BRIEFING

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Adapting US heavy-duty vehicle emission standards to support a zero-emission commercial truck and bus fleet

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INTRODUCTION

Rapid actions to reduce greenhouse gas emissions are necessary to avoid the worst impacts of future climate change. President Biden has taken steps to confront the contribution of the transportation sector to this climate crisis, issuing in August 2021 an Executive Order setting a goal that 50% of all new passenger cars and light trucks sold in 2030 be battery electric, plug-in hybrid electric, or fuel cell electric vehicles.[1] And in November 2021 he signed into law the Infrastructure Investment and Jobs Act, which makes available at least $7.7 billion in funding for development of electric vehicles. The president is working with Congress to secure follow-on legislation that would provide additional funding for vehicle electrification and infrastructure.

The president has prioritized setting clear motor vehicle standards to 'lead the world on clean and efficient cars and trucks.' In his 2021 Executive Order, he called upon the US EPA Administrator to consider establishing new oxides of nitrogen standards for heavy-duty engines and vehicles beginning with model year (MY) 2027; to consider updating existing greenhouse gas emission standards for MY 2027-2029 engines

1 The White House, "Executive Order on Strengthening American Leadership in Clean Cars and Trucks," (August 5, 2021), https://www.whitehouse.gov/briefing-room/presidential- actions/2021/08/05/executive-order-on-strengthening-american-leadership-in-clean-cars-and-trucks/.

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and vehicles ''in consideration of the role that zero-emission heavy-duty vehicles might have in reducing emissions from certain market segments"; and to consider new greenhouse gas emission standards beginning as soon as MY 2030. If designed appropriately, these actions by the US EPA could jump-start the national transition to electric heavy-duty vehicles and take advantage of the infrastructure investments and fiscal policies the president is pursuing through legislation.

New motor vehicle standards are one of several effective policies to support the transition to a zero-emission fleet. For many decades US EPA set new vehicle emission standards under Section 202 of the Clean Air Act, focusing on the incremental improvement of internal combustion engine-powered vehicles. Standards for nitrogen oxides and particulate matter have encouraged the widespread adoption of diesel oxidation catalysts, diesel particulate filters, and selective catalytic reduction. Standards on greenhouse gases have encouraged the adoption of more efficient engines and transmissions, low rolling-resistance tires, improved vehicle aerodynamics, and low-GWP refrigerants. These emission standards have increased in stringency, generating fleet-wide emission reductions over time. The result has been steadily cleaner ambient air and significant public health and welfare benefits.

But the urgency of the climate crisis suggests the need for deeper, more rapid, and more sustained emission reductions than those delivered by previous vehicle and engine standards. This need points to the role of zero-emission powertrains as a leapfrog solution over continued incremental improvements. Delivering the technology transition to zero-emission powertrains in the commercial truck and bus fleet requires an effective adaptation of the United States's existing regulatory framework for internal combustion engines and the vehicles they power. This paper presents an approach for US EPA to consider that offers high certainty of reaching near-term zero-emission HDV deployment goals and sets the stage for the longer-term transition.

REGULATORY OBJECTIVES

We propose a regulatory framework shaped by two interrelated goals: to achieve major reductions in greenhouse gases (GHGs), oxides of nitrogen (NO_x), and particulate matter (PM) from heavy-duty (HD) vehicles, and to begin the transition to zero-emission MD and HD vehicles of all types.[2]

EPA first addressed criteria pollutant emissions from medium- and heavy-duty engines in 1974. Limits today on emissions of particulate matter are more than 98 percent lower than limits first set in 1988. EPA standards for non-methane hydrocarbons, nitrogen oxides, particulate matter, and other pollutants were last updated in 2000 and were fully implemented in MY 2010.

EPA first addressed greenhouse gas emissions in 2009 when the agency determined that emissions from new motor vehicles, including heavy-duty vehicles, caused or contributed to air pollution levels that endangered the public health and welfare.[3] In 2011 EPA issued Phase 1 standards for greenhouse gas emissions from new medium- and heavy-duty vehicles and engines applicable to MY 2014–2018 , and

2 This paper refers to HD vehicles throughout. As appropriate, standards would apply to HD engines.

3 Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Final Rule, 74 Fed. Reg. 66496 (December 15, 2009), https://www.govinfo.gov/content/pkg/FR-2009-12-15/pdf/E9-29537.pdf.

in 2016 issued Phase 2 standards applicable to MY 2019–2027.[4] When EPA sets greenhouse gas standards, as with other motor vehicle standards, it "considers such issues as technology effectiveness, its cost (both per vehicle, per manufacturer, and per consumer), the lead time necessary to implement the technology, and based on this, the feasibility and practicability of potential standards; the impacts of potential standards on emissions reductions of both GHGs and non-GHGs; the impacts of standards on oil conservation and energy security; the impacts of standards on fuel savings by customers; the impacts of standards on the truck industry; and other energy impacts; as well as other relevant factors such as impacts on safety."[5]

The current standards for HD engines are multi-pollutant, including GHGs such as carbon dioxide, nitrous oxide, and methane, as well as criteria pollutants such as NO_x and PM. The engine standards currently apply to internal combustion engines, covering diesel-cycle engines and Otto-cycle engines (gasoline). Current EPA standards for HD vehicles require that the vehicle use an engine certified to meet the engine standards, and that the vehicle meet GHG standards. GHG standards focus on tailpipe emissions of CO_2 and include controls on the emissions of certain refrigerants from air conditioning systems. Zero-emission HD vehicles were not considered commercially feasible in substantial numbers when the current vehicle and engine standards were adopted.

EPA typically revises its standards when more effective control technology becomes available, with revisions focused on the pollutant or pollutants affected by the more advanced technology. Technologies to control NO_x, PM, and GHG emissions from internal combustion engines are sufficiently distinct that EPA often revised NO_x, PM, and GHG emission standards independently. But the nature of zero-emission technology is different. A vehicle powered by an electric motor, with no internal combustion engine, has no tailpipe emissions of GHGs, PM, NO_x, or other pollutants.

We propose two basic regulatory steps to extend the current approach to zero-emission vehicles. First, the EPA can take advantage of new vehicle and engine standards applied to MY 2027-2029 to jumpstart the transition to zero-emission vehicles in the near-term, and to update tailpipe NO_x emission standards applicable to internal combustion engines. Second, it can use a Phase 3 GHG rulemaking applicable to MY 2030 and later engines and vehicles to lay the groundwork for a comprehensive, longer-term transition to zero-emission vehicles for the entire heavy-duty category. These two regulatory actions present a ripe opportunity for EPA to define the minimum pace of the transition to zero-emission HDVs in coming years.

These MY 2027–2029 and MY 2030 and later standards could be structured to project an array of technological advances into the fleet:

1. Improvements in internal combustion emission control technologies to reduce NO_x and PM emissions under the MY 2027 engine standards;

4 Phase 1 at Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule, 76 Fed. Reg. 57106 (September 15, 2011), https://www.govinfo.gov/content/pkg/FR-2011-09-15/pdf/2011-20740.pdf; Phase 2 at Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2, 81 FR 73478 (October 25, 2016), https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf.

5 Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule, 76 FR at 57129 (Phase I), (September 15, 2011), https://www.govinfo.gov/content/pkg/FR-2011-09-15/html/2011-20740.htm.

2. Improvements in internal combustion engines and vehicle efficiency to reduce GHG emissions under the Phase 3 GHG standards, and;
3. Inclusion of zero-emission powertrains, which produce zero NO_x, PM, and GHG exhaust emissions, in the regulatory structure.

The standards could be structured to ensure that the overall emission reductions projected for adoption of these technologies are achieved and the projected transition to zero-emission vehicles occurs. Beginning the desired transition to zero-emission technology in the near-term under the MY2027–2029 standard is critical groundwork for the longer-term and broader transition of the HD sector to zero-emission vehicles under the MY 2030 and later Phase 3 GHG standard. The inclusion of zero-emission powertrains in revising both regulations has the potential to generate significant new reductions in GHG, NO_x, and PM emissions.

DEFINING ZERO-EMISSION VEHICLE REQUIREMENTS

Certain key principles set the pace for including zero-emission vehicles into any future standards. These are:

- » A target year for 100% production of zero-emission medium- and heavy-duty trucks.[6]
- » A minimum annual percentage of zero-emission production in each vehicle market segment tied to the 100% goal.
- » Variation in the minimum percentage by market segment, based on assessments of technology readiness, market availability, and total cost of ownership.
- » Priority for the zero-emission transition placed on short-range urban applications operating in close proximity to sensitive populations and disadvantaged communities

One important step is to identify vehicle applications that are appropriate for transition to the zero-emission class soon—in the MY 2027–2029 time frame—including the appropriate percentage of vehicle production. For purposes of explanation, the regulatory framework could assume that EPA adopts minimum percentage requirements for zero-emission vehicles for every vehicle weight category based on its understanding of what level of adoption is appropriate.

EPA's current Phase 2 greenhouse gas standards have norms for various groupings of HD vehicles—Class 2b-3 vehicles[7], Class 4-8 vocational vehicles, and Class 7-8 tractor trucks. For each of these segments and potentially for subsegments within these three categories, EPA could set a minimum percentage requirement for production of zero-emission vehicles in MY 2027–2029. These percentages would vary between the groupings and would increase over time. The applicable percentage would be determined based on the factors discussed above. Table 1 provides a hypothetical example.

6 In an opinion piece published 12 January 2022 in the New York Times, ICCT Board Chair Margo Oge and Executive Director Drew Kodjak endorsed the goal that 'all new truck and bus sales are emissions-free by 2040.' See https://www.nytimes.com/2022/01/12/opinion/climate-change-biden-trucks-buses.html

7 Incomplete vehicles only. Assumes certified chassis will be regulated under separate LD GHG standards oriented toward a goal of 100% ZEV sales in 2035.

Table 1. Potential zero-emission production requirements for MY 2027–2029 aligned with the California Advanced Clean Truck Program[a]

Vehicle Segment	MY 2027	MY 2028	MY 2029
Class 2b-3 group[b]	15%	20%	25%
Class 4-8 group	20%	30%	40%
Class 7-8 tractor group	15%	20%	25%

[a] The California Advanced Clean Truck rule adopted in 2020 establishes minimum zero-emission sales percentage requirements in all weight categories for medium- and heavy-duty vehicles. For more information visit https://theicct.org/publications/california-hdv-ev-update-jul2020

[b] Includes Class 2b/3 incomplete vehicles. Assumes Class2b/3 certified chassis are regulated under future LD GHG standards that reflect a goal of 100% zero-emission sales in 2035.

This approach ensures the transition occurs across all vehicle segments, but it does not capture all of the potential that exists. EPA could go one step further and identify specific market segments by regulatory source category, based on the segment's readiness for transition to zero-emission vehicles, the need to accelerate emission reductions in non-attainment areas, and the need to reduce exposure disparities in communities of concern. These market segments can be categorized based on their readiness for a fast, medium, or slow transition to zero-emission vehicles. Appropriate minimum percentages could be set for these market segments as a complement to those established in Table 1. Table 2 provides an example.

Table 2. Potential minimum zero-emission production requirement across high-priority vehicle market segments

Pace	Vehicle market segment	Minimum zero-emission production requirement		
		MY 2027	MY 2028	MY 2029
Fast	• Transit buses • Refuse trucks • Short-haul single unit trucks • Other buses	40%	60%	80%
Medium	• School buses[a] • Short-haul combination tractors	20%	30%	40%
Slow	• Long-haul single unit trucks • Long-haul combination trucks	15%	20%	25%

[a] Timeline to cost parity and availability of funds from state/local governments are the primary constraints here—not technology readiness, commercial availability, or TCO.

Under existing Phase 2 greenhouse gas standards, manufacturers earn 'Advanced Technology' credits for the production of zero-emission vehicles. A single battery-electric vehicle earns a credit of 4.5 and a fuel cell vehicle earns a credit of 5.5. These credits were defined at least five years before California and other states adopted sales requirements for zero-emission vehicles. But zero-emission technology has significantly matured since then. As manufacturers produce more zero-emission vehicles in compliance with state laws beginning in MY 2024, they earn Advanced Technology credits that may lead to fewer energy efficiency technologies deployed on vehicles powered by internal combustion engines. As EPA works to adopt zero-emission requirements in line with its air quality and climate goals, the agency could determine that Advanced Technology Credits are no longer necessary.

TWO REGULATORY OPTIONS

To achieve this integration of zero-emission vehicles into the US fleet, we propose two basic regulatory frameworks. In the ‘Dual Averaging Sets’ approach, EPA could set separate requirements for zero-emission vehicles and for vehicles powered by internal combustion engines. In another approach we call ‘Single Combined Averaging Set,’ EPA could combine these requirements into one fleet-wide average. Under both approaches the standards would reflect the projected use of zero-emission technology for minimum specified percentages of vehicles and the cleanest and most efficient technologies for the remaining vehicles powered by internal combustion engines. The outlines of these two approaches are discussed in more detail below.

For simplicity of discussion the options below generally refer to standards and requirements for vehicles and vehicle manufacturers, and assume that the current regulatory structure is retained (engine standards apply to internal combustion engines only, covering NO_x, PM, other pollutants, and GHGs, with vehicle standards covering primarily CO_2 and refrigerants). EPA can consider other approaches, as it has discretion in how it defines and distributes responsibility among various manufacturers for implementing the recommended increase in zero-emission vehicles. The important point is that EPA evaluate and adopt regulatory provisions that efficiently and effectively achieve the projected increases in production of zero-emission vehicles.

Option 1 – Dual Averaging Sets

EPA could require a vehicle manufacturer to meet a zero-emission standard for CO_2 for the specified percentage of production in each segment. The new zero-emission CO_2 standard would be in addition to the current GHG standards; for example, limits on emissions of refrigerants would still apply to these vehicles. For the purposes of this paper, the vehicles subject to this minimum percentage requirement are called “transition” vehicles. This standard would require a vehicle to be powered by an electric motor and not to have an internal combustion engine, resulting in no tailpipe emissions of GHGs. The multi-pollutant coverage of this control technology also means the transition vehicles would produce no emissions of NO_x or PM.

The vehicles not subject to the percentage requirement are called “non-transition” vehicles. As part of the vehicle certification and production process, manufacturers would designate their vehicles as either transition or non-transition vehicles. A manufacturer would need to show that the transition vehicles were zero-emission vehicles and met the applicable percentage of production, as well as other applicable requirements.

As discussed below, transition and non-transition vehicles would be distinct and separate averaging sets. This means the emissions standards for each group would be distinct and separate. The standards and requirements for each group would be based on the nature of their projected emissions control technology. For transition vehicles this would reflect technology that produces zero tailpipe emissions for multiple pollutants. Non-transition vehicles would be subject to standards based on technology to control emissions from vehicles powered by internal combustion engines.[8]

The engines used in non-transition vehicles would be subject to a new, more stringent NO_x standard, based on projections of substantial advances in emissions control for internal combustion engines. These non-transition vehicles and their engines would remain subject to current GHG and PM standards. The current provisions for categorization and averaging, banking, and trading would apply to non-transition vehicles and engines.

Credits generated by producing more zero-emission transition vehicles than required could be banked to meet that segment's percentage requirement in future MYs or could be used to show compliance with the percentage requirement for transition vehicles in another segment. For example, a manufacturer that produces greater than the minimum zero-emission vehicles in Segment A in MY 2027 could bank those credits for use in that segment in future MYs. Or the manufacturer could use the credits to show compliance with the percentage requirement for Segment B in MY 2027. EPA could establish appropriate adjustments for the transfer of these transition credits from one segment to another, to account for differences in emissions and other variables.

Transition vehicles and non-transition vehicles would be distinct and separate averaging sets. Credits from producing more zero-emission transition vehicles than the required percentage could not be used to show compliance with the standards for non-transition vehicles, and vice versa. This would best ensure that the overall emissions reduction and zero-emission vehicle production goals are achieved.

However, manufacturers would retain flexibility in designating vehicles as either transition or non-transition vehicles. A manufacturer that produces greater zero-emission vehicles than the required percentage could certify some or all those extra zero-emission vehicles as non-transition vehicles and include them to demonstrate compliance with the standards for non-transition vehicles. Those extra zero-emission vehicles, certified as non-transition vehicles, could not be used to show compliance with the standards and percentage requirements for transition vehicles. This provides manufacturers flexibility while preserving the goals of overall emission reductions and production of zero-emission vehicles.

Option 2 – Single combined averaging set

Option 2 differs from Option 1 by including transition and non-transition vehicles in the same averaging set, for each segment. There would not be a requirement that a specified percentage of zero-emission vehicles be produced. Instead, the standards for these larger groupings of vehicles would reflect the combination of projected internal combustion and zero-emission technology.

For example, consider a truck segment where EPA determines that the share of zero-emission vehicles should be 20% for MY 2027. EPA could set MY 2027 GHG standards that reflect an average emission level for the combination of 20% production

8 Based on Tables 1 and 2, the zero-emission standard for CO_2 could apply to different percentages of production each model year. GHG standards are not subject to the Clean Air Act's four-year lead time and three-year stability provisions for heavy-duty vehicles; those provisions apply to standards for criteria pollutants such as NO_x and PM. See 76 FR 57106, 57129 (September 15, 2011), 81 FR 73478, 73518 (October 25, 2016). EPA will need to consider how to apply the lead time and stability provisions for the NO_x and PM engine standards that apply if they change as the percentage of zero-emission vehicles increases. The critical point is to ensure that any provisions for NO_x and PM standards do not allow a loss in overall reductions of NO_x and PM across the transition and non-transition vehicles.

of zero-emission vehicles and 80% production of vehicles using internal combustion engines. There would be no requirement that 20% of trucks in the segment be zero-emission vehicles. Credits from this segment could be banked or transferred to another segment, subject to the appropriate adjustments set by EPA to account for differences among segments in usage patterns.

For both options, EPA could adopt a bin structure that sets standards achievable by zero-emissions technology; a near-zero-emissions standard, achievable by long-range PHEVs; and a stringent NO_x bin, achievable by engines in IC-powered vehicles. Hybrid vehicles could be certified using a test procedure that appropriately reflects usage. EPA could allow Family Emissions Limits in a defined range around the NO_x bin.

TREATMENT OF PLUG-IN HYBRID ELECTRIC VEHICLES (PHEVS)

EPA could consider treating PHEVs as non-transition vehicles that do not meet the zero-emission vehicle percentage requirements.

Under the Option 1 regulatory approach, PHEVs would not be considered transition vehicles and would not be part of the averaging set for the percentage requirement of zero-emission vehicles. Instead, PHEVs would be non-transition vehicles, providing manufacturers with significant flexibility in achieving the more stringent engine and vehicle standards. This approach would avoid undercutting the critical goal of transitioning the vehicles in each segment to the desired percentage production of zero-emission vehicles.

The Option 2 regulatory approach already includes PHEVs within the averaging set for each segment. Under Option 2 the averaging set for each segment covers all vehicles in the segment—zero-emission vehicles, PHEVs, HEVs, and ICE-powered vehicles. The average level of the standards that would apply for each segment would be based on the projected penetration and emission levels of each of these technologies.

ACCOMMODATIONS FOR CALIFORNIA AND SECTION 177 STATES

EPA could consider how vehicles subject to standards set by California and Section 177 States are addressed.

If the standards adopted by California and Section 177 states for internal combustion vehicles are more stringent, or require a greater percentage of zero-emission vehicles compared to EPA's corresponding standards, then US EPA may consider not including vehicles certified to the California and Section 177 state standards in demonstrating compliance with EPA's corresponding standards. For example, assume California and Section 177 states require a greater percentage requirement of zero-emission vehicles for Segment A than EPA. In that case EPA's percentage requirement would only apply to vehicles that are not certified to the California and Section 177 state standards.

If the California and Section 177 state standards are the same as EPA's or provide that compliance with the federal standards is deemed to be compliance with the state standards, then EPA could apply its standards to the entire national fleet. In any case the federal standard should ensure that the appropriate percentage of ZEVs are produced above and beyond any production called for by California and the Section 177 states.

RECOMMENDATIONS

EPA has two regulatory opportunities to define the minimum pace of the transition to zero-emission HD vehicles over the coming years. Achieving the transition in the near-term under a MY 2027-2029 standard is critical groundwork for the longer-term and broader transition of the HD sector to zero-emission vehicles under the MY 2030 and later Phase 3 GHG standards. The choices EPA makes in the structure of these regulations will determine how effective they will be in delivering the transition to zero-emission vehicles.

This paper discusses two basic regulatory structures for EPA to consider. Under Option 1, zero-emission vehicles are treated as a separate group, with standards set to reflect the use of zero-emissions technology. The remaining vehicles are in a separate group, with standards reflecting the GHG emission reduction capabilities of vehicles using internal combustion engines. Under Option 2 the vehicles are treated as a single group, with standards reflecting the average emissions control projected for the combination of IC powered and zero-emission vehicles.

This paper recommends option 1 over option 2. Option 1 provides high certainty that the projected transition to a percentage of zero-emission vehicles will occur. It does this by requiring a percentage of vehicles to meet standards based on zero-emission technology. It also provides high certainty that the overall level of projected GHG, NO_x, and PM reductions would be achieved.

Option 2 provides less certainty that the projected transition to a percentage of zero-emission vehicles will occur. Option 2 would provide greater compliance flexibility to manufacturers by setting the level of the applicable standard on a projected average level of both ICE vehicles and zero-emission vehicles. But this added flexibility would come at the expense of added uncertainty that the projected percentage transition to zero-emission vehicles will be achieved. This uncertainty introduces the possibility that higher-than-expected NO_x and PM emissions could result, such as with greater use of PHEVs in a segment to achieve an average level of GHG reductions but a lower percentage of zero-emission vehicles. This uncertainty increases as the range of technologies and related emission levels that are averaged to determine the level of the standard is broadened. Such compliance flexibility could seriously undercut and delay the critically important long-term transition of the HD fleet to zero-emission vehicles.

It is critical that we achieve the long-term goal of broadly transitioning to zero-emission vehicles with their elimination of tailpipe criteria pollutant, air toxic, and greenhouse gas emissions over the full life of the vehicle. EPA has regulatory design options such as Option 1 outlined in this paper that can clearly and reliably start the transition to that goal.