POLICY UPDATE

SEPTEMBER 2024

SUMMARIZES REGULATORY AND OTHER DEVELOPMENTS RELATED TO CLEAN TRANSPORTATION WORLDWIDE

U.S. EPA Phase 3 greenhouse gas emission standards for heavy-duty vehicles

Yihao Xie

INTRODUCTION

On April 22, 2024, the U.S. Environmental Protection Agency (EPA) published the Phase 3 greenhouse gas (GHG) emission standards for heavy-duty vehicles (HDVs) final rule, which set CO_2 emission limits for Class 2b–8 vehicles of model years (MYs) 2027 to 2032.[1] The Phase 3 standards require CO_2 emission reductions per ton-mile of freight moved by up to 60% for vocational trucks and up to 40% for tractor trucks in MY 2032 compared with the Phase 2 MY 2027 levels. Importantly, the new standards follow the same technology-neutral principle as the previous standards and do not mandate the sales of zero-emission vehicles (ZEVs), such as battery electric or hydrogen fuel-cell vehicles.

As in previous phases, the Phase 3 standards retain the same fleet-average regulatory scheme. This does not require individual vehicles to meet the standards but instead allows manufacturers to meet the standards based on the average emissions within each weight class. The regulation retained the non-CO_2 GHG emission standards from Phase 2, including nitrous oxide (N_2O), methane (CH_4), and hydrofluorocarbon (HFC). The heavy-duty engine CO_2 emission standards are also unchanged. The new standards also largely retained the existing compliance provisions, flexibilities, and testing procedures for HDVs.

HDVs are a major source of greenhouse gas emissions in the United States, contributing to 25% of transportation emissions. According to EPA, the new standards will reduce approximately 1 billion metric tons of HDV CO_2 emissions from 2027

1 Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3, 89 F.R. 29440 (April 22, 2024) (to be codified at 40 C.F.R. § 86, 1036, 1037, 1039, 1054, and 1065), https://www.govinfo.gov/content/pkg/FR-2024-04-22/pdf/2024-06809.pdf; Only Class 2b-3 vocational vehicles are subject to the HDV regulation. Other Class 2b–3 vehicles are regulated by the Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles.

www.theicct.org

communications@theicct.org

@theicct.org

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

through 2055. This will lessen air pollution for the 72 million people who live close to major truck freight routes and who are disproportionately more likely to be people of color or reside in low-income households.[2]

With the promulgation of the Phase 3 HDV GHG standards, EPA has completed the final regulatory piece of the Clean Trucks Plan announced in 2021, which also includes the Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards, finalized in December 2022, and the Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, finalized in March 2024.[3]

KEY ELEMENTS

EMISSION STANDARDS

The Phase 2 MY 2027 emission standards are used as the baseline for the new Phase 3 standards. EPA modeled a potential compliance pathway from MY 2027 to MY 2032, projecting a production mix of internal combustion engine (ICE) vehicles and ZEVs. Phase 3 CO_2 limits are determined based on the projected ZEV adoption rates in this potential compliance pathway. To arrive at the projected ZEV adoption rates, EPA developed the Heavy-Duty Technology Resource Use Case Scenario (HD TRUCS), a tool that projects technology feasibility and payback of zero-emission HDV technologies for more than a hundred vehicle types in MYs 2027, 2030, and 2032.[4] Payback periods were then converted to ZEV adoption rates using an adoption rate curve based on National Renewable Energy Laboratory's TEMPO model.[5] EPA capped the maximum ZEV technology penetration at 20% in MY 2027 and 70% in MY 2032. The final adoption rates for all model years were then calculated by linearly interpolating between MY 2027 and MY 2030, and between MY 2030 and MY 2032.[6] Figure 1 summarizes the key steps in EPA's determination of the new standards. The ZEV adoption rates in the modeled potential compliance pathway are also the percentage of CO_2 emission reductions from HDVs, presented in Table 1.

2 U.S. Environmental Protection Agency, *Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3 Regulatory Impact Analysis*, March 2024, https://www.epa.gov/system/files/documents/2024-03/420r24006.pdf.

3 Yihao Xie, *U.S. Heavy-Duty Vehicle NO_x Standards: Updates to Emission Limits, Testing Requirements, and Compliance Procedures* (International Council on Clean Transportation, 2023), https://theicct.org/publication/us-nox-standards-update-jul23/; Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 89 F.R. 27842 (April 18, 2024) (to be codified at 40 C.F.R. § 85, 86, 600, 1036, 1037, 1066, and 1068), https://www.govinfo.gov/content/pkg/FR-2024-04-18/pdf/2024-06214.pdf.

4 Eastern Research Group, *External Peer Review of Report: Heavy-Duty Technology Resource Use Case Scenario (HD TRUCS) Tool—Final Peer Review Summary Report* (U.S. Environmental Protection Agency, 2023), https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548983&Lab=OTAQ.

5 Matteo Muratori et al., "Exploring the Future Energy-Mobility Nexus: The Transportation Energy & Mobility Pathway Options (TEMPO) Model," *Transportation Research Part D: Transport and Environment* 98, (September 2021): 102967, https://doi.org/10.1016/j.trd.2021.102967.

6 The exception is sleeper cab tractors, where the percentage of ZEVs in MY 2031 is not a linear interpolation but 33% of the difference between MY 2030 and MY 2032.

Figure 1

A simplified illustration of EPA's Phase 3 emission standard setting

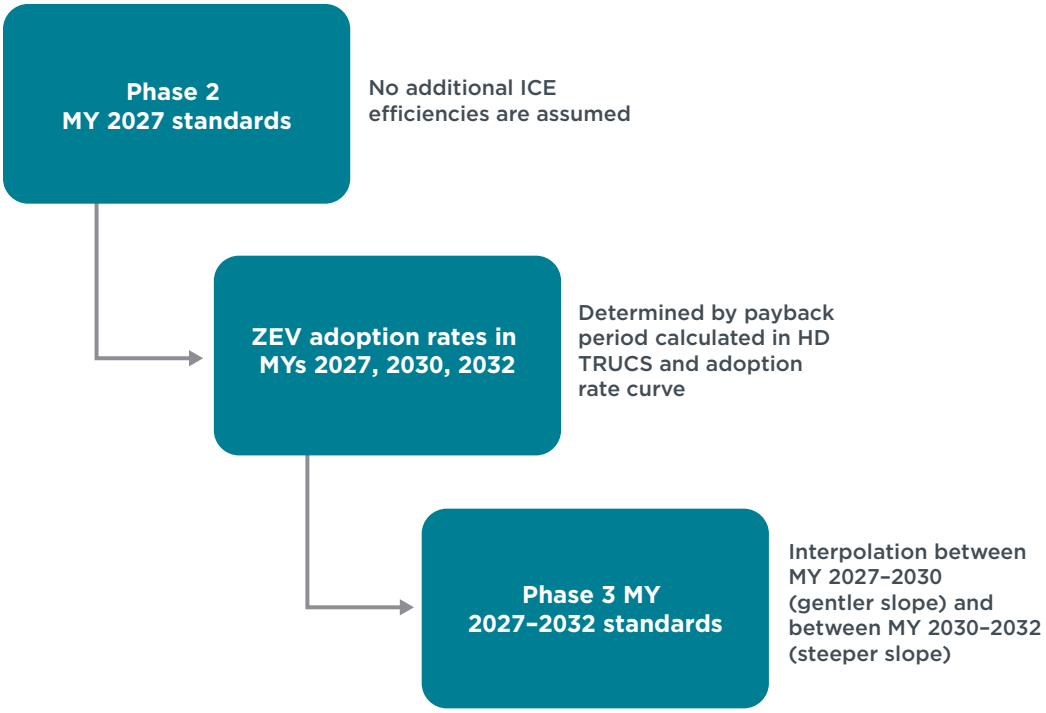


Table 1

EPA's projected zero-emission vehicle shares for the modeled potential compliance pathway

Regulatory group	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032
Light heavy-duty vocational	17%	22%	27%	32%	46%	60%
Medium heavy-duty vocational	13%	16%	19%	22%	31%	40%
Heavy heavy-duty vocational	—	—	13%	15%	23%	30%
Medium heavy-duty all cab and heavy heavy-duty day cab tractors	—	8%	12%	16%	28%	40%
Sleeper cab tractors	—	—	—	6%	12%	25%
Heavy-haul tractors	—	—	1%	1%	3%	5%

The Phase 3 CO_2 limits between MY 2027 and MY 2032 were set for 10 subcategories of tractors based on weight rating, cab configuration, and roof height; 15 subcategories of vocational vehicles; and 8 optional custom chassis vocational vehicle categories. The numerical emission limits—in terms of g/ton-mile, for each category of vocational trucks powered by compression ignition (CI) and spark ignition (SI) engines and tractors in MY 2032, when Phase 3 standards are fully phased in—are shown in Table 2 and Table 3.

Table 2

Phase 3 MY 2032 and later vocational vehicle CO_2 limits by vehicle service class in g/ton·mile

Subcategory	Light heavy-duty compression ignition	Medium heavy-duty compression ignition	Heavy heavy-duty compression ignition	Light heavy-duty spark ignition	Medium heavy-duty spark ignition
Urban	179	176	177	225	215
Multipurpose	142	153	138	184	186
Regional	103	136	97	131	165

Table 3

Phase 3 MY 2032 and later tractor CO_2 limits in g/ton·mile

Roof height	Class 7 all cab styles	Class 8 day cab	Class 8 sleeper cab	Heavy-haul tractor
Low	57.7	44	48.1	45.9
Mid	62	46.8	52.2	
High	60	45.4	48.2	

The ICE technology packages developed for the Phase 2 were used the Phase 3 rulemaking. Therefore, the Phase 3 standards did not assume any improvements in engine efficiency or efficiency gains from other features, such as improved aerodynamics or low rolling-resistance tires, for example. Manufacturers can choose to deploy these technologies to reduce emissions of their ICE vehicle fleet toward compliance and thus may not sell as many ZEVs as the modeled potential compliance pathway suggests.

UPDATES TO CREDIT AVERAGING, BANKING, AND TRADING SYSTEM

Credit generation and usage

Under the Phase 3 rule, manufacturers can continue to generate advanced technology credit multipliers through MY 2027 for sales of plug-in hybrid electric, battery electric, and hydrogen fuel-cell vehicles. These multipliers are set at 3.5 for plug-in hybrid electric vehicles, 4.5 for battery electric vehicles, and 5.5 for hydrogen fuel-cell electric vehicles. Manufacturers can use these multiplier credits to offset existing Phase 2 deficits through MY 2029, and toward Phase 3 compliance after exhausting any normally accumulated credits, or base credits, from prior years. Multiplier credits for advanced technology will expire in MY 2030 while base credits previously earned from plug-in hybrid, battery electric, or fuel-cell electric vehicle sales that are still within the 5-year credit life will be retained.

In the standards, HDV production that occurs in states that have emission standards different from federal standards are now considered part of the "U.S.-directed production volume." This means that between MY 2024 and MY 2027, manufacturers can generate federal advanced technology credit multipliers by complying with state-level regulations—such as the Advanced Clean Trucks (ACT) regulations adopted

by multiple states—and using these credits to count toward federal compliance of the Phase 3 emission standards. This change effectively increases the number of advanced technology credits available for averaging, banking, and trading during that period.

Averaging sets

In the Phase 3 standards, several changes were made to the existing averaging, banking, and trading system, giving more flexibility to manufacturers to facilitate compliance with the emission limits. In the Phase 1 and 2 standards, credit trading could only occur within averaging sets, which are HDV regulatory groups aggregated based on vehicle weight class.[7] Between MY 2027 to MY 2032, emission credits can be averaged, traded, and banked across HDV averaging sets, with no limitations on the direction or volume of credits. EPA further extends the interim flexibility to allow one-way credit transfers from averaging sets of medium-duty vehicles certified to the light and medium-duty vehicle standards, to averaging sets of Class 2b–5 and Class 6–7 HDVs (i.e. light HDVs and medium HDVs). In other words, between MY 2027 and MY 2032, manufacturers can trade and use CO_2 credits generated from the production of Class 2b–3 pickups and vans, which are subject to the light- and medium-duty standards, to offset emissions deficits in their Class 6–7 vocational vehicles or tractor trucks. They can also use credits from the production of Class 4–5 vocational vehicles to offset deficits in Class 8 vocational vehicles and tractors.

To mitigate any dilution of the Phase 3 emission benefits, EPA has created a priority list for manufacturers to use credits within an averaging set to count toward Phase 3 compliance. Specifically, manufactures can use credits in the following order:

- Base credits banked or traded within the same averaging set
- Base credits earned in the same model year from other averaging sets
- Base credits banked or traded in other averaging sets and used across averaging sets
- Multiplier credits within the same averaging set for the same model year
- Multiplier credits banked or traded within the same averaging set.
- Multiplier credits earned in the same model year from other averaging sets
- Multiplier credits banked or traded in other averaging sets

HYDROGEN INTERNAL COMBUSTION ENGINE VEHICLES

Hydrogen internal combustion engine (H_2-ICE) vehicles are a nascent technology being explored by manufacturers. H_2-ICE vehicles can either run on pure, or neat, hydrogen or via dual-fuel, which is when diesel fuel is also involved in the combustion process. Both types of H_2-ICE vehicles have tailpipe emissions of air pollutants and GHGs because NO_X and particulate matter (PM) are formed during the combustion process, thus requiring an aftertreatment system. CO_2 emissions from dual-fuel H_2-ICE vehicles come predominantly from the diesel fuel. H_2-ICE vehicles fueled by neat H_2 still produce trace amounts of tailpipe CO_2 stemming from urea decomposition and engine lubricant oil in the selective catalytic reduction system.

Consistent with the existing treatment emissions from urea decomposition in diesel vehicles, trace CO_2 emissions from H_2-ICE vehicles operating on neat hydrogen are not counted when determining compliance with the Phase 3 GHG standards. Dual-fuel H_2-

7 The three averaging sets in the HDV GHG standards are light heavy-duty (Class 2b–5), medium heavy-duty (Class 6–7), and heavy heavy-duty (Class 8).

ICE vehicles are to be certified to the GHG emission levels resulting from the existing testing provisions.

BATTERY HEALTH, DURABILITY, AND WARRANTY

Given that the Phase 3 standards are expected to drive the production and sales of zero-emission HDVs, the rule includes new requirements for batteries; degraded batteries affect life-cycle mileage and are therefore an important component in vehicle emissions performance.

The rule requires manufacturers to provide a customer-facing battery state-of-health (SOH) monitor which tracks and displays battery energy capacity for all battery electric and plug-in electric vehicles. This SOH expresses a vehicle's usable battery energy as a percentage of the original energy when the battery is new. The rule does not mandate a specific testing procedure for determining the usable battery energy. It instead provides specific requirements for a test procedure to ensure accurate results that represent in-use operation.

The rule includes the high-voltage battery in battery electric and hydrogen fuel-cell electric vehicles as emission-related components that must be covered by warranty, along with other powertrain components such as the fuel-cell stack, electric motors, and inverters. The emissions warranty periods in the Phase 2 standards—5 years or 50,000 miles for light HDVs and 5 years or 100,000 miles for medium HDVs and heavy HDVs—apply to these components.

PROJECTED BENEFITS

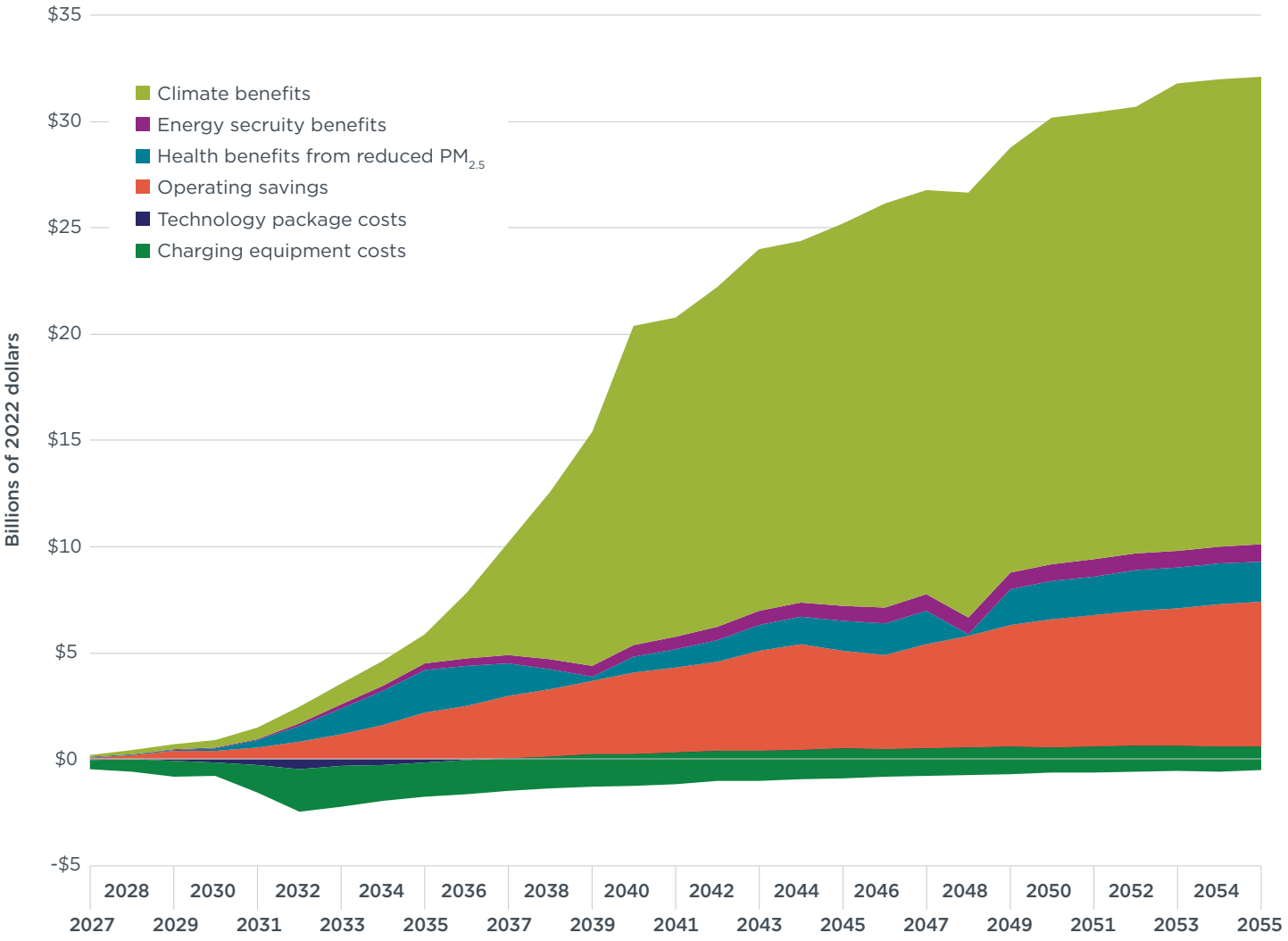
According to EPA, the Phase 3 standards will reduce cumulative CO_2 emissions from the HDV sector by over 1 billion metric tons between 2027 and 2055 compared to the reference case.8 EPA's reference case in the final standards includes higher ZEV adoption levels to account for the production and sales of zero-emission HDVs in states that have adopted the Advanced Clean Trucks regulation. It is worth noting that EPA's analysis finds an increase in upstream GHG emissions from electricity generation related to operating HD ZEVs, but the emission increases are more than offset by GHG emission reductions from upstream refineries and downstream HDV activities.

Figure 2 shows EPA's calculations of Phase 3 vehicle and infrastructure technology costs, health and climate benefits, operating savings, and energy security benefits from 2027 to 2055. Except in the first few years, benefits brought by the Phase 3 standards are projected to far outweigh the costs. Overall, EPA estimates that the Phase 3 standards will bring $13 billion in annualized net benefits through the year 2055, at a 2% discount rate. The total includes around $10 billion in annualized climate benefits from reduced greenhouse gas emissions, and up to $300 million in annualized health benefits from reduced fine particulate matter ($PM_{2.5}$) precursor emissions. The annualized cost of production to the industry is expected to be about $1.1 billion while operating savings are valued at $3.5 billion. An additional $450 million in annualized benefits are expected from reduced dependency on oil imports.

8 Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3; U.S. Environmental Protection Agency, *Phase 3 Regulatory Impact Analysis*.

Figure 2

Costs and benefits of EPA's Phase 3 GHG standards for heavy-duty trucks through 2055, relative to the reference case



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

2026 ASSESSMENT

EPA plans to collaborate with the Department of Energy and the Department of Transportation to review charging and refueling infrastructure growth and issue regular status reports beginning as early as 2026. EPA has identified several areas for data collection, including the number, size, location and growth rate of public and depot charging sites, the sales of electric vehicle service equipment, charging facility installation timelines, electric distribution system upgrades, and hydrogen fuel production and fueling station developments. Based on findings of the reports, EPA may decide to issue guidance documents or modify the Phase 3 rule to give more lead time to manufacturers.

POLICY CONTEXT IN OTHER MARKETS

On May 13, 2024, the Council of the European Union ratified the agreement on the revision of HDV CO_2 standards.[9] Compared to the original standards adopted in 2019, the revision ramps up the stringency of targets and widens the scope of vehicles covered to include more types of trucks, buses, coaches, trailers, and vocational vehicles.

At a high level, the European Union's revised CO_2 standards kept the 2025 CO_2 reduction target of 15%, raised the 2030 target to 45%, and added a 65% reduction target for 2035 and a 90% reduction target for 2040 relative to a baseline reporting period. The reduction targets are further broken down to vehicle bins and groups based on type, axel configuration, and weight.

With the exception of urban buses in the European Union, both the EU and U.S. standards are performance based and do not mandate sales numbers for zero-emission vehicles. Compared to the U.S. Phase 3 standards, the European Union's revised GHG standards for HDVs have a longer temporal scope and a higher stringency. Table 4 compares the key differences between the two regulations.

Table 4

Comparison of the most recent EU and U.S. CO_2/GHG emission standards for HDVs

	Revised EU standards	U.S. EPA Phase 3 standards
Level of stringency	45% CO_2 reduction in 2030, 65% in 2035 and 90% in 2040 across all new HDVs relative to respective baseline	Stringency varies by segment, ranging from 5% to 60% reduction by 2032 relative to 2027 baseline.
Regulatory period	2025, 2030, 2035, 2040; no interim targets between those years.	2027–2032, with annual targets
ICE efficiency improvements	Considers low-cost ICE efficiency technologies available to manufacturers to meet the standards	No consideration of improvements beyond Phase 2 ICE vehicle efficiency technologies
Trailers	Includes targets for semitrailers, drawbar trailers, and center-axle trailers with box body configurations	No trailer targets

The Advanced Clean Trucks (ACT) regulation is the other important supply-side HDV regulation in the United States that will drive manufacturers' production of zero-emission trucks. Adopted by the California Air Resources Board in 2020, it requires manufacturers to sell increasing percentages of zero-emission Class 2b–8 trucks.[10] EPA granted a waiver for preemption regarding the ACT regulation in April 2023.[11] ACT has gone into effect in California, with nine additional states poised to begin implementation in the next few years. As mentioned previously, manufacturers' compliance with ACT can generate multiplier credits between MY 2024 and MY 2027 that will also aid their compliance with the federal Phase 3 standards.

9 Eammon Mulholland, The Revised CO_2 Standards for Heavy-Duty Vehicles in the European Union (International Council on Clean Transportation, 2024), https://theicct.org/publication/revised-co2-standards-hdvs-eu-may24/.

10 Claire Buysse and Ben Sharpe, California's Advanced Clean Trucks Regulation: Sales Requirements for Zero-Emission Heavy-Duty Trucks (International Council on Clean Transportation, 2020), https://theicct.org/publication/californias-advanced-clean-trucks-regulation-sales-requirements-for-zero-emission-heavy-duty-trucks/.

11 California State Motor Vehicle and Engine Pollution Control Standards; Heavy-Duty Vehicle and Engine Emission Warranty and Maintenance Provisions; Advanced Clean Trucks; Zero Emission Airport Shuttle; Zero Emission Power Train Certification; Waiver of Preemption; Notice of Decision, 88 F.R. 20688 (April 6, 2023), https://www.govinfo.gov/content/pkg/FR-2023-04-06/pdf/2023-07184.pdf.

The California Air Resources Board adopted the Advanced Clean Fleets (ACF) regulation in April 2023.[12] As a complement to the ACT regulation, ACF requires federal, state, and local government fleets, in addition to large private fleets, to begin purchasing zero-emission HDVs starting in in 2024. ACF also requires that manufacturers sell only zero-emission medium- and heavy-duty vehicles starting in 2036. The regulation is intended to work in tandem with the ACT regulation to ensure there is both a supply and demand for zero-emission HDVs. Combined, the ACT and ACF regulations position California as the world leader in terms of legally-binding zero-emission HDV regulations.

12 California Air Resources Board, "California Approves Groundbreaking Regulation That Accelerates the Deployment of Heavy-Duty ZEVs to Protect Public Health," press release, April 28, 2023, https://ww2.arb.ca.gov/news/california-approves-groundbreaking-regulation-accelerates-deployment-heavy-duty-zevs-protect.

www.theicct.org

communications@theicct.org

@theicct.org

icct
THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

BEIJING | BERLIN | NEW DELHI | SAN FRANCISCO | SÃO PAULO | WASHINGTON DC