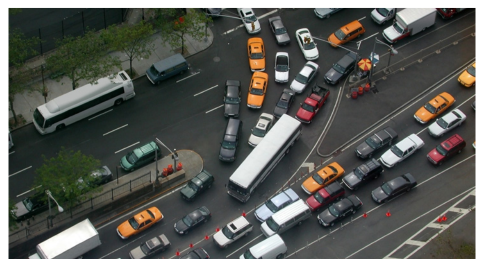
Federal Clean Trucks Program

An Analysis of the Impacts of Low NOx and Zero-Emission Medium- and Heavy-Duty Trucks on the Environment, Public Health, Industry, and the Economy



ERM

Acknowledgments

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This report was developed by ERM for the Natural Resources Defense Council and the Union of Concerned Scientists.

About ERM, formerly M.J. Bradley & Associates

M.J. Bradley & Associates (MJB&A) was acquired by ERM Group company in 2022. Continuing what MJB&A started, ERM provides strategic consulting services to address energy and environmental issues for the private, public, and nonprofit sectors. ERM creates value and addresses risks with a comprehensive approach to strategy and implementation, ensuring that clients have timely access to information and the tools to use it to their advantage. Our approach fuses private sector strategy with public policy in air quality, energy, climate change, environmental markets, energy efficiency, renewable energy, transportation, and advanced technologies. Our international client base includes electric and natural gas utilities, major transportation fleet operators, investors, clean technology firms, environmental groups, and government agencies. Our seasoned team brings a multi-sector perspective, informed expertise, and creative solutions to each client, capitalizing on extensive experience in energy markets, environmental policy, law, engineering, economics, and business. For more information we encourage you to visit our website, www.erm.com or www.sustainability.com.

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Overview

ERM was commissioned by the Natural Resources Defense Council and the Union of Concerned Scientists to evaluate the costs and benefits of policy options under various scenarios using available information from U.S. Environmental Protection Agency (EPA) proposed rulemaking. Specifically, ERM modeled (1) EPA's current baseline trajectory, (2) an enhanced baseline which accounts for specific states adopting California's Advanced Clean Truck (ACT) regulation, (3) an EPA proposed NOx Option 1 regulation and (4) a U.S.-wide Federal ACT plus NOx Omnibus policy scenario.

The results of the analysis and evaluation show the following:

1) By underestimating the number of Zero Emission Vehicles (ZEVs), EPA overestimates the impact of the more stringent NOx emission standard. The NOx reductions under the EPA NOx Option 1 scenario are one fifth lower when compared to the Enhanced Baseline instead of the EPA Baseline.

2) Lower, Medium- and Heavy-Duty Vehicles (M/HDV) M/HDV NOx emissions would result in substantial public health benefits. The estimated health benefits under EPA NOx Option 1 include the avoidance of over 13,000 premature deaths and almost 8 million health incidences from 2020 to 2050, which include respiratory symptoms and lost activity and workdays.

3) The average Class 4 through 8 ZEV vehicle reaches parity for total cost of ownership by model year (MY) 2030. By MY 2040, ZEV owners save more than $27,000 over the course of the vehicle lifetime.

4) Adopting ACT and NOx Omnibus rules federally would increase U.S. Gross Domestic Product (GDP) and create better paying jobs. In 2035, a Federal ACT + NOx Omnibus would create over 63,000 net jobs with the average annual compensation of the added jobs close to $100,000 annually. This would correspond with a $10.1 billion increase in GDP.

5) If the EPA tightens GHG emission standards to account for ZEV sales, adopting the ACT federally could result in substantial climate benefits. Under the Federal ACT + NOx Omnibus scenario, GHG emissions are reduced by roughly one-third compared to the EPA Baseline. This represents a social benefit of $161 billion.

Introduction

The analysis examines all on-road vehicles registered in the U.S. with greater than 14,001 pounds gross vehicle weight, encompassing vehicle weight Classes 4 through 8.[1] This is a diverse set of commercial vehicles that includes school and shuttle buses; sanitation, construction, and other types of work trucks; and freight trucks ranging from local delivery trucks to tractor-trailers that weigh up to 80,000 pounds when loaded.

Collectively the U.S. M/HD fleet includes 10.2 million vehicles that annually travel more than 285 billion miles and consume almost 39 billion gallons of petroleum-based fuels.

M/HD vehicles are currently responsible for a disproportionate amount of pollution from on-road vehicles. Despite making up only 3.5 percent of the on-road fleet, Class 4 to 8 M/HD vehicles emit an estimated 469 million metric tons (MMT) of greenhouse gas (GHG) emissions annually—approximately 22 percent of all GHGs from the on-road vehicle fleet.[2] M/HD vehicles are also responsible for 52 percent of the nitrogen oxide (NOx) and 56 percent of the particulate matter (PM[3]) emitted by on-road vehicles, both of which contribute to poor air quality and resulting negative health impacts in many areas, including more densely populated urban areas, low-income neighborhoods, and communities of color that are often disproportionately affected by emissions from freight movement due to their proximity to transportation infrastructure.

Prior work by ERM (2020) conducted in consultation with the New Jersey Environmental Justice Alliance and members of the Coalition for Healthy Ports NY NJ demonstrated that emissions from diesel trucks and buses produce higher levels of air pollution, which can lead to greater health concerns in populations exposed to diesel emissions.[4] Communities located adjacent to goods-movement infrastructure (e.g., warehouses, intermodal terminals, logistics centers, rail yards, etc.) experience higher levels of truck traffic, both from surrounding thruways and on local streets, which exacerbates health concerns. Since these emissions are local in their effects, policies to reduce transportation emissions from medium- and heavy-duty vehicles can improve the health and well-being of communities in urban areas or around transportation corridors, which are often home to people of color or low income or those who are otherwise vulnerable or disadvantaged. But to ensure reductions in those communities, program requirements on truck manufacturers, such as a Federal Advanced Clean Truck Rule discussed below, would need to be accompanied by additional policies designed specifically with these communities in mind.

1 For this analysis, ERM excluded Class 2b and 3 vehicles. EPA estimates that only 4.2% Class 2b-3 vehicles are engine-certified and would be impacted by these new regulations.

2 The remainder of emissions are from passenger cars and trucks (Class 1-3). This includes tailpipe emissions and "upstream" emissions from fuel production and transport.

3 In this report all references to PM are particulate matter with mean aerodynamic diameter less than 2.5 microns (PM2.5).

4 Allen, Paul et al. *Newark Community Impacts of Mobile Source Emissions: A Community-Based Participatory Research Analysis*. M.J. Bradley & Associates. November 2020. http://www.njeja.org/wp-content/uploads/2021/04/NewarkCommunityImpacts_MJBA.pdf.

Background

On March 28, 2022, the U.S. Environmental Protection Agency (EPA) proposed[5] new heavy-duty engine and vehicle standards aimed at reducing nitrogen oxide (NOx) and greenhouse gas (GHG) emissions for new vehicles sold after model year 2027. The proposed rule not only strengthened the emissions limits applicable for heavy duty vehicles and engines, but also extended the period to which these limits would be applicable.

As part of EPA's proposed rule, the agency calculated the costs and benefits of the proposed rulemaking compared against a "no action scenario" or "baseline" trajectory. In their baseline emissions trajectory, EPA assumed ZEV sale and adoption levels from the 2018 Annual Energy Outlook. Table 1 contains the ZEV sales percentages EPA uses in their analysis. As EPA states in the Draft Regulatory Impact Analysis, the AEO data "likely reflects a conservative estimate of future BEV and FCEV sales."[6] Due to the crediting provisions in the EPA proposed rule, underestimating the baseline level of ZEV adoption, overestimates the impact of tightening the NOx standard.

Scenarios

This report summarizes the projected environmental and economic effects of four scenarios:

1. EPA Baseline
2. Enhanced Baseline
3. EPA NOx Option 1
4. Federal ACT + NOx Omnibus

EPA Baseline Scenario

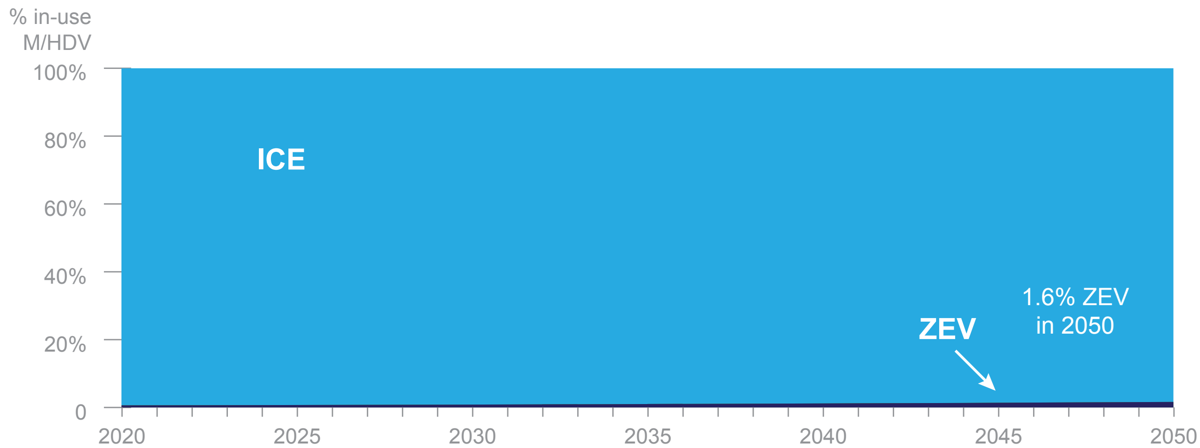
This scenario is based on details provided in the Federal Register notice of proposed rulemaking "Control of Air Pollution from New Motor Vehicles: Heavy-duty Engine and Vehicle Standards" and the accompanying draft Regulatory Impact Analysis. This trajectory includes current federal emissions regulations, warranty and engine and vehicle useful life requirements, as well as a small percent of ZEVs. Under the EPA Baseline, all new trucks sold in the U.S. continue to meet existing EPA NOx emission standards and ZEV sales increase only marginally.

Figure 1 shows the in-use M/HD fleet for the EPA Baseline. By 2050, only 1.6 percent of the M/HD fleet are ZEVs.

5 Environmental Protection Agency. Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards. Vol.87, No.59. March 28, 2022. https://www.govinfo.gov/content/pkg/FR-2022-03-28/pdf/2022-04934.pdf.

6 U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, *Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards – Draft Regulatory Impact Analysis* (EPA-420-D-22-001, March 2022), 267, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10144K0.pdf.

Figure 1 EPA Baseline In-Use Fleet



ZEV = zero-emission vehicles. ICE = internal combustion engine vehicles. Low NOx = low NOx internal combustion engine vehicles

The assumed low ZEV market share included in EPA's Baseline from their draft Regulatory Impact Analysis (RIA) through 2045 fails to include recent state action, anticipated ZEV-ICE parity for many Class 4-8 vehicles, federal and state funding, and fleet commitments by cities and private companies.

Per EPA's draft RIA, federal or state actions (including California's ACT and NOx omnibus regulations) were not included in their air quality modeling analysis since they were not finalized at that time.[7]

See Table 1 for the assumed ZEV sales percentages used by EPA in their Baseline trajectory.

Table 1 ZEV Sales Percentages Used by EPA in their draft RIA (Table 1-9)

	2027	2045
Medium-heavy Duty	1%	2%
Heavy-heavy Duty	0.4%	0.7%
Buses	0.8%	1%

Enhanced Baseline Scenario

An enhanced ZEV baseline was developed by ERM to account for the many factors impacting ZEV adoption that EPA failed to consider in their analysis, including state regulatory action, federal and state ZEV funding, the falling total cost of ownership for ZEVs, and public and private fleet commitments.

7 While the emissions modeling does not include California's adoption of the ACT, EPA does factor it in for for their estimation of M/HD ZEV sales in 2027 for the GHG portion of the regulation.

Currently, six states have adopted the Advanced Clean Trucks (ACT)[8] regulation: California, Oregon, Washington, New Jersey, New York, and Massachusetts. These states account for 19 percent of the total M/HDV in the U.S. Other states including Colorado, Connecticut, and Rhode Island are currently holding ACT proceedings and are anticipated to adopt the regulation soon.[9] Further, sixteen states[10] as well as the District of Columbia have signed the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding (MOU). The MOU goal is to reach 30 percent ZEV truck sales by 2030 and 100 percent by 2050. These states account for 32 percent of the total M/HDV in the U.S.

ZEV trucks are currently more expensive than their internal combustion engine (ICE) counterparts, but some vehicle types are projected to be cost competitive with ICE vehicles within the next 10 years. Fleets and individual vehicle owners could shift their purchasing behaviors to favor ZEVs due to their reduced maintenance and operating costs.

Further, Federal actions such as the Infrastructure Investment and Jobs Act (IIJA) as well as state purchasing incentives like the New York State Truck Voucher Incentive Program (NYTVIP) can further accelerate ZEV sales. These programs can provide direct incentives to vehicle owners, helping to offset the incremental cost of ZEVs when they retire their older trucks. This can be important to fleet and vehicle owners who may have constrained capital asset budgets, allowing them to transition to zero-emission vehicle technologies without disrupting their cashflow.

Lastly, many large vehicle fleets including Amazon, FedEx, UPS, DHL, Walmart, PepsiCo as well as others have made commitments to purchase ZEVs with some announcing long term goals of having 100% fleet electrification within the next decade.[11]

The Enhanced Baseline scenario accounts for the current six states that have adopted the ACT, assumes California adopts the Advanced Clean Fleets Regulation[12] as currently drafted, and assumes the remaining U.S. signatories of the M/HD ZEV MOU adopt the ACT.[13] The Enhanced Baseline assumes increased ZEV sales within the ACT states, but for non-ACT states ZEV sales stay near zero. This would require an increasing percentage of new trucks purchased in the ACT state to be ZEVs beginning in the 2024, 2025, or 2026 model year.[14] The percentage of new vehicles that must be ZEV varies by vehicle type and increase with each model year between 2024 and 2035.

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8 "Advanced Clean Trucks." California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks.

9 Hsu, Adam. "California Leads, States Follow on Zero-Emission Rule for MD, HD Trucks." ACT News. February 8, 2022. https://www.act-news.com/news/california-leads-states-follow-on-zero-emission-rules-for-md-hd-trucks/.

10 "Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding." California, Colorado, Connecticut, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, and Washington, March 29, 2022. https://www.nescaum.org/documents/mhdv-zev-mou-20220329.pdf/. At the time this analysis started, Nevada had not signed the M/HD ZEV MOU.

11 Hawkins, Andrew. "Amazon will order 100,000 electric delivery vans from EV startup Rivian, Jeff Bezos says." The Verge. September 19, 2019. https://www.theverge.com/2019/9/19/20873947/amazon-electric-delivery-van-rivian-jeff-bezos-order; Banerjee, Arunima. "FedEx expands fleet to add 1,000 Chanje electric vans." Reuters. November 20, 2018. https://www.reuters.com/article/us-fedex-chanje-vans/fedex-expands-fleet-to-add-1000-chanje-electric-vans-idUSKCN1NP1C3; Hanley, Steve. "UPS Places Order For 950 Workhorse N-GEN Electric Delivery Vans." CleanTechnica. June 20, 2018. https://cleantechnica.com/2018/06/20/ups-places-order-for-950-workhorse-n-gen-electric-delivery-vans/#:~:text=UPS%20Places%20Order%20For%20950%20Workhorse%20N-GEN%20Electric,to%20UPS%2C%20bringing%20the%20total%20order%20to%201%2C000; https://www.dhl.com/us-en/home/press/press-archive/2019/dhl-expands-green-fleet-with-addition-of-new-electric-delivery-vans.html;Lambert, Fred. "Tesla Semi receives order of 30 more electric trucks from Walmart." Electrek. September 6, 2018. https://electrek.co/2018/09/06/tesla-semi-new-order-electric-truck-walmart/; https://www.pepsico.com/sustainability/focus-areas/climate

12 "Advanced Clean Fleets." California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets

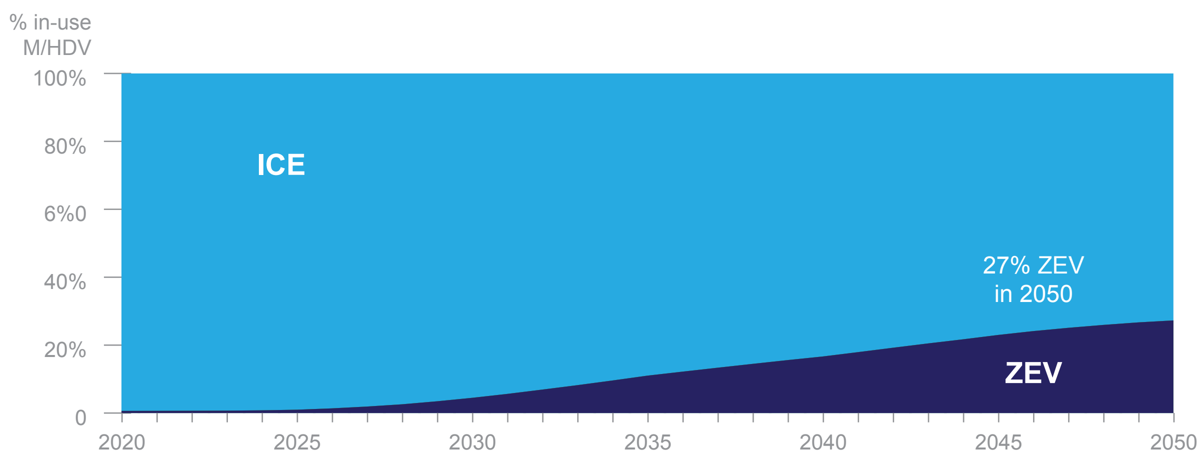
13 This analysis was initiated before Nevada signed onto the M/HD ZEV MOU and as such, they are not included in the Enhanced Baseline.

14 The first model year (MY) with ZEV sales requirements in CA is 2024. For the five states that adopted the ACT in 2021 (MA, NJ, NY, OR, and WA), the first MY with ZEV sales requirements is 2025. For the remaining states, it is assumed they will adopt the ACT in 2022 and the first MY with ZEV sales requirements is 2026.

While it is quite possible that some of the M/HD ZEV MOU states will not adopt the ACT, the scenario does not include federal and state funding, economic factors, or fleet commitments in the scenario which would increase projected ZEV adoption. Given the current uncertainty surrounding many aspects of the ZEV market, the authors believe the Enhanced Baseline represents a reasonable projection when all factors are considered.

Figure 2 shows the in-use M/HD fleet in the Enhanced Baseline scenario.

Figure 2 Enhance Baseline In-Use Fleet



ZEV = zero-emission vehicles. ICE = internal combustion engine vehicles. Low NOx = low NOx internal combustion engine vehicles

As shown under the Enhanced Baseline scenario, 17 percent of the in-use M/HD fleet will turn over to ZEV by 2040, and 27 percent are ZEV by 2050; all of these ZEVs are assumed to be battery electric vehicles.

EPA Proposed NOx Option 1 Scenario

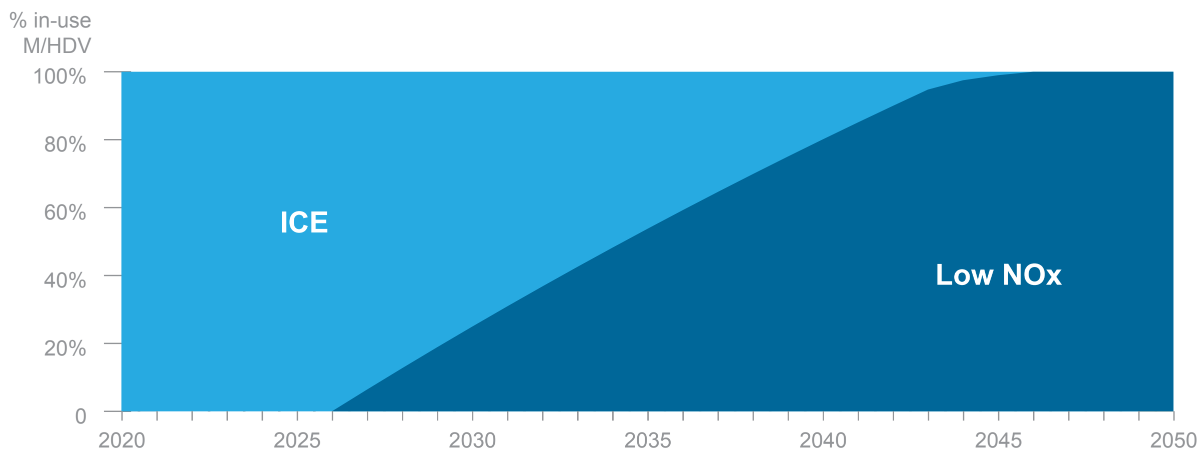
Based on EPA's proposed NOx Option 1 emission standards for medium- and heavy-duty certified engines sold starting in MY 2027. Certified engines between MY 2027 and 2030 will be required to reduce running exhaust NOx emission intensity between 82.5 and 90 percent, increasing to 90 percent for MY2031 and beyond.[15] While the same EVs in the above "Enhanced Baseline" scenario would be regulated by EPA's proposed Option 1 NOx emission standards, the credits generated by these vehicles would be used to offset the tailpipe emissions requirements such that conventionally powered trucks would exceed the average required standard. Rather than track the intricacies of such a crediting program, for simplicity this scenario assumes no ZEVs to allow for accurate modeling of the average NOx standard. However, this inhibits the ability to compare EPA NOx Option 1 scenario to the other scenarios on PM emission reductions or possible GHG emission reductions.

15 This analysis does not incorporate EPA's proposed requirement on closed crankcases for diesel trucks, which would slightly reduce direct PM emissions in the EPA NOx Option 1 scenario.

Though EPA proposed three rules (Option 1, Option 2, and Alternative), this analysis only models Option 1 which has the strongest NOx emission reductions. Option 2 only reduces running exhaust NOx emissions by 75 percent and according to EPA's draft RIA, under Option 2, in 2045, M/HDV NOx emissions would be 25 percent higher than with Option 1.

Figure 3 shows the in-use M/HD fleet for the EPA NOx Option 1 scenario.

Figure 3 EPA NOx Option 1 In-Use Fleet



ZEV = zero-emission vehicles. ICE = internal combustion engine vehicles. Low NOx = low NOx internal combustion engine vehicles

Under the EPA NOx Option 1 scenario, the fleet turns over to low NOx ICE vehicles by 2046.

It should be noted that the EPA NOx Option 1 scenario only contemplates sales of low NOx vehicles and not ZEVs; therefore, this scenario does not directly impact climate or PM emissions. Because of this, the EPA NOx Option 1 scenario is only discussed in the NOx emissions reduction section.

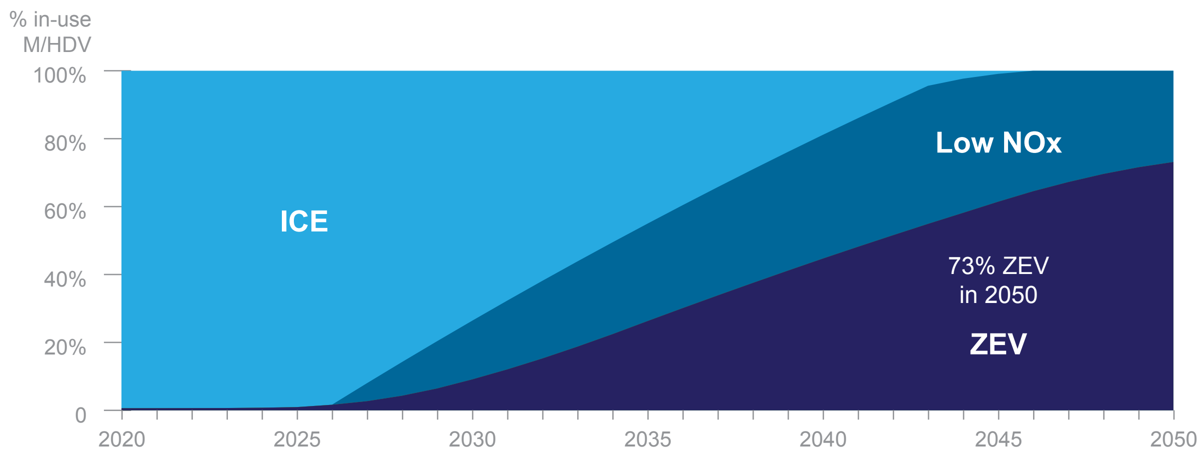
Federal ACT + NOx Omnibus Scenario

This scenario assumes Federal adoption of the ACT Rule and requirements analogous to those adopted by California under the Heavy-Duty Omnibus Rule (referred to herein as the NOx Omnibus Rule). This rule requires a 90 percent reduction in running NOx emissions for trucks sold beginning in the 2027 model year.[16]

See Figure 4 for the in-use M/HD fleet under the Federal ACT + NOx Omnibus scenario.

16 Reductions are relative to current federal EPA new engine emission standards. This rule does not require additional PM reductions but includes anti-backsliding provisions to ensure that PM emissions do not increase compared with engines designed to meet current federal standards.

Figure 4 Federal ACT + NOx Omnibus In-Use Fleet



ZEV = zero-emission vehicles. ICE = internal combustion engine vehicles. Low NOx = low NOx internal combustion engine vehicles

Under the Federal ACT + NOx Omnibus policy scenario, 45 percent of the in-use fleet turns over to ZEV by 2040 and 73 percent do so by 2050. By 2046, all M/HDV are either Low NOx or ZEV.

Methodology Utilized Across Scenarios

For a full description of the modeling approach and sources of assumptions used for this analysis, see the addendum to the report: *Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies and Assumptions*, June 2021 (https://www.erm.com/globalassets/documents/mjba-archive/reports/2021/clean-trucks-technical-report-final-09jun21.pdf).

The analysis assumes that M/HD annual vehicle miles traveled (VMT) in the U.S. will continue to grow by approximately 1.8 percent annually through 2050, projected by EPA's Motor Vehicle Emission Simulator 3 (MOVES3), as the economy and population continue to grow. The modeled policy scenarios do not include freight system enhancements or mode shifting to slow the growth of, or reduce, M/HD truck miles; this would be expected to provide additional emission reductions.

The analysis was conducted using ERM's STate Emission Pathways (STEP) Tool. The climate and air quality impacts of each policy scenario were estimated on the basis of changes in M/HD fleet fuel use and include both tailpipe emissions and "upstream" emissions from production of the transportation fuels used in each scenario. These include petroleum fuels used by conventional internal combustion engine vehicles (gasoline, diesel, natural gas) and electricity and hydrogen used by ZEVs, which are assumed to include both battery electric (EV) and hydrogen fuel cell electric (FCV) vehicles.

To evaluate climate impacts, the analysis estimated changes in all combustion related GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To evaluate air quality impacts, the analysis estimated changes in total nitrogen oxide (NOx) and particulate matter (PM) emissions and resulting changes in ambient air quality and health metrics such as premature deaths, hospital visits, and lost workdays.

The economic analysis estimated the change in annual M/HD fleet-wide spending on vehicle purchase, charging/fueling infrastructure to support ZEVs, vehicle fuel, and vehicle and infrastructure maintenance under each scenario. Currently ZEVs are more expensive to purchase than equivalent gasoline and diesel vehicles, but they have lower fuel and maintenance costs. Over time the incremental purchase cost of ZEVs is also projected to fall. Technologies required to meet the more stringent NOx standards of the EPA NOx Option 1 emission standards and NOx Omnibus Rule are also projected to increase purchase costs for compliant vehicles.

On the basis of estimated changes in fleet spending, the analysis estimated the macroeconomic effects of each scenario on national jobs, wages, and gross domestic product (GDP).

The analysis also estimated the impact of each scenario on U.S. electric utilities, including the total nationwide change in power demand (kW) and energy consumption (kWh) for M/HD EV charging, as well as the additional revenue and net revenue that would be received by the electric utilities for providing this power. On the basis of projected utility net revenue, the analysis estimates the potential effect on electricity rates for residential and commercial customers.

In addition, the analysis estimated the total number of vehicle chargers that will be required to support the increase in M/HD EVs under the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios—both depot-based chargers and shared public chargers.

The U.S. electric grid mix and energy cost assumptions used can also be found in the Appendix to this report.

Federal Analysis Results

The sections below provide a summary of the results from the scenario analysis, followed by detailed sections describing the current U.S. M/HDV fleet and the projected fleet, the environmental and public health benefits, and the economic impacts of the modeled fleet transitions under the scenarios.

Summary of Results

Under the Enhanced Baseline scenario, estimated cumulative net societal benefits total almost $137 billion (in constant 2020$[17]) through 2050, compared with the EPA Baseline scenario. This increase in net societal benefits is due to the presence of increased ZEVs not included under the EPA Baseline. The net societal benefit calculation includes the monetized value of public health benefits resulting from reduced NOx and PM emissions, net cost savings to fleets from operating zero-emission trucks, and savings to all residential and commercial electricity customers due to lower electric rates made possible by the additional electricity sales for electric vehicle charging.

Under the EPA NOx Option 1 scenario, cumulative public health benefits from NOx reductions total $201 billion compared to the EPA Baseline and $156 compared to the Enhanced Baseline. Looking at the more optimistic policy scenario (Federal ACT + NOx Omnibus, discussed below) ZEV sales are assumed to increase across the U.S. Relative to the EPA Baseline, cumulative net societal benefits through 2050 are more than $488 billion under this Federal ACT + NOx Omnibus scenario. Compared to the Enhanced Baseline trajectory, cumulative net societal benefits in 2050 from the Federal ACT + NOx Omnibus scenario still reach $350 billion.

Implementation of the modeled Federal ACT + NOx Omnibus scenario will help accelerate the on-going shift away from internal combustion engine vehicles to zero-emission vehicles, further transitioning from petroleum fuels to electricity and hydrogen. This analysis indicates that this transition will have positive macroeconomic effects, including increased net jobs and gross domestic product (GDP), as well as increased wages for the new jobs that will be added, relative to the jobs that will be replaced.

Compared with the EPA Baseline scenario, net national job gains under the Federal ACT + NOx Omnibus policy scenario total 63,256 in 2035. This will be accompanied by a $10.1 billion increase in 2035 GDP. Under this comparison, average wages for the new jobs created are expected to be, on average, more than twice as high as average wages for the jobs that will be replaced.

U.S. M/HD Vehicle Fleet

Table 2 summarizes the current M/HD fleet in the U.S., broken down by the three major vehicle types used to frame the Federal analysis.

17 All values cited in this report are in constant 2020$, unless otherwise stated.

Table 2 Current U.S. M/HD Fleet[18]

Vehicle Type		No. of Vehicles (million)	Annual VMT (billion miles)	Annual Fuel (million gallons)
Bus **Class 4–8**		1.02	18.4	2,300
Single-Unit Work and Freight Truck **Class 4–8**		5.90	72.4	8,812
Combination Truck **Class 7–8**		3.24	194.1	28,080
TOTAL		**10.16**	**318.5**	**39,193**

Approximately 10 percent of the fleet are buses, which account for 6 percent of annual VMT and 6 percent of annual fuel use. This includes relatively small shuttle buses (class 4–5) as well as school buses, transit buses, and intercity/charter coach buses.[19] Fifty-eight percent of the fleet are single-unit freight and work trucks, which account for 25 percent of annual VMT and 22 percent of annual fuel use. These vehicles come in a wide variety of sizes (Class 4–8) and have a wide variety of uses, from vans and box trucks used to deliver freight, to sanitation and construction trucks, to boom-equipped utility trucks. Only 32 percent of the fleet are combination truck-tractors, but these vehicles account for 68 percent of annual VMT and 72 percent of annual fuel use, since approximately two-thirds of these vehicles are used primarily for long-distance freight hauling and typically log many more daily and annual miles than other M/HD vehicles.

Today less than 1 percent of the national M/HD fleet is powered by electricity or alternative fuels (natural gas and propane).

Approximately 4.7 percent of existing Class 4–8 trucks and buses are retired each year and replaced with new vehicles.[20]

18 Class 2b and 3 trucks are also considered medium duty, however they have been excluded from this analysis

19 Note that the ACT Rule does not include ZEV requirements for transit buses, as these vehicles are covered by a separate Innovative Clean Transit regulation in California.

20 This is a long-term average based on analysis done by ERM on the Transportation Energy Data Book. Actual annual turnover is highly correlated to economic conditions and can vary widely from year to year. Stacy Davis and Robert Boundy, Transportation Energy Data Book Edition 39 (Oak Ridge National Laboratory, U.S. Department of Energy, August 2021), Tables 4.3-4.7 and 5.1-5.3, https://tedb.ornl.gov/wp-content/uploads/2021/02/TEDB_Ed_39.pdf.

Changes in Fleet Fuel Use

Under the Enhanced baseline and Federal ACT + NOx Omnibus scenarios, a significant portion of the U.S. M/HD fleet is assumed to turn over to EV trucks and buses. This will result in a shift from petroleum fuels—primarily gasoline and diesel fuel—to electricity.[21]

Under the EPA Baseline scenario, total petroleum fuel use by the U.S. M/HD fleet in 2050 is projected to be 38.7 billion gallons. Compared to the EPA Baseline, the Enhanced Baseline projects total fuel use in 2050 to fall to an estimated 31.0 billion gallons (-20 percent) and cumulative reductions in diesel and gasoline use by the M/HD fleet total 99.4 billion gallons between 2020 and 2050. This petroleum fuel is replaced by 1.81 million gigawatt-hours (GWh) of electricity between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 152 million MWh, a 4 percent increase to estimated baseline electricity use by U.S. residential and commercial customers that year (3.44 billion MWh).

The EPA NOx Option 1 regulation does not result in additional reductions in petroleum fuel use.

Under the Federal ACT + NOx Omnibus scenario, estimated petroleum fuel use by the M/HD fleet in 2050 falls to 17.3 billion gallons (–55 percent), and cumulative reductions in diesel and gasoline use by the M/HD fleet total 266 billion gallons between 2020 and 2050, compared with the EPA Baseline. This petroleum fuel is replaced by 4.86 billion MWh of electricity between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 421 million MWh, a 12 percent increase to estimated baseline electricity use by U.S. residential and commercial customers that year.

Because all four scenarios are assumed to take place under the same national GHG standards, every M/HD ZEV sold will be used to offset tailpipe requirements from the remaining diesel fleet, which will yield a reduction in fuel efficiency in those diesel vehicles. Thus, these results potentially underestimate the benefits of transitioning part of the fleet to zero-emission vehicles, in terms of reductions in fuel usage and associated costs. If the EPA tightens the GHG standards to account for ZEV adoption, the full reduction in fuel usage and costs can be realized.

Public Health and the Environment

The modeled policy scenarios produce significant reductions in NOx and PM emissions from the M/HD fleet, even after accounting for the emissions from producing the electricity needed to power ZEVs. NOx and PM reductions will improve air quality resulting in public health benefits from reduced mortality and hospital visits. Assuming the EPA tightens GHG standards to account for ZEV adoption, a significant reduction in GHG emissions is also possible. The results below include emissions from M/HDV tailpipe exhaust as well as upstream emissions from petroleum and electricity production.

The electricity grid mix used in this analysis is shown in the Appendix. For all scenarios, the analysis uses a modified business-as-usual (BAU) grid mix calculated from 2021 Integrated Planning Model (IPM) runs and then weighs the Enhanced Baseline ACT states' electricity production at 50 percent and the remainder of the country at 50 percent. As shown in the Appendix, this grid mix is broadly consistent with the projected U.S. average grid mix in EIA's Annual Energy Outlook 2022.

In 2022, the grid mix used in this analysis is 13.1 percent coal-fired generation, 37.8 percent natural gas–fired generation, and 49.1 percent "zero-emitting" generation sources.[22] By 2050, the share of coal-fired generation falls to 9.3 percent, gas-fired generation falls to 30.3 percent, and zero-emitting generation grows to 60.3 percent.

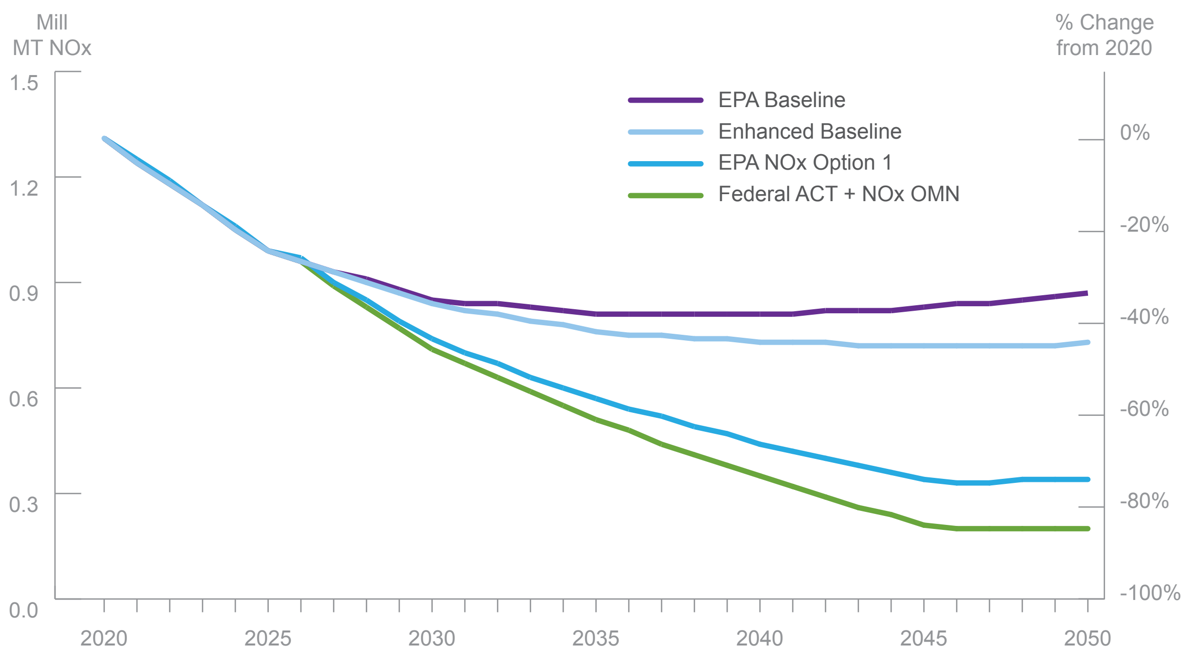
21 A small number of M/HD trucks and buses in the U.S. currently use natural gas.

22 For this analysis, coal-fired generation includes oil and biomass. Zero-emitting sources include nuclear and renewable sources such as wind, solar, and hydropower.

Air Quality Impacts

Figures 5 and 6 show estimated annual M/HD fleet NOx and PM emissions for the four modeled scenarios. Under the EPA Baseline scenario, annual M/HD fleet NOx emissions are projected to fall by 38 percent and annual fleet PM emissions are projected to fall 68 percent through 2045 relative to 2020, as the current fleet turns over to new gasoline and diesel trucks that meet current EPA stringency for new engine emissions standards. After 2045, baseline annual NOx and PM emissions are then projected to start rising again as annual fleet VMT continues to grow.

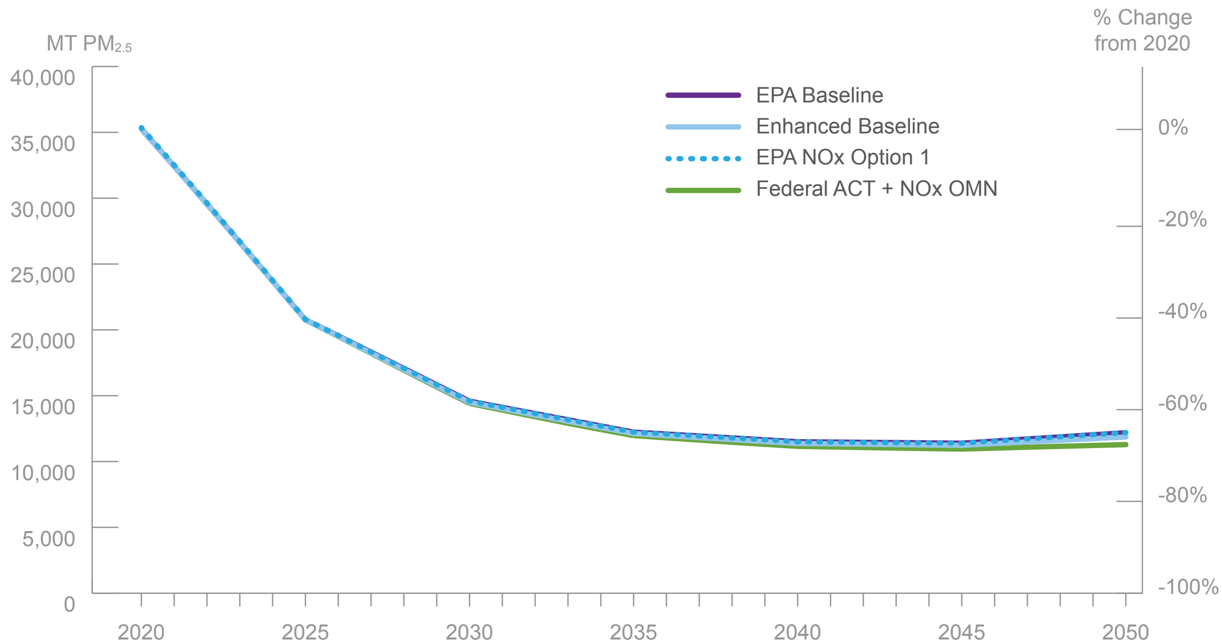
Figure 5 Projected M/HD Fleet NOx Emissions



Compared with the EPA Baseline, by 2050, the Enhanced Baseline is estimated to reduce annual fleet NOx by 16 percent as diesel and gasoline trucks are replaced with electric vehicles within the ACT states. The EPA NOx Option 1 scenario will reduce annual fleet NOx emissions due to turnover of the diesel and gasoline fleet to new vehicles with low NOx engines. Compared to the Enhanced Baseline, the EPA NOx Option 1 scenario results in lower NOx emissions; by 2050 annual NOx emissions are projected to be 53 percent lower. The Federal ACT + NOx Omnibus scenario contributes to reductions that are 85 percent lower in NOx and 68 percent lower in PM in 2050 compared to today's levels.

Because the EPA NOx Option 1 scenario assumes no ZEVs, it slightly overestimates NOx emissions from upstream petroleum production emissions and slightly underestimates NOx emissions from upstream electricity production. These emissions almost entirely cancel out. See the Appendix for a figure with solely tailpipe NOx emissions.

Figure 6 Projected M/HD Fleet PM Emissions



As shown in Figure 6, the EPA Baseline and EPA NOx Option 1 scenarios have nearly identical PM emissions, while the Enhanced Baseline reduces PM emissions by 3 percent and the Federal ACT + NOx Omnibus scenario reduces PM emissions by 7 percent, compared with the EPA Baseline.

If the share of coal in the electricity grid mix decreases more than is assumed in this analysis (13 percent in 2022 to 9 percent in 2050), the PM reductions in the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios would be higher. Tailpipe PM emissions are reduced by 18 percent and 49 percent in 2050 for the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios respectively when compared to the EPA Baseline. See the Appendix for a figure with solely tailpipe PM emissions.

Over the next 30 years, cumulative NOx and PM emission reductions from the Enhanced Baseline (compared with the EPA Baseline scenario) total 1.7 million metric tons (MT) and 3,550 MT, respectively. Cumulative NOx reductions from the EPA NOx Option 1 scenario (compared with the EPA Baseline scenario) are estimated at 7.6 million MT over the same time. Cumulative NOx and PM emission reductions from the Federal ACT + NOx Omnibus scenario (compared with the Enhanced Baseline) are projected to total 7.9 million MT and 5,530 MT, respectively.

Public Health Benefits

The reduced annual NOx emissions under all four scenarios (and PM emissions under the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios) will decrease ambient particulate levels in the air, which will reduce the negative health effects on U.S. residents breathing in these airborne particles.[23] Estimated public

23 PM is directly emitted to the atmosphere from combustion sources as solid particles. NOx is emitted from combustion sources as a gas but contributes to the formation of secondary particles via chemical reactions in the atmosphere. Both direct and secondary particles have negative health effects when taken into the lungs.

health impacts include reductions in premature mortality and fewer hospital admissions and emergency room visits for asthma. There will also be reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and fewer restricted activity days and lost workdays. Shown in Table 3 are the cumulative estimated reductions in these health outcomes under all modeled scenarios compared to the EPA Baseline. Table 4 shows PM-related health outcomes from the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios, again providing the cumulative benefits (2020 to 2050). These benefits were estimated using the U.S. Environmental Protection Agency's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool.

Table 3 Cumulative Public Health Benefits from NOx Reductions (Relative to EPA Baseline Scenario), 2020–2050

Health Metric	Enhanced Baseline	EPA NOx Option 1	Federal ACT + NOx OMN
Avoided Premature Deaths	3,881	17,212	21,803
Avoided Hospital Visits[a]	3,644	16,174	20,478
Avoided Minor Cases (million)[b]	2.29	10.13	12.84
Monetized Value, 2020$ (billion)	$45.4	$201	$255

[a] Includes hospital admissions and emergency room visits.

[b] Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

The monetized value of cumulative public health benefits from the Enhanced Baseline over the next 30-year period (2020 to 2050) totals more than $45.4 billion. Looking at the EPA NOx Option 1 scenario, the monetized value of cumulative net public health benefits reaches $201 billion by 2050. The monetized value of cumulative public health benefits under the Federal ACT + NOx Omnibus policy scenario totals $255 billion through 2050.

Table 4 Cumulative Public Health Benefits from PM Reductions (Relative to EPA Baseline), 2020–2050

Health Metric	Enhanced Baseline	Federal ACT + NOx OMN
Avoided Premature Deaths	459	1,205
Avoided Hospital Visits[a]	423	1,111
Avoided Minor Cases (million)[b]	0.31	0.81
Monetized Value, 2020$ (billion)	$5.4	$14.1

[a] Includes hospital admissions and emergency room visits.

[b] Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

Compared with EPA's Current Baseline, the monetized value of cumulative PM-related public health benefits from the Enhanced Baseline scenario over the same 30 year period totals $5.4 billion while cumulative net public health benefits from the Federal ACT + NOx Omnibus policy scenario reaches $14.1 billion by 2050. Because the EPA NOx Option 1 scenario is modeled without any ZEVs, the scenario does not experience any further PM reductions compared with the EPA Baseline. Assuming the same level of ZEVs as the Enhanced Baseline with the new stricter NOx Option 1 standards, similar PM reductions would be experienced.

EPA Baseline vs Enhanced Baseline

By underestimating the number of ZEVs, EPA overestimates the impact of the more stringent NOx emission standard. When considering only tailpipe emissions, under the Enhanced Baseline Scenario, NOx emissions are projected to fall by 113,700 MT relative to the EPA Baseline in 2045 due to the adoption of ZEVs. This accounts for 23 percent of the reduction seen in NOx emissions under the EPA NOx Option 1 Scenario (489,200 MT lower than the EPA Baseline in 2045).

Cumulative tailpipe NOx reductions under the EPA NOx Option 1 Scenario are 1.1 million MT higher when comparing it to the EPA Baseline instead of the Enhanced Baseline. This accounts for more than one-fifth of the NOx reductions.

Climate Benefits

Figure 7 illustrates estimated annual M/HD fleet GHG emissions under the modeled scenarios assuming the EPA tightens GHG standards to account for an increasing share of ZEVs. By allowing for ZEV crediting, vehicle manufacturers will be able to delay improvements to fuel economy and GHG emissions which will not necessarily decrease with more ZEVs on the road.

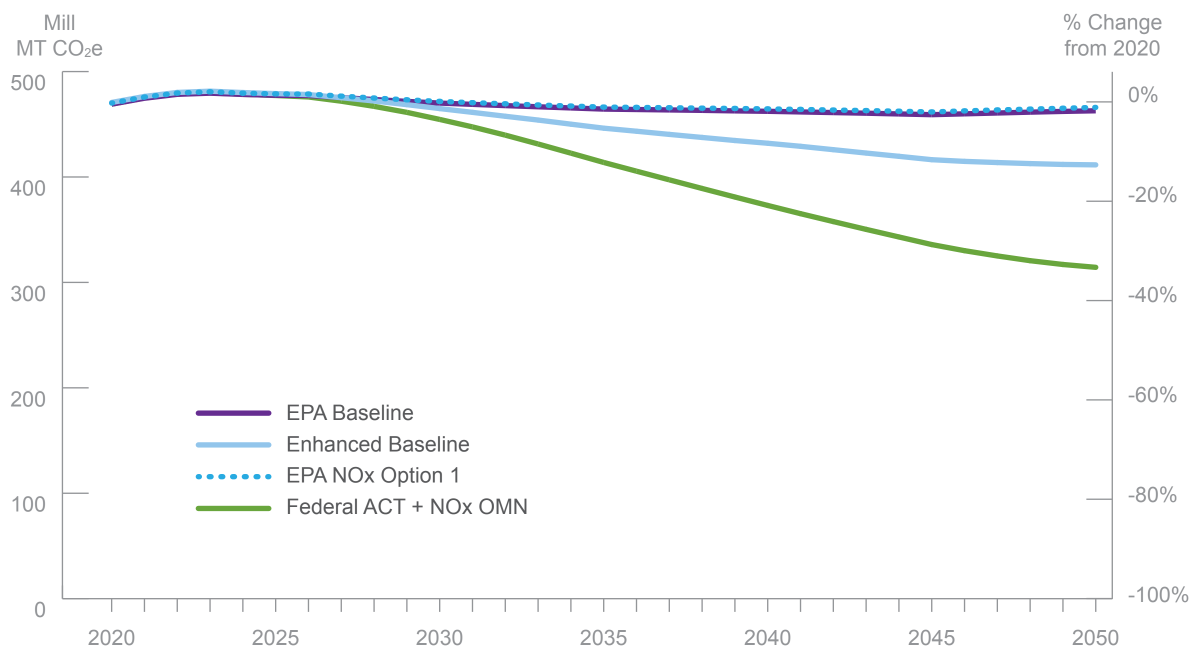
As shown, under the EPA Baseline scenario, annual M/HD fleet GHG emissions are projected to fall by 1 percent through 2050. While the current fleet turns over to new, more efficient gasoline and diesel trucks that meet current EPA new engine and vehicle emission standards, VMT increases cancel out nearly all climate benefits.

Compared with the EPA Baseline, by 2050, the level of ZEVs in the Enhanced Baseline make an 11 percent reduction in GHG emissions possible, as diesel and gasoline trucks continue to improve fuel efficiency and the share of electric vehicles increases.

The EPA NOx Option 1 scenario would be expected to have a similar level of ZEVs as the Enhanced Baseline scenario. As such, it would experience the same level of GHG reduction as the Enhanced Baseline.

If the EPA tightens GHG standards so that diesel and gasoline trucks continue to increase their fuel economy and do not backslide, the Federal ACT + NOx Omnibus policy scenario would have the lowest fleet emissions due to replacement of a larger share of gasoline and diesel trucks and buses with EVs by 2050. With the level of ZEVs in the Federal ACT + NOx Omnibus scenario, a 32 percent reduction in GHG emissions, compared to the EPA Baseline, is possible.

Figure 7 Projected M/HD Fleet GHG Emissions



Assuming the EPA tightens GHG standards, over the next 30 years, cumulative GHG emission reductions from the Enhanced Baseline (relative to the EPA Baseline scenario) could total 621 million MT and reductions from the Federal ACT + NOx Omnibus policy scenario (relative to the EPA Baseline) could total 1.83 billion MT. These estimates of GHG reductions from the Enhanced Baseline and Federal ACT + NOx Omnibus policy scenario account for reductions in petroleum fuel use (gasoline, diesel fuel) by the M/HD fleet, the decreased upstream emissions from gasoline and diesel production, as well as increased emissions from electricity production to fuel EVs.

Using the social cost of greenhouse gases as estimated by the federal government's Interagency Working Group, these possible cumulative GHG reductions could have a monetized value of $53.6 billion for the Enhanced Baseline scenario and $160.6 billion for the Federal ACT + NOx Omnibus policy scenario.[24] The social value of GHG reductions represents the monetary value of the net harm to society associated with the impacts of incremental increases in greenhouse gas emissions in a given year. These impacts include sea level rise in coastal communities, the damage inflicted by stronger tropical cyclones and flooding, health and agriculture impacts from extreme summer temperatures, increased environmental migration, and many other consequences of climate change.[25]

24 For the social cost values used, see Lowell, Dana et al. Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies & Assumptions. M.J. Bradley & Associates. June 10,2021. https://mjbradley.com/clean-trucks-analysis.

25 The Interagency Working Group developed GHG social cost estimates using a range of discount rates. These values are based on the average 3 percent discount rate, which is in the middle of the range of estimated values. The monetized value of cumulative GHG reductions under each policy scenario would be 72 percent lower if using the lowest published social cost values, and three times greater if using the highest published values.

Economic Impacts

This section summarizes projected economic impacts of the modeled scenarios, including changes in annual operating costs for fleets; impacts to electric utilities and their customers; net societal benefits; and macroeconomic effects on jobs, wages, and gross domestic product from the transition to low NOx and zero-emission trucks and buses. This section also estimates the required public and private investment in electric vehicle charging infrastructure to support the electric M/HD fleet under scenarios including ZEV sales.

Costs and Benefits to Fleets

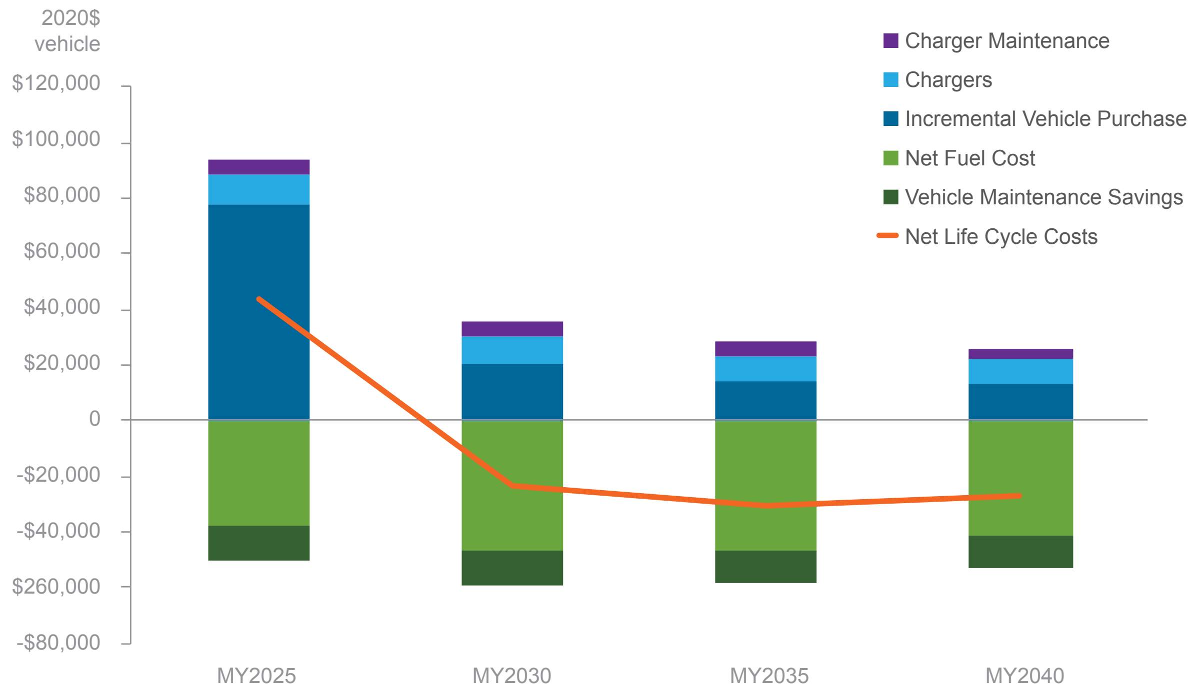
For the modeled scenarios, this analysis estimated annual incremental costs associated with purchase and use of M/HD ZEVs compared with baseline conventional vehicles with combustion engines that operate on petroleum fuels (gasoline, diesel). These costs include the incremental purchase cost of the new ZEVs added each year (instead of new combustion vehicles), the cost of installing the charging infrastructure required by these new ZEVs, and net fuel and maintenance costs for all ZEVs in the fleet, both those newly purchased each year and those purchased in prior years and still in use. Incremental purchase costs for low NOx vehicles have also been included for the Federal ACT + NOx Omnibus policy scenario.

Net fuel costs include reductions in purchases of diesel fuel and gasoline[26] (due to fewer combustion vehicles), offset by the increased purchase of electricity to power ZEVs. The modeled level of diesel and gasoline required for each MY vehicle assumes GHG standards will continue to improve the fuel efficiency of internal combustion engine vehicles. If the EPA fails to tighten GHG standards to account for growing ZEV adoption, the savings from net fuel costs would be higher. Net maintenance costs include net savings in annual vehicle maintenance for the ZEVs in the fleet compared with combustion vehicles, offset by annual costs to maintain the charging and hydrogen fueling infrastructure needed to support in-use ZEVs.

Figure 8 shows projected average lifetime incremental costs for new ZEVs purchased compared with lifetime costs for combustion vehicles purchased in the same model year; the bars show fleet average values for all Class 4–8 ZEVs purchased each year under the Federal ACT + NOx Omnibus policy scenario. Incremental fuel and maintenance costs are discounted lifetime costs, assuming 21-year vehicle life, and 6 percent annual discount rate. Vehicle financing, which is often used by fleets when purchasing vehicles, was not considered in this analysis.

26 The gasoline and diesel prices used in this analysis represent long-term projections from the EIA's 2021 Annual Energy Outlook. If the current high gas and diesel prices continue, net fuel savings would be higher than modeled.

Figure 8 Projected Lifetime Incremental Costs for ZEVs Compared with Combustion Vehicles



As shown, the average M/HD ZEV is projected to produce over $45,000 in discounted fuel[27] and maintenance cost savings over its lifetime (dark and light green bars). For ZEVs purchased in the very near term, this savings may not be enough to offset the projected incremental cost of vehicle purchase and fueling infrastructure for some ZEVs, resulting in net increased lifetime costs compared with those of combustion vehicles. However, by 2030 incremental ZEV purchase costs are projected to fall significantly, such that the average ZEV will reach lifetime cost parity with combustion vehicles, when discounted lifetime fuel and maintenance savings are considered. By 2040, the average ZEV purchased that year is projected to realize more than $27,000 in discounted net lifetime savings (2020$) compared with the costs of an equivalent combustion vehicle.

It is important to reiterate that the values in Figure 8 are fleet average values, which mask a significant amount of variability across vehicle types and among different fleets of the same vehicle type. Also note that the utility impact analysis (in the next section) indicates that the cost of providing power to charge M/HD EVs is lower than expected utility revenue under current rate structures. This suggests that the U.S. could consider changes to rates that would not only be fairer for fleets, but also lower electricity costs for M/HD EV charging, thus reducing net fleet operating costs further than estimated here. However, this would reduce the potential benefits that would accrue to other ratepayers from M/HD vehicle charging (see discussion below).

M/HD ZEVs in some fleets will likely achieve lifetime cost parity with combustion vehicles much earlier than 2030, while others may lag. In addition, this analysis, and the values shown in Figure 8, assume no government incentives for vehicle purchase or development of fueling infrastructure. If existing and potential incentives are considered, or policies such as improved electricity rates for fleets, then actual net costs to fleets will be lower, resulting in cost parity sooner.

27 Fuel prices used for this analysis are long-term averages projected by the EIA as part of their Annual Energy Outlook. These prices do not reflect the recent high fuel prices that the U.S. is experiencing.

Electric Utility Impacts

Current annual electricity sales to residential and commercial customers in the U.S. total 2.73 billion MWh and are projected to grow to 3.44 billion MWh in 2050.[28]

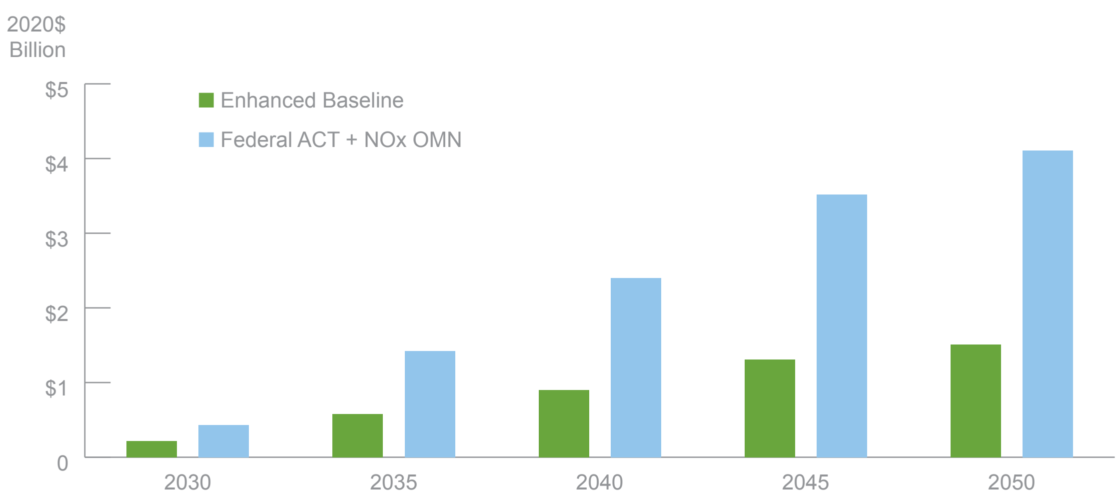
Under the Enhanced Baseline scenario, additional annual electricity sales for M/HD EV charging are estimated to total 18.5 million MWh in 2030, rising to 151.7 million MWh in 2050. This incremental load represents 0.6 percent and 5.2 percent of the total electricity demand in 2030 and 2050, respectively. Incremental monthly peak charging demand under this scenario is estimated at 4.6 GW in 2030, rising to 44.4 GW in 2050.

Under the Federal ACT + NOx Omnibus policy scenario, incremental peak charging demand is estimated at 10.2 GW in 2030, rising to 124.1 GW in 2050, and annual incremental electricity sales are estimated to be 39.3 million MWh in 2030, rising to 420.7 million MWh in 2050 (1.1 percent and 12.2 percent of the total electricity demand, respectively).

This analysis estimated the revenue that electric utilities would receive from these incremental electricity sales, the marginal generation and transmission costs of providing this power, and the net revenue that utilities would earn (net revenue = revenue – marginal cost). The estimated marginal cost includes costs associated with procuring the necessary additional peak generation and transmission capacity to serve the load ($/MW) as well as marginal generation and transmission energy costs ($/MWh).

Figure 9 summarizes estimated annual utility net revenue from M/HD EV charging under the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios. Looking at the Enhanced Baseline scenario, annual utility net revenue is projected to be $216 million in 2030, rising to $901 million in 2040 and $1.5 billion in 2050. Under the Federal ACT + NOx Omnibus policy scenario, utility net revenue is projected to be $433 million in 2030, rising to $2.4 billion in 2040 and $4.1 million in 2050.

Figure 9 Projected Annual Utility Net Revenue From M/HD EV Charging



28 This growth assumption is from the EIA 2021 Annual Energy Outlook. It does not include sales to large industrial customers.

In general, a utility's costs to maintain its distribution infrastructure increase each year with inflation, and these costs are passed on to utility customers in accordance with rules established within each state's utility commission via periodic increases in residential and commercial electric rates. However, projected utility net revenue from increased electricity sales for M/HD EV charging would lower distribution rates ($/kWh), since fixed annual distribution system costs would be spread over a larger base of energy sales.

This analysis indicates that under Federal ACT + NOx Omnibus policy scenario, by 2050 incremental utility net revenue from M/HD EV charging could potentially reduce average residential and commercial electricity rates in the nation by as much as 1.26 percent ($0.0023/kWh in 2020$). This could save the average U.S. household $25 per year and the average commercial customer $153 per year on their electricity bills (2020$).[29]

Jobs, Wages, and GDP

The on-going transition from standard gasoline and diesel M/HD vehicles to ZEVs will have continued impacts, with job gains in many industries (e.g., battery and electric component manufacturing, charging infrastructure construction, electricity generation), accompanied by contractions in other industries (e.g., engine manufacturing, oil exploration and refining, gas stations, auto repair shops).[30]

This analysis used the IMPLAN model to estimate these macroeconomic effects of the modeled Enhanced Baseline and Federal ACT + NOx Omnibus scenarios based on estimated changes in spending in various industries (relative to the EPA Baseline scenario). These estimates of spending changes by industry were developed from the fleet cost analysis. For example, under the modeled scenarios, more money will be spent to manufacture batteries and electric drive components for ZEVs, but less will be spent to manufacture gasoline and diesel engines, and transmissions. Similarly, less money will be spent by fleets to purchase petroleum fuels, but more will be spent to purchase electricity.

The IMPLAN analysis also includes the effects of induced economic activity due to consumers having more money to spend, thanks to return of utility net revenue in the form of lower electric rates, and net fleet cost savings returned as lower shipping costs for goods, resulting in lower consumer prices for those goods.

The IMPLAN analysis was run at the national level and assumed industry spending changes (from application of the scenarios) occurring due to M/HD vehicle purchase and use.

Table 5 offers a summary of estimated macroeconomic effects of the modeled scenarios on jobs, GDP, and wages compared to the EPA Baseline.

Compared with the EPA Baseline scenario, the Enhanced Baseline along with adoption of the Federal ACT + NOx Omnibus policy scenario will increase national net jobs through 2045. Both scenarios also increase annual GDP for all years. The average wages for new jobs added to the economy are more than twice the average wages for jobs that are replaced. This is because the largest number of added jobs are in electrical component manufacturing and in construction of charging infrastructure, requiring many well-paid electricians and electrical engineers, while the largest job losses are in vehicle repair—due to lower maintenance required by ZEVs—as well as relatively low-paid retail workers at gas stations.

29 Figures are based on average annual electricity use of 10,918 kWh per housing unit and 65,697 kWh per commercial customer in the U.S.

30 For example, national battery manufacturing is estimated to increase by 28,915 jobs in 2045 under the Federal ACT + NOx Omnibus scenario.

Table 5 Macroeconomic Effects of Scenarios

Metric		Enhanced Baseline		Federal ACT + NOx Omnibus	
		2035	2045	2035	2045
Net Change in Jobs		22,317	17,394	63,256	14,402
Net Change in GDP 2020$ (billions)		$3.7	$4.1	$10.1	$7.4
Average Annual Compensation	Added Jobs	$94,474	$91,250	$94,012	$93,079
	Replaced Jobs	$44,132	$45,891	$43,571	$45,625

Today, many components used in electric and fuel cell vehicles—most notably batteries, but also many electric drivetrain components—are manufactured outside the United States and imported for final vehicle assembly. The percentage of imported content is higher for ZEV drivetrains today than for conventional drivetrains (gasoline and diesel engines, and transmissions). The scale of U.S. macroeconomic effects from the modeled policy scenarios will depend on how the nascent M/HD ZEV industry develops; for this analysis, ERM assumed that all incremental spending on ZEV batteries and electric drivetrain components would be in the United States, with no imported content. As such, the results summarized in Table 5 represents a higher-end estimate of what is possible from the ZEV transition, with the right federal and state policy supports in place to incentivize development of U.S.-based ZEV component manufacturing. If vehicle manufacturers continue to rely primarily on imported batteries and electric drivetrain components, the net job and GDP gains will be lower than those summarized here.

This macroeconomic analysis only includes direct, indirect, and induced impacts from changes in M/HD vehicle manufacturing and use, and from consumer re-spending of net utility revenue and fleet cost savings returned as lower prices for electricity and shipped goods. It does not include any effects on freight industry growth and investment due to lower operating costs, or any macroeconomic effects associated with the estimated climate and air quality (health) benefits of the modeled scenarios. These effects may increase economic and job numbers compared to those presented here.

Public and Private Charging Infrastructure Investments

Using a detailed charging model that considers typical daily usage patterns for different vehicle types, this analysis assumes that most M/HD ZEVs in the U.S. will use overnight charging at their place of business, though about 10 percent will need to rely on a publicly accessible network of higher-power chargers.[31] The exception are combination trucks, 70 percent of which are assumed to require high-power public chargers since they are used primarily for long-haul freight operations.

Table 6 summarizes the estimated charging ports and cumulative financial investment (2020 to 2050) to support M/HD electric trucks and buses, while Figure 10 shows the annual charging infrastructure investment required to purchase, install and maintain charging infrastructure under the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios.

31 See the methodology report for a detailed discussion of M/HD EV charging needs.

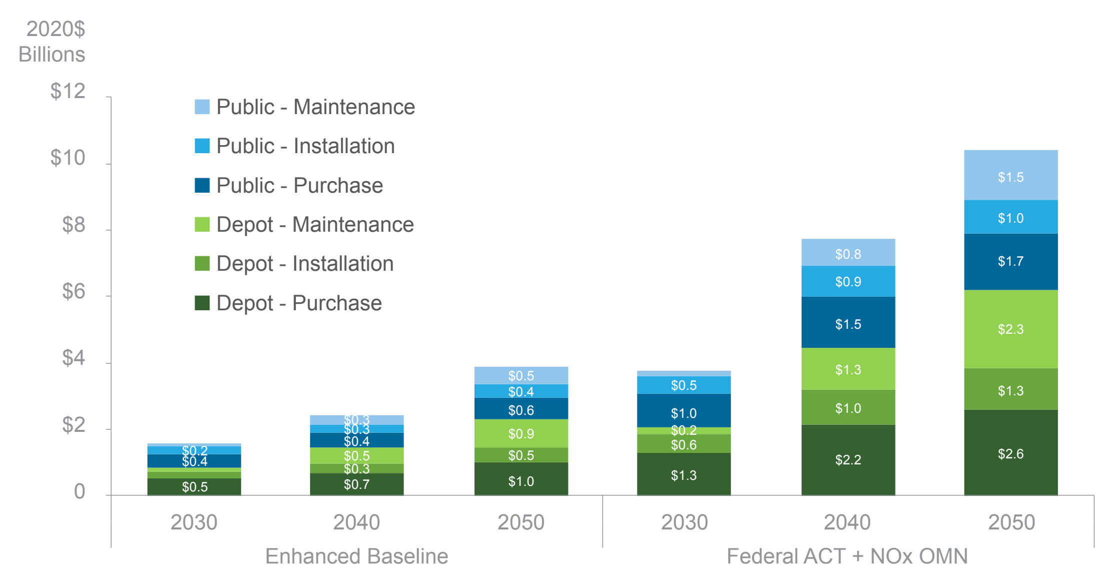
Table 6	Projected Charging Infrastructure Required for Scenarios

Metric		Enhanced Baseline			Federal ACT + NOx Omnibus		
		2035	2045	2050	2035	2045	2050
Charge Ports	Depot	1,033,212	2,694,483	3,526,855	2,620,133	7,512,500	9,842,966
	Public 150 kW	16,097	42,319	55,680	41,323	119,302	156,849
	Public 500 kW	17,078	40,407	49,369	42,277	110,191	137,413
Cumulative Investment, 2020$ (millions)	Depot	$7,439	$18,628	$25,630	$18,518	$50,953	$69,504
	Public	$6,407	$14,932	$19,928	$15,936	$40,868	$54,220

Under the Enhanced Baseline scenario, private investments (e.g., fleet owners and site hosts) would likely average $1.03 billion per year (2020$) between 2025 and 2050 to purchase and install depot-based charging infrastructure. The government and private investors will likely invest an average of $0.80 billion per year over the same period to build out a publicly accessible charging network across the nation to serve the EV M/HD truck fleet. By 2050, over 3.5 million depot and 100,000 public direct current fast-charging (DCFC) ports are required, resulting in a cumulative infrastructure investment of $25.6 billion and $19.9 billion, respectively.

Under the Federal ACT + NOx Omnibus scenario, fleet and site host investments in depot charging infrastructure from 2025 to 2050 will increase to an average of $2.78 billion per year, and investments in the public charging network will rise to an average of $2.17 billion per year. Through 2050, 9.8 million depot-based charging ports and over 294,000 public DCFC ports will likely be needed, resulting in a cumulative investment of $69.5 billion and $54.2 billion, respectively.

Figure 10 Projected Annual Charging Infrastructure Investment



Depot chargers will need to be 10–50 kW per port depending on vehicle type. The smaller 150 kW public chargers are needed primarily to support single-unit freight trucks, while the higher-capacity 500 kW public chargers are needed mostly for combination trucks.

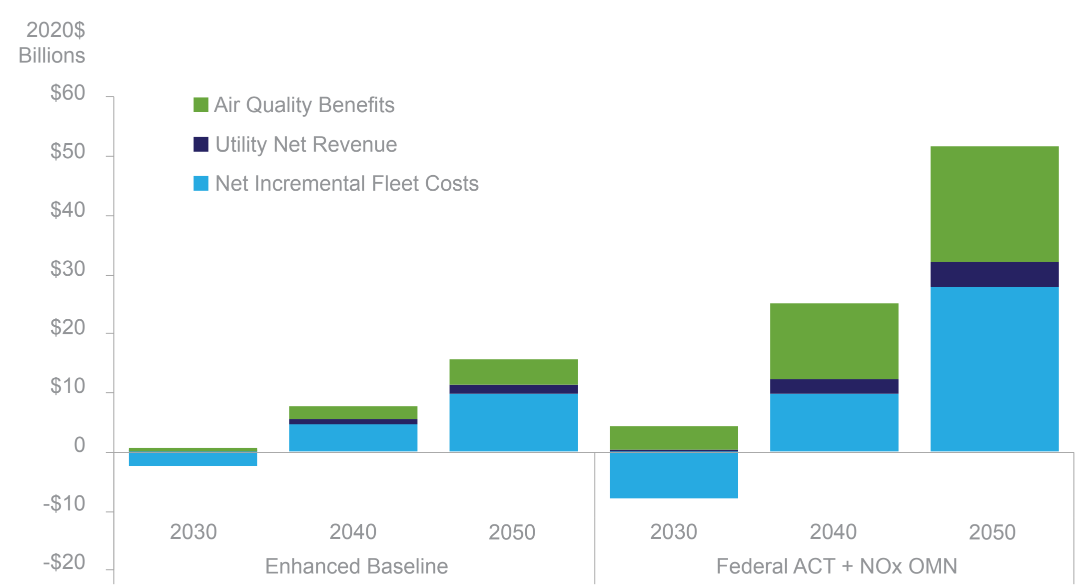
As of May 2022, there were 118,075 publicly accessible charging ports in the U.S. with a total of 23,431 direct current fast-charging (DCFC) ports (>50 kW).[32] Over 50 percent of these DCFC ports are Tesla superchargers that currently can be used only by Tesla owners.[33] In the U.S., there are 9,946 DCFC ports fully available to any vehicle.

Net Societal Benefits

The net societal benefits from the modeled Enhanced Baseline and Federal ACT + NOx Omnibus scenarios include the monetized value of public health and climate benefits, net cost savings for fleets, and net utility revenue from electricity sales for EV charging are shown in Figure 11[34]. These scenarios are compared against the EPA Baseline.

Under both the Enhanced Baseline and Federal ACT + NOx Omnibus scenarios, near-term fleet costs are higher than fleet costs under the EPA Baseline.[35] However, after approximately 2030, these scenarios show annual net societal benefits, despite net fleet costs, due to growing utility net revenue in addition to public health and climate benefits. After approximately 2035 there is an annual net savings in fleet costs from operating ZEVs instead of diesel and gasoline trucks, and net societal benefits grow quickly.[36]

Figure 11 Projected Annual Net Societal Benefits from the Enhanced Baseline and Federal ACT + NOx Omnibus Scenarios



32 U.S. Department of Energy, Vehicle Technologies Office. "Alternative Fueling Station Locator." https://afdc.energy.gov/stations#/analyze.

33 Hamilton Asher, Isobel. "Tesla has started selling chargers for non-Tesla cars, just as it begins to open up its Supercharger network to other vehicles." Business Insider. November 2, 2021.https://www.businessinsider.com/tesla-elon-musk-chargers-supercharger-network-2021-11.

34 The net societal benefits calculation excludes climate-related benefits since these are contingent upon EPA revising current GHG and fuel economy standards.

35 If an individual truck owner finances a vehicle, it would better equalize payments for increased vehicle price and fuel savings, resulting in a better balancing of cash flow. On a net fleet-wide basis, however, the cost of financing reduces total net fleet savings.

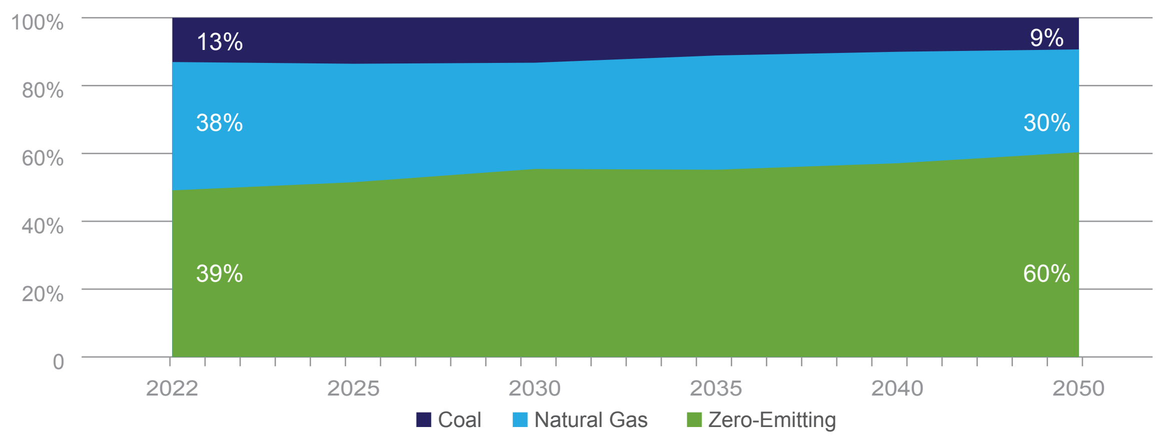
36 Note that fleet-wide annual net savings under the scenarios lag average ZEV life-cycle cost parity to combustion vehicles by about 5 years. This is because even after life-cycle cost parity is achieved, most ZEVs will still have higher up-front purchase costs (vehicle plus charger) than combustion vehicles; these higher costs are then paid back over the next few years via fuel and maintenance cost savings.

Under the Enhanced Baseline scenario, by 2050 annual net societal benefits are estimated to be $15.8 billion, including $4.3 billion in air quality benefits, $10.0 billion in net fleet savings and $1.5 billion in utility net revenue. Cumulative estimated societal net benefits under this scenario total $137.3 billion between 2020 and 2050.

For the Federal ACT + NOx Omnibus scenario, by 2050 annual net societal benefits are estimated to be $51.6 billion, with $20.0 billion in air quality benefits, $28.0 billion in net savings to fleets and $4.1 billion in utility net revenue. Cumulative estimated societal net benefits under this scenario total $487.7 billion between 2020 and 2050.

APPENDIX

Figure A1 U.S. Modified Business-as-Usual Grid Mix Assumptions



This business-as-usual grid mix assumption was applied to all scenarios analyzed (EPA Baseline, Enhanced Baseline, EPA NOx Option 1 and Federal ACT + NOx Omnibus scenarios). As discussed above, the grid mix weighs the ACT states in the Enhanced Baseline as 50 percent of the grid and remainder of the country as the other 50 percent. This is due to the expectation that the vast majority of ZEV adoption will occur in those states for the two Baseline scenarios and a higher share will occur in those states under the Federal ACT + NOx Omnibus scenario. Given that the 2022 AEO U.S. reference case grid mix (Figure A2) is broadly consistent with the grid mix used in this analysis, ERM believes that even if ZEV adoption occurs more evenly across the U.S., the emissions projections from upstream electricity production are still reasonable.

Figure A2 2022 AEO U.S. Reference Grid Mix

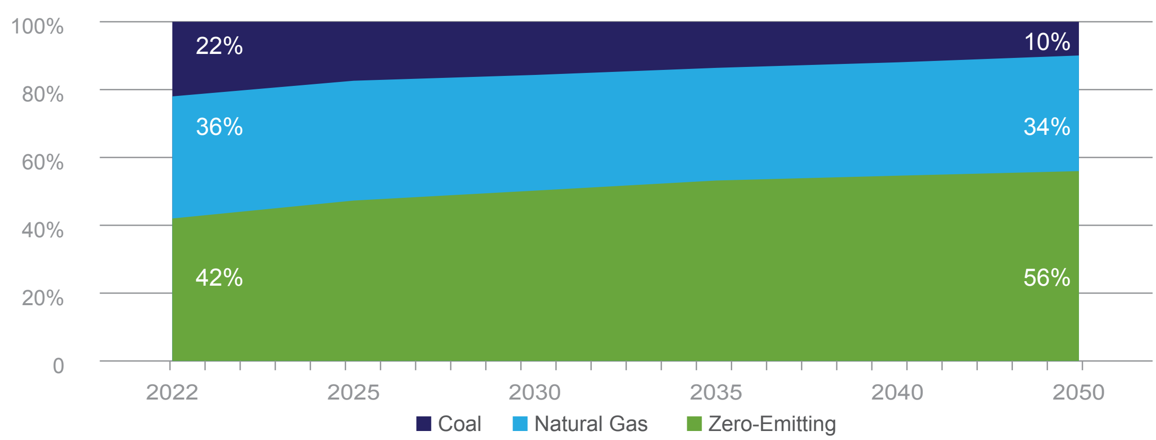


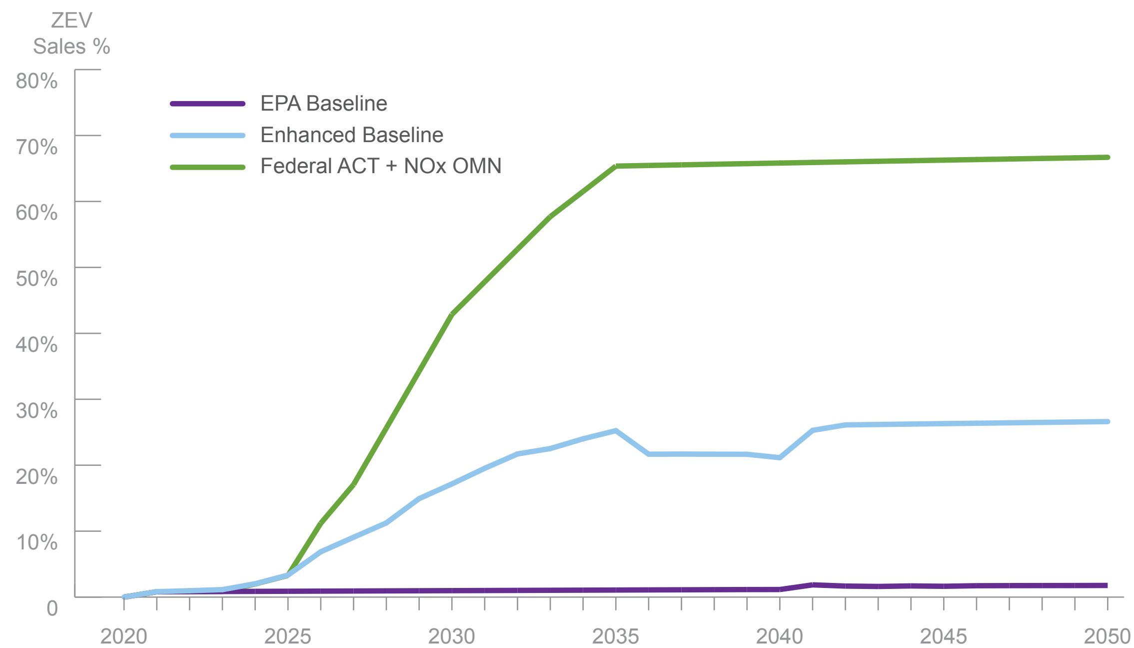
Table A1 M/HDV In-Use ZEVs Population

M/HDV In-Use ZEVs	2025	2030	2035	2040	2045	2050
EPA Baseline	83,872	107,693	139,595	179,911	229,168	292,178
Enhanced Baseline	111,823	551,112	1,486,933	2,470,960	3,709,804	4,819,879
EPA NOx Option 1						
Federal ACT + NOx Omnibus	109,266	1,117,274	3,545,633	6,626,459	9,907,299	12,917,090
Total M/HDV Fleet (ZEV + ICE + Low NOx)	11,165,511	12,241,274	13,461,672	14,799,864	16,116,250	17,656,811

Table A2 M/HDV In-Use ZEVs Population

M/HD ZEV Sales Percentages	2025	2027	2030	2035	2040	2045	2050
Bus	4.3%	11.6%	22.7%	32.8%	27.8%	33.2%	33.4%
Single Unit Truck	3.8%	9.8%	18.4%	27.8%	23.2%	28.5%	28.7%
Combination Truck	1.8%	6.3%	11.5%	14.3%	11.7%	15.5%	15.6%
M/HD Average	3.3%	9.1%	17.2%	25.2%	21.1%	26.3%	26.6%

Figure A3 M/HD ZEV Sales Percentages Averaged over Vehicle Types



Note: The EPA NOx Option 1 scenario is not plotted in the figure above because the scenario assumes no ZEV sales.

The fall in ZEV sales between 2036 and 2040 in the Enhanced Baseline is due to the provisions of the Advanced Clean Fleets (ACF) regulation California is assumed to adopt. Since the ACF requires large fleet owners to meet in-use fleet ZEV milestones, it raises expected ZEV sales above the manufacturers required sales level. Once large fleet owners have met their ZEV milestones, ZEV sales fall slightly as the ZEV credits are used. This analysis assumes only a 2-year lifetime for ZEV credits. While the ACT allows for credits to be used 5 years after they were created, it is expected that manufacturers will only hold onto credits for 2 years.

Table A3 Net Incremental Fleet Benefits

2020$ (millions)	2025	2030	2035	2040	2045	2050
Enhanced Baseline	($1,437)	($2,354)	$115	$4,583	$7,322	$10,000
EPA NOx Option 1						
Federal ACT + NOx Omnibus	($1,453)	($7,917)	($1,184)	$9,979	$20,184	$27,961

Table A4 Average U.S. Household and Commercial Customer Electric Bill Savings in 2050

2020$	Household	Commercial Customer
Enhanced Baseline	$9	$56
Federal ACT + NOx Omnibus	$25	$153

Figure A4 U.S. Average Fuel Costs

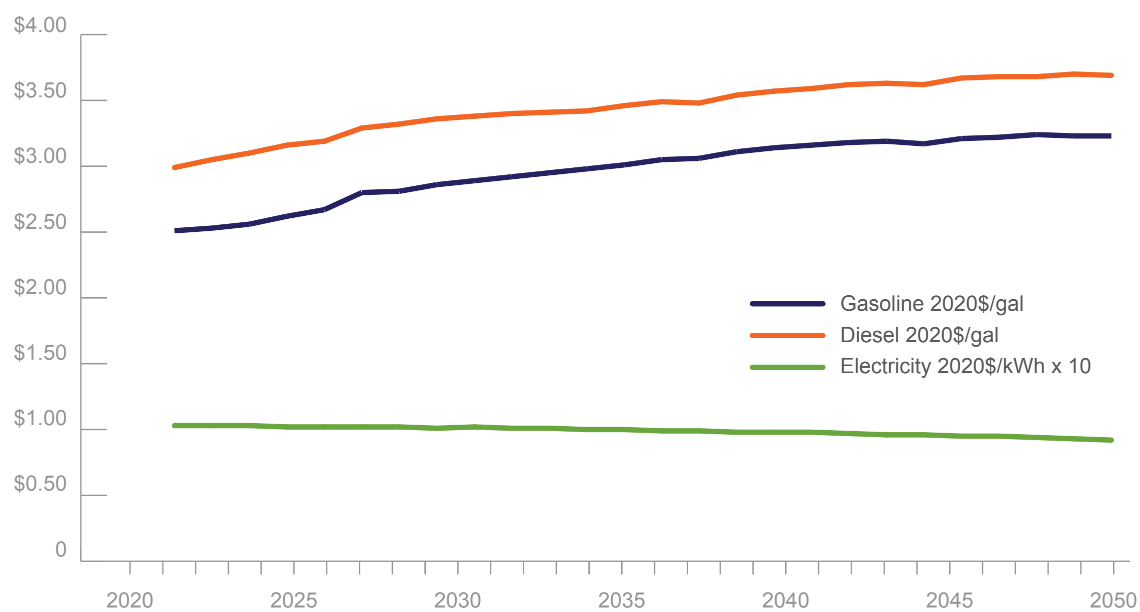


Figure A5 Projected M/HD Fleet Tailpipe NOx Emissions

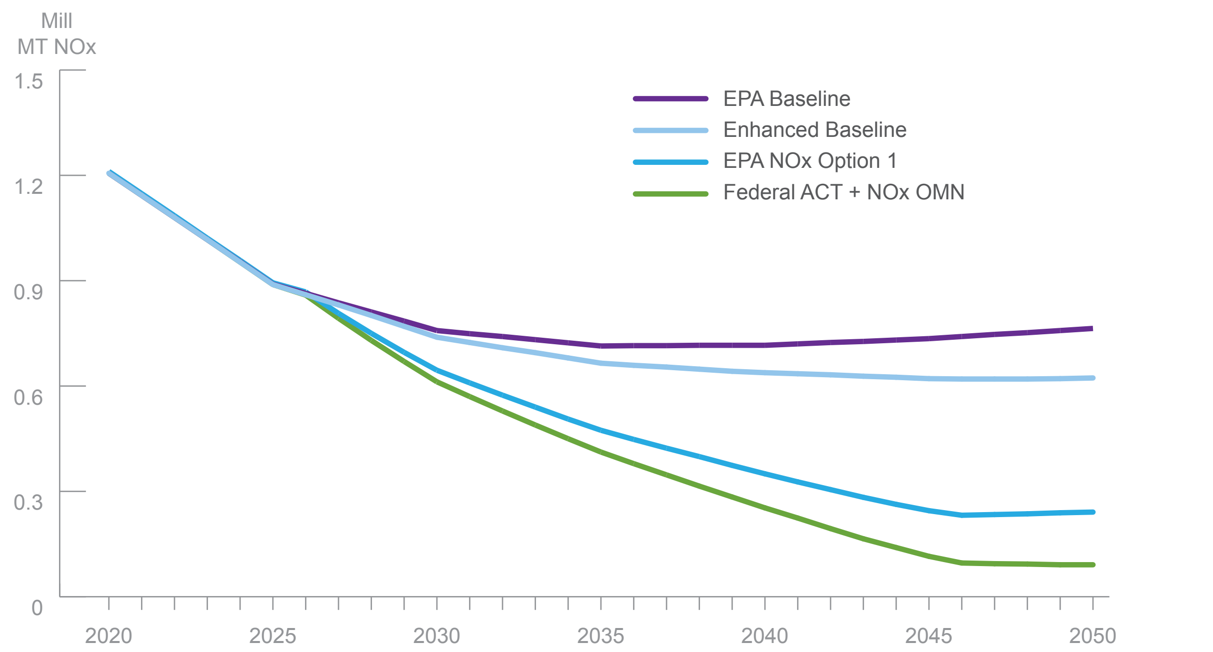
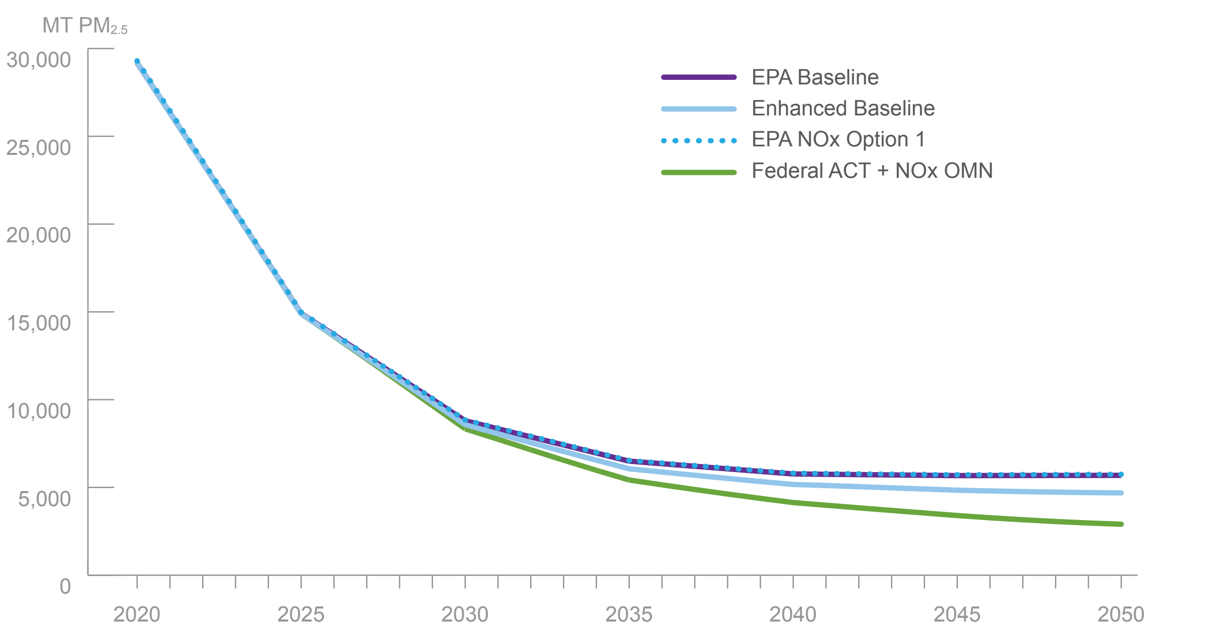


Figure A6 Projected M/HD Fleet Tailpipe PM Emissions



The following chart is being provided for direct comparison to EPA's draft RIA calculated NOx emissions in short tons.

Figure A7 Projected M/HD Fleet Tailpipe NOx Emissions (Short Tons)