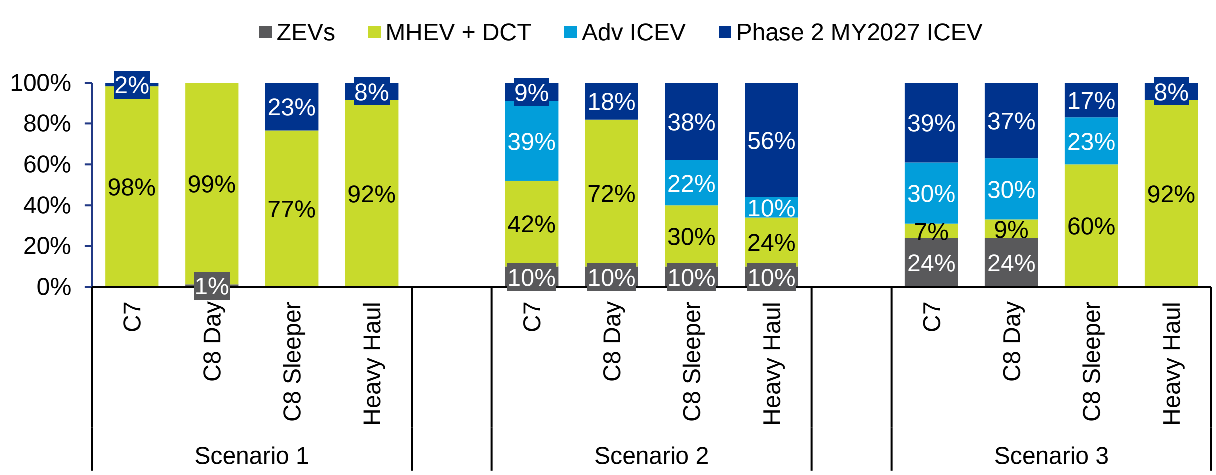


Figure ES-2: Possible Compliance Pathways for EPA's Proposed 2032 Tractor Standards



Analysis

This analysis investigates manufacturers' ability to comply with EPA's Proposed Standards with fewer ZEVs than EPA projections, focusing on other viable technology options such as further ICEV emissions control, strong hybrids, and PHEVs. Our analysis evaluates model year (MY) 2032, the first model year covered by the greatest stringency in EPA's proposal. Since the earlier years in the program have lower stringency, the same conclusion likely holds that other pathways will less reliance on ZEVs than EPA projected are feasible for manufacturers.
Our analysis separately examines viable alternative pathways for vocational vehicles and tractors, as they are expected to employ different technologies. For vocational vehicles subject to the Proposed Standards, we assess additional viable pathways through more reliance on ICEV emission reduction, strong hybrids, and PHEVs. For Class 7 and 8 tractors, we assess pathways that rely only on more ICEV control.

1. Baseline ZEVs

This analysis conservatively assumes only ACT-driven ZEV sales would occur in the absence of further EPA standards. As previously described by EDF and others,[2] there has been significant growth in HD ZEV adoption across the U.S. and around the world. This growth is expected to continue because of strong market trends (described below) and actions by states. California's Advanced Clean Trucks (ACT) rule, which requires increasing sales of ZEVs across heavy-duty vehicle segments, has been adopted by ten additional states with several more expected to adopt the standards in the near future.[3] Depending on the data source, these states account for an estimated 22% to 26%[4] of HD sales within the U.S. In this analysis, EDF accounted for the possible range in ZEV sales estimated to occur due to the ACT rule.

[2] Rachel MacIntosh et al., Electric Vehicle Market Update: April 2023, ERM for EDF, https://www.edf.org/sites/default/files/2023-05/Electric%20Vehicle%20Market%20Update%20April%202023.pdf; Marissa Nixon, Electric truck deployment by U.S. companies grew five times in 2023, EDF Blog, December 13, 2023, https://blogs.edf.org/energyexchange/2023/12/13/electric-truck-deployments-by-u-s-companies-grew-five-times-in-2023/; Jacob Richard et al., Zeroing in on Zero-Emission Trucks: The State of the U.S. Market, CALSTART, January 2024, https://calstart.org/zio-zets-jan-2024-update/. Trends in electric heavy-duty vehicles, IEA Global EV Outlook 2023, https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-heavy-duty-vehicles;

[3] The states that have adopted ACT include California, Colorado, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, and Washington. Connecticut, Maine, and North Carolina all have rulemakings underway or have indicated an intention to adopt the regulation. https://www.sierraclub.org/transportation/clean-vehicle-programs-state-tracker

[4] The impact ACT states will have on national ZEV sales is dependent on the share of HDV sales those states represent. Depending on the data source, there is a range of values that represent ACT state-share. California Air Resources Board's Section 177 States Regulation Dashboard uses the state shares of registered heavy-duty vehicles from the Federal Highway Administration table MV-1 from 2020 and find current ACT states make up 26.4% of national vehicle registrations. Sierra Club's Clean Vehicle Programs State Tracker uses new registrations by state

ACT requires the sale of 60% ZEVs in 2032 for vocational vehicles Class 4 to 8. Nationwide, this would result in vocational ZEV sales between 13% and 16%. Our analysis assumes the ZEV adoption is evenly spread across Class 4 to 8 vocational vehicles.

For heavy-duty tractors, ACT requires 40% ZEV sales in 2032, combining all Class 7 and 8 tractors into one category. EPA, on the other hand, sets different standards for Class 7 day, Class 8 day, and Class 8 sleeper cab tractors.[5] Given the differences in duty cycles and uses between day and sleeper cabs, it is possible ACT-related ZEV tractor sales will not be spread evenly across those categories. We considered two scenarios in our analysis – one where ZEV tractor sales to meet ACT are spread evenly across all tractor categories and one where ZEV tractor sales are concentrated within day cab tractors.

Spread evenly, ACT-driven ZEV tractor sales would range between 9% and 10% of all national tractor sales in 2032. In the scenario where all ACT-driven ZEV tractor sales are concentrated within day cabs, national ZEV day cab tractor sales would range between 22% and 26% and all other types of ZEV tractor sales would be near-zero. In our analysis below, we assume these ZEV sales will occur in the absence of EPA's Phase 3 standards so that any ZEV sales resulting from the Phase 3 standards would be incremental to these baselines.

Even accounting for the ACT rule, our analysis reflects a conservative assessment of ZEV deployment in the coming years. The historic investments in the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL) have rapidly accelerated an American electric vehicle manufacturing renaissance, dramatically advancing purchase price parity for heavy-duty ZEVs, and accelerating already declining costs for vehicles at the same time. Leveraging these trends, some manufacturers and fleets have already made commitments exceeding the levels of ZEV deployment EPA projects in the proposal. EDF comments submitted to the docket on June 16, 2023, summarized extensive evidence by a large and growing body of analyses of the declining

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in 2021 from Atlas Public Policy and HIS Markit and find current ACT states make up 22.0% of national new registrations. Using EPA's MOVES3 HD state population values, ACT states represent 25.6% of national vocational vehicles and 24.5% of tractors.

https://www.sierraclub.org/transportation/clean-vehicle-programs-state-tracker; https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/states-have-adopted-californias-vehicle-regulations; https://www.sierraclub.org/transportation/clean-vehicle-programs-state-tracker; https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/states-have-adopted-californias-vehicle-regulations; https://www.epa.gov/moves/moves-versions-limited-current-use's

[5] While there are 7 different Class 8 tractor standards and 3 different Class 7 tractor standards set, the rule allows all Class 8, vocational and tractor, to be averaged together in one averaging set and all Class 6 and 7 vehicles, vocational and tractor, to be averaged together in one averaging set. See Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles, Notice of Proposed Rulemaking, 88 Fed. Reg. 25957 (April 27, 2023).

upfront costs of electrification and the significant cost savings over time.[6] Our comments also summarized the substantial investments in the IRA and BIL that have accelerated the manufacture and deployment of ZEVs. Since the submission of our earlier comments, WSP and EDF updated our investment and job analysis in August 2023, finding that over $165 billion in private EV supply ecosystem investments and nearly 180,000 new jobs have been announced in the last eight years, with more than half of the announced investments happening since the passage of the IRA.[7] Of the announced investments, $14.5 billion is specific to HD EV manufacturing. And in January 2024, Cummins, Daimler and PACCAR, three top U.S. HD manufacturers, announced joint plans to build a $2 billion HD battery plant.[8]

Manufacturer commitments also signal a continued growth in ZEV investment and deployment. For example, Daimler Trucks has a goal of selling only CO2-neutral vehicles in Europe, Japan, and North America by 2039.[9] Both Traton SE, the parent company of Navistar, and Volvo Trucks set a global target that 50% of all truck sales will be electric by 2030, with Volvo setting a higher target in North America and Europe to reach 70% electric trucks sales by 2030.[10] In a recent shareholder meeting, Daimler, the largest HDV manufacturer in the U.S., told investors they projected their ZEV sales would account for 40% of their vehicle sales by 2030 in North America.[11] These market trends indicate that ZEV deployment in 2032 will likely be higher than what will result from the ACT state regulations alone and underscore the extremely conservative nature of our analysis here.

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[6] https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0985-1644

[7] WSP and EDF, U.S. Electric Vehicle Manufacturing Investments and Jobs Characterizing the Impacts of the Inflation Reduction Act after 1 Year, August 2023. https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0985-2671

[8] https://investor.cummins.com/news/detail/634/accelera-by-cummins-daimler-truck-and-paccar-select

[9] David Cullen, Daimler to Offer Carbon Neutral Trucks by 2039, Truckinginfo (Oct. 25, 2019), https://www.truckinginfo.com/343243/daimler-aims-to-offer-only-co2-neutral-trucks-by-2039-in-key-markets.

[10] De Lombaerde, Geert, Traton boosting its trucking electrification investments, Fleet Owner (16 Mar 2022). https://www.fleetowner.com/emissions-efficiency/article/21236316/traton-adding-to-electrification-investments. Volvo Trucks, Record order from Maersk for Volvo electric trucks, Volvo Trucks. 29 March 2022. https://www.volvotrucks.com/en-en/news-stories/press-releases/2022/mar/volvo-trucks-receives-record-order-for-electric-trucks-from-maersk.html.

[11] Daimler Truck Capital Market Day 2023 Presentation, July 11, 2023, https://www.daimlertruck.com/fileadmin/user_upload/documents/investors/capital-market-days/daimler-truck-ir-capitalmarketday-2023-07-11.pdf.

2. ICEV improvements

In its proposal, EPA assumed manufacturers would reduce ICEV emissions only to the levels required under Phase 2 and that all emission reduction that Phase 3 would require beyond that would result from ZEV adoption. However, as laid out by several reports from the International Council on Clean Transportation (ICCT) and Argonne National Laboratory (ANL), and demonstrated by real world examples, including SuperTruck, manufacturers can reduce heavy-duty ICEV emissions much further than required to meet Phase 2, indicating that manufacturers could pursue further ICEV improvement as part of an alternative compliance strategy to meet Phase 3 standards.

To understand the potential of ICEV technologies in controlling HDV tailpipe emissions, EDF reviewed analyses by ICCT including Buysee et al 2021[12] and Ragon et al 2023.[13] Buysse et al 2021 looks at two vehicle types, medium heavy-duty (MHD) multi-purpose (MP) vocational vehicles and Class 8 sleeper cab high roof tractors for MY2035. The study includes the following emissions control technologies:

- MHD MP Vocational Vehicles
    - Improved engine efficiency (49% peak BTE)
    - Advanced axle efficiency (97%)
    - Rolling resistance tires (Level 7v)
    - Lightweighting (LHD-850 lb, MHD-1,100 lb, HHD-1,580 lb)
    - Improved aerodynamics (improvements of LHD-0.2 m^2, MHD and HHD-0.5 m^2)
    - Reduced accessory load (2.1% efficiency improvement)
    - Mild hybridization with stop-start
- Class 8 Sleeper Cab High Roof Tractors
    - Improved engine efficiency (55% peak BTE)
    - Advanced axle efficiency (97%)
    - Rolling resistance tires (Level 5)
    - Lightweighting (day-1,940 lb and sleeper-1,990 lb reductions)
    - Improved aerodynamics (Bin VI CdA 4.1-5.2 m^2)

[12] Claire Buysse, Ben Sharpe, Oscar Delgado, "Efficiency Technology Potential for Heavy-duty Diesel Vehicles in the United States through 2035," ICCT (Nov. 18, 2021). https://theicct.org/publication/efficiency-technology-potential-for-heavy-duty-diesel-vehicles-in-the-united-states-through-2035/

[13] Pierre-Louis Ragon et al., Potential benefits of the U.S. Phase 3 greenhouse gas emissions regulation for heavy-duty vehicles, Table C1, International Council on Clean Transportation, April 14, 2023, https://theicct.org/publication/hdv-phase3-ghg-standards-benefits-apr23/.

- Reduced accessory load (1.5% efficiency improvement)
- Predictive cruise control (3% efficiency improvement)
- Dual-clutch transmission (2.0 final drive ration, 10% engine downsizing)
- Mild hybridization

Ragon et al 2023 modeled all of the EPA regulatory categories for vocational vehicles, urban, MP, and regional for light heavy-duty (LHD), MHD, and heavy heavy-duty (HHD), as well as all of the tractor categories, low, mid, and high roof for Class 7, Class 8 day cab, and Class 8 sleeper cab tractors with all of the technologies identified in Buysse et al as having payback periods of fewer than 2 years and modeled this for MY2036. For tractors, this meant removing dual-clutch transmission and mild hybridization. For vocational vehicles, the analysis removed mild hybridization but left stop-start. While mild hybridization with stop-start had a 1.8-year payback period in Buysse et al 2021, Ragon et al 2023 found there was not currently enough commercial interest in mild hybrid technology in HD vocational vehicles to justify using it in their study. For both studies, we assumed manufacturers would produce vehicles with these levels of emissions control technology a few years earlier than ICCT modeled (i.e., MY2032 instead of MY2035). Many of them are commercially available now or have been demonstrated in real world tests supporting the idea that manufacturers could reach these emission reduction levels within the timeframe.

Since Buysse et al 2021 only modeled two vehicle categories, we applied the relative improvements from these additional technologies to the results from Ragon et al 2023 to estimate the remaining vehicle categories with this additional technology added. In the remainder of the analysis the Buysse et al 2021-like technology package is referred to as Mild Hybrid (MHEV) for vocational vehicles and MHEV + Dual-Clutch Transmission (DCT) for tractors.

We also wanted to isolate the portion of ICEV improvements possible without any electrification (in this case, removing mild hybrid and stop-start). In Buysse et al 2021, for MHD MP vocational vehicles, the analysis specifies the emissions with all of the technologies described above including mild hybridization and stop-start (155 g/ton-mi) and without mild hybridization or stop-start (169 g/ton-mi). Additionally, Ragon et al 2023 modeled vocational vehicles with stop-start, but without mild hybridization. The emissions level they modeled for MHD MP vocational vehicles is 163 g/ton-mi. The emissions impact of removing start-stop is an increase of 6 g/ton-mi, a 3.9% increase in emissions. We applied this 3.9% increase in emissions to all the Ragon et al 2023 results for all of the EPA vocational vehicle categories in order to represent the capability of ICEV improvements without start-stop or any hybridization. In the case of tractors, the values in Ragon et al 2023 do not include mild hybridization or stop-start so no adjustments were needed. The Ragon et al 2023 modeling also did not include dual-clutch transmission since it had a payback period of longer than two years. In the remainder of this analysis, this level of emissions control is referred to as Advanced ICEV (Adv ICEV) and includes only technologies with payback periods of less than 2 years. The emissions and percent change from Phase 2 MY2027 standards for Adv ICEV and MHEV/MHEV + DCT are below in Table 1. EPA sets separate urban, multi-purpose, and regional standards for vocational vehicles and separate low, mid, and high roof standards for tractors. The values included in Table 1 and for the remainder of the analysis are sales-weighted averages.[14]

TABLE 1: Heavy-duty Vehicle Emissions for ICEV Technologies and Percent Change from Phase 2 MY2027 Standards

	Phase 2 MY2027	Adv ICEV		MHEV/MHEV+DCT		Proposed MY2032	
		g/ton-mi	% diff	g/ton-mi	% diff	g/ton-mi	% diff
LHD	333	246	-26%	225	-32%	145	-57%
MHD	242	175	-28%	160	-34%	160	-34%
HHD	240	202	-16%	185	-23%	148	-38%
C7	98.1	74.5	-24%	64.2	-35%	64.8	-34%
C8 Day	74.6	57.6	-23%	49.8	-33%	49.2	-34%
C8 Sleep	65.1	50.2	-23%	43.8	-33%	48.8	-25%
Heavy	48.3	43.6	-10%	40.4	-16%	41.1	-15%

a. Examples of highly fuel efficient ICEVs in the real world

The recent results of the SuperTruck II program bolster the projections in the ICCT analyses and are further evidence that manufacturers could reasonably choose to pursue greater use of ICEV efficiency controls in HD vehicles. SuperTruck, a public-private partnership with the U.S. Department of Energy, promotes research and development to improve the freight efficiency of heavy-duty Class 8 long-haul tractor-trailer trucks. The program aims to accelerate the development of cost-effective advanced emissions control technologies not currently widely available in the market. SuperTruck I began in 2009 and funded four truck makers to develop a heavy-duty truck with 50% better efficiency than anything in production at the time.[15]

[14] Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2: Regulatory Impact Analysis, EPA-420-R-16-900, Tables 2-286 and 5-16, August 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF.

[15] https://www.energy.gov/eere/vehicles/articles/report-adoption-new-fuel-efficient-technologies-supertruck

SuperTruck II kicked off in 2017 and tasked OEMs with achieving a 100% freight efficiency improvement over their submitted 2009 baseline. Some OEMs have exceeded DOE's goal, illustrating that significant improvements in ICEV efficiencies still remain.

Volvo Trucks' SuperTruck II program announced in October 2023 that it had achieved a 134% efficiency improvement over 2009 levels. Volvo focused heavily on advanced aerodynamics, achieving 50% lower drag than 2009.[16] In addition to the aerodynamics advancements, engineers implemented several weight reduction strategies to achieve a significantly reduced curb weight. Volvo Trucks worked with the project partner trailer manufacturer and tire manufacturer on aerodynamics and weight reduction. The company plans to integrate the technology improvements into upcoming models, noting, "[o]ur engineers have already begun implementing some of the learnings from SuperTruck II into our future truck models. The future of trucks is just around the corner."

The Cummins SuperTruck II team focused research and development on heavy-duty diesel engine technology, achieving 55% brake thermal efficiency (BTE) from an engine equipped with waste heat recovery in 2021.[17] Cummins' engine is part of Peterbilt's SuperTruck II vehicle, which announced in January 2024 that it also exceeded the program goals with a 132% improvement over the 2009 baseline.[18] Peterbilt focused on advanced and highly efficient powertrain systems and vehicle technologies including a mild hybrid powertrain, Cummins' waste heat recovery system and a lightweight chassis for improved fuel economy.

Daimler Truck North America (DTNA) developed a SuperTruck II vehicle in 2023 with enhanced tractor aerodynamics, low-rolling resistance tires, powertrain improvements and energy management with advanced technologies.[19] In February 2023, when Freightliner, a DTNA subsidiary, debuted their SuperTruck II vehicles they said, "[t]aken all together, the combined innovations developed for the Freightliner SuperTruck II have provided us the opportunity to explore the technologies needed to meet stringent and forthcoming Greenhouse Gas reduction requirements in the coming years."[20] DTNA has also been awarded a grant for SuperTruck III to "develop a hydrogen fuel cell electric tractor that exceeds heavy-duty long-haul sleeper

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[16] https://www.volvotrucks.us/news-and-stories/press-releases/2023/october/volvo-trucks-supertruck-exceeds-freight-efficiency-goals-with-focus-on-aerodynamics-and-advanced-engineering/

[17] https://www.cummins.com/news/2021/08/10/supertruck-ii-team-reaches-never-achieved-55-brake-thermal-efficiency

[18] https://www.peterbilt.com/news-and-events/press-releases/peterbilt-demonstrates-advanced-technology-and-innovation-at-ces-with-supertruck-ii

[19] https://corpcomm.blob.core.windows.net/media/supertruck-ii_press-release.pdf

[20] https://www.ccjdigital.com/trucks/article/15306208/freightliner-debuts-second-supertruck

performance, efficiency, and range requirements without compromising payload."[21] The design is set to be revealed by 2027.

3. Strong Hybrid and Plug-In Hybrid Improvements

The ICCT studies only considered mild hybrid vehicles that have limited electrification. They did not consider strong hybrids (SHEVs) or plug-in hybrids (PHEVs). Our analysis includes SHEV and PHEV technologies for vocational vehicles because they can provide additional pathways for manufacturers to meet the proposed Phase 3 standards, and they are mainstream technologies in the light-duty truck market, making their extension to the heavy-duty fleet feasible.[22] One study that considers the improvements possible from SHEVs and PHEVs for HDVs is from Argonne National Laboratory (ANL).[23] The study includes a Class 4 Box Truck (C4 Box), Class 6 Box Truck (C6 Box), and Class 8 Vocational Truck (C8 Voc) with a range of powertrains. The study looks at vehicles in MY2020 and MY2025. For MY2025, ANL considered a higher technology progression ("high") and a lower technology progression ("low").

EDF converted the fuel economy (mpg) values in the ANL study to fuel consumption (gal/100 miles) values to allow us to better identify emissions reductions. The improvements from strong hybrids for the three vehicles in question range from 12% to 23% reduction in fuel consumption over the ICEV as shown in Table 2.

TABLE 2: Fuel Consumption for ANL Report Powertrains

		Fuel Consumption (gal/100 miles)								
		ICEV	SHEV	PHEV	BEV		SHEV Improv		Calculated Utility Factor for PHEV	PHEV Improv
C8 Voc	MY25 low	13.35	11.56	9.55	5.29		-13%		32%	-41%
	MY25 high	11.68	10.22	8.18	4.67		-12%		37%	-45%
C6 Box	MY25 low	9.15	8.09	6.18	3.36		-12%		40%	-47%
	MY25 high	7.58	6.36	5.14	2.94		-16%		36%	-46%
C4 Box	MY25 low	7.27	5.87	4.54	2.12		-19%		35%	-48%
	MY25 high	6.33	4.87	4.07	1.84		-23%		27%	-44%

[21] Id.

[22] EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Draft Regulatory Impact Analysis," (April 2023) EPA-420-D-23-003; Chapter 3. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10175J2.pdf

[23] Andrew Burnham et al., Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains, Argonne National Laboratory, April 2021, https://publications.anl.gov/anlpubs/2021/05/167399.pdf.

The value given by ANL for PHEV fuel economy includes the efficiency of the electricity powered portion of the duty-cycle. To get at the emission reductions from PHEVs, we calculated a utility factor (UF). Since a PHEV is a SHEV + BEV with the fraction of operation as a BEV being the UF, we used the fuel consumption (FC) values for PHEVs, SHEVs, and BEVs to calculate the UF, using the relationships below.

Formula to equate the FC of PHEVs, SHEVs, and BEVs:

$$FC_{PHEV} = FC_{BEV} * UF + FC_{SHEV} * (1 - UF)$$

Solving for UF:

$$UF = \frac{FC_{PHEV} - FC_{BEV}}{FC_{SHEV} - FC_{BEV}}$$

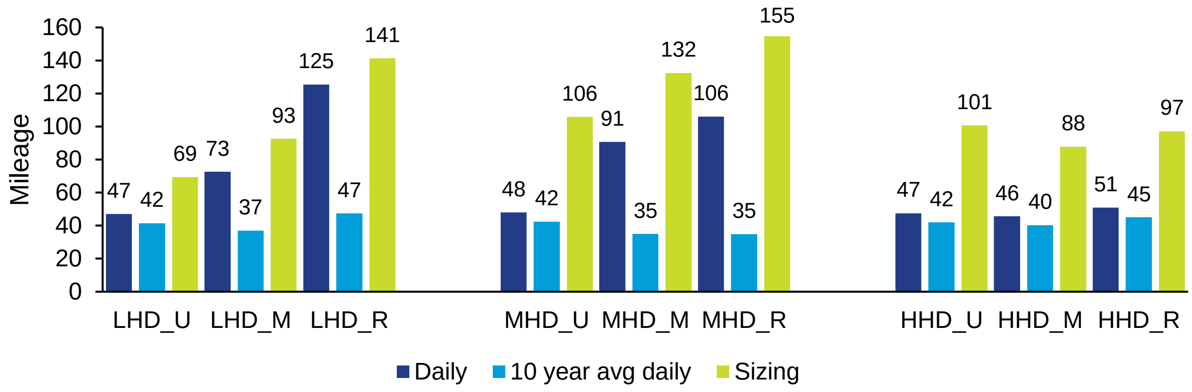
Using this formula, we calculated the UF for the HD vehicles within the ANL study. As shown in Table 2, the calculated UF ranged from 27% to 40% with the improvement of PHEV emissions over the ICEV ranging from 41% to 48%.

For the remainder of the analysis, we use the higher of the two values for SHEV improvement and PHEV UF. Since these are improvements in 2025 and we are looking at 2032, using the high value is a reasonable choice.

We applied the values for C4 Box to all LHD vocational vehicles, the C6 Box to all MHD vocational vehicles, and the C8 Voc to all HHD vocational vehicles. To understand how reasonable an assumption it is to apply the improvements for the ANL vehicles to the Urban, MP, and Regional vehicles, we looked at the daily mileage assumed by EPA and in the ANL study.

In the HD TRUCS model, EPA includes a daily, 10-year average daily, and battery sizing mileage values for each of the 101 vehicle categories it models. We aggregated the 101 vehicle categories into the nine vocational vehicle EPA standards and calculated the sales weighted average for each of the different daily mileages. Figure 1 shows these values.

FIGURE 1: HD TRUCS Average VMT by Category



For LHD and MHD, the daily and sizing VMT increases between Urban and MP and between MP and Regional but the 10-yr average that were used to determine operating and maintenance costs is similar across Urban, MP, and Regional. For HHD, the Urban, MP, and Regional vehicles are similar for all three VMTs.

The PHEV electric ranges for the vehicles modeled in ANL varied with C4 Box and C6 Box having 75 miles of electric range and the C8 Voc having 100 miles. ANL uses VIUS 2002 data to determine the annual VMT for vehicles over the lifetime of the vehicle. This data is not exactly comparable to the values included in EPA's HD TRUCS. Using the annual milage for each year of the vehicle's life, then calculated the lifetime daily mileage - assuming 250 days of driving per year and the highest average daily mileage using the year with the most annual miles. These are reflected in Table 3 below.

TABLE 3: VMT from EPA HD TRUCS and ANL Report

	EPA HD TRUCS (U/M/R)			ANL		
	Daily VMT	10-yr avg daily VMT	Sizing VMT	Avg Annual	Highest Daily (250 days)	Average Daily (250 days)
LHD/C4 Delivery	47/73/125	42/37/47	69/93/141	14,000	76	54
MHD/C6 Delivery	48/91/106	42/35/35	106/132/155	17,000	110	68
HHD/C8 Voc	47/46/51	42/40/45	101/88/97	21,000	124	85

Comparing the daily milage used in the ANL report to EPA's HD TRUCS, the ANL daily milage is higher in most cases, supporting the application of the utility factor and PHEV improvements of the Argonne results to all the Urban, MP, and Regional vehicles.

In addition to the improvements from hybridization, emission reduction technologies like aerodynamics and axel efficiency improvements can also be applied to these vehicles. Because

SHEVs only use gasoline and PHEVs use gasoline and electricity, slightly different methodologies were used to combine the emission control technologies.

The improvements from SHEV were applied to the Adv ICEV vocational vehicle emissions levels as to not double count the benefits from mild and strong hybrids.

For PHEVs, the UF was used to calculate the emissions benefits of making vehicles PHEVs. As discussed above, a PHEV is a BEV combined with a SHEV with the utility factor describing the ratio of electricity to gasoline use. The UF calculated above (shown in Table 1) was applied to MHEV emission levels. The study may underestimate the possible benefits because it only included mild hybridization and not strong hybridization which is how a PHEV operates in charge sustaining mode.

In both cases, SHEVs and PHEVs, a 0.9 dis-synergy factor was applied to account for "decreases in technology effectiveness as a result of multiple technologies being applied to an engine" or vehicle. This is consistent with what EPA used in Phase 2 MY2024 and MY2027 modeling.[24] The emissions and percent change from Phase 2 MY2027 standards for SHEV and PHEV are below in Table 4 for a sales-weighted average of urban, multi-purpose, and regional.

TABLE 4: Heavy-duty Vocational Vehicle Emissions for SHEVs and PHEVs and Percent Change from Phase 2 MY2027 Standards

	Phase 2 MY2027	SHEV		PHEV		Proposed MY2032	
		g/ton-mi	% diff	g/ton-mi	% diff	g/ton-mi	% diff
LHD	333	195	-41%	145	-56%	145	-57%
MHD	242	149	-38%	95	-61%	160	-34%
HHD	240	178	-26%	117	-51%	148	-38%

a. Examples of HD SHEV and PHEV

Strong hybrid and plug-in hybrid technologies have become mainstream in the light-duty truck market and are now also being operationalized in some vehicles within the medium- and heavy-duty sector. For example, Xcelcior makes a hybrid electric transit bus that achieves 10-29% fuel economy improvement over a conventional bus, depending on the route.[25] Nova Bus also sells

[24] Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2: Regulatory Impact Analysis, Page 2-81, August 2016 https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF.

[25] https://www.newflyer.com/bus/xcelsior-hybrid/

a hybrid transit bus that can reduce fuel consumption by up to 30% while also reducing harmful criteria pollutant emissions by up to 40%.[26] Odyne Hybrid Systems offers an advanced plug-in hybrid system for medium- and heavy-duty work trucks. The system provides improved driving efficiency as well as stationary electric power for auxiliary systems.[27] Scania makes a heavy-duty hybrid electric tractor or rigid truck with up to 10 mi range and a plug-in hybrid truck with up to 37 mi all electric range available in Europe.[28] These examples indicate that strong hybrid and plug-in hybrid technologies can be part of a feasible pathway to compliance with the Phase 3 standards.

4. Results

The above sections outline how we calculated the vehicle emissions for four technology packages for vocational vehicles, Adv ICEV, MHEV, SHEV, and PHEV, and two for tractors, Adv ICEV and MHEV + DCT. To evaluate the impact these different levels and packages of emission control technology would have on Phase 3 compliance strategies, we looked at each technology in isolation and in combination. We determined the percent of ZEV adoption needed in 2032 assuming the remaining fleet adopted each of the technologies. Additionally, we modeled a few of the many possible compliance pathways manufacturers could use.

Vocational Vehicles

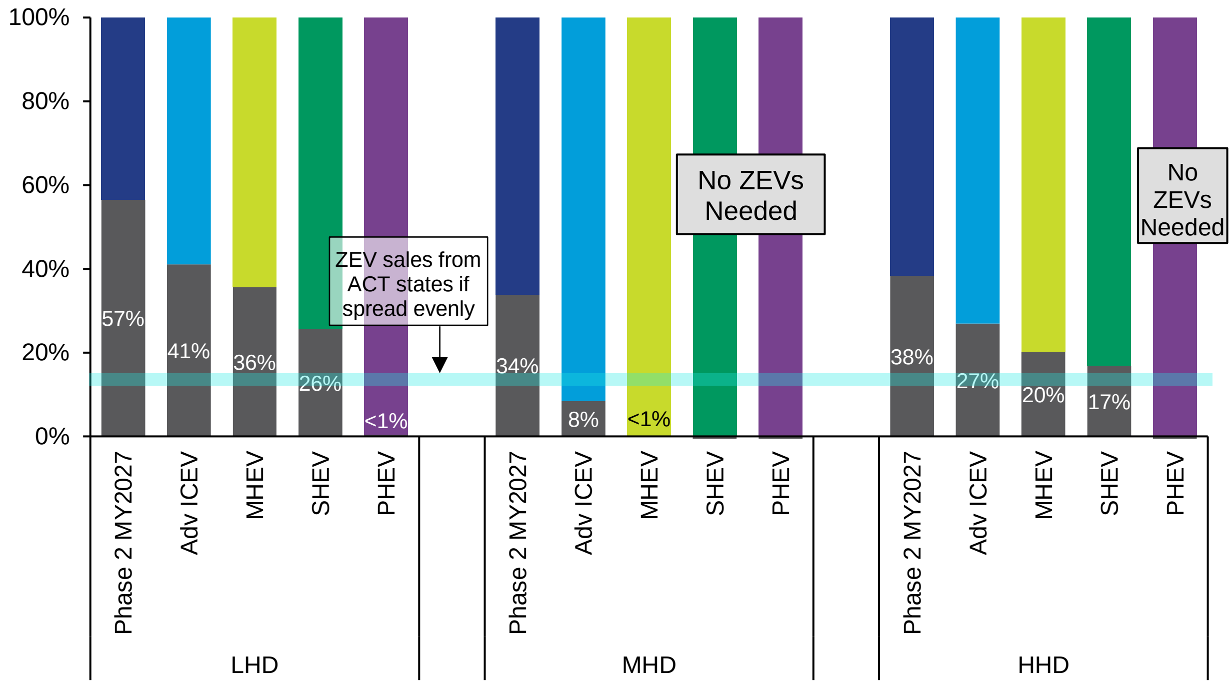
Figure 2 shows the precent ZEV adoption needed to meet MY2032 Proposal using each technology for a sales weighted combination of urban, multi-purpose, and regional. The horizontal light blue bar in Figure 2 represents the range of ZEV sales required in current ACT states - the minimum level of ZEVs that would be sold in the U.S. in 2032 in the absence of any additional regulations, between 13% and 16%. As described above, this is an exceedingly conservative estimate of ZEV sales in 2032 absent additional EPA action due to expected favorable economics of ZEVs, manufacturer commitments, and corporate climate target.

[26] https://novabus.com/blog/bus/lfs_hev/

[27] https://www.odyne.com/wp-content/uploads/2019/02/020215allisonodynebrochure6singlepagessm.pdf

[28] https://www.scania.com/group/en/home/products-and-services/trucks/plug-in-hybrid-truck.html

FIGURE 2: Vocational Vehicles: Percent ZEV Adoption to Meet 2032 Proposed Standards using Different Control Technology Packages



All of the additional technologies included in Figure 2 would reduce the level of ZEV adoption needed to meet the Proposed Standards as compared to what EPA projected (the dark blue bars in Figure 2). For LHD vocational vehicles, which have the highest level of emission reductions in the Phase 3 Proposed Standards, the level of ZEVs needed if the remaining fleet only meets Phase 2 MY2027 standards is 57%. The ZEV share falls to 41% with Adv ICEV, 36% with MHEV, 26% with SHEV, and less than 1% with PHEV.

For MHD vocational vehicles, EPA projected 34% ZEV adoption in the Phase 3 Proposal, with the remaining fleet meeting the Phase 2 MY2027 standards.[29] If the remaining fleet is Adv ICEV, only 8% ZEVs are needed to comply with Phase 3 and less than 1% ZEV with MHEV. When the remaining fleet is SHEV and PHEV, no ZEVs are needed. The MHD SHEVs and PHEVs have lower emissions than the MY2032 Phase 3 Proposed Standards. A fleet of 89% SHEVs and 11% Phase 2 MY2027 vehicles would comply, as would a fleet of 56% PHEVs and 44% Phase 2 MY2027 vehicles.

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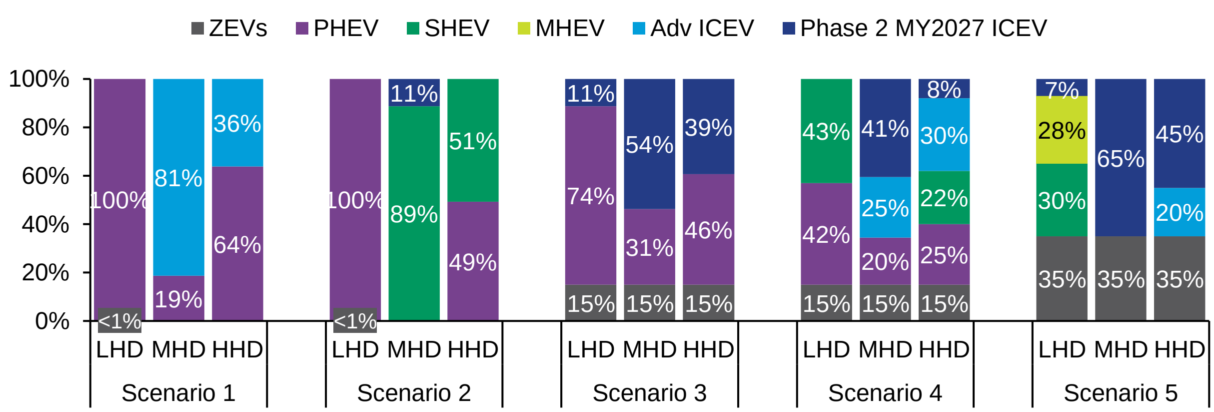
[29] In some of the tables in the preamble for EPA's Proposed Standards, they list only the multi-purpose vehicle emission reduction (e.g., Table ES-3). The values here are using a sales-weighted average of urban, multi-purpose, and regional vehicles.

Finally, for HHD vocational vehicles, EPA projected 38% ZEV adoption by MY2032 with the remaining fleet being Phase 2 MY2027 ICEVs. If the remaining fleet was instead Adv ICEVs, the ZEV percentage would drop to 27%. If the remaining fleet was MHEVs, the ZEV percentage would drop to 20%, SHEVs to 17%, and no ZEVs are needed if the rest of the fleet is made up of PHEVs. A combination of 75% PHEVs and 25% Phase 2 MY2027 ICEVs would comply with EPA's Proposed MY2032 Standards for HHD vocational vehicles.

Possible Compliance Pathways – Vocational Vehicles

While many compliance pathways exist for manufacturers, we looked at five possible scenarios for vocational vehicles using a sales-weighted average of urban, multi-purpose, and vocational. Figure 3 below shows the percentage of each technology type for each of the potential compliance pathways modeled here. The first two scenarios assume less than 1% ZEV deployment for LHD vocational vehicles and no ZEV deployment for MHD and HHD vehicles, showing that the Phase 3 standards could be met with almost no ZEV deployment. Scenarios 3 and 4 have 15% ZEVs to be consistent with ACT state-driven ZEV sales, which is still unrealistically low even without EPA's proposed regulations. Finally, Scenario 5 includes a baseline of 35% ZEVs, consistent with ACT Research's projections for 2032.[30] These scenarios show that all of EPA's proposed Phase 3 standards can be met with ZEV levels below those that will result from HD ZEV sales in ACT states and many of the proposed standards can be met without any ZEVs at all.

FIGURE 3: Possible Compliance Pathways For EPA's Proposed 2032 Vocational Vehicle Standards



[30] Half of all Commercial Vehicles will be Zero Emissions by 2040, ACT Research, September 12, 2023, https://www.actresearch.net/resources/blog/charging-forward-blog.

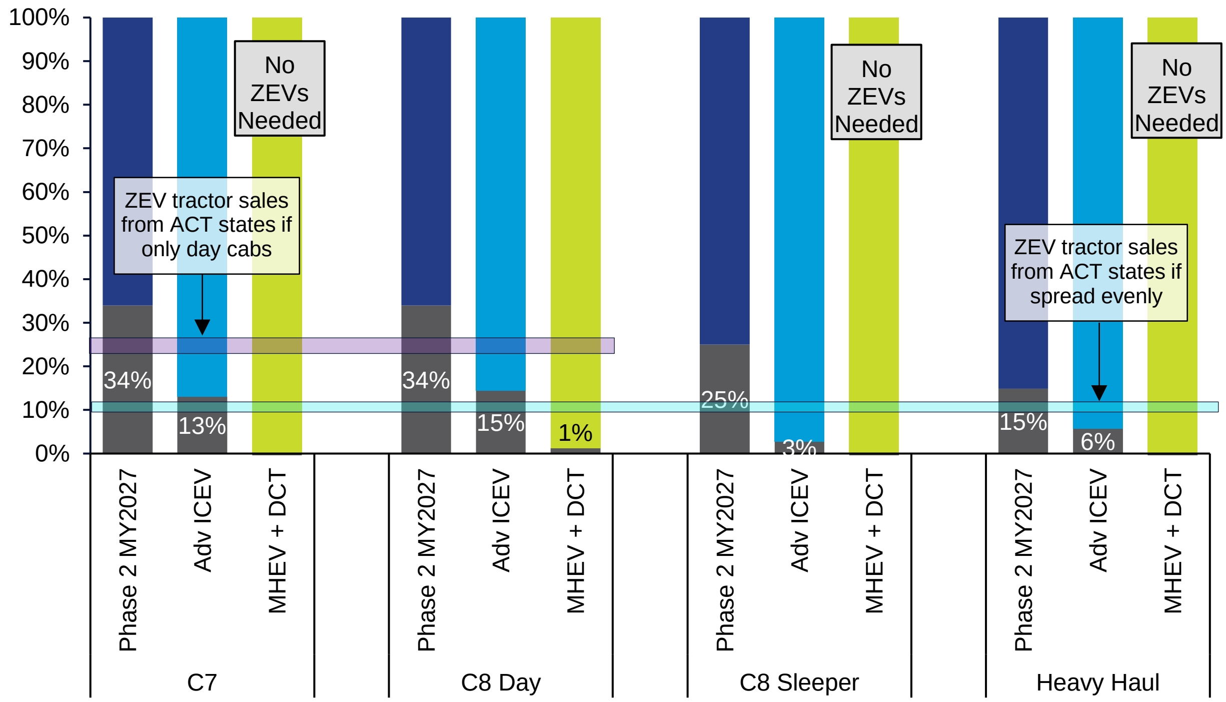
Class 7/8 tractors

As discussed above, it is not currently clear what types of ZEV tractors manufacturers will sell in ACT states. We analyzed two possibilities. First, if we assume that manufacturers sell primarily ZEV day cab tractors instead of sleeper cabs to comply with ACT, the share of national ZEV day cab tractors sales will be 22% to 26%. This is represented by the horizontal purple bar in Figure 4. Second, if we instead assume manufacturers spread their ZEV tractor production across all tractor types, national ZEV tractor sales for all tractor categories will be 9% to 11% from ACT required sales alone. This is represented by the horizontal blue bar in Figure 4. EPA sets separate standards for low, mid, and high roof tractors for Class 7 day, Class 8 day, and Class 8 sleeper cabs. The analysis below was

Because the level of emissions improvement proposed in Phase 3 is lower for tractors than for vocational vehicles, the relative impact of ICEV improvements beyond those required by Phase 2 on vehicle emissions is greater. In the Proposal, EPA projected that 34% of Class 7 and Class 8 day cab tractors would be ZEVs in 2032, assuming the rest of the fleet produced emissions consistent with Phase 2 MY2027 levels. If the remaining fleet were Adv ICEVs, the share of ZEVs would be around 13% in 2032. This level of ZEVs is lower than what would occur if manufacturers met ACT tractor requirements with day cab ZEV tractors and no sleeper cab ZEVs. If manufacturers applied more emission control technology to Class 7 and Class 8 day cab tractors, consistent with MHEV + DCT, the share of ZEVs required to meet the proposed Phase 3 standards would be reduced to almost zero.

For Class 8 Sleeper cabs, EPA projects 25% ZEV sales in 2032 with the remaining ICEVs meeting only Phase 2 MY2027 standards. However, if manufacturers produced Adv ICEVs, they would only need 3% ZEVs and if they produced MHEV + DCTs, they could fully comply with Phase 3 emissions reductions without any ZEV sales. A fleet of 77% MHEV + DCTs and 23% Phase 2 MY2027 ICEVs would meet the proposed MY2032 sleeper cab standard. Similarly for heavy haul sleeper cabs, EPA proposed a 15% emissions reduction, which can easily be met with ICEV improvements alone.

FIGURE 4: Tractors: Percent ZEV Adoption to Meet 2032 Proposed Standards Using Different Control Technology Packages



An additional flexibility available to manufacturers is the averaging set. All vehicles within each set are averaged together, allowing manufacturers to improve some of the vehicle emissions more than is required by Phase 3 and offset a failure to meet reduction requirements for other vehicles. The averaging occurs across all vehicles within an averaging set, regardless of whether they are vocational or tractors. There are three averaging sets for HD vehicles, incomplete chassis LHDVs, MHDVs, and HHDVs, respectively.[31] In particular, this combines most of the tractors (excluding the share of Class 7 tractors) together with the HHD vocational vehicles to be one averaging set. This analysis did not explicitly take into account the averaging set flexibility but it is another important mechanism manufacturers have available to them to meet the standards.

Possible Compliance Pathways - Tractors

Similarly for tractors, several compliance pathways were modeled. We modeled 3 scenarios. The first includes almost no ZEVs, the second scenario includes 10% ZEVs for all tractor

[31] In previous HD GHG rulemakings (i.e., Phase 1 and Phase 2), there was a forth averaging set, complete HD pickups and vans, but these vehicles are included in the proposed light- and medium-duty multi-pollutant emission standard rule.

categories consistent with ACT state ZEV tractor sales being evenly distributed, and the third scenario includes 24% ZEVs for day cabs and no ZEVs for sleeper and heavy haul tractors, consistent with ZEV sales in ACT states being focused on day cabs.

FIGURE 5: Possible Compliance Pathways for EPA's Proposed 2032 Tractor Standards

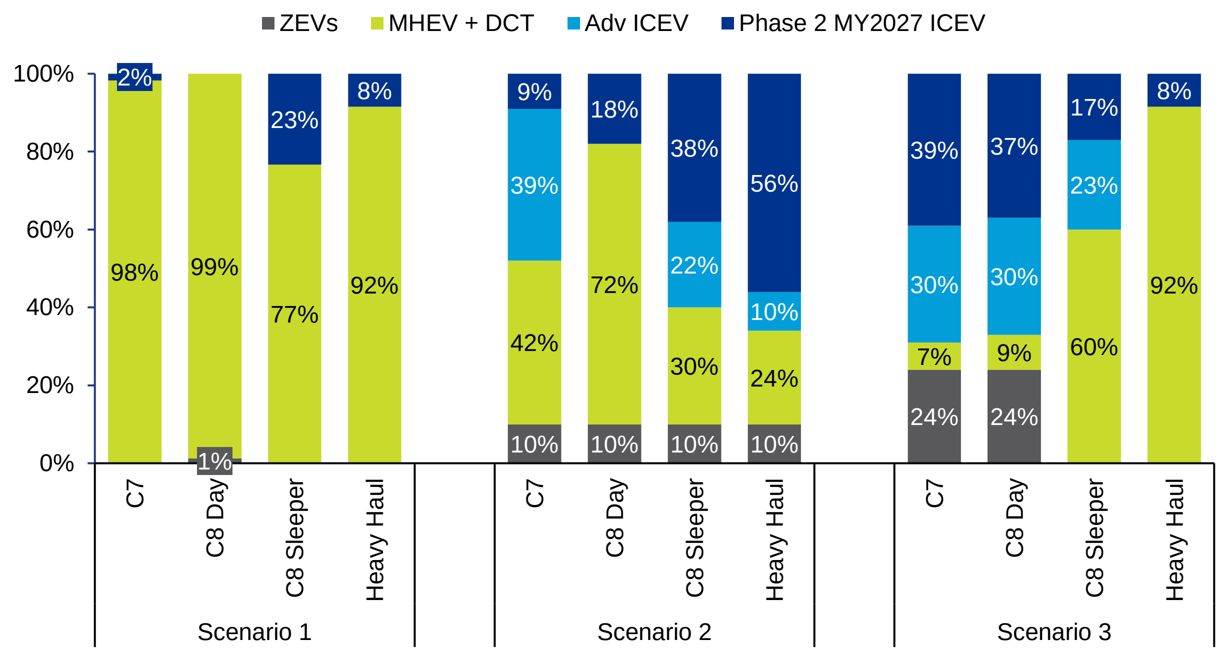


Figure 5 shows that additional ICEV improvements result in little to zero need for ZEVs across all of the modeled scenarios. Even under scenarios where some ZEV sales are estimated to be needed to meet the proposed Phase 3 standards, the level of ZEVs is considerably lower than what is expected to occur within ACT states even without further EPA regulation.

Conclusion

As shown above, there are many compliance pathways manufacturers can use to meet the EPA proposed standards that are less reliant on ZEVs than the scenario EPA modeled in their Proposal. Our analysis concludes that most of EPA’s Proposed Standards can be met without any ZEVs and all can be met with ZEV levels well below those that will result from HD ZEV sales in ACT states.

We welcome any questions about our analysis.

Sincerely,

Environmental Defense Fund