September 22, 2025

Submitted via Regulations.gov

Attention: Docket ID No. EPA-HQ-OAR-2025-0194

Re: Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards; 90 Fed. Reg. 36288 (August 1, 2025)

Environmental Defense Fund (EDF) respectfully submits comments on the Environmental Protection Agency's (EPA) Proposed Rule, *Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards*, 90 Fed. Reg. 36288 (August 1, 2025) ("Proposal" or "Proposed Repeal").[1] EDF submits these comments in addition to detailed legal and technical comments it is filing jointly with other health and environmental organizations opposing EPA's deeply damaging proposal to repeal the Endangerment Finding and separate joint legal and technical comments on EPA's proposal to repeal all federal motor vehicle greenhouse gas (GHG) standards ever issued. These comments do not repeat the responses to the myriad deep and pervasive flaws of the Proposal set forth in those other submissions. Instead, this submission focuses on additional technical and scientific information that further evidences those flaws.

The Proposal would rescind federal GHG emission standards for light, medium, and heavy-duty on-road vehicles. Based on EPA's own modeling platforms supplemented with current data and peer-reviewed tools, our analysis shows that rescinding these safeguards would significantly increase harmful pollution and impose very large costs on the public—reversing decades of progress in cutting transportation emissions, undermining public health, and weakening U.S. industrial competitiveness.

Key Findings (through 2055). Relative to a baseline in which today's standards remain in place, the Proposal would **increase** harmful air pollution and climate damages at national scale from light-, medium- and heavy-duty vehicles:

- **Particulate Matter (PM): 68,000** to **169,000 U.S. tons**

[1] We note EPA's request that "commenters include the corresponding identifier when providing comments relevant to that comment solicitation" and "that commenters include the identifier either in a heading or within the text of each comment, to make clear which comment solicitation is being addressed." 90 FR 36288. Pursuant to EPA's request, we note that this comment letter addresses many of EPA's comment solicitations, including but not limited to C-1 through C-27 (exclusive of C-17 and C-18 relating to certain NHTSA programs and C-22 relating to the Paperwork Reduction Act), as well as other germane comments.

- **Nitrogen Oxides (NOx): 2.0** to **4.7 million U.S. tons**
- **Sulfur Oxides (SOx): 37,000** to **54,000 U.S. tons**
- **Volatile Organic Compounds (VOCs): 1.8 to 4.3 million U.S. tons**
- **Greenhouse Gases (GHG): 9.1** to **17.9 billion metric tons**

These increases in pollution will result in significant harms to Americans' health including an increase of:

- **33,000 to 77,000 premature deaths**
- **22 to 52 million asthma attacks**
- **8 to 19 million lost school and work days**
- **52,000 to 122,000 hospital and emergency room visits**

Through 2055, our analysis of emissions from all light-, medium-, heavy-duty vehicles, using a 3% discount rate, projects significant health and climate costs to society:

- **PM2.5 health costs: $100–$260 billion**
- **Climate costs: $1.7–$3.9 trillion**

The net societal harms of the Proposal are overwhelming. Through 2055, our analysis of light- and medium-duty vehicles (LMDVs), using a 3% discount rate, projects:[2]

- **Net costs: $1.7–$4.7 trillion**
- **Additional fuel expenditures: $790–$1,700 billion**

These results reflect a comprehensive assessment that (1) applies EPA's OMEGA compliance and effects models with necessary corrections and conservative assumptions; (2) incorporates the International Council on Clean Transportation's (ICCT) Roadmap modeling for heavy-duty vehicles; (3) accounts for upstream fuel-cycle emissions using DOE's GREET model (2024) and the Energy Information Administration's AEO 2025 (including the Alternate Transportation case aligned with the Proposal's policy environment); and (4) uses up to date power sector emissions factors from Energy Innovation. In multiple areas where EPA's Regulatory Impact Analysis (RIA) departs from current evidence—for example, by excluding core components of upstream emissions, disregarding widely accepted discounting guidance, omitting consumer fuel costs from net benefits, or relying on outdated battery cost assumptions—we identify and correct those deficiencies.

Our analysis also demonstrates that the GHG standards established in the 2024 Rules are **performance based, technologically feasible, and technology neutral,** consistent with decades of standards set by EPA. Multiple, performance-based compliance pathways—centered on improved internal combustion engine efficiency, strong hybrids, and plug-in hybrids, with low to

[2] We were not able to calculate these costs for heavy-duty vehicles due to the limited time provided for comments. Total costs would be higher if heavy-duty vehicles were also included.

moderate levels of battery electric vehicles—can achieve the standards at reasonable cost, even under conservative assumptions. In addition, states with more protective clean vehicle standards already exhibit **significantly greater model availability**, particularly for electrified powertrains, contradicting claims that stronger standards reduce consumer choice.

Organization of these comments. The sections that follow:

1. quantify the Proposal's emissions impacts and public-health and climate damages;
2. detail modeling methods and input updates (vehicles, upstream fossil fuel and ethanol pathways, and power-sector emissions);
3. present cost–benefit results and identify errors in EPA's assessment (fuel savings, discounting, upstream accounting, and grid claims);
4. evaluate technical feasibility and provide alternative compliance pathways for light-, medium-, and heavy-duty segments; and
5. assess market impacts, including effects on model availability, innovation, and U.S. competitiveness.

In addition, we include an appendix setting forth scientific evidence relating to EPA's 2009 finding that greenhouse gases endanger human health and welfare, with a particular focus on scientific literature published after the Duffy et al. 2018 review paper. Like Duffy et al., we find that the latest scientific literature provides even more extensive and definitive support for EPA's 2009 conclusion that greenhouse gas emissions endanger human health and welfare. Finally, we include an appendix noting that EPA itself has consistently reaffirmed and further reinforced the scientific conclusions supporting the Endangerment Finding in its rulemakings and denials of petitions for reconsideration since 2009. The Proposal fails to justify EPA's departure from these long-held, firmly-grounded agency positions.

Taken together, our analysis shows that rescinding federal vehicle GHG standards would substantially harm public health and welfare; in contrast, maintaining—and, where appropriate, strengthening—those standards is both feasible and essential to protect health, advance vital climate safeguards, and support a robust and competitive automotive sector. EPA must withdraw its unlawful and deeply damaging Proposal.

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GLOSSARY OF ABBREVIATIONS

Term	Meaning
2024 HDP3 Rule	EPA, Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles-Phase 3, 89 FR 29440 (Apr. 22, 2024)
2024 HDP3 Rule RIA	Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3 Regulatory Impact Analysis, EPA-420-R-24-006 (Mar. 2024), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101A93R.pdf
2024 HDP3 Rule RTC	EPA, Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3 Response to Comments, EPA-420-R-24-007 (Mar. 2024), https://www.epa.gov/system/files/documents/2024-03/420r24007.pdf
2024 LMDV Rule	EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 89 FR 27842 (Apr. 18, 2024)
2024 LMDV Rule RIA	EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Regulatory Impact Analysis, EPA-420-R-24-004 (Mar. 2024), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1019VPM.pdf
2024 LMDV Rule RTC	EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Response to Comments, EPA-420-R-24-005 (Mar. 2024), https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P1019WE6.pdf
2024 Rules	2024 LMDV Rule and 2024 HDP3 Rule, collectively
CWG Report	Climate Working Group, A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate (July 23, 2025), https://www.energy.gov/sites/default/files/2025-07/DOE_Critical_Review_of_Impacts_of_GHG_Emissions_on_the_US_Climate_July_2025.pdf
EF	Endangerment Finding

Term	Meaning
EF Comment	Comments of Environmental and Public Health Organizations addressing EPA's proposed repeal of the 2009 Endangerment Finding in EPA's Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards, 90 Fed. Reg. 36288
BEV	Battery electric vehicle
EREV	Extended range electric vehicle
EV	Electric vehicle
ICE	International combustion engine
PEV	Plug-in electric vehicle, including BEV and PHEV
PHEV	Plug-in hybrid electric vehicle
ZEV	Zero-emission vehicle

I. U.S. GHG VEHICLE EMISSIONS HAVE LARGE AND CONSEQUENTIAL IMPACTS ON GLOBAL CLIMATE CHANGE

The transportation sector is the largest contributor to greenhouse gas emissions in the United States, emitting more than 1.8 billion metric tons in 2023.[3] Highway vehicles are responsible for 82% of those emissions, making them responsible for 22% of total U.S. greenhouse gas emissions. Transportation sector emissions are also a significant share of global emissions. If the U.S. transportation sector were its own country, it would be the fifth highest emitting country in the world.[4] Our transportation sector emits nearly the same amount of climate pollution as all of Russia each year. And U.S. onroad vehicle emissions alone would be the seventh highest emitting country.[5]

Globally, the U.S. onroad vehicle fleet emits far more carbon pollution than any other nation's onroad sector. In fact, according to a recent analysis by the Institute for Policy Integrity, the U.S.

[3] EPA, Inventory of Greenhouse Gas Emissions and Sinks, 1990-2023. https://library.edf.org/AssetLink/145ky510ew61fk1tq5c2klp5kq5yp33j.pdf
[4] Climate Watch website, Historical GHG Emissions (last accessed Sept. 18, 2025). https://www.climatewatchdata.org/ghg-emissions?end_year=2022&start_year=1990
[5] Id.

onroad vehicle sector emitted more greenhouse gases in 2022 than the next three highest-emitting on-road vehicle sectors - China, India, and Brazil - *combined*.[6] And if we look at cumulative emissions between 1970 to 2022, the U.S. onroad vehicle fleet ranks first in the world, having emitted more than the next *nine* highest countries' vehicles combined.[7]

The U.S. transportation sector's emissions have a consequential influence on global climate. Carbon dioxide (CO_2), the most prevalent greenhouse gas, can persist in the atmosphere for thousands of years, with each year's emissions adding to the existing concentration. This cumulative impact is what makes CO_2 emissions so concerning.[8] EDF climate scientists recently published a study in NPJ Climate and Atmospheric Science calculating the impact of emissions from different economic sectors on global average surface air temperature (GSAT). The published and peer reviewed study looks at the emissions for sectors globally. Using the same methodology, our climate scientists examined the impact of U.S. sector-specific emissions on GSAT. Considering emissions from1750 to 2023, they found the U.S. is responsible for nearly of one-quarter (24%) of the current GSAT warming experienced today, when not considering land use change. Additionally, they found that emissions from 1750 to 2023 from U.S. transportation account for 5.7% of change in GSAT since 1750.[9] If emissions from the upstream fossil supply chain processes in the transportation sector are considered, then the U.S. transportation sector is responsible for more than 6.5% of global contributions to GSAT.[10,11] Therefore, the decisions made today about U.S. transportation emissions will shape the climate for centuries to come, affecting ecosystems, economies, and human health for generations.

Federal GHG standards are effective in reducing climate pollution from the transportation sector. New passenger vehicles today emit 24% less climate pollution than they did in 2011, the year before the first EPA vehicle GHG standard.[12] These improvements reflect technology-neutral, performance-based greenhouse gas standards that have incentivized greater deployment of existing technologies and have spurred advances in engine and transmission design, improved aerodynamics, and electrification.

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[6] Howard, P. et. al. The Scale of Contribution: Vehicles; U.S. Vehicles Are By Far the World's Largest Source of Transportation Pollution, Institute for Policy Integrity, July 2025. https://policyintegrity.org/files/publications/Vehicle_Sector_GHG_Contribution_Issue_Brief_v2.pdf
[7] Id.
[8] EPA, *Climate Change Indicators in the United States: Fifth Edition* 28 (2024) at 7. www.epa.gov/climate-indicators.
[9] Buma, B., Ocko, I., Walkowiak, B. et al. Considering sectoral warming and cooling emissions and their lifetimes can improve climate change mitigation policies. npj Clim Atmos Sci 8, 287 (2025). https://doi.org/10.1038/s41612-025-01131-8. And spreadsheet "Climate Forcers Analysis U.S. 08.02.2025 for EPA" with results from US specific emissions analysis, highlighted cells are for numbered used in comment.
[10] Id.
[11] Electricity emissions are not included in the "fossil fuel production and distribution" emissions for the transportation sector. Because the estimate considers emissions from 1750 through 2023, upstream electricity emissions would have a minimal impact. Accounting for upstream electricity emissions would increase the relative impact of the U.S. transportation sector.
[12] EPA, "The 2024 EPA Automotive Trends Report," 2024. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101CUU6.pdf

The U.S. has been a leader in designing, developing, manufacturing, and deploying advanced technologies that make highway vehicles cleaner and more efficient. Strong federal standards not only drive these innovations forward and cut harmful emissions at home—they also have a powerful ripple effect. Because the United States is the world's second-largest market for vehicle sales and production, and because of our historic leadership in applying emissions control technologies, the U.S. auto sector has had a significant influence on the propagation of these technologies worldwide.[13] Global automakers integrate U.S.-developed technologies into their fleets worldwide, helping reduce emissions in other nations as well. This Proposal to rescind all federal greenhouse gas emissions standards will significantly increase climate pollution from the U.S. transportation sector and could have global implications if technology advancement is halted or slowed.[14]

II. REPEALING VEHICLE GHG STANDARDS WOULD CAUSE MASSIVE EMISSIONS INCREASES AND SOCIETAL HARMS

EPA failed to consider the change in emissions of GHGs and other air pollutants resulting from the Proposal, though quantifying the significant increase in emissions and monetizing certain impacts are readily doable. Indeed, prior to the current proposal, the agency had consistently quantified emissions impacts from all eight of its motor vehicle GHG emission standards rules, applying its own state-of-the-art modeling tools. In the absence of an EPA analysis, EDF analyzed the impact of the Proposal on light- and medium-duty (LMD) vehicle emissions and the associated costs. We also present an analysis ICCT performed to assess the impact of the Proposal on heavy-duty (HD) vehicle emissions.

[13] International Trade Administration webpage, SelectUSA Automotive Industry (last accessed Sept. 20, 2025). https://www.trade.gov/selectusa-automotive-industry#:~:text=Industry%20Overview,the%20United%20States%20in%202023.

[14] Peter H. Howard, Jason A. Schwartz & Mythili Vinnakota, The Scale of Contribution: Vehicles U.S. Vehicles Are By Far the World's Largest Source of Transportation Pollution 3, IPI (July 2025), https://policyintegrity.org/files/publications/Vehicle_Sector_GHG_Contribution_Issue_Brief_v2.pdf (noting the "growing evidence that countries may reciprocally reduce their own emissions in response to U.S. emissions-cutting policies and goals, meaning that every ton of emissions reduced in the United States may be worth several additional tons of reductions abroad. Conversely, increased U.S. emissions could undermine foreign efforts to reduce their emissions. Through a combination of technological spillovers, policy diffusion, and tit-for-tat dynamics, every ton of U.S. emissions could be tied to 2.4-10.8 tons of foreign emissions").

A. The Proposed Repeal would cause significant increases in LMD vehicle emissions and associated fuel, health, and climate costs

1. Methodology

Our analysis uses the EPA OMEGA compliance and effects models to estimate costs and benefits of EPA's Proposal. OMEGA is a state-of-the-art peer-reviewed model developed by EPA to evaluate policies for reducing GHG emissions from LMD vehicles. We made several modifications to EPA's inputs to these models to better reflect the future fleet if the endangerment finding is reversed and all GHG standards for highway vehicles are rescinded. We also improved upon EPA's analysis of the U.S. fuel industry's response to the rescission, as well as the cost of batteries based on recent research. The analysis estimates the increase in emissions and costs to society relative to a baseline where today's standards remain in place and IRA tax credits have been repealed.

Using EPA's OMEGA effects model, EDF was not able to properly run light-duty scenarios which were less stringent than the "NTR" scenario EPA modeled in its 2024 rule and the recent Proposal, which includes the current GHG standards through MY 2026. In order to reasonably estimate vehicle emissions under these scenarios, EDF estimated their values outside the model using projected annual vehicle VMT for each affected scenario and emissions per mile from the 2024 standard scenario.

EPA's assumption in 2024 that 50% of the incremental fuel consumed after a rescission would come from reduced fuel exports makes their "refinery" emission factors incremental in nature. EDF did the same in a more comprehensive manner. As such, the emission factors developed have to apply to the difference in the volume of fuel being refined. This is not possible if different emission factors are being applied to the refined fuel volumes in various scenarios. In OMEGA effects, the same upstream fossil fuel emission factors need to be applied to all scenarios. Thus, we adjusted upstream fossil fuel emissions in all of the scenarios to reflect the emission factors of the 2024 Rules standards scenario (also called the No Action scenario).

The changes to vehicle and upstream fossil fuel emissions necessitated analogous changes to the PM benefits in the social_effects_global_ghg_annual output file from the OMEGA effects model. EDF calculated the PM benefits of the Proposal outside the model by multiplying the changes in emissions from the adjusted physical_effects_annual model output file by the benefits per ton listed in EPA's cost_factors_criteria file.

The OMEGA effects model also estimates vehicular NMOG and NOx emissions on a per ICE and PHEV vehicle basis. This ignores the fact that the standards for NMOG and NOx apply to the fleet as a whole, including zero-emitting BEVs. Based on this corporate averaging, fleetwide NMOG and NOx emissions should not change. To reflect this, EDF set the effect of the various scenarios on tailpipe NMOG and NOx emissions to zero in the OMEGA effects output and removed any PM-related benefit associated with NMOG and NOx emissions.[15]

a. Fleet

For the Proposal, EPA's modeling only removed the GHG standards finalized in 2024 retaining the current standards (finalized in 2021) that increase in stringency through MY 2026 that it also proposes to repeal. Our analysis retains the current GHG standards through MY 2025 but sets the standards in MY2026 to 500 g/mi in EPA's models to simulate repeal of all GHG standards.[16] In an attempt to capture the range of possible outcomes for the vehicle fleet absent all standards, EDF modeled a low and high emitting fleet for both light-duty and medium-duty, as described below. While it is possible that automakers will backslide by manufacturing dirtier vehicles in the coming years compared to today's sales as a result of the Proposal, we do not assume backsliding in any of our scenarios, making this a conservative analysis.

Light-Duty. For LDVs, our low emitting scenario ("No Standards (Low)" in the figure below) is consistent with EPA's modeling of the proposal where BEV sales are allowed to increase as projected for compliance with today's MY2026 standards. The high emitting scenario ("No Standards (High)") assumes EV sales stay at the current level of 10%.[17] This was achieved by restricting the battery capacity in OMEGA. All IRA credits are removed starting in MY2026. This is similar to the assumption EPA makes in its modeling. While we disagree with EPA's removal of the 45X credit in its modeling, to be conservative about the impacts of the tax credit on lowering EV prices, we have also excluded the 45X credit in our analysis.

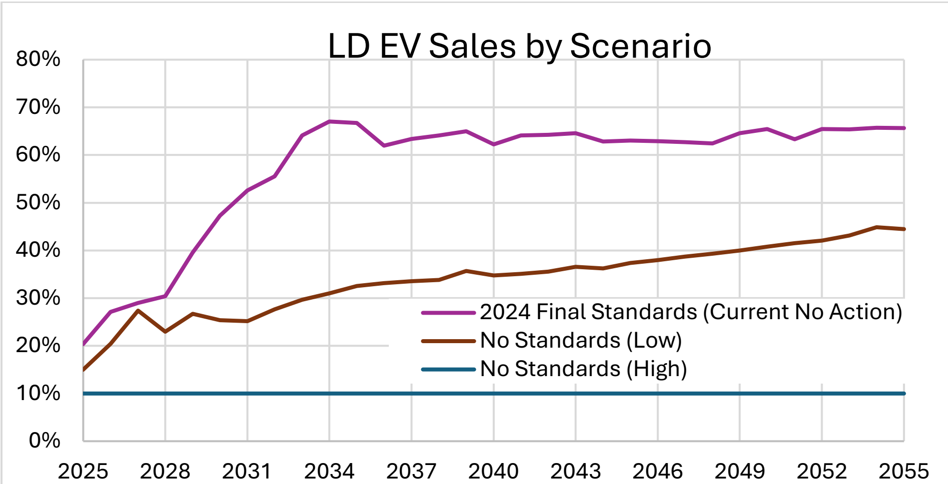
Our baseline, or No Action scenario, assumes the continuation of 2024 LMDV Rule final standards and is the scenario EPA included in its Proposal.

[15] Given the time limitations of the comment period, EDF zeroed out the changes in tailpipe NMOG+NOx since OMEGA does not model this as a fleetwide standard. There is a small increase in NMOG+NOx expected from lowering the VMT in the proposal since it undoes the rebound VMT effects from the 2024 standards. This change is negligible.

[16] The model requires a number so we chose one higher than any vehicles would realistically emit.

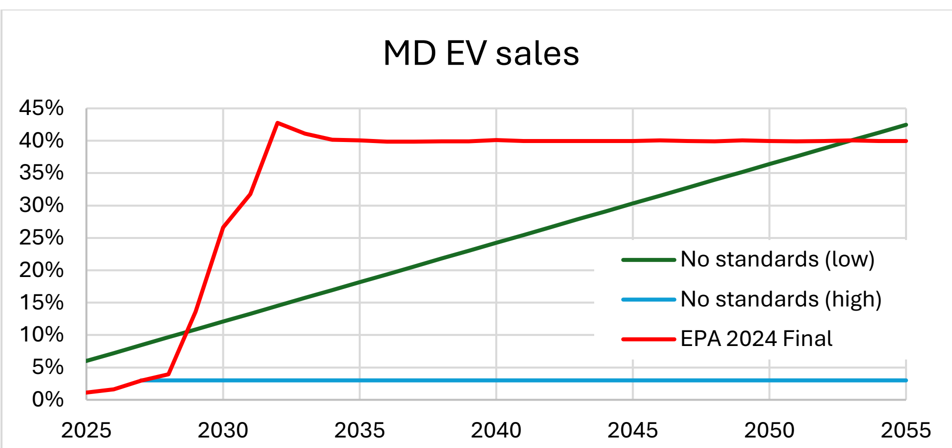
[17] Current EV sales, BEV + PHEV are around 10% with 2024Q4 sales at 10.9% with 8.7% BEVs and 2.2% PHEVs. For the ease of modeling, EDF assumed 10% BEVs for all years going forward in the high-emitting case.

Figure 1: Light-duty EV Sales by Scenario



Medium-Duty. For the action case with a low emitting MD fleet, EDF assumed the level of EV growth from 2022 to 2025 of 1.2% points per year would continue. This is based on MDV sales from Atlas's EV Hub dashboard.[18] It is also consistent with CALSTART's sales dashboard, though the exact numbers differ slightly.[19] For the action case with a high emitting fleet, EDF assumed the current level of BEV sales of 3% going forward. Similar to the LD scenarios, the No Action case assumes the continuation of 2024 LMDV Rule standards that was also used by EPA in its Proposal.

Figure 2: Medium-duty EV Sales by Scenario



[18] Atlas EV Hub (last accessed Sept. 20, 2025). https://www.atlasevhub.com/
[19] Calstart, Zeroing in on zero-emissions trucks Dashboard; MHD ZET deployments and total truck stock by model year (2017-2024), December 2024. Attached. https://calstart.org/zio-zets/#zet-dashboard

b. Strong Hybrid Technology

ICCT recently published a paper analyzing the effect of strong hybrid technology on CO2 emissions.[20] ICCT also estimated the cost of achieving this technology over that estimated by EPA in its 2024 LMDV Rule. In summary, ICCT found that strong hybrids could reduce tailpipe CO2 emissions an additional 15% beyond that estimated by EPA.

EDF incorporated this improved effectiveness for both strong HEVs and PHEVs into EPA's simulated_vehicles_rse_ice and simulated_vehicles_rse_phev files. EDF also increased the cost of strong hybrid technology for ICE vehicles in EPA's powertrain_cost file. EDF did not increase the cost of PHEV technology. The additional ICCT costs pertained to increasing battery size to improve the effectiveness of regenerative braking and time operating on the battery and the size of the electric motor. Both the battery and electric motor capacities on PHEVs are already well above strong hybrid levels, necessitating no change in PHEV design.

c. Upstream – Fossil

EDF conducted a thorough analysis of upstream fossil fuel emission factors to better assess the impacts of the proposal. The discussion that follows describes in detail the approach we undertook to more fully capture the impacts of upstream fossil fuel emissions.

DOE's GREET2024 model[21], in concert with the projections contained in EIA's AEO2025 were used to generate emissions per gallon of fuel delivered to retail fuel stations for crude oil production, crude oil transportation, fuel refining, ethanol production, and distribution of gasoline blendstock, gasoline, ethanol and diesel fuel. Fossil fuels are produced primarily from crude oil. However, oil refineries use many other chemicals to produce finished fuels like gasoline and diesel fuel. These include ethanol, natural gas liquids and hydrogen. The addition of ethanol occurs outside of the refinery after the hydrocarbon blendstock has been produced. The addition of natural gas liquids and hydrogen occurs during the refining process.

There are two primary factors that affect upstream fossil fuel emissions in the context of projecting the environmental and health impacts of GHG standards: 1) the chemical composition of the specific crude oils being refined and 2) the location of the various activities involved in providing fossil fuels to end users. Location of the emissions does not necessarily affect the amount of pollutant emissions. However, in its regulatory analyses, EPA has traditionally excluded emissions of criteria pollutants occurring outside of the U.S. Thus, whether the upstream fossil fuel emissions occur within or outside of the U.S. matters here.

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[20] Aaron Isenstadt and Peter Slowik, *Hybrid Vehicle Technology Developments and Opportunities in the 2025-2035 Timeframe*, ICCT (2025). https://theicct.org/publication/hybrid-vehicle-technology-developments-and-opportunities-in-the-2025-2035-time-frame-feb25/

[21] DOE,R&D GREET Life Cycle Assessment Model webpage, (last accessed Sept. 20, 2025) https://www.energy.gov/eere/rd-greet-life-cycle-assessment-model

No two refineries are identical. The specific chemical processes used to convert crude oil into useable fuels vary across refineries. However, comprehensive analyses of national emissions, like those used in developing DOE's GREET model, consider these differences and their results consider the variety of chemical processes occurring in U.S. refineries. Because EPA's GHG standards affect the use of gasoline and diesel fuel nationwide, they affect all U.S. refineries to roughly the same extent. While changes in national fuel consumption could affect the volumes of fuel produced by some refineries more than others, EPA and NHTSA have historically considered this beyond the scope of their analyses, and we follow the same approach in not further considering this factor.

Both in addressing the impact of crude oil chemistry on upstream fossil fuel emissions and the location of these emissions, it is useful to break down the overall process into several steps: 1) the production of crude oil, 2) the transportation of crude oil to refineries, 3) the refining of the crude oil, including the emissions related to refinery feedstocks other than crude oil, 4) for gasoline, the production and transportation of ethanol to fuel stations, and 5) the distribution of the gasoline blendstock, gasoline containing ethanol, and diesel fuel, to fuel stations. The production of ethanol is handled separately from other feedstocks used to produce gasoline and diesel fuel, like natural gas liquids, as ethanol is not added during refinery processing, but almost always in the tanker truck delivering gasoline to the retail fuel station. The in-refinery processes and the production of non-crude oil feedstocks could be separated. However, the production of the non-crude oil feedstocks strongly tends to be domestic for domestic refineries, so there is no gain here from separating these two items into two steps.

DOE's GREET model estimates emissions occurring in all of these steps. Given that these additional steps associated with petroleum fuel generate emissions, and GREET provides a well-established methodology for evaluating them, We use GREET here to develop a more comprehensive estimate of upstream fossil fuel emissions.

Crude Oil Composition. GREET estimates emissions from producing and transporting roughly a dozen distinct crude oils varying by its source region (e.g., Middle East) and production technology (e.g., U.S. tight oil (fracked oil), Canadian tar sands). EIA's AEO2025 provides important insight into the source of additional crude oil used to produce the gasoline and diesel fuels required due to the rescission of EPA's GHG standards. The reference case of AEO2025 incorporated EPA's 2024 Rules and NHTSA's CAFE standards promulgated in 2024. In contrast, the Alternate Transportation case assumed, among other things, that EPA's and NHTSA's 2024 rules were repealed.[22] The changes between the Reference and Alternative Transportation cases

[22] In addition, the Alternate Transportation case also assumed that EPA's low NOx standards for MY2027 and later heavy-duty vehicles and California's ACT standards were repealed. Also, this case assumed reduced levels of infrastructure build-out related to electric vehicles and that passenger vehicle manufacturers introduce new EVs endogenously based on growth in EV sales, rather than based on plans announced in 2024. See EIA, Annual Energy Outlook 2025: Case Descriptions 9 (Apr. 2025), https://www.eia.gov/outlooks/aeo/assumptions/pdf/case_descriptions.pdf.

reflect the actions proposed by EPA, other announcements made by the Administration relating to enforcement of the CAFE standards, and the resulting business and regulatory climate. Therefore, AEO2025 provides considerable insight into the impact of EPA's proposal on the crude oil and fossil fuel market in the U.S.

Table 11, entitled Petroleum and Other Liquids Supply and Disposition, from the two relevant AEO2025 cases provides most of the relevant data for determining the source of crude oil needed to supply the increased demand for fossil fuels associated with EPA's proposal. Starting with crude oil, Table 11 presents projections of: 1) the volume of crude oil production in the U.S., 2) the volume of crude oil imported, 3) the volume of crude oil exported and 4) the volume of crude oil used in U.S. refineries.

The U.S. both imports and exports significant volumes of crude oil at the same time. This occurs for a variety of reasons, including: 1) the geographical location of refineries (East Coast, Gulf Coast, West Coast, Midwest) and 2) the differences in the chemical composition of crude oil (e.g., heavier oil from Canada and Venezuela, mid-range crude oil from conventional drilling in the U.S., Europe, Middle East, and light fracked oil from the U.S.). Some U.S. refineries, particularly on the Gulf Coast, are designed to process heavier crude oils. GREET incorporates the differences in the oil production and refining technologies in its emission estimates.

Returning to Table 11 of AEO2025, the volume of crude oil used in U.S. refineries to produce fossil fuels is basically the level of: A) domestic crude oil production, B) less exports, and C) plus imports. Imported crude oil is assumed to be produced outside of the U.S. Exported crude oil is assumed to be produced in the U.S.[23] The differences in these crude oil volumes between the two AEO2025 cases is a good indication of the incremental effect of EPA's Proposal. Thus, the analysis presented here should be considered an incremental analysis and not just the application of average crude oil sources under one set of circumstances to a very different set of circumstances.

Table 1 summarizes the changes in domestic crude oil production, imports and exports likely to occur as a result of removing EPA's 2024 Rules for LMD and HDVs on the crude oil market in the U.S. Changes in crude oil volumes in Table 11 between the Reference Case and the Alternate Transportation case were divided by the change in total crude oil processed in U.S. refineries in order to allow the use of the results in GREET. The projections presented in Tables 1 and 2 were averaged over roughly 5-year periods in order to smooth out year-to-year variations consistent with prior and current EPA and NHTSA analyses. The values presented in each row of Table 1 sum to 100%, which represents their contribution to the supply of crude oil necessary to satisfy incremental fuel demand due to the EPA proposal.

[23] Some heavy crude oil from Alberta, Canada is shipped to the U.S. Gulf Coast for export. EDF does not believe that this transitory presence of this crude oil in the U.S. is included in either the levels of imports nor exports of crude oil listed in Table 11 of AEO.

Table 1: Impacts of EPA's Proposal on the Volume of Domestic Crude Oil Used in U.S. Refineries			
Time Period (CY)	Increased Domestic Crude Oil Production	Increased Imported Crude Oil	Decreased Crude Oil Exports
2025-2030	20%	9%	71%
2031-2035	14%	35%	51%
2036-2040	34%	20%	46%
2041-2045	52%	-14%	63%
2046-2050	68%	-64%	96%

For example, during 2036-2040, increased domestic crude oil production provides 34% of the additional crude oil processed in U.S. refineries. Increased imports of crude oil supplies 20% of the incremental crude oil used in U.S. refineries. Reduced exports of crude oil supplies 46% of the incremental crude oil used in U.S. refineries.

The two AEO2025 cases indicate that imports of crude oil would actually decrease after 2040 with the repeal of the 2024 Rules and CAFE standards. To compensate for this reduction in supply in the face of increased demand, the increase in domestic crude oil production and decrease in exports together supply has to exceed the incremental demand for crude oil processed by U.S. refineries. This indicates the importance of considering crude oil economics (e.g., pricing and transportation costs) in making such projections. Table 12 of AEO shows projected crude oil prices, which rise considerably with the repeal of GHG and CAFE standards. Existing crude oil fields are constantly being depleted and new fields drilled. While most crude oil is priced relative to the two reference crude oils (West Texas Intermediate (WTI) and Brent), their absolute prices differ. Oil from new fields will be priced differently from those from older fields. Demand for fossil fuels abroad is also changing, sometimes increasing and sometimes decreasing. Projections of the future based simply on the status quo ignore all such changes.

Crude Oil Refining and Ethanol Production. The above figures indicate the source of incremental crude oil used to produce the higher demand for fossil fuels under the EPA Proposal, but the question remains whether this added supply of domestic fossil fuel production is sufficient to satisfy demand. As well as addressing crude oil supply and demand, AEO2025 Table 11 also shows the volumes of fossil fuels being supplied to the U.S. market, as well as imports and exports of these fuels. Unfortunately, gasoline and diesel fuel production in U.S. refineries is not shown directly. Imports and exports of finished fuels and blendstock are also not broken down by specific fuel. Thus, EDF's estimate of the portion of incremental demand due to EPA's Proposal must be made for gasoline and diesel fuel together. This was the approach taken in prior EPA and NHTSA analyses, as well.

Further compounding this task, fuel exports and imports include fuels or fuel blendstock other than gasoline and diesel fuel.[24] EDF assumes here that any change in fuel exports and imports is either gasoline or diesel fuel, as these are the only two fuels for which supply changes significantly between the two AEO2025 cases. This is conservative from the perspective of this analysis, since the absolute values of the changes in fuel exports are much larger than those for fuel imports. A decrease in fuel exports due to the Proposal means lower incremental emissions from U.S. refineries, which were already producing that fuel.

Given EDF's assumption that the imports and exports of fuel were entirely gasoline or diesel fuel, domestic production of these fuels was determined simply by subtracting the change in fuel imports and adding the change in fuel exports to the change in total incremental fuel supply. Estimating the change in domestic fuel production based on the change in crude oil volume processed in domestic refineries plus refinery volume swell (swell is the increase in liquid volume that occurs during refining due to the fact that fuels are generally less dense than crude oil) yielded comparable results, confirming our approach taken here. Ethanol volume was excluded from these calculations. Ethanol is added to gasoline after the refining of crude oil into gasoline blendstock. The import and export of ethanol is also independent of the import and export of gasoline blendstock. EIA presents projections of ethanol use, imports and exports separately in Table 11 of AEO, which were used to determine the percentage of incremental ethanol use coming from domestic ethanol production.

Table 2 presents the results of this process as a percentage of the total change in domestic fuel supply.

Table 2: Source of Incremental Fossil Fuel and Ethanol Demand Due to EPA's Proposal

Time Period (CY)	Domestic Refining of	Decreased Export of Finished Fuels and Blendstocks	Increased Imports of Finished Fuels and Blendstocks	Domestic Ethanol Production
2025-2030	131%	-32%	1%	84%
2031-2035	109%	-8%	0%	91%
2036-2040	75%	25%	0%	102%
2041-2045	64%	36%	0%	107%
2046-2050	61%	39%	0%	108%

For example, during 2036-2040, domestic fuel production accounts for 75% of incremental gasoline and diesel fuel demand, while decreased exports account for the remainder. Prior to 2036, especially during 2025-2030, the increase in domestic fuel production exceeds the increase

[24] Note that imports and exports of "gasoline" refer to gasoline blendstocks without ethanol. Ethanol's affinity to water restricts the transport of ethanol containing gasoline to very controlled, short distance transportation like the tanker trucks used to convey gasoline to retail fuel stations.

in domestic demand for fuel and exports actually increase. The changes in these fuel volumes prior to 2036 are smaller than those in later years given that the 2024 GHG standards take time to affect the onroad vehicle fleet. Thus, the base values from which the percentages were determined, while significant, are smaller in terms of absolute fuel volumes than those of later years and reflect greater variability.

The percentages shown in AEO Table 11 were used to generate upstream fossil fuel emission factor estimates for each time period using two methodologies: one for criteria pollutants and one for GHGs. Starting with criteria pollutants, one, the upstream fossil fuel emission estimates for each step in the fuel production process were weighted by the domestic and foreign crude oil sources shown in the first two columns of Table 1. Two, the emissions from crude oil production were multiplied by the percentage of increased domestic crude oil production shown in the first column of Table 1. Three, the emissions from refining were multiplied by the percentages for domestic refining shown in the first column of Table 2. Four, the emissions from ethanol production were multiplied by the percentages for domestic ethanol production shown in the last column of Table 2.

EDF assumed that emissions from the transportation of crude oil and distribution of gasoline blendstock, ethanol and diesel fuel occurred regardless of the source of crude oil or finished fuel. This is obvious for gasoline and diesel fuel, as these fuels needed to be shipped to fuel stations regardless of their source. The changes in crude oil transportation are more complex. Increases in crude oil imports increase the emissions of their transportation directly and is included in step 1 above. The same is true for increases in domestic crude oil production. However, reductions in crude oil exports result in less transportation of crude oil to a few shipping hubs and more transportation of crude oil to numerous refineries spread across the country. EDF assumed that the emissions associated with the more extensive shipment of domestic crude oil to refineries was the same as that for domestic crude oils as estimated in GREET. This is reasonable given that the locations of crude oil being exported (tight oil) are more geographically concentrated than average U.S. crude oil production and its shipment to refineries nationwide is more extensive than that for the average domestic crude oil.

The process is much simpler for GHG emissions factors. EDF includes all GHG emissions in its analysis here including the emissions produced in other countries for the fossil fuels used domestically.

The resulting total upstream emission factors for gasoline and diesel fuel are shown in Tables 3 and 4.

Table 3: Upstream Gasoline Emission Factors (g/gallon)					
	2030	2035	2040	2045	2050
VOC	4.18	3.58	2.66	2.34	2.21
CO	2.29	2.10	1.58	1.30	1.13
NOx	3.28	3.33	2.59	1.91	1.39
PM2.5	0.22	0.23	0.17	0.12	0.09
SOx	0.51	0.71	0.50	0.20	0.04
CH4	10.11	11.79	9.45	6.68	5.01
N2O	0.29	0.30	0.30	0.29	0.29
CO2	1,240	1,464	1,267	957	787
GHG	1,622	1,899	1,629	1,234	1,015

Table 4: Upstream Diesel Fuel Emission Factors (g/gallon)					
	2030	2035	2040	2045	2050
VOC	1.31	1.12	0.77	0.63	0.58
CO	2.11	1.95	1.33	0.99	0.87
NOx	2.81	2.94	2.06	1.21	0.67
PM2.5	0.15	0.16	0.11	0.06	0.02
SOx	0.34	0.56	0.38	0.00	(0.30)[25]
CH4	10.9	12.8	9.88	6.29	3.27
N2O	0.03	0.04	0.03	0.02	0.01
CO2	1,358	1,659	1,390	1,010	715
GHG	1,690	2,093	1,693	1,202	814

The upstream emission factors for all pollutants decrease over time. This is primarily due to the decrease in the contribution of crude oil imports and domestic refining over time. Increases in the contribution of domestic crude oil production and ethanol production work in the opposite direction but overall are smaller than the other two factors.

[25] Given that AEO2025 Alternative Transportation case shows a decrease in crude oil imports and an increase of domestic crude oil, the SOx emissions associated with diesel production in the absence of the 2024 rules actually goes down slightly causing this negative emission factor.

Tables 5 and 6 show the upstream emission factors used by EPA in its analysis.

Table 5: EPA Upstream Gasoline Emission Factors (g/gallon)					
	2030	2035	2040	2045	2050
VOC	0.20	0.21	0.22	0.22	0.22
CO	0.19	0.20	0.21	0.21	0.21
NOx	0.29	0.30	0.31	0.32	0.32
PM2.5	0.07	0.07	0.07	0.08	0.08
SOx	0.09	0.09	0.09	0.09	0.09
CH4	0.04	0.04	0.04	0.04	0.04
N2O	0.01	0.01	0.01	0.01	0.01
CO2	663	695	721	736	739
GHG	666	697	724	739	742

Table 6: EPA Upstream Diesel Fuel Emission Factors (g/gallon)					
	2030	2035	2040	2045	2050
VOC	0.04	0.04	0.04	0.04	0.04
CO	0.04	0.03	0.03	0.04	0.04
NOx	0.05	0.05	0.05	0.05	0.05
PM2.5	0.01	0.01	0.01	0.01	0.01
SOx	0.02	0.02	0.02	0.02	0.02
CH4	0.01	0.01	0.01	0.01	0.01
N2O	0.00	0.00	0.00	0.00	0.00
CO2	133	133	133	134	139
GHG	134	133	133	135	140

As the Tables demonstrate, the upstream fossil fuel emission factors used by EPA are a fraction of those estimated here. There are several reasons for this disparity. One, EPA only included emissions from refining. They did not include emissions from crude oil production and transportation, ethanol production, nor fuel and blendstock distribution. Two, EPA based its estimate of refining emissions on its Platform 2016 v3, which only includes emissions from process heaters. These emissions are a fraction of those addressed in GREET. Three, EPA assumed without any supporting analysis or sources that only 50% of the incremental fuel consumption resulting from the Proposal would be refined domestically. The Alternative Transportation case in AEO2025 shows that this is an under-estimation.

d. Upstream – EGU

For electricity emissions, EDF used average emissions from modeling done by Energy Innovation[26] that includes the changes from the recent reconciliation OBBBA and project a lower level of wind and solar construction than EPA's IPM modeling from the 2024 rulemaking. EI's modeling includes EPA's power plant standards including those finalized in 2024 (CPS and MATS).

Table 7: Average Upstream EGU Emissions						
	CO2	VOC	CO	NOx	PM2.5	SOx
	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
2025	304.6	0.0057	0.0775	0.1561	0.0164	0.1502
2030	213.0	0.0045	0.0471	0.0920	0.0111	0.0637
2035	133.4	0.0035	0.0328	0.0622	0.0081	0.0322
2040	104.7	0.0029	0.0277	0.0523	0.0066	0.0289
2045	108.2	0.0026	0.0204	0.0372	0.0055	0.0076
2050	98.1	0.0024	0.0185	0.0338	0.0049	0.0068

e. Changes to other modeling inputs

Battery costs. EDF changed the battery prices used by EPA as they are too high. Updated data on the actual battery price for 2024, according to BNEF, was $115/kWh. EDF instead used battery price projections produced by Roush Industries that were recently updated.[27] EDF extended these battery costs from 2035 to 2055 by applying a learning factor of 1.5%, the same as that used by EPA.

Table 8: Direct Manufacturing Battery Cost ($/kWh)		
Model Year	EDF	EPA
2030	$65	$104
2035	$58	$87
2040	$54	$82
2045	$50	$76
2050	$47	$70
2055	$43	$65

[26] Updated: Economic Impacts of U.S. "One Big Beautiful Bill Act" Energy Provisions, Energy Innovations, (July 1, 2025).
https://energyinnovation.org/report/updated-economic-impacts-of-u-s-senate-passed-one-big-beautiful-bill-act-energy-provisions/ Spreadsheet "EI_EGU_Emissions_Aug2025" attached to comments includes more detailed modeling outputs.
[27] S. Stone*, N. Heck, C. Irwin*, "Battery Cost Projections – Midterm Report," Roush (September 2025).

Due to the short comment period, the changes in battery costs were made after running the OMEGA compliance and effects models using the EPA battery costs. Thus, the change in battery cost affected the cost-benefit analysis but did not affect the composition of the fleet projected by OMEGA.

Gasoline and diesel prices. EDF adjusted fuel prices to reflect the more recent and comprehensive EIA's AEO 2025, while EPA used fuel prices from AEO2023. The relevant gasoline, diesel fuel and electricity prices are shown in Table 9.

Table 9: AEO Fuel Prices			
	AEO2023 Reference	AEO2025 Reference	AEO2025 Alternate Transportation
	Gasoline ($ per gallon)		
2030	$3.07	$2.76	$2.81
2035	$3.10	$2.71	$2.94
2040	$3.16	$2.63	$3.04
2045	$3.18	$2.44	$3.06
2050	$3.33	$2.46	$3.18
2055	$3.48	$2.46	$3.18
	Diesel Fuel ($ per gallon)		
2030	$3.65	$3.34	$3.37
2035	$3.74	$3.43	$3.50
2040	$3.79	$3.53	$3.60
2045	$3.82	$3.66	$3.66
2050	$3.92	$3.78	$3.80
2055	$3.93	$3.78	$3.80
	Electricity ($ per kilowatt- hour)		
2030	$0.14	$0.13	$0.13
2035	$0.14	$0.13	$0.13
2040	$0.14	$0.13	$0.13
2045	$0.15	$0.13	$0.13
2050	$0.14	$0.13	$0.13
2055	$0.13	$0.13	$0.13

EDF used the fuel prices from the Alternative Transportation case of AEO2025 in its estimate of the cost of the Proposal. We did so, because this AEO case closely reflected EPA's Proposal, which is the cause of the increased fuel use and cost. EDF also used the difference between the AEO2025 Alternate Transportation case and the AEO2025 Reference case to estimate the transfer payment which would occur with the Proposal from consumers to oil companies, which is presented at the end of this document.

As was done with battery costs and again because of the short comment period, these changes in fuel prices were made after running the OMEGA compliance and effects models.

2. Results

This section estimates the health, environmental, and economic impacts of the proposed rescission of all greenhouse gas emissions standards for light- and medium-duty vehicles. The increases in harmful pollution and costs to society are relative to the 2024 LMDV Rule. As explained above, EDF made the conservative assumption that no backsliding would occur. However, because EPA's Proposal would removal all federal greenhouse gas standards ever adopted, such backsliding is possible, and if any backsliding did occur with the removal of all standards, the resulting emission impacts and social costs would be even greater.

a. Emission Results

Through 2055, the Proposal is expected to result in an increase from the LMD fleet of:

- **PM emissions: 56,000 to 141,000 US tons**
- **NOx emissions: 0.9 to 2.2 million US tons**
- **SOx emissions: 51,000 to 87,000 US tons**
- **VOC/NMOG emissions: 1.5 to 3.7 million US tons**
- **GHG emissions: 7.9 to 15.3 billion metric tons**

Table 10: PM emissions impact of the Proposal for LMD vehicles (US Tons)

	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	309	953	(447)	**815**	1,469	3,347	(1,849)	**2,967**
2035	1,137	3,353	(1,422)	**3,068**	3,040	7,520	(3,422)	**7,138**
2040	1,096	3,798	(1,844)	**3,050**	2,786	8,315	(4,223)	**6,878**
2045	594	3,404	(1,819)	**2,179**	1,621	7,697	(4,279)	**5,039**
2050	172	2,971	(1,701)	**1,442**	711	7,389	(4,408)	**3,692**
2055	(7)	2,829	(1,606)	**1,216**	355	8,053	(4,772)	**3,635**
Cumulative thru 2055	16,434	80,304	(41,063)	**55,675**	50,717	197,284	(107,360)	**140,641**

Table 11: NOx emissions impact of the Proposal for LMD vehicles (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	-	13,960	(3,713)	**10,247**	-	49,115	(15,359)	**33,756**
2035	-	49,970	(10,965)	**39,005**	-	112,017	(26,390)	**85,627**
2040	-	58,460	(14,552)	**43,908**	-	127,902	(33,325)	**94,576**
2045	-	52,947	(12,429)	**40,518**	-	119,628	(29,231)	**90,397**
2050	-	45,795	(11,621)	**34,174**	-	113,789	(30,109)	**83,680**
2055	-	43,602	(10,969)	**32,633**	-	124,030	(32,597)	**91,433**
Cumulative thru 2055	-	1,228,198	(300,628)	**927,571**	-	3,010,761	(791,277)	**2,219,484**

Table 12: SOx emissions impact of the Proposal for LMD vehicles (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	185	2,644	(2,570)	**259**	686	9,292	(10,629)	**(650)**
2035	775	10,087	(5,666)	**5,195**	1,737	22,617	(13,638)	**10,716**
2040	1,204	8,495	(8,031)	**1,668**	2,634	18,603	(18,392)	**2,844**
2045	1,448	3,886	(2,539)	**2,795**	3,270	8,679	(5,971)	**5,978**
2050	1,491	1,562	(2,353)	**700**	3,701	3,593	(6,095)	**1,199**
2055	1,419	1,516	(2,221)	**714**	4,035	3,890	(6,599)	**1,325**
Cumulative thru 2055	29,664	136,205	(114,869)	**51,000**	73,091	329,646	(316,151)	**86,586**

Table 13: VOC/NMOG emissions impact of the Proposal for LMD vehicles (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	-	16,435	(182)	**16,253**	-	54,961	(726)	**54,234**
2035	-	49,282	(574)	**48,708**	-	111,178	(1,416)	**109,762**
2040	-	62,013	(739)	**61,274**	-	136,476	(1,735)	**134,740**
2045	-	69,042	(804)	**68,239**	-	155,831	(1,929)	**153,902**
2050	-	69,710	(755)	**68,955**	-	171,138	(1,982)	**169,156**
2055	-	67,458	(721)	**66,737**	-	186,398	(2,143)	**184,255**
Cumulative thru 2055	-	1,526,602	(17,440)	**1,509,162**	-	3,740,342	(46,057)	**3,694,285**

Table 14: GHG emissions impact of the Proposal for LMD vehicles (MMT)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	36	39	(8)	**68**	137	24	(33)	**128**
2035	161	55	(22)	**195**	365	61	(52)	**374**
2040	253	78	(27)	**305**	556	74	(61)	**569**
2045	305	93	(33)	**366**	692	74	(78)	**688**
2050	315	97	(31)	**381**	784	75	(80)	**779**
2055	300	95	(29)	**365**	856	82	(87)	**851**
Cumulative thru 2055	6,234	2,343	(691)	**7,886**	15,317	1,795	(1,816)	**15,296**

b. Cost and Benefit Results

The costs of EPA's Proposal to rescind all GHG emissions standards for LMD vehicles are overwhelming. Through 2055, using a 3% discount rate, the low and high emitting cases result in:

- **Net social costs: $1.7 to $4.7 trillion.**
- **Increase in fuel costs for consumers: $785 to $1,740 billion.**
- **PM2.5 health harm costs: $81 to $209 billion**
- **Climate harm costs: $1.4 to $3.3 trillion.**

Table 15: Costs and benefits of the Proposal for LMD vehicles: Low Emitting Case ($billions - 2022 dollars)			
	CY 2055	NPV 3% (GHG 2%)	NPV 7% (GHG 2%)
Vehicle Technology Costs	$(33)	$(663)	$(383)
Insurance Costs	$(1.9)	$(33)	$(19)
Congestion Costs	$(1.4)	$(14)	$(7.4)
Noise Costs	$(0.02)	$(0.2)	$(0.1)
Maintenance Costs	$31	$240	$112
Repair Costs	$3.7	$5.8	$(1.3)
Sum of Costs	$(2)	$(464)	$(298)
Pre-tax Fuel Savings	$(81)	$(785)	$(408)
EVSE Port Costs	$(9)	$(160)	$(96)
Sum of Fuel Savings less EVSE Port Costs	$(73)	$(625)	$(312)
Drive Value Benefits	$(2.9)	$(28)	$(15)
Refueling Time Benefits	$(1.8)	$(11)	$(6)
Energy Security Benefits	$(3.0)	$(34)	$(18)
Sum of Non-Emission Benefits	$(8)	$(73)	$(38)
Climate Benefits, 2% Near-term Ramsey	$(111)	$(1,394)	$(1,394)
PM2.5 Health Benefits	$(4.5)	$(81)	$(48)
Sum of Emission Benefits	$(115)	$(1,475)	$(1,442)
Net Benefits	**$(194)**	**$(1,708)**	**$(1,493)**

Table 16: Costs and benefits of the Proposal for LMD vehicles: High Emitting Case ($billions - 2022 dollars)			
	CY 2055	NPV 3% (GHG 2%)	NPV 7% (GHG 2%)
Vehicle Technology Costs	$(60)	$(1,101)	$(665)
Insurance Costs	$(4.2)	$(68)	$(40)
Congestion Costs	$(2.6)	$(25)	$(13)
Noise Costs	$(0.04)	$(0.4)	$(0.2)
Maintenance Costs	$75	$591	$291
Repair Costs	$17	$80	$33
Sum of Costs	$25	$(524)	$(394)
Pre-tax Fuel Savings	$(218)	$(1,740)	$(888)
EVSE Port Costs	$(8.6)	$(160)	$(96)
Sum of Fuel Savings less EVSE Port Costs	$(209)	$(1,580)	$(792)
Drive Value Benefits	$(5.4)	$(49)	$(25)
Refueling Time Benefits	$(0.2)	$(8.1)	$(5.3)
Energy Security Benefits	$(8.5)	$(81)	$(42)
Sum of Non-Emission Benefits	$(14)	$(138)	$(73)
Climate Benefits, 2% Near-term Ramsey	$(308)	$(3,317)	$(3,317)
PM2.5 Health Benefits	$(14)	$(209)	$(125)
Sum of Emission Benefits	$(322)	$(3,526)	$(3,443)
Net Benefits	**$(571)**	**$(4,721)**	**$(3,913)**

The increase in fuel costs above only capture the increase associated with the incremental fuel (i.e., the gasoline and diesel that will be needed absent the standards) but the gasoline and diesel used in the 2024 rule case will also experience an increase in fuel price associated with repealing the GHG standards. As discussed previously, AEO2025 modeled the removal of the 2024 EPA standards and projected gasoline and diesel would be more expensive with the repeal. This cost would be $438 billion with a 3% discount rate, $241 billion with a 7% discount rate, and $38 billion for the costs only in 2055. EPA has previously considered these costs to be a transfer payment; however, it will result in consumers paying billions of dollars more for fuel. EPA should consider increased consumer fuel costs in the Proposed Repeal.

B. The Proposed Repeal would cause significant increases in HD vehicle emissions and associated fuel, health, and climate costs

The Proposed Repeal would cause significant increases in HD vehicle emissions and associated fuel, health, and climate costs.

1. Methodology

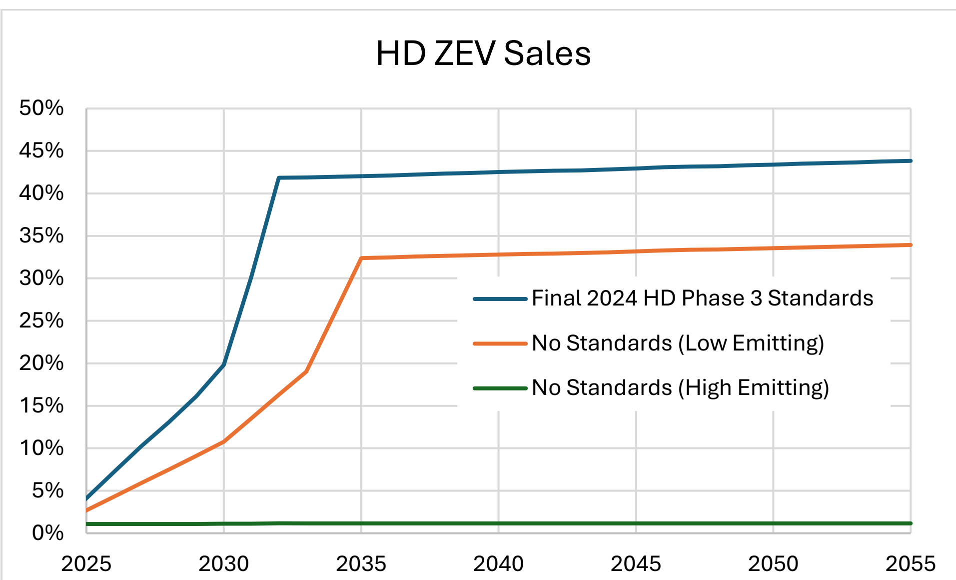
ICCT modeled Class 4 through 8[28] tank-to-wheel emissions using its Roadmap model, which is a global transportation emissions model covering all on-road vehicle activity in over 190 countries. The Roadmap model allows transparent, customizable estimation of transportation emissions for a broad range of policy cases.[29] ICCT's modeling only extended through 2050. For years 2051 through 2055, EDF linearly extrapolated using the change from 2049 to 2050.

a. Fleet

Similar to the methodology used for LDVs and MDVs, ICCT modeled two scenarios of what might occur absent any HD GHG standards. The low emitting scenario ("No Standards (Low Emitting)" in the figure below) uses HD TRUCS to establish a level of ZEVs that might occur absent the standards. The IRA tax credits were removed from the model. The outputs from HD TRUCS were also delayed by three years, so the projections for 2027 are assumed to occur in 2030 and the projections for 2032 occur in 2035, to account for the absence of the regulatory certainty that would have ensured the market was able to keep pace with economic demand for ZEVs as well as the negative pressure the current administration is putting on the ZEV market. The high emitting scenario ("No Standards (High Emitting)") assumes the MY2024 fleet continues as is with no further increase in ZEV sales or improvements in ICEV efficiency.

The baseline or No Action scenario models the continuation of the 2024 HDP3 standards.

Figure 3: Heavy-duty ZEV Sales by Scenario



[28] The HD Phase 3 regulations also covered a small number of incomplete chassis Class 2b/3 vehicles. Those are not included in this analysis since given the short response timeframe, it was not possible to model them.
[29] ICCT website, Roadmap (last accessed Sept. 18, 2025). https://theicct.github.io/roadmap-doc/

b. Upstream

EDF applied the same upstream emission factors discussed above to the fuel use outputs from ICCT's analysis. In addition to gasoline, diesel, and electricity, ICCT modeled vehicles using CNG and hydrogen. EDF used the same assumption EPA did in the 2024 HPD3 Rule that hydrogen would be created using grid electrolysis. EDF used the kWh/kg H2 factors EPA did in their rule, 58.4 kWh of electricity/kg H2 in 2025 and 54.0 kWh of electricity/kg H2 in 2055.[30] For CNG, a relatively minor fuel source, EDF used GREET 2022 well-to-tank values for CNG. EDF used the values for 2021 and 2040 (Table 17) and extrapolated or interpolated for the other years.

Table 17: GREET 2022 upstream emission factors for compressed natural gas (g/kg,100 yr GWP)								
	VOC	NOx	PM2.5	SOx	CH4	N2O	CO2	GHG
2021	0.53	2.1	0.025	0.589	12.0	0.072	429	786
2040	0.53	2.0	0.022	0.55	11.9	0.071	386	740

2. Results

Through 2055, the proposal to rescind GHG emissions standards for HDVs will result in an increase of:

- **PM emissions: 12,000 to 29,000 US tons**
- **NOx emissions: 1.1 million to 2.5 million US tons**
- **VOC/NMOG emissions: 250,000 to 580,000 US tons**
- **GHG emissions: 1.2 to 2.6 billion metric tons**

Table 18: PM emissions impact of the Proposal for HDVs (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	22	68	-28	**62**	54	183	-100	**137**
2035	145	471	-208	**408**	283	907	-387	**803**
2040	338	537	-293	**582**	697	1,168	-590	**1,275**
2045	510	409	-332	**586**	1,151	951	-697	**1,404**
2050	627	197	-360	**464**	1,513	506	-778	**1,241**
2055	688	228	-418	**498**	1,744	608	-921	**1,430**
Cumulative through 2055	10,279	9,240	-7,457	**12,063**	23,677	20,677	-15,674	**28,680**

[30] Table 4-54 Electricity required to produce hydrogen using PEM electrolysis (kWh/kg H2) of the 2024 HDP3 RIA (https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101A93R.pdf)

Table 19: NOx emissions impact of the Proposal for HDVs (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	1,257	1,234	-231	**2,261**	6,317	3,374	-829	**8,863**
2035	9,889	8,571	-1,597	**16,863**	23,798	16,478	-2,971	**37,306**
2040	26,992	10,161	-2,319	**34,834**	58,943	21,918	-4,675	**76,186**
2045	47,409	8,455	-2,246	**53,618**	102,999	19,363	-4,713	**117,648**
2050	63,060	6,165	-2,486	**66,739**	141,295	14,824	-5,364	**150,755**
2055	77,256	7,127	-2,881	**81,502**	176,464	17,686	-6,354	**187,796**
Cumulative through 2055	970,843	196,733	-53,971	**1,113,605**	2,186,824	437,138	-113,400	**2,510,562**

Table 20: SOx emissions impact of the Proposal for HDVs (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	-	168	-160	**9**	-	443	-574	**-131**
2035	-	1,675	-827	**849**	-	3,218	-1,538	**1,680**
2040	-	1,921	-1,281	**640**	-	4,140	-2,583	**1,556**
2045	-	250	-459	**-208**	-	621	-963	**-342**
2050	-	-1,921	-500	**-2,422**	-	-4,298	-1,079	**-5,377**
2055	-	-2,261	-580	**-2,840**	-	-5,114	-1,278	**-6,392**
Cumulative through 2055	-	4,319	-18,780	**-14,462**	-	6,812	-39,299	**-32,486**

Table 21: VOC emissions impact of the Proposal for HDVs (US Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	453	818	-11	1,260	1,012	1,985	-41	2,957
2035	2,186	3,924	-90	6,020	4,154	7,563	-167	11,550
2040	3,809	4,406	-129	8,086	8,178	9,833	-259	17,751
2045	5,815	4,882	-157	10,541	13,202	11,748	-329	24,620
2050	8,387	5,483	-177	13,693	19,714	13,868	-381	33,201
2055	11,066	6,353	-205	17,214	26,712	16,648	-451	42,909
Cumulative through 2055	135,785	117,784	-3,464	250,105	309,197	276,443	-7,286	578,354

Table 22: GHG emissions impact of the Proposal for HDVs (Million Metric Tons)								
	Proposal: Low Emitting Fleet				Proposal: High Emitting Fleet			
	Vehicle	Upstream Fossil	EGU	**Total**	Vehicle	Upstream Fossil	EGU	**Total**
2030	3	1	0	**3**	9	2	-2	**9**
2035	23	5	-3	**25**	44	10	-6	**49**
2040	38	7	-4	**41**	82	16	-8	**89**
2045	52	7	-6	**53**	117	16	-12	**120**
2050	63	6	-7	**62**	147	14	-14	**147**
2055	73	7	-2	**78**	175	17	-17	**175**
Cumulative through 2055	1,115	152	-101	**1,167**	2,516	339	-266	**2,589**

EDF used these emissions results to monetize the health and climate harms from the proposal to rescind GHG emissions standards for HDVs.

For health harms, EDF used the 3% high 2040 benefit-per-ton (BPT) values for PM and PM precursors for internal combustion vehicles, electricity generating units, and oil and natural gas for the upstream refinery emissions.[31] The BPT factors are in 2019$ so EDF converted them to 2022$. Through 2055, the increase in PM and PM precursors as a result of eliminating HD GHG standards would result in between $20.4 billion and $46.6 billion health harms in 3% PV.

For climate harms, EDF used the 2% discounted SC-GHG values from EPA's November 2023 report on social cost of greenhouse gases.[32] These values are in 2020$ so were converted to 2022$. Through 2055, the increase in greenhouse gas emissions from HDVs will result in between $260 billion and $576 billion in climate harms.

C. Conclusions

Key Findings (through 2055). Relative to a baseline in which today's standards remain in place, the Proposal would **increase** harmful air pollution and climate damages at national scale from light-, medium- and heavy-duty vehicles:

- **Particulate Matter (PM): 68,000** to **169,000 U.S. tons**
- **Nitrogen Oxides (NOx): 2.0** to **4.7 million U.S. tons**
- **Sulfur Oxides (SOx): 37,000** to **54,000 U.S. tons**
- **Volatile Organic Compounds (VOCs): 1.8 to 4.3 million U.S. tons**
- **Greenhouse Gases (GHG): 9.1** to **17.9 billion metric tons**

[31] EPA BenMAP website (last accessed Sept. 18, 2025). https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors

[32] Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf , Table A.5 Annual Unrounded SC-CO2, SC-CH4, and SC-N2O Values, 2020-2080

Using EPA's incidences-per-ton factors for 2040[33], EDF calculated the health harms that would result from the increase in emissions using both PM/PM-precursor and O3 precursor factors. Through 2055, the proposal would result in:

- **33,000 to 77,000 premature deaths**
- **22 to 52 million additional asthma attacks**
- **8 to 19 million lost school and work days**
- **52,000 to 122,000 hospital and emergency room visits**

Through 2055, our analysis of all light-, medium-, heavy-vehicles, using a 3% discount rate, projects significant health and climate costs to society:

- **PM2.5 health costs: $100–$260 billion**
- **Climate costs: $1.7–$3.9 trillion**

The net societal harms of the Proposal are overwhelming. Through 2055, our analysis of light- and medium-duty vehicles (LMDVs), using a 3% discount rate, projects:

- **Net costs: $1.7–$4.7 trillion**
- **Additional fuel expenditures: $790–$1,700 billion**

III. EPA'S COST-BENEFITS ANALYSIS IS FLAWED AND UNSUBSTANTIATED

As shown in the EDF analysis above, the Proposal will result in a significant cost increase to society valued in trillions of dollars, including increases in fuel costs, and health and climate harms. EPA's estimation of costs and benefits in the Proposal are inaccurate, and many of the assumptions used to develop the analysis are incorrect and unsubstantiated.

A. EPA's battery costs are unreasonably high

EPA's analysis fails to account for updated battery costs. A new report by Roush shows a continued reduction in battery costs in the next 5-10 years, increasing the affordability of EVs and other electrified vehicles and helping reach price parity with ICE vehicles.[34] The report finds that over the past decade, battery cost projections have consistently overpredicted the price of batteries, meaning the cost of batteries has fallen faster than predictions for both LD and HD

[33] EPA BenMAP webpage (last accessed Sept. 20, 2025). https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors
[34] S. Stone*, N. Heck, C. Irwin*, Battery Cost Projections – Midterm Report, Roush (September 2025).

applications. The price difference between LD and HD applications is also closing as the architecture for battery packs converges on a common cell factor and battery production increases in scale. Further development in battery chemistries, including higher energy density, together with improved EV efficiency designs and supply chain efficiencies will continue to drive down the costs of batteries. EPA failed to acknowledge the current state of battery costs and battery price projections in its Proposal.

EPA also erred in excluding the battery production tax credits (45X) from its analysis to estimate the impact of rescinding federal vehicle GHG rules. As EPA notes in the RIA, "the OBBB modified but did not eliminate the battery production tax credits in 45X."[35] Therefore, it does not make practical sense to exclude those important tax credits from the agency's modeling of the impacts. The 45X credits have already catalyzed billions of dollars in domestic investment—as of July 2025, nearly $186 billion in investments in the US were linked to 45X qualifying facilities.[36]

B. EPA improperly accounted for fuel costs

EPA's assumptions about fuel savings in the Proposal are also incorrect. For example, EPA assumes that consumers only consider 2.5 years of fuel savings, which is unjustified, as we explain in the joint comments of Environmental and Public Health Organizations. The joint comments also address EPA's decision to assign reduced gasoline and diesel fuel prices, despite AEO2025 values and modeling that show repealing the GHG standards will drive gas prices up.

One of EPA's most egregious mistakes in its cost-benefit analysis is failing to account for the massive fuel cost savings that GHG emissions standards deliver to consumers under its Revealed Preferences model. In this portion of the RIA, EPA states that it does not include the fuel expenditures "in order to avoid double counting."[37] An increase in ICEV use, as would occur if the GHG rules are revoked, would clearly result in an increase in fuel consumption by Americans. Every gallon of fuel has a cost, and those costs are borne by American consumers. Calculating the additional fuel expenditures by consumers as a result of this Proposal is imperative to fully understand the cost of rescinding the GHG rules. Indeed, EPA itself appears to recognize this fact, as five of its seven modeling scenarios (outside of the Revealed Preferences model) continue to account for fuel savings, though some erroneously only include 2.5 years of fuel costs or savings. Prior EPA GHG rules have also accounted for the significant fuel savings the GHG standards create for consumers, and EPA does not adequately explain why it no longer agrees with its longstanding approach.[38]

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[35] RIA at 27.
[36] Khatib, M., "Nearly $186 billion in investments linked to 45X Qualifying Facilities," Atlas EV Hub (June 17, 2025).
https://www.atlasevhub.com/weekly-digest/nearly-186-billion-in-investments-linked-to-45x-qualifying-facilities/
[37] RIA at 43.
[38] See, e.g., 89 Fed. Reg. 28092.

C. EPA's use of 3% and 7% discount rates is outdated and incorrect

EPA explains in the RIA that it followed a 2003 OMB Circular A-4 guidance that "recommends agencies to use three and seven percent annual discount rates" for comparing near- and long-term costs and benefits of the Proposal.[39] In contrast, EPA used a 2-percent discount rate when finalizing the 2024 LD rule. At that time, EPA relied on 2023 updated OMB Circular A–4, "in which it recommended the general application of a 2-percent discount rate to costs and benefits (subject to regular updates)."[40]

OMB Circular A-4 provides guidance to federal agencies on how to conduct regulatory benefit-cost analysis. The latest version was issued in November 2023, superseding the 2003 version, and incorporated updated scientific and economic understandings on numerous topics including discounting future effects, assessing the distribution of regulatory impacts, and valuing environmental amenities.[41] Less than two weeks into his term, President Trump directed OMB to rescind the 2023 update to Circular A-4 and to reinstate the outdated 2003 version. This was despite the fact that experts recognized the 2003 guidance was outdated and the discount rates inflated.

EPA should use a 2-percent discount rate as directed by the 2023 A-4 Update because it aligns with economic consensus and represents the best available science. The 2023 update lowered the default, risk-free consumption discount rate used in regulatory impact analysis from 3 percent to 2 percent, based on updated data and extensive economic scholarship.[42] Also reflecting current economic research, the Update eliminated the use of the capital discount rate (7%) and replaced it with the shadow price of capital approach. The update is both consistent with the best available evidence and widely supported by the leading experts in the field. For example, in an article in *Science*, nearly 20 experts (Howard et al.) expressed strong support for OMB's discounting update, explaining that it is consistent with the leading research in the field.[43]

OMB's approach to setting the updated discount rate was consistent with both the agency's past practice and recent economic evidence. In revising the discount rate down to 2%, OMB applied the same basic methodology that was used to calculate the 3% rate back in 2003, averaging the 10-year Treasury rate over the last 30 years.[44] And other approaches support similar or even lower risk-free social discount rates. For example, more sophisticated models based on Treasury yields identify a range of 0.5% to 1.3% with a central estimate of 0.7%.[45] Medium-run forecasts

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[39] 90 Fed. Reg. 36,326.
[40] 89 Fed. Reg. 28106 fn 1361.
[41] OMB, Circular No. A-4, November 9, 2023. https://bidenwhitehouse.archives.gov/wp-content/uploads/2023/11/CircularA-4.pdf
[42] Id.
[43] Peter H. Howard et al., U.S. Benefit-Cost Analysis Requires Revision, 380 Science 803 (2023). https://www.science.org/doi/10.1126/science.adi5943
[44] Proposed OMB Circular No. A-4, "Regulatory Analysis," 88 Fed. Reg. 20,915 (Apr. 7, 2023) at 76. As OMB explains in the Preamble, it adjusted its methodology slightly by applying the 10-year Treasury Inflation-Protected Securities (TIPS) yield for the years it is available (2003-2022). Preamble at 19.
[45] Michael D. Bauer & Glenn D. Rudebusch, The Rising Cost of Climate Change: Evidence from the Bond

from the Congressional Budget Office and Council of Economic Advisors also support rates lower than 2%.[46] Expert elicitations peg the median risk-free social discount rate at about 2%[47] and support a central discount rate of 1% when accounting for the effects of relative prices.[48] Given the availability of updated Treasury yields and other economic data, it makes no sense to retain the use of discount rates based on data from the late twentieth century to the exclusion of more recent data. EPA's decision to use 3% and 7% discount rates in the proposal is out of touch with recent science and economics and should at the very least be updated to 2% to better reflect the impact of the Proposal on future generations.

D. EPA improperly considered the impact the Proposal would have on emissions

EPA's assumption that fossil fuel use will increase in other parts of the world is unfounded and unsupported—in fact, projections show fuel use going down across the world. EPA claims in the RIA that, "discouraging fossil fuel use by U.S. vehicles will encourage additional fossil fuel use elsewhere in the U.S. and world economies." Again, the agency fails to provide any basis for this unfounded claim. In fact, according to IEA's Oil 2025 report that forecasts oil supply, demand, refining and trade dynamics through to 2030, global oil demand is forecast to peak around 105.5 mb/d by the end of the decade.[49] Specifically, China—which has led global oil consumption—is expected to see consumption peak in 2027, as a result of a surge in EVs, the continued deployment of high-speed rail and trucks running on natural gas and a declining population. The increase in EV use is already replacing demand for gasoline in China and there has not been a correlated increase in fossil fuel use elsewhere in the world.[50] It is illogical to assume such a thing would happen in the U.S. where oil displacement associated with increased electrification projected from the 2024 Rules would be drastically smaller than China's. Indeed, any decrease in oil demand in the U.S. by EVs will be far eclipsed by the millions of barrels of oil displaced each

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Market, REV. ECON. & STAT. 12 tbl.1 (2021). https://glennrudebusch.com/wp-content/uploads/Bauer-Rudebusch-SCC-and-rstar-REStat-2023b.pdf (finding an average equilibrium real rate of interest over the past decade of 1.3% using ten-year Treasury notes and 0.7% using one-year Treasury notes).

[46] CONG. BUDGET OFFICE, THE 2021 LONG TERM BUDGET OUTLOOK 43, Tbl.A-2 (2021) (calculating average forecasts of 1.3% to 1.5% over the next 30 years); COUNCIL OF ECON. ADVISERS, DISCOUNTING FOR PUBLIC POLICY: THEORY AND RECENT EVIDENCE ON THE MERITS OF UPDATING THE DISCOUNT RATE 4 (2017), at 6 (citing forecasts from Congressional Budget Office and Blue Chips of 1.2% and 1.5%, respectively.) https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701_cea_discounting_issue_brief.pdf

[47] Moritz Drupp et al., Discounting Disentangled, 10 AM. ECON. J.: ECON. POL'Y 109, 111 (2018). https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2015/06/Working-Paper-172-Drupp-et-al.pdf; Peter H. Howard & Derek Sylvan, Wisdom of the Experts: Using Survey Responses to Address Positive and Normative Uncertainties in Climate-Economic Models, 162 CLIMATIC CHANGE 213, 219 (2020); Robert S. Pindyck, The Social Cost of Carbon Revisited, 94 J. ENV'T ECON. & MGMT. 140 (2019). https://web.mit.edu/rpindyck/www/Papers/SCCRevisitedJEEM2019.pdf

[48] Moritz Drupp et al., Discounting Disentangled, 10 AM. ECON. J.: ECON. POL'Y 109, 111 (2018), at 123 (supporting a discount-rate range of 0% to 2% with a central estimate of 1%).

[49] IEA, Oil 2025, Executive Summary. https://www.iea.org/reports/oil-2025/executive-summary

[50] *Id*.

day across the rest of the world as nations adopt electrification at a far greater pace than the U.S.[51]

EPA fails to consider any impacts from the increased GHG emissions that would result from the Proposal, contrary to how EPA has conducted its previous eight cost-benefit assessments for past rulemakings. And similarly, the assessment largely fails to consider the impact of increased criteria pollutants that would result from this Proposal.

The discussion in EPA's Appendix B Section 2 asserts that there will be leakage of emissions as a result of the standards without providing a single piece of support. This discussion also claims that upstream emissions are not part of EPA's analysis of vehicle standards; where in fact EPA has included upstream emissions in the assessment of the impacts of vehicle GHG standards in all of its prior regulatory analyses. While asserting that upstream emissions were not properly considered in previous rulemakings, this Proposal makes no attempt to include the upstream fossil fuel impacts from increasing gasoline and diesel use (production, refinery, transportation, etc.) or upstream electricity emissions, despite having an assessment of the grid in the revealed preferences model (*see* below for more discussion of the deficiencies of that assessment).

E. EPA's analysis on the electric grid impact of the Proposal is unjustified and incorrect

EPA asserts in the RIA that the Proposal would improve grid resilience in the U.S. and offer $10-$21 billion in annualized cost savings.[52] However, EPA does not conduct the power system modeling it has long relied on to estimate these grid costs. Instead, its calculations are based on a non peer-reviewed working paper, grafts on an invented "80% renewables" frame, misstates units and scaling, and ignores large, quantified liquid fuel costs while double-counting purported EV electricity "opportunity costs." That is arbitrary and capricious. A lawful analysis must rerun EPA's own models with current inputs, treat fuels symmetrically, and incorporate well documented managed charging benefits. Below we outline a list of critical technical defects with EPA's RIA, based principally on work by ERM.[53]

First, EPA abandoned its own tools without justification. In the 2024 Rules, EPA used its state-of-the-art Integrated Planning Model (IPM) and the Retail Price Model to forecast retail prices and found that the 2024 Rules would cause no change to retail electricity prices in 2030 and only

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[51] See IEA, Outlook for energy demand, https://www.iea.org/reports/global-ev-outlook-2025/outlook-for-energy-demand ("Expanding EV adoption continues to reduce oil demand, with oil displacement growing by 30% to over 1.3 mb/d in 2024 – equivalent to Japan's entire transport sector oil demand today. By the end of the decade, EVs are set to displace over 5 mb/d of diesel and gasoline in the STEPS, and China's EVs to account for half of displaced oil."); BNEF, 2025 Electric Vehicle Outlook ("By 2030, road fuel consumption would have been 5.3 million barrels per day higher had every kilometer driven by EVs been driven with an ICE vehicle.").
[52] RIA at 37, Table RIA-1.
[53] ERM, Review of the electricity grid opportunity cost in the EPA's 2025 Draft Regulatory Impact Analysis on vehicle GHG emissions standards (Sept. 2025).

a ~2.5% increase by 2055, driven by distribution upgrades, after fully accounting for needed capacity, T&D, and distribution upgrades. In its draft RIA, EPA did not rerun those models, did not update inputs (e.g., permitting sensitivities), and did not explain why it refused to use tools it previously called state of the art. Failing to use readily available, agency standard models—and failing to explain that choice—is arbitrary and capricious. EPA had the models, didn't use them, and didn't say why.

Second, EPA's assumption that the 2024 Rules would require an electric grid with 80% renewables is unjustified. EPA's "strained grid" calculation hinges on a 2023 Fitzgerald & Mulligan (F&M) working paper[54] that prices EV electricity in an electricity system assumed to be 80% renewables. The vehicle GHG standards do not require an 80% renewable share in any year, nor does EPA include the emissions impacts associated with an 80% renewable grid in this RIA. Rather, EPA's 2024 Rules assume ~45% non-hydroelectric renewables by 2035 and >75% by 2050 based on market and other factors, and actual 2023 U.S. generation was far lower. Assuming 80% renewables in *every* year is wrong on its face. EPA never justifies this assumption, never explains why benefits of higher renewables are excluded, and never ties it to the vehicle standards. That is indefensible.

Third, EPA relies on outdated renewable cost inputs that inflate costs. EPA and the F&M paper lift the renewable cost curve from an old literature chain (e.g., from an older 2014 paper by Mai with scenarios built on 2009–2010 capex) and then treat that as today's marginal supply cost. Those vintage costs are 4.6 times (solar) and 2.5 times (onshore wind) higher than updated EPA IPM and IRENA projections—meaning the DRIA's "opportunity cost" is systematically overstated. Using decade old costs when current agency datasets exist is arbitrary and capricious.

Fourth, EPA's calculations of "opportunity cost" are opaque, mis-scaled, and error prone. The RIA imports F&M's 1 billion MWh EV load premise (then misstates it as 1 TWh in places), arbitrarily estimates a cost of $107/MWh, subtracts $50/MWh with no sourced basis, and scales a $57 billion resulting cost to $10–21 billion via an unexplained discounting of EV shares. EPA provides no coherent method for these steps and points to an appendix that doesn't contain the method. Basing a decisive line item on unexplained unit errors and undisclosed scaling is indefensible.

Fifth, EPA's approach treats different fuels asymmetrically. The RIA effectively debits EVs for electricity costs (via "opportunity cost") while it refuses to count massive liquid -fuel spending that the same RIA tallies earlier (at up to $1,300 billion[55])—waiving it away as "embedded in consumer surplus." That is classic double counting and cherry -picking: charging EVs for fuel but not charging ICE vehicles for fuel when the agency has quantified those costs. EPA offers no defensible explanation.

[54] Fitzgerald and Mulligan, The economic opportunity cost of green recovery plans, NBER Working Paper 30956, (Feb. 2025).
[55] RIA 28.

Sixth, the premise that EV load raises electricity prices is contradicted by evidence. That premise is backwards. Empirical studies show EVs add utility revenue faster than costs and can lower average rates—especially with managed charging (off-peak) and as sales grow.[56] EPA ignores this body of evidence.

Seventh, EPA contradicts itself on load drivers and transmission. EPA elsewhere concedes that data centers—not EVs—dominate new demand,[57] and its 2024 rules found minimal new transmission needs (~1% or less), largely within existing rights of -way.[58] Nothing in the RIA shows those findings are wrong. Yet EPA still blames the vehicle GHG standards for the "strained electric grid" without updated modeling, while simultaneously appearing intent on pushing through massive development of AI data centers through expedited processes, without the usual Clean Air Act permitting safeguards.[59] That is arbitrary and capricious.

Eighth, EPA's suggestions that the grid is generally strained by increasing EV demand and other factors are also belied by other robust analysis. A 2025 Analysis Group report examined the main drivers of current and projected electricity demand, along with practices and technologies for managing demand growth.[60] It found no evidence of an "energy emergency" in the United States: forecasted demand remains within historical norms, and existing markets and planning processes are well equipped to meet demand growth. Importantly, forecasts already conservatively account for rising demand from data centers and the electrification of vehicles and buildings. Demand over the next decade is expected to be higher than recent decades but is still within growth rates that the industry has experienced and reliably met previously. And historically, forecasts have overestimated future needs. The analysis also concluded that, regardless of demand growth levels, the supply response will be sufficient due to declining connectivity costs, net capacity growth, transmission investments, improved efficiency, and stronger planning, policies, and practices.

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[56] Synapse Energy, Electric Vehicles are driving rates down for all customers, National Update, January 2024, https://www.synapse-energy.com/sites/default/files/Electric%20Vehicles%20Are%20Driving%20Rates%20Down%20for%20All%20Customer%20Update%20Jan%202024%2021-032.pdf ; Yanning Li and Alan Jenn, Impact of electric vehicle charging demand on power distribution grid congestion, April 2024, https://www.pnas.org/doi/epdf/10.1073/pnas.2317599121

[57] The RIA states that the massive demand growth from AI and other data centers "significantly outweighs the level of incremental electricity demand from LD, MD, and HD PEV charging projected by the adoption of LMDV and HD GHG Phase 3 Standards" and that "the impact of reducing demand from PEV charging is likely to be small in comparison to the impact from increased data center demand. For example, in 2030, PEV charging demand from all vehicle categories will be reduced by approximately 64 terawatt-hour (TWh) compared to new demand from data centers of approximately 600 TWh." RIA 12.

[58] 89 FR 28020-21.

[59] EPA, EPA Convenes AI Roundtable at White House, Administrator Zeldin Highlights Permitting Reform to Make U.S. the AI Capital of the World (Sept. 15, 2025), https://www.epa.gov/newsreleases/epa-convenes-ai-roundtable-white-house-administrator-zeldin-highlights-permitting.

[60] Paul Hibbard et. al. "Meeting Forecasted Growth in Electricity Demand," Analysis Group (Aug. 6, 2025).

In sum, EPA fails to give any sound reasoning why the 2024 Rules would cause stress or disruptions to the U.S. electric grid or why the Proposal would provide any improved grid resilience. The above technical errors, individually and collectively, are fatal to EPA's claims about the grid. EDF recommends that EPA should conduct full power system modelling to understand the true cost impact of removing the GHG standards on the electricity grid—using accurate renewable electricity technology cost data, correcting the above-noted errors, applying updated data and assumptions, treating electric and liquid fuels symmetrically by accounting for the costs of both fuels, and considering both the costs of additional electricity use and the benefits of managed charging and VGI. EPA often does such modelling for CAA rules and has the capacity and tools needed. It is inexcusable that EPA failed to do so in this proposal.

F. An increase in EVs will not impact safety

In the 2024 LMDV Rule, EPA considered the impact of projected changes in vehicle weight on safety, including heavier BEV vehicles.[61] EPA consulted with, and considered analysis provided by, the National Highway Traffic Safety Administration (NHTSA), which found no statistically significant impact on safety due to vehicle weight changes, holding vehicle footprint constant.[62] EPA notes in the final rule there is "strong reason to believe that PEVs are at least as safe as ICE vehicles, if not more so."[63] EPA also considered the possible safety effects of changes in fleet composition due to changes in new vehicle sales and fleet turnover, also considering underlying analysis by NHTSA.[64] Based on these analyses, EPA concluded that "there are no changes to the vehicles themselves, nor the combined effects of fleet composition and vehicle design, that will have a statistically significant impact on safety."[65]

EPA also explained in its 2024 Phase 3 Heavy-Duty GHG rulemaking that numerous standards and codes are required by manufacturers to govern heavy-duty BEV safety.[66] The agency noted that BEVs must meet the same federal safety requirements and undergo the same safety testing as combustion vehicles.[67] EPA also requested input from NHTSA during the rulemaking process and included a summary of the correspondence to the docket.[68] Among other conclusions, NHTSA noted that when considering BEV weight risk, it is "not aware of differences in crash outcomes between electric and non-electric vehicles" and continues to monitor the topic closely and conduct extensive ongoing research. As part of NHTSA's Battery Safety Initiative, the agency works closely with the U.S. Department of Energy, U.S. Department of Homeland

[61] 89 Fed. Reg. at 28137-8; RIA Ch. 9.4.
[62] 89 Fed. Reg. at 28137.
[63] Id.
[64] RIA Ch. 9.4.
[65] 89 Fed. Reg. at 28138.
[66] 89 Fed. Reg. at 29493; Phase 3 RIA Ch. 1.5.2.
[67] DOE, *Maintenance and Safety of Electric Vehicles,* Alternative Fuels Data Center, https://afdc.energy.gov/vehicles/electric_maintenance.html
[68] Landgraf, Michael. Memorandum to docket EPA–HQ–OAR–2022–0985. Summary of NHTSA Safety Communication. February 2024. https://www.regulations.gov/document/EPA-HQ-OAR-2022-0985-3561

Security, vehicle manufacturers, standards development organizations, first responders, vehicle owners, and others to help advance high-voltage battery safety.[69] NHTSA is currently chairing the development of Phase 2 of Global Technical Regulation No. 20 for Electric Vehicle Safety at the United Nations.[70]

There is also significant evidence supporting the safety of EVs from the scientific community. Evidence shows that BEVs "are at least as safe" as combustion vehicles in terms of crashworthiness test performance, while "injury claims are substantially less frequent" for BEVs than for combustion vehicles.[71] And on some safety metrics, BEVs perform substantially better than combustion vehicles. Due to their battery architecture, for example, BEVs typically have a lower center of gravity than combustion vehicles, which increases stability and reduces the risk of rollovers.[72]

G. The impacts of the Proposal on fleet turnover are small

EPA's claim in the Proposal that "GHG emission standards may harm, rather than advance, public welfare" by reducing fleet turnover is unsupported by the record and contrary to the evidence and EPA's findings in previous rulemakings. The agency cites no data or analysis to substantiate this assertion, and moreover, it fails to demonstrate how a minimal and temporary decrease in fleet turnover would outweigh the significant public health and welfare benefits of reduced emissions of greenhouse gases and other pollutants resulting from the standards.

In recent LD and HD vehicle GHG rulemakings, EPA estimated and accounted for a decrease in new vehicle sales resulting from the proposed regulations. In each proposal, EPA found a very small decrease in new vehicle sales and determined that the emissions reductions from the final standards far outweigh any temporary effect from delayed new vehicle purchases.

For example, in the 2021 LD rule, EPA estimated that vehicle sales would only decrease by up to 1 percent compared to sales in the baseline.[73] And in the 2024 LMDV Rule, EPA estimated the drop in new vehicle sales to be even smaller than in the 2021 rule.[74] EPA used OMEGA to model the impacts of changing vehicle sales – as new vehicle sales fall, OMEGA adjusts the VMT of the existing vehicles upward. EPA then used vehicle sales, fleet turnover, VMT, vehicle weight and other factors to determine the impact of the rulemaking on safety. EPA found that under the 2024 rule, "there is no statistically significant change in the estimated risk of fatalities

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[69] NHTSA website, Battery Safety Initiative (last accessed Sept. 18, 2025). https://www.nhtsa.gov/battery-safety-initiative
[70] Id.
[71] Insurance Inst. for Highway Safety, *With More Electric Vehicles Comes More Proof of Safety* (Apr. 22, 2021), https://www.iihs.org/news/detail/with-more-electric-vehicles-comes-more-proof-of-safety
[72] DOE, *Maintenance and Safety of Electric Vehicles,* Alternative Fuels Data Center.
[73] 2021 LD Rule RIA 8-10.
[74] 2024 LMDV Rule RIA 4-65.

per distance traveled."[75] In the Proposal, EPA does not provide any justification for the agency's change in position.

In the 2024 HDP3 rule, EPA also considered the impacts of fleet turnover based on the amount of pre-buy or low-buy estimated to occur. EPA stated that if pre-buy or low-buy were to occur there would be a decrease in sales of new vehicles subject to the standards. However, EPA expected the rule "to result in little pre-buy or low-buy, if it occurs at all."[76] In the Proposal, EPA asserted the price demand elasticity for MD and HD to be -1 without providing any sources or justification for that value.

In the above-cited GHG rulemakings, EPA addressed the impact of decreased new vehicle sales on fleet turnover and determined that the impacts were small or unlikely to occur at all. In the current Proposal, the agency fails to show awareness of its prior findings, to explain its change in position, or to provide any new analysis showing that fleet turnover effects would outweigh the massive benefits of the existing GHG standards on public health and welfare.

H. EPA's assertions about utilization rates are misguided

EPA argues in the Proposal that the 2024 Rules will alter utilization rates, with ICE vehicle driven more miles than EVs. The agency provides no supporting evidence or credible justification for this claim. Its only citation is an analogy to post-1960s Cuba, where consumers maintained American-made ICE vehicles well beyond their useful life after losing access to new ones. This comparison is wholly misguided as the 2024 standards would not deprive Americans of access to ICE vehicles. On the contrary, new ICE vehicles would continue to improve in quality and efficiency, while EVs would expand consumer choice in clean affordable vehicles rather than restrict it.

EPA goes so far as to quantify the ICE-EV utilization rate elasticity as 0.3 without providing any support for that value. This approach is in direct contrast to the approach EPA took in the 2024 LMD Rule where it extensively reviewed the research and the literature and concluded that "the existing empirical evidence does not support the conclusion that current or future average annual eVMT differs or will differ from annual VMT for ICE vehicles. Therefore, EPA uses the same annual VMT for PEVs and ICE vehicles throughout our analyses."[77]

EDF looked at a number of studies that compare the VMT of EVs and ICEVs and what factors impact utilization rates. In sum, they conclude that today's EVs are driven the same or more than ICEVs. While some earlier studies found that EVs were driven fewer miles per year than their ICE counterparts, those conclusions were based on the shorter range of first generation PEVs, as

[75] 89 FR 28093.
[76] 2024 HDP3 RIA 414.
[77] 2024 LMD Rule RIA at 4-25.

EPA acknowledged in the 2024 LMD Rule.[78] Newer studies described below rely on the longer range of today's EVs.

A 2022 study by Jia et al found ZEVs are driven as much as, or more than, ICEVs.[79] The study also concluded that the eVMT of BEV households is positively associated with Level 2 home charging capability, vehicle range, access to workplace DC fast charging, and access to public Level 2 and DC fast charging stations. Another 2022 study reaffirms this conclusion.[80] Their results show that newer model EVs are driven the same amount as ICEVs and eVMT is correlated with traditional factors like population density, vehicle range, refueling infrastructure, attitudes towards technology, and lifestyle preferences. There is no indication that offering additional access to EVs would drive up the use of ICE vehicles. To the contrary, another study provides evidence that households' adoption of EVs reduces both annual ICE mileage and gasoline consumption.[81] That study also finds among EV buyers, lower income households reduce fuel consumption more than higher-income households by either substituting an EV for a less fuel-efficient vehicle or by further increasing EV use for household driving.

I. EPA's calculation of vehicle composition impacts in its revealed preferences modeling is unjustified and filled with errors

Resources for the Future's comments include a robust discussion about many of the flaws in EPA's revealed preferences modeling. In addition to the problems they identified in their comments which focus on the "market" scenarios, EPA also erred in its calculation of the "EPA" scenarios. EPA's use of previous technology costs and assumption that technology costs will scale linearly with stringency is unsupported. EPA's entire methodology for the revealed preferences modeling is contrary to the previous eight EPA vehicle regulations, and EPA provides extremely limited justification for the change. This is an improper way of assessing the cost and benefits of a CAA regulation.

In addition to the entire methodology being flawed, there are also many errors within the choices EPA made. EPA's use of the SAFE rule as "zero" in assessing the relative stringency of standards is unsupported and arbitrary. If EPA used 0 mi/ton CO2 as zero instead of using 4,975 mi/ton CO2, the relative stringency of the 2024 rule would be 1.9 times the 2012 standards and 2.0 times the 2021 standards. Instead of using the detailed technology costs EPA calculated in the

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[78] 2024 LMD Rule RIA at 4-23.

[79] Jia, W. et. al. 2022. Beyond Adoption: Examining Electric Vehicle Miles Traveled in Households with Zero-Emission Vehicles. *Transp. Res. Rec*. 2676(7). DOI: 10.1177/03611981221082536

[80] Chakraborty, D et. al. 2022. Integrating plug-in electric vehicles (PEVs) into household fleets- factors influencing miles traveled by PEV owners in California. *Travel Behaviour and Society*, 26, 67-83. https://www.sciencedirect.com/science/article/pii/S2214367X21000867

[81] Blundell, W. et. al. 2024. Households' short-run heterogeneous use of electric vehicles: Implications for public policy, Washington State University, School of Economic Sciences. https://static1.squarespace.com/static/57525876e32140c54971248e/t/66873c4f9034666299f0fb54/1720138832923/EV_Utilization_and_Policy_July.pdf

2024 rule, the Proposal uses a scaling of a previous rule's costs without any justification for why this would be a good proxy.

IV. EPA FAILED TO CONSIDER TECHNICAL FEASIBILITY OF GHG POLLUTION CONTROLS

EPA's Proposal offers scant discussion of technological feasibility. In the preamble, EPA asserts that no requisite technology exists for motor vehicles to remove GHGs from the ambient air.[82,83] But the agency provides no analysis of the feasibility of the standards it proposes to repeal, none of which require vehicles to remove GHGs from the ambient air. At the same time, EPA does not seem to contest the continued availability of GHG control technologies—such as improved ICE and transmissions, hybrid technology, PHEVs, and zero-emission BEVs—and the effect of GHG emission standards in driving their adoption.[84]

In contrast to this Proposal, each prior vehicle GHG rule included rigorous analysis of technical feasibility. Both of the 2024 Rules devoted thousands of pages of text, supported by comprehensive technical modeling, to support the feasibility of the final standards. Over the last decade, EPA has catalogued the availability of diverse GHG control technologies for light, medium, and heavy-duty vehicles. These include but are not limited to:

- advanced internal combustion engine efficiency technologies, including low-rolling resistance tires, improved aerodynamics, lightweighting, and improved engine technologies;
- fuel-switching to other fuels with internal combustion engines, e.g., natural gas vehicles and hydrogen internal combustion vehicles (principally for heavy-duty); and
- powertrain electrification, e.g., mild hybrids, strong hybrids, plug-in hybrid electric vehicles, battery electric vehicles, and fuel cell electric vehicles.

EPA also consistently evaluated the supply chain of materials to produce control technologies, concluding that such materials were sufficiently available within the lead-time provided. In addition to detailing the feasibility of available technology, EPA used modeling to show that the performance-based standards could be achieved through a combination of technologies, with no singular technology being required. This Proposal fails to address any of these prior analyses, or to provide an updated analysis of technological feasibility. Our updated analysis continues to

[82] Preamble V.A-B
[83] The absurdity of this claim that vehicles would need to remove GHGs from the ambient air is further discussed in the Joint Environmental and Health Organization comments.
[84] See 90 FR 36306/2 (alleging that "our GHG emission standards mandate an increased and faster shift from gasoline fueled vehicles to electric vehicles on the theory that a substantial reduction in GHG emissions is necessary to address global climate change concerns").

demonstrate the technical feasibility of the GHG standards, including the latest standards set in the 2024 Rules.

A. New developments since finalization of 2024 Rules further support the feasibility of the standards

Despite EPA's failure to provide any information on feasibility, and despite the significant erosion of supportive federal policies and programs, it has only become clearer that the transition to clean and zero-emission vehicles remains on a firm and irreversible trajectory. The momentum toward electrification is being sustained by manufacturer commitments, technology and manufacturing innovations and intense global competition. Manufacturers have made clear, through their announced commitments and multi-billion-dollar investments, that electrification is the future and have directed their focus toward making electrification profitable and sustainable.

1. Domestic legal and policy changes

Actions including the imposition of tariffs on imported vehicles, parts, battery cells, and critical raw materials; the repeal of critical tax credits; changes to enforcement policies and civil penalties for fuel economy standards; and the unprecedented and improper Congressional Review Act resolutions purporting to disapprove EPA waivers that have historically allowed California to implement stricter vehicle emissions standards have undermined clean vehicle investments.

EPA points to these events as increasing the costs of clean vehicles[85] and undermining the analysis performed in the 2024 Rules.[86] However, EPA fails to recognize that clean vehicle adoption is driven not merely by the policies of the current administration, but by diverse economic, technological, market, and regulatory factors. Despite the administration's attempts to undermine the clean vehicle ecosystem, a holistic review of the landscape demonstrates continuing progress toward clean vehicle production and use.

2. Manufacturers continue to invest in clean vehicles

In the face of this policy upheaval, major U.S. vehicle manufacturers have not abandoned their clean vehicle strategies but have instead redefined their strategies to prioritize profitability and long-term sustainability. In recent months, manufacturers have repeatedly affirmed that electric vehicles are the future. For example:

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[85] 90 FR 36313.
[86] RIA 4.

- In his 2025 Sustainability and Financial Report, Ford Motor Company CEO Jim Farley emphasized that Ford is "deep into the development of our future electric vehicles, which we expect to be profitable, affordable, and high-volume."[87]
- General Motors CEO Mary Barra recently noted that "[f]rom an EV perspective, that is still our North Star."[88]
- Stellantis recently announced a breakthrough in solid-state battery cells and stated that "[t]his achievement marks a significant step forward on the path to bringing next-generation electric vehicle (EV) batteries to market."[89]
- Hyundai CEO José Muñoz noted," We are delivering comprehensive electrified portfolios across all segments, localizing production in key markets, and leveraging breakthrough technologies from Software-Defined Vehicles to next-generation batteries."[90]
- Honda Global CEO Toshihiro Mibe said "there is no change in the Honda position that EVs are the optimal solution to achieve carbon neutrality of passenger vehicles."[91]

These statements are backed up by real investments of billions of dollars and hundreds of thousands of jobs. As of January 2025, auto manufacturers had announced investments of almost $200 billion toward electric vehicle manufacturing in the U.S. and 195,000 new U.S. electric vehicle-related jobs.[92] Those investments could also generate up to 826,000 additional jobs in the broader economy. However, since President Trump took office, businesses have already canceled billions of dollars in planned electric vehicle manufacturing investments, with thousands of jobs lost. A recent analysis by Atlas Public Policy tracked cancelations in 2025 representing nearly 24,000 jobs lost and $18.7 billion in investments lost.[93] Congress's decision to repeal core provisions of the Inflation Reduction Act puts more jobs at risk and repealing EPA's clean vehicle standards will further threaten these vital jobs and investments.

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[87] Ewing, J., How Republican E.V. Cuts Could Put U.S. Carmakers Behind China, NYT (July 2, 2025). https://www.nytimes.com/2025/07/02/business/ev-cars-us-china-trump.html

[88] Summer Ballentine, Mary Barra stands by GM's electric vehicle strategy, The Detroit News (Sept. 11, 2025), https://www.detroitnews.com/story/business/autos/general-motors/2025/09/11/gm-mary-barra-stands-by-electric-vehicles/86065188007/?gnt-cfr=1&gca-cat=p&gca-uir=false&gca-epti=z117049p119450c119450u116549e003500v117049&gca-ft=17&gca-ds=sophi; see also https://www.bloomberg.com/news/features/2025-04-14/inside-gm-mary-barra-s-35-billion-bet-on-electric-cars (noting that "[w]e're about giving customers choice" and "[o]ver the long term, we think EV demand will grow.")

[89] Stellantis and Factorial Energy Reach Key Milestone in Solid-State Battery Development (Apr. 24, 2025), https://www.media.stellantis.com/uk-en/corporate-communications/press/stellantis-and-factorial-energy-reach-key-milestone-in-solid-state-battery-development

[90] Hyundai Motor Company Unveils Bold 2030 Vision and Product Roadmap at 2025 CEO Investor Day (Sept. 18, 2025), https://www.prnewswire.com/news-releases/hyundai-motor-company-unveils-bold-2030-vision-and-product-roadmap-at-2025-ceo-investor-day-302560446.html

[91] Summary of 2025 Honda Business Briefing (May 20, 2025), https://global.honda/en/newsroom/news/2025/c250520eng.html

[92] EDF, U.S. Electric Vehicle Manufacturing Investments and Jobs Turning Investment into Action, 2025. https://library.edf.org/AssetLink/j1n8dp1041c0g2m68lf0m5qp7p1e2i45.pdf

[93] Atlas Public Policy, Clean Energy Manufacturing State of Play: August (2025).

Despite the headwinds, automakers continue to make enormous investments in electrification. In August 2025, Ford announced what it termed a "Model T moment" for its EV business– a $2 billion investment to retool a Kentucky factory to produce EVs and a complete reinvention of its EV architecture and assembly process to drastically cut costs.[94] The new platform is designed for simplification, reducing the number of parts by 20% and replacing a traditional assembly line with an "assembly tree" that will make assembly 15% faster. The first vehicle from the new system—a midsize, four-door electric pickup truck—is expected to launch in 2027 from the Louisville Assembly Plant, with a target starting price of about $30,000. The electric trucks will be powered by lower-cost batteries manufactured at Ford's $3 billion Michigan battery factory that produced its first battery this month and is expected to create 1,700 new jobs when fully operational.[95] CEO Jim Farley stated it will be "an affordable electric vehicle that we expect to be profitable."[96]

EV manufacturers also continue to expand operations and announce new businesses. Rivian plans to build a $120 million supplier park in Normal, Illinois at the same location as its main EV production plant.[97] The supplier park will house suppliers for light assembly and manufacturing of component parts and is expected to streamline production, reduce logistics costs, and strengthen the company's supply chain while adding hundreds of supplier jobs and 100 direct Rivian jobs over the next two years.

Slate Auto, a company backed by Amazon's Jeff Bezos, has also announced it will build the first of its low-cost electric pickup trucks at the former LSC Communications printing plant in Warsaw, Indiana.[98] Slate will bring about 2,000 jobs to the Warsaw area, with the first vehicles expected at the end of 2026 and a goal of building 150,000 vehicles annually by the end of 2027.

3. Adoption of clean vehicles continues to grow internationally

U.S. automakers operate in a competitive global market where the transition to electrification is accelerating, driven by both stringent regulations and aggressive new entrants. BNEF projects that plug-in electric vehicles will represent one in four passenger vehicles sold globally this year,

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[94] Schreiner, Ford hits the pedal on EV production with $2 billion overhaul of Kentucky plant, AP (Aug. 11, 2025). https://apnews.com/article/ford-louisville-assembly-plant-electric-vehicles-bde8fee4209176be186e6b4f91252dd2

[95] Drake, L. Ford-Owned American LFP Battery Plant Paves Way for Next-Gen Electric Vehicles, Ford (June 23, 2025). https://www.fromtheroad.ford.com/us/en/articles/2025/ford-owned-american-battery-plant-future-electric-vehicles

[96] Ford hits the pedal on EV production with $2 billion overhaul of Kentucky plant, NBC News (Aug. 11, 2025). https://www.nbcnews.com/business/autos/ford-hits-pedal-ev-production-2-billion-overhaul-kentucky-plant-rcna224314

[97] Miranda Davis, Rivian to Build $120 Million Supplier Park in Illinois, Transport Topics (May 5, 2025). https://www.ttnews.com/articles/rivian-illinois-investment

[98] Guffy, A. Why new Bezos-backed automaker Slate will build electric vehicle trucks in northern Indiana, Indy Star (May 5, 2025). https://www.indystar.com/story/news/local/transportation/2025/05/05/slate-auto-will-build-evs-in-warsaw-indiana-backed-by-jeff-bezos/83386507007/

and more than half of the market in China.[99] This global context creates a powerful incentive for U.S. automakers to continue their investments in electrification, despite the above-described lack of support from the current Administration. The Alliance for Automotive Innovation echoed this, noting recently that the "U.S. must bolster its EV manufacturing to maintain relevance in a global market where EVs are projected to dominate in the future."[100]

Europe remains aggressively committed to electrification. The EU recently reaffirmed its plan to shift to all zero-emitting vehicles by 2035,[101] and EV sales across Europe are climbing – 20-35% of new car sales in many Western European countries are electric.[102] The EU is also investing in charging infrastructure at a record pace, and major global automakers have doubled down on EV rollouts in Europe.

Emerging economies have recently become some of the fastest-growing EV markets. For example, Vietnam, Thailand, and Brazil have all seen EV sales rise dramatically over the last two years, and some now have higher adoption rates than the U.S.[103]

China continues to make substantial investment. In 2024, China alone accounted for 70% of global EV production and sold 11 million EVs – 65% of all global EV sales – dwarfing all other nations. Chinese automakers like BYD are producing EVs at low cost – a notable example is the BYD Seagull, a subcompact electric car starting under $10,000.[104] Launched in April 2023, the Seagull became China's best-selling EV; by mid-2025 it surpassed 1 million units sold in just 25 months of production. In November 2024, the Seagull outsold every other model in China, including gas-powered models. Sales of electric trucks and vans are also booming in China.

BYD and other Chinese brands are now expanding to markets in Europe, Latin America, and beyond, bringing intense competition and driving innovation and scale, including lower battery costs and new model offerings. In response, the EU and U.S. both imposed tariffs to prevent an influx of cheap Chinese EVs and adopted policies to incentivize domestic manufacturing.[105] While tariffs can temporarily insulate US manufacturers from foreign competition, US companies must continue to innovate clean vehicle technologies and reduce their costs to strengthen global competitiveness.

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[99] BNEF, 2025 Electric Vehicle Outlook. https://about.bnef.com/insights/clean-transport/electric-vehicle-outlook/
[100] Get Connected, EV Quarterly Report, First Quarter 2025, AAI (2025). https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%202025%20Q1.pdf
[101] Philip Blenkinsop, "EU Says It Sticks To Zero-Emission Car Path To 2035," Reuters, March 5, 2025. https://www.reuters.com/business/autos-transportation/eu-sticks-2035-zero-emissions-target-new-cars-2025-03-05/
[102] Id.
[103] Id.
[104] Peter Johnson, BYD has now sold over 1 million Seagull EVs, the $10,000 electric car that's going global, Electrek (June 18, 2025). https://electrek.co/2025/06/18/byd-seagull-sales-top-1-million-as-10000-ev-goes-global/
[105] Gil Lan, Electric Vehicle Tariffs by the US, EU, and Canada: Different Approaches and Implications for the WTO, American Society of Int'l Law, 28 (12) Dec. 2024. https://www.asil.org/insights/volume/28/issue/12

U.S. policy changes cannot stop the global momentum toward electrification. In 2024, global EV sales topped 17 million (up ~25% from 2023), and they are expected to exceed 20 million in 2025 – representing 25% all new cars sold worldwide.[106] This global scale validates that the automotive industry as a whole is pivoting to zero-emission vehicles.

4. EV sales remain strong in the U.S. as automakers continue to offer a growing number of models across all market segments

Manufacturers continue to produce—and consumers and businesses continue to purchase—clean vehicles in record numbers. Nationally, more than 1.5 million electric vehicles were sold in 2024 – 10% of all new passenger vehicle sales in the U.S.[107] And the first half of 2025 saw a record 740,000 light-duty EV purchases in the U.S.[108] Analysts continue to project significant U.S. EV sales going forward. BNEF expects passenger EV sales in the United States to rise to 4.1 million in 2030, making up 27% of total passenger car sales by the end of the decade.[109] Recent slowing of this growth can be attributed to new domestic policies removing regulations and incentives for EV manufacturing and purchasing.

EV sales continue to rise as consumers are offered a growing number of models across every market segment. The number of passenger EV models has increased considerably over the last year alone, from 113 models in Q1 2024 to 149 models in Q1 2025, an increase over 30% in just a year.[110] EVs are now available across all market segments, including passenger cars, SUVs, crossovers, minivans, pickup trucks and utility vehicles. And consumers can choose models from nearly every automaker. As the EV market has matured and diversified, startup brands like Tesla have ceded market share to historic automakers like General Motors and Ford.

Electric medium- and heavy-duty (MHD) vehicles have also seen rapid growth in sales, model availability, and supporting infrastructure over the last few years. In 2024 there were over 120,000 MHD EVs sold in the U.S., up from just a few hundred in 2021. While most of these were Class 2b/3 vehicles, Class 4-8 EV sales are also on the rise.[111] There is also an increasing

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[106] IEA, Global EV Outlook, Executive Summary, 2025. https://www.iea.org/reports/global-ev-outlook-2025/executive-summary

[107] ANL, LDV Total Sales of PEV and HEV by Month (updated through July 2025) https://www.anl.gov/sites/www/files/2025-08/Total%20Sales%20for%20Website_July%202025.pdf

[108] Id.

[109] BNEF, 2025 Electric Vehicle Outlook, updated August 2025.

[110] Compare Alliance for Automotive Innovation, Get Connected: Electric Vehicle Quarterly Report 2025 (Q1), https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%202025%20Q1.pdf, with Alliance for Automotive Innovation, Get Connected: Electric Vehicle Quarterly Report 2024 (Q1), https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%202024%20Q1.pdf

[111] Reolffi, R. U.S. Market & Policy Update: Medium- and Heavy-Duty Electric Vehicles, Atlas EV Hub (July 7, 2025). https://www.atlasevhub.com/data-stories/u-s-market-policy-update-medium-and-heavy-duty-electric-vehicles/

number of MHDV models becoming available in the United States, growing from 24 models in 2019 to over 160 models in 2025.[112]

5. New technologies have been developed since the 2024 Rules

While EPA identified a wide array of technologies to support the 2024 Rules, an even larger variety of GHG control technologies have become available over the past year. Notably, extended range EV (EREV) technology has developed significantly since EPA finalized the 2024 Rules. An EREV is a type of hybrid-electric vehicle that can operate in an electric only mode like a BEV or a range extended mode that uses an ICE generator that powers the battery to provide additional range. EREVs require a smaller battery than a BEV and a smaller ICE engine than a conventional PHEV, which can reduce their overall costs. A recent report from McKinsey shows that the smaller batteries could bring the powertrain production costs down by as much as $6,000, compared to BEVs.[113] And the extended range may be enticing to customers who are worried about the range of a BEV.

While there are currently no EREVs on the market in the U.S. today, there are some on the horizon. Stellantis has announced plans to sell the 2026 Ram Ramcharger beginning in the second half of 2025.[114] According to Stellantis, the Ramcharger will have a 92kWh battery and can go up to 145 miles on full EV power, and up to 690 miles combined with its 27-gallon fuel tank. An EREV version of the Jeep Grand Wagoneer is also under development and Volkswagen is planning to begin production of an EREV pickup truck and SUV in 2027 under its Scout brand name.[115] Hyundai is also developing an EREV model with a 600-mile range.[116]

While the technology is nascent in the U.S., EREVs in China are the fastest-growing drivetrain in the world – sales rose 83% in 2024 to 1.2 million compared to the year before, mostly in the SUV segment.[117] Domestic automakers in China Li Auto, Seres and Changan dominate the market currently, but Stellantis, Hyundai, VW and Ford have all announced plans to launch similar vehicles in China.[118] EREVs have also been growing in popularity in Europe. Over half

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[112] https://globaldrivetozero.org/tools/zeti-data-explorer/

[113] McKinsey and Co, Could extended-range EVs nudge more car buyers toward full electric? (2025). https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/could-extended-range-evs-nudge-more-car-buyers-toward-full-electric#/

[114] Kevin Williams, The 2026 Ram Ramcharger Gets A 92 kWh Battery, 20.5 MPG, 690 Miles Of Range, Inside EVs (Feb. 24, 2025). https://insideevs.com/news/751663/ramcharger-ev-and-ice-mpg/

[115] D'Allegro, J. As EVs stumble, automakers are bringing back a kind of hybrid that promises long range, CNBC (May 30, 2025). https://www.cnbc.com/2025/05/30/automakers-bringing-back-a-kind-of-hybrid-that-promises-long-range-.html

[116] P. Geoge, Hyundai's Big 2027 Launch: An EREV With 600 Miles of Range, Inside EVs (Sept. 18, 2025). https://insideevs.com/news/772645/hyundai-erev-2027-release/

[117] BNEF, 2025 Electric Vehicle Outlook.

[118] Jo Borras, They're real, and they're spectacular: Ford launches Bronco EV and EREV, Electrek (July 17, 2025). https://electrek.co/2025/07/17/theyre-real-and-theyre-spectacular-ford-launches-bronco-ev-and-erev/

of London's famous black taxis are EREVs.[119] Scania and DHL are piloting an EREV delivery truck for packages with an extended range of 800 km.[120]

Roush conducted a study for EDF on the cost and efficiency of a mid-sized SUV EREV. They found that EREVs are a cost competitive technology with BEVs and PHEVs.[121] With their extended range and potentially lower upfront costs, EREVs have become another viable technology option for meeting the 2024 Rules. Using Roush's incremental prices in the report, EREVs, particularly EREV100s would be a very cost-effective compliance strategy for manufacturers looking at providing customers with dual-fuel vehicles like a PHEV.

Advanced technologies for ICE vehicles are also developing. According to ICCT, strong hybrid electric vehicles currently represent the maximum level of GHG reductions achievable in non-plug-in vehicles, and the technology continues to improve.[122] Compared to an equivalent non-hybrid vehicle, strong hybrids in 2024 provide on average a 30% reduction in tailpipe GHG emissions at an average price increase of $2,000, with average 10-year fuel cost savings reaching $4,500. Future strong hybrids can provide an additional 15% reduction in GHG emissions at an average additional price premium of between $300 and $800.

There have also been significant developments in battery technology since the 2024 rule was adopted – many of which are expected to increase range and reduce pricing. For example, GM announced a breakthrough with a newer battery chemistry that will enable a 400-mile range in its pickup trucks.[123] General Motors is working with LG Energy Solutions to develop lithium manganese-rich (LMR) batteries that will be safer, more energy dense, and less costly than their current technology. LMR chemistry substantially reduces the use of both nickel and cobalt making the batteries less expensive than existing Nickel-Manganese-Cobalt (NMC) chemistries. LMR batteries are also expected to have a higher energy density than LFP, requiring less raw materials and further reducing costs. GM plans to start commercial production of the new batteries in the US by 2028. Ford has also announced that it will start adopting LMR batteries by the end of the decade.[124] These developments since the finalization of the 2024 Rules indicate

[119] Half of London's iconic black cabs are now electric, and you can Uber one too, Electrek (Dec. 7, 2023). https://electrek.co/2023/12/07/half-of-londons-iconic-black-cabs-are-now-electric-and-you-can-uber-one-too/
[120] Scania news, Scania and DHL to test electric truck with fuel- powered range extender (Feb. 20, 2025). https://www.scania.com/group/en/home/newsroom/press-releases/press-release-detail-page.html/4993330-scania-and-dhl-to-test-electric-truck-with-fuel-powered-range-extender
[121] Noah R. Heck, Vishnu R. Nair, Sawyer D. Stone*, Christopher Irwin, 2032 EREV Compact SUVs: Purchase Price, Efficiency, and Market Viability, Roush (Sept. 2025).
[122] Aaron Isenstadt and Peter Slowik, Hybrid vehicle technology developments and opportunities in the 2025–2035 time frame, ICCT (2025). https://theicct.org/publication/hybrid-vehicle-technology-developments-and-opportunities-in-the-2025-2035-time-frame-feb25/
[123] Andrew Hawkins, GM says new battery chemistry will enable 400-mile range EVs, The Verge (May 13, 2025). https://www.theverge.com/news/665223/gm-lmr-ev-battery-chemistry-range-miles?utm_source=chatgpt.com
[124] Charniga, J., GM joins Ford on announcing breakthrough battery tech, Detroit Free Press (May 13, 2025). https://www.freep.com/story/money/cars/general-motors/2025/05/13/gm-battery-tech-lg-energy-solution-lithium-manganese-rich-batteries/83598833007/

that the GHG standards have only become more feasible as emissions reducing technologies provide increasing effectiveness at lower costs.

B. Updated modeling demonstrates that the LMDV GHG standards continue to be achievable through diverse technological pathways

We discuss above the many ways that EPA failed to consider new information—including new studies, investments, announcements, technologies and global policy changes—that further supports the feasibility of the 2024 GHG standards. In addition, we have modeled additional pathways manufacturers can take to meet the 2024 LMD standards in light of policy changes enacted since January 2024, including the removal of the IRA and other assumptions EPA includes in its Proposal. Our analysis again underscores the technology neutrality of the standards and further demonstrates that the 2024 rule is not a BEV mandate.[125,126]

EDF performed a detailed analysis, set forth below, assessing pathways to compliance for the 2024 LMDV Rule standards relative to the 2021 LD standards and 2016 HD Phase 3 standards for Class 2b/3 vehicles. The analysis shows example pathways to compliance through reliance on PHEVs, hybrids, and ICE efficiency improvements with zero to moderate levels of BEVs. Our analysis concludes that EPA's 2024 LMDV Rule standards can be met with varying levels of technology and that no single technology is required to meet the fleet-average standards. This is true even in exceedingly unrealistic low- and no-BEV baseline scenarios. Our analysis also finds that even a zero-BEV pathway used to comply with the 2024 standards would result in significant net benefits, and as BEV sales increase so do the net benefits.

1. Methodology

EDF evaluated three light-duty compliance pathways which assume even lower BEV sales than EPA assessed in 2024:

- cap of 22% BEVs, consistent with the BEV share OMEGA projects in MY2032 under the 2021 standards
- cap of 10% BEVs, consistent with the current level of EV sales today
- no BEVs in the fleet at all

EDF chose these three pathways to demonstrate a set of options available to OEMs, but these are not the only pathways.

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[125] Our analysis is complementary to EPA's own analysis in the 2024 Rules, where it modeled multiple alternative compliance pathways for both the LMDV and HDP3 rules. See 89 FR 27855; 89 FR 29452-53.
[126] EDF submitted an alternative pathways analysis in December 2023 on alternative pathways for LDVs for EPA's proposed 2024 LMD standards. It found similar results. https://www.edf.org/sites/default/files/2024-03/EDF_LD_EPA_Alt_Pathways_12.06.23.pdf

EDF used OMEGA compliance to model these alternative pathways. EDF included the improved GHG effectiveness of strong hybrid and PHEV technology, as well as the increased cost of strong hybrid technology, discussed above.

The first two pathways were accomplished through setting maximum BEV production levels for all vehicle segments in the "producer-constraints" file input to the OMEGA compliance model. The third pathway was accomplished by setting the BEV cap in the "production-constraints" file input to zero and reducing the absolute value of the GHG standards by 5%. The first change prevented BEVs from being added to the fleet. The second change accounted for the 5% BEVs in the MY 2022 baseline fleet. EDF confirmed that the fleetwide GHG targets and emissions were 5% lower than in the other OMEGA runs. EDF divided the costs and PHEV sales in this "zero BEV" run by 0.95 to account for the BEVs in the compliance fleet.[127]

Because the only significant difference in the cost-benefits for these different scenarios are the technology costs, that is the only piece modeled individually for each pathway. If EPA had provided a more reasonable period of time for public comment, EDF could have more thoroughly modeled each pathway. It can be reasonably assumed that the remaining cost and benefit categories would be the same or improved with the alternative scenarios modeled.

2. Results

Using OMEGA, EDF modeled the distribution of technologies that could be used to comply with the 2024 LD standards with different levels of BEVs. As the percentage of BEVs decreases across the alternate scenarios, the model predicts that manufacturers will comply through ICE vehicles with other advanced technologies, principally PHEVs.

Table 23: Technology shares to comply with MY2032 standards using different pathways			
Name of Scenario	BEV Share	PHEV Share	ICE/HEV Share
Central Case	52%	12%	36%
22% BEVs	22%	46%	37%
10% BEVs	10%	62%	28%
No BEVs	0%	73%	27%

EDF compared fleetwide vehicle costs for meeting the 2024 Rules' LDV GHG standards under these three alternate pathways to those with unrestricted BEV sales, the central case modeled by EPA. These pathways result in greater costs with increasing PHEV penetration, reflecting that

[127] This shifted vehicle sales in the baseline fleet somewhat away from smaller vehicles to larger ones and from sedans to pickups. EDF attempted to adjust the sales of ICE vehicles to compensate for the reduction in BEV sales, but OMEGA compliance model would not accept our adjusted "vehicles_file" files. In any event, the non-BEV vehicles in the MY 2022 fleet is a dirtier fleet on average and should present a more challenging situation for compliance with the 2024 standards.

BEVs likely remain the most cost-effective technology for achieving GHG reductions. The results are shown in Table 24.

Table 24: Net Present Value (Billions 2022$) of Incremental Vehicle Costs of Three Alternative Pathways to Achieving the 2024 LMDV Rule Light-Duty GHG Standards			
	MY2032 and later PHEV Sales Enabling Compliance	NPV at 3%	NPV at 7%
Central Case (Unrestricted BEVs)	12%	---	---
22% BEV	46%	$73	$15
10% BEV	62%	$134	$52
Zero Percent BEV	73%	$286	$155

EPA only evaluated one alternate pathway for MDVs: no BEV sales. Given the relatively smaller size of the medium-duty fleet and the lower level of BEV sales in the central case, the incremental cost of eliminating BEVs toward meeting the 2024 Rules' MDV GHG standards is much smaller than those for LDVs, ranging from $12-20 billion, representing 7% and 3% discount rates. Given the exceedingly short comment period, EDF used EPA battery costs. As EPA's battery cost projections are unreasonably high (see early in comments), these costs are an overestimate.

While we have not been able to conduct a comprehensive net benefits analysis for each alternative pathway, each alternative pathway would nonetheless result in large net benefits relative to repealing the GHG standards. This is because the incremental vehicle costs of each alternative pathway are a small fraction of the net benefits of the central case, which are $1.4-$1.9 trillion.

- **Maintenance costs**: Per EPA, maintenance costs for strong HEVs and PHEVs are higher than those for BEVs, but lower than for ICEVs. And there are many more strong HEVs and PHEVs in the alternate pathways than in the central pathway. Thus, maintenance cost savings should be similar across the various pathways.
- **Fuel savings**: Fuel savings should be greater in the alternate pathways than in the central pathway.
- **GHG Emission reductions:** Overall tailpipe CO2 emissions are the same across the pathways due to compliance with the GHG standards. The alternate pathways achieve a much larger portion of their GHG benefit from strong HEVs, which achieve their reduction in GHG emissions entirely from reducing fossil fuel use. BEVs and PHEVs reduce fossil fuel use, but increase electricity usage. Likewise, the emissions reductions

and thus emissions-related benefits of the alternative pathways are likely to be larger than those of the central case due to a smaller increase in grid emissions.

- **Criteria pollutant emissions:** PHEVs are certified while operating entirely on gasoline (i.e., battery depleted mode). In the real world, PHEVs operate mostly on grid electricity, with zero tailpipe emissions. Thus, most of the zero-emitting benefits of BEVs will be reflected in the battery-depleting operation of PHEVs. There could be some increase in tailpipe criteria air pollutant (CAP) emissions in the alternate pathways due to the reliance on the improved gasoline efficiency of strong HEVs and PHEVs. However, upstream fossil fuel emissions dominate those from the tailpipe, and their impacts in the alternative pathways will be the same as those in the central case. As in the case of GHG emissions, the increase in CAP emissions from the grid will be smaller in the alternate pathways than in the central case. Thus, EDF is confident that the reduction in CAP emissions seen in the central case will occur in the alternate pathways.

Thus, we expect that the net benefits of these alternate pathways towards meeting the 2024 LMDV Rule standards over no GHG standards would be large and positive. By contrast, eliminating the GHG standards would produce net social costs, with higher fuel costs, and massive harms to public health and the environment.

C. The HDV GHG standards continue to be achievable through diverse technological pathways

While the provided comment period did not allow adequate time to also redo alternative pathways analyses for the heavy-duty rule, EDF continues to find that the 2024 HD standards remain feasible with little to no BEV penetration.

After the publication of the 2024 HD Phase 3 proposal, EDF conducted an evaluation of alternative technology pathways for manufacturers to meet the proposed standards, different from those presented by EPA.[128] EDF's alternative-pathways analysis for model year 2032, the year of highest stringency, demonstrates this flexibility in concrete terms.[129] EDF modeled multiple compliance packages in which ZEV shares are zero or very small across all of the major HDV subcategories.[130] In the light-heavy-duty vocational segment, the feasible pathways include less than 1% ZEVs; for Class 8 day-cab tractors, the modeled pathways include a 1% ZEV share. Other categories can comply with zero ZEVs under the modeled technology packages. In short,

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[129] See Docket ID No. EPA-HQ-OAR-2022-0985-2700. https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0985-2700 EDF also submitted a series of similar alternative pathways analyses and comments to the docket for EPA's proposed Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 88 Fed. Reg. 29184 (May 5, 2023). See Docket ID Nos. EPA-HQ-OAR-2022-0985-0451 and EPA-HQ-OAR-2022-0985-5118.

[130] See 89 FR 29575 (section II.F.4 "Additional Example Compliance Pathway Technology Packages To Support the Final Standards") (discussing wide variety of non-ZEV technologies that enable compliance).

additional ZEVs beyond very low levels are not a prerequisite for meeting the Phase 3 performance standards in 2032, which manufacturers could choose to primarily achieve through combustion-vehicle improvements, hybridization, and PHEVs. We acknowledge that the modeling does not eliminate ZEVs entirely in every case—specifically, it includes <1% ZEVs for LHD vocational and 1% for Class 8 day cabs—but those shares are minimal and well within reach given recent market data and technological developments, as discussed further below.

While EDF's pathways were run against the proposal, the conclusions remain relevant after EPA's targeted adjustments in the final rule. The preamble explains the updates from proposal to final show a pattern of reduced stringency in the early years (2027–2030), modest increases in some later years (2031–2032), lighter overall stringency for heavy heavy-duty vocational vehicles, parity for sleeper tractors, and somewhat higher 2032 stringency for day-cab tractors and light/medium vocational vehicles. That mix of changes leaves the core insight of EDF's modeling intact: multiple non-ZEV-heavy pathways remain available. If anything, the easing in the early years makes near-term compliance easier; and the modest late-year increases are small relative to the pace of ongoing efficiency gains discussed below.[131]

Recent market data demonstrates significant manufacturer progress on producing ZEVs and batteries well in advance of the MY2027 compliance date for the Phase 3 rule. Zero-emission truck deployments in the United States surpassed 52,500 as of December 2024, reflecting broader availability and real-world operational experience that can serve manufacturers who choose ZEVs for part of their portfolios.[132] Battery pack prices fell 20% in 2024 from the year before to a record average of $115/kWh—increasing the cost-competitiveness of ZEV as well as PHEV applications.[133] In parallel, domestic cell manufacturing capacity is scaling, including the Accelera-Daimler Truck-PACCAR joint venture's 21-GWh LFP plant now under construction in Mississippi, with production slated for 2027.[134]

Non-ZEV combustion technologies have also advanced in recent years and directly support compliance with the performance-based GHG standards. Volvo's all-new VNL platform, introduced in January 2024, is engineered for up to a 10% fuel-efficiency improvement through a comprehensive aerodynamic redesign and an updated powertrain (D13 + faster-shifting I-Shift).[135] Cummins' 2027-certified X15 diesel targets up to a 7% fuel-economy improvement

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[131] 89 FR 29479.

[132] CALSTART, Zeroing-in on Zero-Emission Trucks (June 2025 Market Update), https://calstart.org/wp-content/uploads/2025/05/ZIO-ZET-June.pdf

[133] BloombergNEF, Lithium-Ion Battery Pack Prices See Largest Drop Since 2017, Falling to $115 per Kilowatt-Hour: BloombergNEF, https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/

[134] Daimler Truck, Amplify Cell Technologies, a joint venture between Accelera by Cummins, Daimler Truck and PACCAR, begins construction of Mississippi battery cell factory, https://www.daimlertruck.com/en/newsroom/pressrelease/amplify-cell-technologies-a-joint-venture-between-accelera-by-cummins-daimler-truck-and-paccar-begins-construction-of-mississippi-battery-cell-factory-52757135

[135] Volvo Trucks North America Unveils All-New Volvo VNL Designed to Change Everything (Jan. 23, 2024), https://www.volvotrucks.us/news-and-stories/press-releases/2024/january/volvo-trucks-north-america-unveils-all-new-volvo-vnl-designed-to-change-everything/

versus the EPA-2024 version of the X15.[136] Achates Power's opposed-piston Class 8 demonstration has shown double-digit fuel-efficiency improvements versus a current production baseline, reporting route-average fuel-economy gains of 10% and up to 22% on certain duty cycles.[137] Volvo introduced earlier this month the first tractor with stop/start engine functionality which will improve efficiency and reduce CO2 emissions.[138]

Beyond conventional diesel, other combustion pathways are also moving into the market. Cummins began full production of the 15-liter X15N natural-gas engine for Class 8 tractors in 2024, enabling immediate tailpipe CO_2 reductions relative to legacy fleets.[139] Hydrogen internal-combustion technology has also advanced. Volvo and Westport recently closed a joint venture to commercialize high-pressure direct-injection (HPDI) fuel systems for long-haul applications.[140] Southwest Research Institute's H2-ICE consortium reported ultra-low carbon and criteria-pollutant emissions with engine efficiencies exceeding 40%[141]—evidence that hydrogen ICE platforms can materially cut GHGs while leveraging familiar heavy-duty engine architectures.

Hybrids likewise continue to improve. Allison's eGen Flex hybrid propulsion allows engine-off operation for significant portions of transit duty cycles, reducing CO_2 and criteria emissions without requiring full battery-electric platforms.[142] For work trucks, plug-in electric power-take-off (ePTO) systems such as Terex's HyPower SmartPTO enable zero-emission job-site operation and eliminate extended idling, delivering material CO_2 and fuel savings in real-world fleet use.[143]

In addition to all of the technology pathways available to them, OEMs have significant credit banks available that would allow them to make minimal improvements to their vehicles for several years.

[136] How the Newest Cummins X15 Engine Meets EPA 2027 Emissions Regs (Aug. 21, 2024), https://www.truckinginfo.com/10226866/cummins-showcases-2027-x15-engine
[137] ACT Expo 2024: Achates OP engine shows up to 20% efficiency gain (May 24, 2024), https://achatespower.com/act-expo-2024-achates-op-engine-shows-up-to-20-efficiency-gain/
[138] Jack Roberts, Volvo Trucks Introduces Stop/Start Diesel Engine Technology, Heavy-duty Trucking (Spet. 2, 2025). https://www.truckinginfo.com/10246650/volvo-trucks-introduces-stop-start-diesel-engine-technology
[139] Cummins starts full production of X15N™, industry-first big bore natural gas engine, first on the Cummins HELM™ platform (Sept. 12, 2024), https://www.cummins.com/news/releases/2024/09/12/cummins-starts-full-production-x15ntm-industry-first-big-bore-natural-gas
[140] Westport and Volvo Group Announce Closing of the Joint Venture (June 3, 2024), https://www.prnewswire.com/news-releases/westport-and-volvo-group-announce-closing-of-the-joint-venture-302162313.html
[141] SwRI's H2-ICE consortium demonstrates ultra-low emissions from hydrogen-fueled heavy-duty engine (May 21, 2024), https://www.swri.org/newsroom/press-releases/swri-s-h2-ice-consortium-demonstrates-ultra-low-emissions-hydrogen-fueled-heavy-duty-engine
[142] Electrify Your Fleet with Allison's Revolutionary eGen Flex® Electric Hybrid (2024), https://allisontransmission.bynder.com/m/5ab210bca57cedc7/original/eGen-Flex.pdf
[143] Buyers Guide: Hybrid Bucket Trucks (Apr. 20, 2024), https://arbortimes.org/buyers-guide-hybrid-bucket-trucks/

Taken together, the record shows that the HD Phase 3 standards are feasible without significant increases in ZEV penetration. EDF's technical analysis identified credible 2032 compliance pathways with minimal ZEV shares—less than one percent for light-heavy vocational vehicles and one percent for Class 8 day cabs—backstopped by a rapid cadence of combustion-efficiency, hybrid, and alternative-fuel advances. The final rule's early-year stringency reductions only reinforce that conclusion; the modest later-year increases are readily addressed by the efficiency improvements now entering production and the additional low-carbon combustion pathways under active commercialization. EPA's HD GHG program remains what it has always been: a performance standard, not an EV mandate.

D. Investments in the EV charging network are robust and underscore the feasibility of electrification

The EV charging network and announcements of investments have continued at a rapid pace. Atlas Public Policy found that nearly $50 billion of investments in public charging have been announced since 2021.[144] Announced investments in publicly available LDV charging from public, private, and utility sectors totaled $41 billion. This is 99.5% of what EPA projected in the 2024 Rules it would need by 2030. These estimates are likely conservative as they only include announced investments and do not include charging infrastructure that is built but not publicly announced or covered in the media. This demonstrates how well prepared the market is to meet the charger needs of a growing EV fleet. This includes more than 234,000 DC fast charging ports and 351,000 L2 ports and an additional 8,000 ports of undetermined type. Additionally, at least $8.5 billion in investment toward HD charging infrastructure has been announced since 2021, including 42,000 DC fast charging ports, 590 L2 ports and another 22,000 ports of undetermined type.

Despite the recent changes in federal policy, the charger network has continued to grow. Walmart announced in April 2023 they would install EV chargers at every Walmart and Sam's Club in the US by 2030.[145] Since then, Walmart has released more details including they plan to operate their own charger network and opening their first networked site and two pilot sites with four 400kW chargers.[146]

The charging investments described above were made in reliance on 15 years of federal regulatory action requiring progressively more protective greenhouse gas emissions standards. These standards have created reasonable expectations that automakers would continue to produce a growing number of low- and zero-emission vehicles, supporting investments in

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[144] Atlas Public Policy, Announced EV Charging Infrastructure Investment, 2025.
[145] Leading the Charge: Walmart Announces Plan To Expand Electric Vehicle Charging Network, Walmart news (April 6, 2023). https://corporate.walmart.com/news/2023/04/06/leading-the-charge-walmart-announces-plan-to-expand-electric-vehicle-charging-network
[146] Moloughney, T. Walmart Opens Up About Its EV Charging Network: Charge Better, Inside EVs (April 24, 2025). https://insideevs.com/news/757648/walmart-ev-charging-network-revealed/

technological innovation in clean vehicles, charging infrastructure build-out, and battery supply chains and materials. EPA shows no awareness of the impact that its proposed repeal of the vehicle greenhouse gas standards would have on these investment-backed expectations.

E. OEMs can comply with the 2024 LMDV Rule NMOG+NOx standards even absent the GHG standards

In the 2024 LMDV Rule, EPA finalized GHG standards and NMOG+NOx standards that are entirely severable. EPA's proposal to rescind the GHG emissions standards has no impact on the feasibility of the final NMOG+NOx standards. While some of the available control technologies for GHG emissions also control criteria pollutants, EPA established criteria pollutant standards based on separate reasons and based on a separate assessment of available control technologies and their feasibility in light of lead time and cost.[147] Automakers will still be able to comply with the final criteria standards, regardless of whether they are complying with the GHG standards.

Like the GHG emissions standards in the 2024 LMDV Rule, the final NMOG+NOx standard of 15 mg/mile for LDVs was designed to be technology-neutral and does not require a specific number of BEVs or any other technology. Instead, it sets performance-based targets that manufacturers can meet through various compliance paths, including the production of advanced ICEV, hybrids, plug-in hybrids, and BEVs. EPA explicitly considered scenarios where manufacturers produce fewer BEVs than initially projected, and the standards were still found to be feasible.[148] EPA explains in the final rule, "Since technologies are available to further reduce NMOG+NOx emissions from internal combustion engines and vehicles relative to the current fleet, and since more than 20 percent of MY 2021 Bin 30 vehicle certifications already had an FTP certification value under 15 mg/ mile NMOG+NOx, achieving reduced NMOG+NOx emissions through improved ICE technologies is feasible and reasonable."[149] In addition to determining that the NMOG+NOx standards are feasible, EPA also adopted a default compliance schedule to ensure adequate lead time and stability for the regulated vehicles, as well as an optional compliance schedule.[150]

The certification data for LD MY2024-2026 vehicles underscores the feasibility of complying with the NMOG + NOx standards without BEVs.[151] Hundreds of carlines test and certify well below the current standard of 30mg/mi, including 164 carlines that already test below the 15 mg/mi standard and 64 carlines that certify below the 15 mg/mi standard. There are 56 carlines

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[147] 89 FR 28144
[148] 89 FR 27934; RIA Ch. 3.2.5.
[149] 89 FR 27936
[150] 89 FR 27934
[151] EPA, Annual Certification Data for Vehicles, Engines, and Equipment, NMOG NOx certification data (accessed Sept. 20, 2025) uploaded to docket. https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment

that test below 10 mg/mi. This data points to the feasibility of the 15 mg/mi standards, especially given the available lead time.

Table 25: Number of LD carlines that are below different levels of NMOG + NOx for both testing and certification		
NMOG+NOx level	Test	Certification
7.5 m/mi	19	0
10 mg/mi	56	2
12.5 mg/mi	121	29
15 mg/mi	164	64
17.5 mg/mi	233	128
20 mg/mi	268	192
22.5 mg/mi	316	226
25 mg/mi	343	257
27.5 mg/mi	368	277
30 mg/mi	398	305

Table 26: Number of carlines for different vehicle types that test below a range of NMOG + NOx levels					
	LDV / Passenger Car	LDT1 (LVW-3750, GVW 0-6000)	LDT2 (LVW 3751-5750, GVW 0-6000)	LDT3 (ALVW 3751-5750, LVW 0-3750, GVW > 6000)	LDT4 (ALVW > 5750, LVW 0-3750, GVW > 6000)
7.5 m/mi	13	0	6	0	0
10 mg/mi	34	4	17	1	0
12.5 mg/mi	69	10	36	3	3
15 mg/mi	91	10	49	8	6
17.5 mg/mi	125	14	75	10	9
20 mg/mi	138	14	82	14	20
22.5 mg/mi	161	15	95	19	26
25 mg/mi	177	15	99	22	30
27.5 mg/mi	184	15	101	26	42
30 mg/mi	201	15	108	26	48

For MDVs, the certification data similarly demonstrates many vehicles that test or certify below the 75 mg/mi standard finalized in the 2024 rule. There are 9 Class 2b and 2 Class 3 carlines that test at or below 75 mg/mi including 4 carlines that test at or below 30 mg/mi. And there are 4 Class b carlines that certify below 75 mg/mi and 2 that certify below 30 mg/mi.

V. Repealing the GHG Standards Would Reduce the Availability of Vehicle Models and Consumer Choice

Using state registration data from January 2023 through August of 2024, EDF examined the model availability within each state. We purchased this data from S&P Global. For a model to be considered "available" we set the threshold at that model making up 0.01% of new registrations in a state. For Alaska, this meant 5 of a particular vehicle model needed to be sold in that timeframe to be considered "available," and for California, 329 units of a model needed to be sold. The data includes different powertrains. Table 27 shows the powertrain and the total vehicle count for the data included in this analysis.

Table 27: US vehicle registrations by powertrain included in dataset (Jan 2023-Aug 2024)

Powertrain	Count (million)
Gasoline	21.13
Full Hybrid Electric Vehicle	2.43
Electric Vehicle	2.18
Diesel	1.75
Mild Hybrid Electric Vehicle Gasoline	0.88
Plug In Hybrid Electric Vehicle	0.55
Flexible (Gasoline/Ethanol)	0.48
Natural Gas	0.01

The main intention of this analysis is to understand how the availability of models differed across states that have adopted California light-duty vehicle standards. Specifically, we compared the number of models in Advanced Clean Cars I and Advanced Clean Cars II states[152] ("Section 177 states") with that in states that have not adopted these programs.

[152] CARB website, States that have Adopted California's Vehicle Regulations (last accessed Sept. 18, 2025).

Table 28: Average number of models available in Section 177 states and non-Section 177 states				
	PEV Models	HEV Models	Gas Models	Total Models
Section 177 States	77	68	230	419
Non-Section 177 States	55	59	215	382
% Difference	39%	15%	7%	10%

As can be seen in Table 28, Section 177 states have more vehicle models available on average than states that have not adopted these programs. For PEV models (BEV + PHEV), the increase is substantial with nearly 40% more PEV models and 15% more HEV (mild and strong hybrid electric vehicles) in Section 177 states. There is even an increase in total model availability and gasoline model availability though that increase is substantially lower.

Considering whether state population may be a driver of model availability, EDF also looked at the average model availability per million people living in each state. Again, Section 177 states have significantly more PEV and HEV models available per million people (57% and 25%, respectively) and slightly more total (15%) and gasoline (11%) models available per million people as compared to non-Section 177 states.[153]

Table 29: Average vehicle models available per million people in Section 177 and non-Section 177 states				
	PEV models per million	HEV models per million	Gasoline models per million	Total models per million
Section 177	31	28	92	167
Non-Section 177	20	22	83	146
% Difference	57%	24%	11%	15%

This can also be seen graphically. Figures 4 through 6 show total, gasoline, and PEV availability as a function of state population. For states of similar sizes, the Section 177 states (ACCI and ACCII) have more models available, generally.

https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/states-have-adopted-californias-vehicle-regulations

[153] We tested different percent sales thresholds for when a model would be considered available within a state. While the analysis was sensitive to different thresholds, the conclusions held for a very wide range of assumptions. For example, for 0.1% of sales, PEV model availability in Section 177 states was 160% higher than in non-Section 177 states. For 0.001% sales, PEV model availability was 13% higher in Section 177 states.

Figure 4: Number of total vehicle models available in each state as a function of population

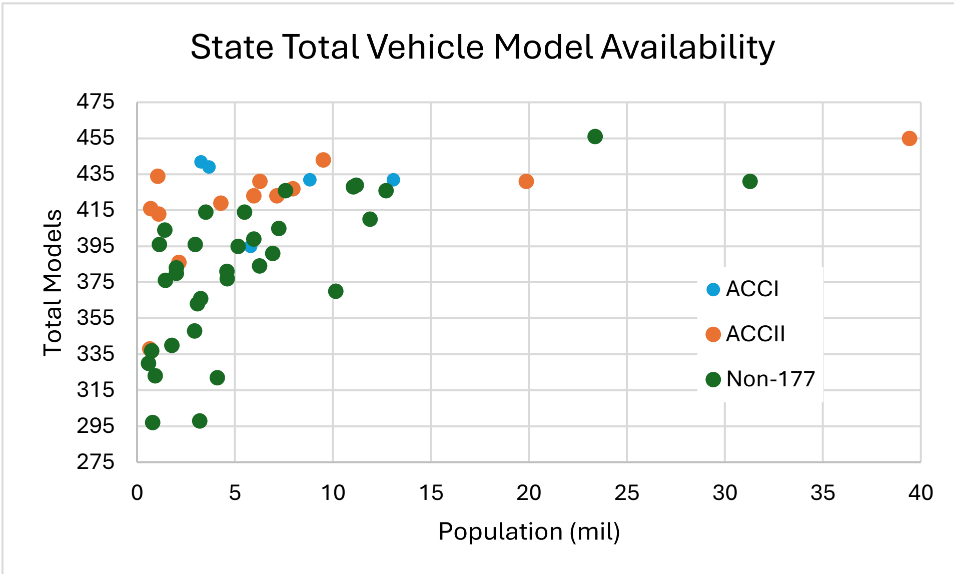


Figure 5: Number of gasoline vehicle models available in each state as a function of population

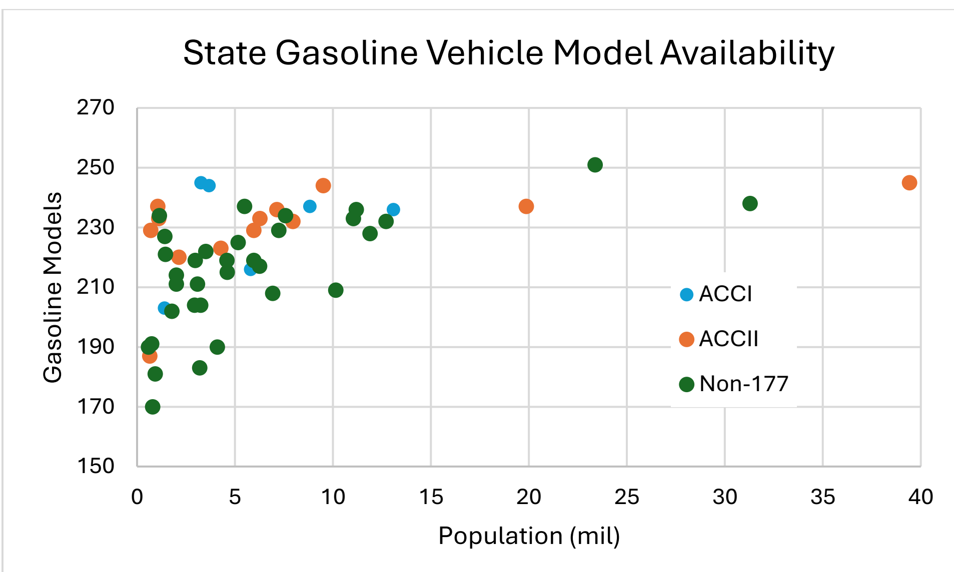
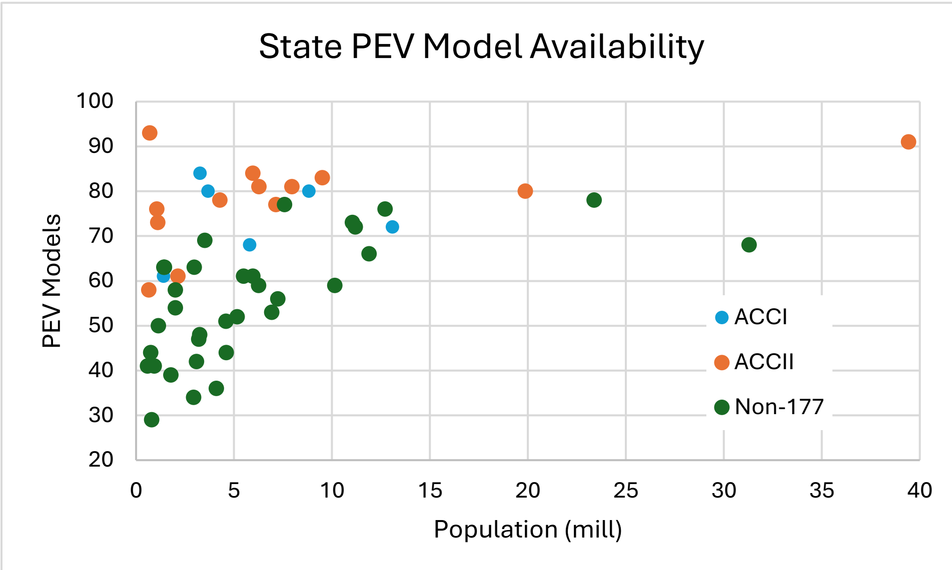


Figure 6: Number of plug-in electric vehicle models available in each state as a function of population



The states with stronger clean vehicle requirements see a significant increase in model availability, particularly for the lowest GHG emitting plug-in electric vehicles. This makes sense: regulatory drivers to sell more clean vehicles results in greater numbers of clean vehicles actually being sold, and greater number of clean vehicles sold mean more diverse model types. While we acknowledge differences between state-level implementation of ACC and federal GHG standards, this analysis nonetheless provides strong, prima facie evidence that federal standards driving clean vehicles are also more likely to result in greater consumer choice for consumers. Such increases in choice are particularly likely for the cleanest vehicles, which also provide the greatest amount of fuel savings for consumers. EPA's contrary assertions in the Proposal are not consistent with this evidence, and the agency offers no analysis to support its conclusory allegations.

VI. CONCLUSION

The foregoing analysis demonstrates that rescinding federal GHG emissions standards for vehicles would have severe and lasting adverse consequences for the United States, amounting to one of the most costly and dangerous regulatory actions in modern history. The Proposed Repeal would significantly increase emissions of GHGs and harmful air pollutants, resulting in catastrophic costs to public health, the environment, and the economy: tens of thousands of lives lost, hundreds of billions of dollars in health costs, and trillions of dollars in total economic damages. These impacts would reverse decades of progress in reducing transportation sector emissions and undermine vital national and global efforts to mitigate the present and escalating dangers of climate change.

Our analysis further reveals critical flaws in EPA's cost-benefit assessment, including outdated assumptions about battery costs, fuel savings, discount rates, and global oil market dynamics. By failing to incorporate the latest data and technological advancements, EPA underestimates both the feasibility and the benefits of maintaining strong GHG standards. In reality, advanced vehicle technologies—including improved internal combustion engines, hybrids, plug-in hybrids, and battery electric vehicles—are increasingly available, cost-effective, and capable of meeting or exceeding current standards. The transition to cleaner vehicles is not only feasible but already underway, driven by industry investment, consumer demand, and global competition.

Robust GHG standards also foster innovation, expand consumer choice, and support domestic manufacturing and job creation. Within the U.S., those States with more protective standards consistently offer a wider range of vehicle models, particularly electric and hybrid options, benefiting consumers and strengthening the marketplace, and demonstrating a positive link between standards and consumer choice in motor vehicles. Rolling back the federal GHG standards would reduce model availability and consumer choice, contrary to EPA's claims.

In sum, maintaining and strengthening federal vehicle GHG standards is essential for protecting public health and welfare, advancing vital climate safeguards, and ensuring the continued competitiveness of the U.S. automotive sector. The overwhelming weight of scientific, technical, and economic evidence supports the continuation of these standards. EPA should withdraw its proposal to rescind the standards and instead promulgate even more protective standards that build on the progress achieved to date, ensuring a cleaner, healthier, and more prosperous future for all.

Any questions about these comments can be directed to Ellen Robo at erobo@edf.org.

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SCIENTIFIC APPENDIX

EPA has asked for comment on the science supporting the Endangerment Finding. As a supplement to the scientific information in the sets of joint comments EDF filed with other health and environmental groups, we set forth this additional information on the harms associated with greenhouse gas pollution and the mountain of scientific evidence supporting the Endangerment Finding.

The addition of greenhouse gases to the atmosphere from the burning of fossil fuels is leading to more extreme temperatures and precipitation, and a host of negative impacts including impacts on human health, ecosystems, infrastructure, settlements, agriculture, forestry, ocean fisheries, national security, and economic well-being. These impacts are pervasive and are already harming American lives and property. In our review of the latest scientific evidence, we found that documentation of the damage caused by climate change to people and ecosystems in the United States has only become more extensive and definitive since 2009. This review focuses on science since 2018 when Duffy et al published a review paper finding that the scientific literature since 2009 further supports EPA's conclusion that climate change and greenhouse gas emissions are a significant threat to human health and welfare. EPA's failure to consider this information is arbitrary and capricious.

The National Academies of Science, Engineering and Medicine released a report on September 17, 2025, entitled "The Effects of Human-Caused Greenhouse Gas Emissions on U.S. Climate, Health, and Welfare. This NASEM report reached conclusions very consistent with our own review of the scientific literature. Specifically, NASEM 2025 found that "EPA's 2009 finding that the human-caused emissions of greenhouse gases threaten human health was accurate, has stood the test of time, and is now reinforced by even stronger evidence." The report provided scientific evidence to conclude that emissions of greenhouse gases from human activities are increasing greenhouse gas concentrations in the atmosphere, and these emissions are warming Earth's surface and changing Earth's climate. Human-caused emissions result in climate changes that harms the health and welfare of people in the United States. The report concluded that "continued emissions of greenhouse gases from human activities will lead to more climate changes in the United States, with the severity of expected change increasing with every ton of greenhouse gases emitted" (NASEM 2025).

I. PUBLIC HEALTH

Greenhouse gases added to the atmosphere are changing the climate, and in turn causing changes in the frequency and/or severity of extreme events and the underlying patterns of temperature and precipitation that have cascading effects on human health.

1. **Extreme Temperatures**

Increased concentrations of greenhouse gases in the atmosphere caused by human activity have led to increases in average temperatures and heatwaves (Sherwood et al. 2020; Jarvis and Forster 2024; Dunn et al. 2020; Dunn et al. 2024; NASEM 2025). Extreme heat poses significant threats to human health and well-being (NASEM 2025). An estimated 21,218 Americans died from heat-related causes between 1999 to 2023 (Howard et al., 2024). Beyond mortality, heat exposure contributes to a broad spectrum of health problems including cardiovascular complications, respiratory illness, kidney dysfunction, and adverse pregnancy outcomes (Bell et al., 2024). Vulnerable populations, such as children, are particularly at risk to the effects of extreme heat. From 2016 to 2018, extreme heat was associated with a 17% increase in emergency department visits across 47 United States children's hospitals (Bernstein et al., 2022).

Extreme heat is also associated with adverse mental health impacts such as elevated rates of anxiety, depression, and suicidal behavior documented alongside increases in aggressive behavior and violence (Bell et al., 2024). Extreme heat was associated with 8% higher rates of mental health related emergency department visits in the United States during the summers of 2010 to 2019 (Nori-Sarma et al., 2022). Research demonstrates the substantial role of human-caused climate change in these heat-related health impacts: an estimated 34.7% of American heat-related deaths from 1991 to 2006 can be attributed to human-induced climate change (Vicedo-Cabrera et al., 2021).

Extreme heat events are becoming increasingly frequent and severe because of changing climate feedback mechanisms, such as land-atmosphere interactions, which amplify hot temperatures (Bartusek et al., 2022). Already, heatwaves affect larger areas, are more intense, and are seven times more common than they were forty years ago (Rogers et al., 2022). The effects have been devastating. From 1987 to 2005, national mortality rates increased by 3.74%, with greatest risks exhibited in the Northeast and Midwest (Anderson & Bell, 2011). More recently, the unprecedented Pacific Northwest (PNW) heat wave of June 2021 caused hundreds of deaths in the United States (White et al., 2023). Climate studies estimate that increased temperatures from anthropogenic climate change made the 2021 PNW heatwave at least 8 times more likely to occur (Leach et al., 2024) and was 59% longer, 34% larger and 6% more intense than the same event would have been without background warming (Jain et al., 2024). Additional research suggests that in the 1950s, the 2021 PNW heatwave was considered a 1-in-500,000-year event. By 2021, it was considered a 1-in-200-year event. With 2C global warming, it could become a 1-in-10-year event (Leach et al., 2024).

In addition to heat-related mortality, heatwaves pose broad risks to human health such as adverse birth effects. A domestic study of 50 metropolitan areas across the United States found that heatwaves are associated with an increase in pre-term and early births, and that consecutive days of heat and higher temperatures modify this association (Darrow et al., 2024). The relationship between heat and timing of birth was strongest amongst mothers under 30 years old, without a college education, and from a minority group and/or Hispanic ethnicity, highlighting the compounding effects of heatwaves on disadvantaged groups (Darrow et al., 2024).

2. Interactions with Air Pollution

Increased air pollution due to anthropogenic activities severely harms public health and increased heat from climate change can compound that risk (Analitis et al., 2014; NASEM 2025). Anthropogenic climate change is projected to increase ozone and $PM_{2.5}$ concentrations and contribute to more air pollution mortality in every region except Africa by the end of the century (Silva et al., 2017). Rising CO_2 levels may increase annual air pollution deaths in the United States by 350 to 1,800 deaths per 1˚C of warming, with ozone and $PM_{2.5}$ most responsible (Jacobsen, 2008).

Climate change also creates feedback loops that exacerbate air pollution problems. For example, elevated temperatures accelerate the formation of ground-level ozone, worsening cardiovascular risks, particularly among older adults, racial and ethnic minorities, and low-income communities (Kazi et al., 2024). Thus, climate change-induced air quality issues may compound existing health inequities caused by class and race. Another example can be seen in the western United States, where extreme drought conditions associated with anthropogenic climate change force electrical systems to increase fossil fuel power plant generation to compensate for reduce hydropower capacity (Qiu et al., 2023). This switch in power generation composition accounted for 63% of fossil fuel generation in the western United States from 2001 to 2021, increasing CO_2, $PM_{2.5}$, NO_2 and SO_2 emissions (Qiu et al., 2023). The health effects resulting from this increase in fossil fuel generation equated to health costs 1.2 to 2.5 times greater than the direct economic cost of the drought itself (Qiu et al., 2023).

3. Wildfires

Anthropogenic climate change has significantly increased the frequency, intensity, and duration of wildfires (Jain et al., 2024; NASEM 2025). Between 2003 and 2019, “global burned area” rose by 15.8%, and more countries are now experiencing longer wildfire seasons as a result of shifting climate patterns (Burton et al., 2024). The western United States is particularly prone to wildfires, contributing significantly to Americans’ exposure to $PM_{2.5}$. In the 2000s, wildfires in this region accounted for less than 20% of $PM_{2.5}$ exposure; by the 2010s, this proportion surged to nearly 50%, with smoke traveling long distances and affecting air quality across other parts of the country (Burke et al., 2021).

Exposure to wildfire smoke is associated with increases in all-cause mortality, asthma, cardiovascular effects, respiratory effects, and low birth weight (Reid et al., 2016). Long-term exposure to wildfire smoke increases mortality rates of lung and heart, digestive, endocrine, diabetes, mental, and chronic kidney diseases, contributing to over 11,400 deaths in the United States from 2007-2020 (Ma et al., 2024). Researchers attribute 68 to 88% of fire-conducive weather conditions in western states to anthropogenic warming (Zhuang et al., 2021). Globally, attribution studies show that fire-related $PM_{2.5}$ mortality attributed to climate change increased from 1.2% in the 1960s to 12.8% in the 2010s (Park et al., 2024).

4. Drought

The southwestern United States and parts of the southeastern U.S. have seen an increase in meteorological drought in the period from 1915-2011 (NASEM 2025). In addition, from 1960 to 2010, researchers observed an increase in concurrent droughts and heatwaves across most of the United States (Mazdiyasni and AghaKouchak, 2015). Under SSP2-4.5, the frequency of two-year compound drought and heatwave events across the eastern United States is projected to more than double (Tripathy et al., 2023). In the drier western United States, compound drought and heatwave events are expected to become more severe and longer lasting (Tripathy et al., 2023).

Drought conditions in the Southwest contribute to increased airborne dust by drying out soil and reducing vegetation cover, which can worsen air quality and pose serious respiratory health risks, particularly for vulnerable populations (NASEM 2025). Dust concentrations in the Southwest due to drought and human land use patterns have been associated with premature mortality and hospitalizations for cardiovascular and respiratory illnesses (Achakulwisut et al., 2018). Under RCP2.6, a conservative prediction of global warming, the rates of premature mortality attributable to dust exposure in adults over 30 years old would increase by 24%, while the annual hospitalization rates for cardiovascular and respiratory illnesses would increase by 59% (Achakulwisut et al., 2018).

5. Interactions with Infectious Diseases

Anthropogenic climate change is increasingly contributing to the emergence and spread of infectious diseases (Mahon et al., 2024; NASEM 2025). Globally, 58% of infectious diseases have been "at some point aggravated by climatic hazards sensitive to" greenhouse gases, highlighting the relationship between anthropogenic activities and greater risk of infectious diseases (Mora et al., 2022). As anthropogenic climate change and current human activities drive habitat degradation and biodiversity loss, populations around the world will be increasingly exposed to myriad infectious diseases (Mahon et al., 2024).

Shifts in temperature, precipitation, and drought frequency are altering the geographic range and seasonal behavior of diseases such as Valley Fever, which is caused by inhaling dust containing coccidioidomycosis fungal spores (Gorris et al., 2019). Rising global temperatures and increased drought conditions have been correlated with spikes in Valley Fever cases across the American Southwest (Head et al., 2022). In California alone, droughts have been linked to thousands of excess cases, and climate models project a 50% increase in incidence by 2100, along with expansion into previously unaffected states (Gorris et al., 2019).

Climate change affects the transmission, spread, and ecosystem habitats of vector-borne diseases (Rocklov and Dubrow, 2020). Increased temperature and altered rainfall patterns are likely to increase the incidence and range of both new and endemic vector-borne infectious diseases in North America (Greer et al., 2008; Edelson et al., 2023). For example, hotter and wetter summers will make larger swaths of the United States hospitable to mosquitos, and therefore mosquito-borne diseases such as Zika (Edelson et al., 2023). Already, milder winters and droughts are associated with an increased risk of West Nile Virus transmission in United States cities (Caminade et al., 2019).

Changes in humidity, rainfall, and temperature also influence the transmission of respiratory viruses such as Respiratory Syncytial Virus (Baker et al., 2019). Future climate scenarios for North America predict that increased humidity and extreme rainfall may shift epidemic patterns northward and intensify outbreaks (Baker et al., 2019). Alarmingly, climate change is also linked to rising antibiotic resistance, with warmer temperatures accelerating the spread of resistant pathogens across regions and threatening our ability to treat these diseases (MacFadden et al., 2018).

6. Increased Exposure to Aeroallergens

Human-caused climate change is the dominant driver in lengthening the pollen season and a significant contributor to increased pollen concentrations, worsening exposure periods for allergy sufferers (Anderegg et al., 2021; NASEM 2025). The effects are more pronounced at latitudes north of 44ºN in North America (roughly how far North Minneapolis is), where the ragweed pollen season has lengthened by 13 to 27 days on average since 1995 (Ziska et al., 2010). An estimated 35,000 to 60,000 annual asthma emergency department visits between 1994 to 2010 were linked to oak, birch, and grass pollen (Neumann et al., 2019).

Modeling studies project that climate change will exacerbate pollen-related health burdens. For example, oak pollen alone was linked to over 21,000 asthma emergency department visits in 2010, with nearly 70% affecting children under 18 (Anenberg et al., 2017). By 2090, under RCP4.5, oak pollen related asthma emergency department visits are expected to increase by 4% compared to the 1994 to 2010 baseline, correlating to a marginal net present value of $8.3 million (Anenberg et al., 2017). Grass pollen concentrations are expected to increase by approximately 200% due to rising atmospheric carbon dioxide, and despite simultaneous rises in ground-level ozone, which suppresses pollen and allergen production (Albertine et al., 2014).

Experimental studies also show that elevated CO_2 not only increases pollen biomass but may enhance pollen allergenicity, intensifying allergic responses (Rauer et al., 2020). Long-term analyses across the Northern Hemisphere reveal that pollen seasons are starting earlier and lasting longer, with annual pollen loads increasing by up to 46% in the United States over recent decades (Ziska et al., 2019; Zhang et al., 2015). Changes in plant phenology, the timing of seasonal events in plants such as flowering, are also linked to increased rates of hay fever and asthma (Sapkota et al., 2019). Adults living in United States counties with very early or very late spring onset had significantly higher odds of hay fever (Sapkota et al., 2019), and in Maryland, very early spring onset was associated with increased asthma hospitalizations, even after adjusting for air pollution and heat (Sapkota et al., 2020).

7. Interactions with Mental Health

Recent research documents the negative impacts of climate change on mental health through direct environmental stressors and indirect social and psychological pathways (NASEM 2025). Direct effects from extreme weather events such as cyclones, floods, and storms worsen mental health outcomes (Obradovich et al., 2018; Ridley et al., 2020). For example, exposure to Hurricane Katrina was linked to a 4% increase in mental health issues (Obradovich et al., 2018), and survivors of California's deadliest wildfire in 2018 showed signs of chronic climate trauma including diminished cognitive processing and heightened neurological responses similar to post-traumatic stress disorder (Grennan et al., 2023). Vulnerable populations—including children, the elderly, pregnant women, and those living in poverty—are disproportionately affected due to limited resources for adaptation and recovery (Trombley et al., 2017). Heat is associated with adverse mental health outcomes: a recent meta-analyses found that each 1°C increase in temperature correlates with a 1.5–1.7% rise in suicide incidence, and heatwaves are associated with nearly a 10% increase in hospital admissions for mental illness (Thompson et al., 2023).

Other studies found a link between higher temperatures and increased emergency department visits for mental health episodes and self-harm in the United States (Mullins and White, 2019).

Air pollution, another consequence of fossil fuel-driven climate change, has also been associated with increased risks of depression and anxiety. Studies have found that exposure to $PM_{2.5}$ and ozone is linked to higher rates of depressive symptoms, particularly among older adults and individuals with lower socioeconomic status (Kioumourtzoglou et al., 2017; Pun et al., 2016). Additionally, infectious diseases influenced by climate change, such as West Nile Virus, have been shown to cause long-term depression in a significant portion of patients, with effects lasting up to eight years post-infection (Murray et al., 2007; Nolan et al., 2012).

There are also indirect impacts from climate change that operate through broader social and environmental disruptions of determinates of psychological well-being, such as food insecurity, safety in homes, schools and recreational spaces (Crandon et al., 2022; Ridley et al., 2020). Climate change is expected to worsen mental health outcomes through reduced agricultural yields from altered rainfall and water supply patterns, more frequent weather-related disasters, and increased likelihood of violent conflict—all of which contribute to poverty, depression, and anxiety (Ridley et al., 2020).

8. Increased Risk of Population Displacement and Conflict

Increased flooding due to sea level rise is expected to intensify outmigration in coastal cities (de Koning and Filatova, 2020). Under 1.8 meters of sea level rise by 2100—which is on the very high end of end-of-century sea level rise estimates—up to 13 million Americans could be displaced (Hauer et al., 2016). In response, Hauer (2017) predicts that net migration would change in every state, 86% of United States Core Based Statistical Areas, and 56% of counties, with Florida projected to lose 2.5 million residents and Texas projected to gain 1.5 million residents.

Changes in extreme events could also influence migration. For instance, increased migration out of Puerto Rico was noted after Hurricane Maria (Acosta et al., 2020), particularly out of regions more vulnerable to high water levels and substandard housing (DeWaard et al., 2020).

Climate variability and climate change may also influence the risk of war and conflict, in part because of displacement and mass migration. Hsiang et al. (2013), for instance, evaluated 60 different studies (45 different data sets covering 10,000 years), and found that for each standard deviation change in climate toward warmer temperatures or more extreme rainfall, the frequency of interpersonal violence rose 4% and the frequency of intergroup conflict rose 14%. Similarly, Ge et al. (2022) attributed 3.8% of conflict risk to long-term deviations from mean climate, and Hao et al. (2023) argued that there is an increasing impact of climate on armed conflict risk over recent decades in Sub-Saharan Africa, the Middle East, and South Asia. Other studies have linked the 2007-2010 Syrian drought---and resulting Syrian conflict---to anthropogenic warming (Kelley et al., 2015), connected adverse rainfall shocks and civil conflict in Sub-Saharan Africa (Maertens et al., 2020), and showed increased violence under growing-season drought in Asia and Africa for agriculturally-dependent groups (Uexkell et al., 2016). However, conflict risk is driven by a range of social and environmental factors, which makes it difficult to isolate the impact of climate. Thus, evidence is far from conclusive about the impact of climate on displacement and conflict, although experts generally agree that some (3-20%) of past conflict risk is attributable to climate (Mach et al., 2019).

II. PUBLIC WELFARE

1. Food Production and Agriculture

Agriculture is highly vulnerable to climate change, with crops responding directly to shifts in temperature, precipitation, and atmospheric CO_2 concentration (NASEM 2025). These responses vary by crop and location, but global evidence suggests that long-term trends in average temperature and precipitation have already reduced consumable food calories in the world's ten major crops, which provide roughly 70% of human energy intake, by an estimated 1% (Ray et al., 2019).

A meta-analysis of 230 studies projects that each 1°C rise in global average temperature will reduce global maize yields by 7.5%, wheat by 6.0%, rice by 1.2%, and soybeans by 6.8% (Hu et al., 2024). In the United States, maize yield losses are projected to be even larger, at 10.3% (Zhao et al., 2017), and negative impacts have also been observed in sorghum and soybean yields (Kukal and Irmak, 2018). A 2°C rise could cut maize exports from the top four exporting countries—including the United States—by 53 million tons, or 43% of global export volume

(Tigchelaar et al., 2018), and a 0.26% reduction in global gross domestic product (GDP) even when trade and production patterns are allowed to adjust (Costinot et al., 2016). Coupled climate–agriculture models estimate end-of-century United States maize productivity will decline between 6% (SSP1-2.6) and 24% (SSP5-8.5). Under RCP4.5, climate penalties are expected to erase all productivity gains made between 1981 and 2010 by around 2035. Sustaining current levels would require a doubling of technological progress (Liang, 2017).

Short-term extremes are also critical. Crops are sensitive to the frequency, duration, and intensity of weather events, not just long-term averages. In the Midwest, specialty crops are particularly affected by excessive rainfall (Kistner et al., 2017). Increasingly frequent heat waves expose crops to acute heat stress, which can stunt growth and reduce the nutritional quality of cropy (e.g., Zhao et al., 2020; Kumar et al., 2022; Mishra et al., 2023)).

Climate change also indirectly impacts crops by altering pest and pathogen dynamics. Each degree of warming is predicted to increase pest-driven losses of maize, wheat, and rice by 10 to 25% globally (Deutsch et al., 2018). In North America, a 2˚C temperature rise is anticipated to cause 32%, 18%, and 1% reductions in maize, wheat, and rice yields from insect pests, respectively (Subedi et al., 2023). Rising temperatures promote soil-borne fungal pathogens that can "spill over" into croplands, reducing yields (Delgado-Baquerizo et al., 2020).

Warming also threatens animal agriculture. In the northeastern United States, higher temperatures reduce dairy cattle fertility, while heat stress-induced inflammation lowers the energy available for milk production (Hristov et al., 2017). From 2000 to 2018, heatwaves and an average national temperature increase of 1.023˚C led to a $1.2 billion United States dairy sector loss (Wankar et al., 2021). By 2030, domestic milk yields are projected to fall 0.6–1.35% relative to 2010, depending on the climate model scenario, with losses exceeding 2% in several southern states (Key et al, 2014).

Marine and freshwater food production faces parallel challenges. Globally, warming oceans may reduce maximum catch potential by 6%, decreasing fisheries revenues and affecting the livelihoods of those dependent upon them (Cheung et al., 2021). In the United States, suitable habitats for some fish may expand northward (e.g., in Alaska), but ocean acidification will increasingly threaten shellfish-growing regions (Froehlich et al., 2018). According to a recent study assessing 82 fish and invertebrate species, over 40 species are projected to suffer adverse impacts from warming and acidification (Hare et al., 2016).

Regional studies show steep declines in biomass and landings. In the North Atlantic Ocean, divisions with high landings are projected to see 5 to 40% biomass losses (Bryndum-Buchholz et al., 2020). By 2100, between roughly 10% (SSP1-1.9) to 60% (SSP5-8.5) of species may face reproduction-threatening water temperatures (Dahlke et al., 2020). A specific case includes , an 8 to 31% loss of trout habitat under 1 to 3°C warming (Isaak et al., 2018)Beyond long-term trends, acute marine heat waves (MHWs) amplify risks. By 2050, MHWs are projected to double the impact of climate warming on key fisheries, with biomass of 22 stocks in the northeast Pacific expected to fall 2.8% during MHW events (Cheung and Frölicher, 2020).

2. Forestry

Forest ecosystems across the United States have continued to experience observable declines from both direct and indirect impacts of climate change (NASEM 2025). Much of the recent body of literature focuses on the western United States, where forestry inventory data from 1999 to 2020 shows that adverse effects of climate change tend to overwhelm any benefits (Hogan et al., 2024). A significant amount of the discussion focuses on increased fire risk to water-limited forest ecosystems. An eight-fold increase was observed in the annual area burned at high severity across the western United States between 1985 and 2017, along with strong links between projected fire severity and climatic variables (Parks and Abatzoglou 2020). A California-specific study found nearly all the increase in burned area from 1996 to 2021 was attributable to anthropogenic climate change (Turco et al., 2023). Climate change has also been observed to affect the meteorological conditions, such as precipitation and vapor pressure deficit, for fire that directly modulate the size of the burned area (Holden et al., 2018). Additionally, through decreasing snowpack and extending the length of fire season, climate change is associated with changing fire behavior, with wetter regions of the United States predicted to have an increase in frequency and drier regions expected to see increases in severity (Wasserman and Mueller, 2023). Paleoclimate records indicate that contemporary fires that have burned across the United States, especially in the West, were both widespread and of higher severity than in the past, driven partially by climate change (Margolis et al., 2020). Furthermore, reduction in fuel for future fires from these burns is not projected to substantially dampen the modeled increase in fire under climate scenarios (Abotzoglou et al., 2021).

Climate change is increasingly disrupting post-fire forest regeneration, with many regions projected to experience conditions that are unfavorable for tree recovery following wildfires (Coop et al., 2022). In addition to climate-related stressors, human fire management practices in the United States (i.e., an increase in fire exclusion practices) have contributed to an accumulation of fuel, increasing the risk of high-severity fires (Hagmann et al., 2021; Margolis et al., 2025). These intense fires often leave behind fewer seeds and depleted soil nutrients, further hindering post-fire forest regeneration (Hagmann et al., 2021; Margolis et al., 2025).

Increases in drought frequency and temperature, aside from increasing fire prevalence, can also directly affect forests, impacting both immediate forest health and long-term resiliency. Sudden tree mortality events have been documented in regions such as California, where tens of millions of trees died in association with a severe drought from 2012 to 2016 and New Mexico, where over 95% of some tree species died and old growth forest was converted to shrubland and grassland during an extremely hot drought between 2002 to 2004. These case studies exemplify that many of Earth's forests are vulnerable to die-off when drought and heat thresholds are reached (Hartmann et al., 2022). There is evidence that the impact of warming alone on subalpine species is particularly severe, with a significant decline of certain subalpine tree species across the western United States from 2001 to 2018, including a 32% decline in lodgepole pine (Stanke et al., 2021).

The compounding impacts of heat, temperature, and water scarcity also play an important role in affecting overall forest health and ability to rebound from future extreme events; Liu et al., (2024) found that the primary productivity of forests in the United States was more sensitive to water stress after drought and fire disturbances, and Forzieri et al., (2022) observed global declines in temperate and arid forest resilience linked with water scarcity and changes in climate variability. Drought and warm temperatures are also associated with an increase in the frequency of plant pathogen outbreaks and with increase outbreaks of insect pests, such as the pine park beetle, with an observed 29% increase in ponderosa pine mortality during drought directly attributable to the pine park beetle (Jaime et al., 2024, Robbins et al., 2021, Baldrian et al., 2023). In general, the impact of warming and drying associated with climate change on forests is well-summarized by Hammond et al., (2022): "Where the pace of climate change outruns the adaptive or acclimation capacities of historically dominant tree individuals and species, additional die-off events are likely to occur, and some forests may even cease to exist."

The impact of climate change on forests in the United States is projected to have important and detrimental economic impacts. Observational studies have shown a 1.64% decrease in forest-based employment in association with every 1% increase in temperature in the United States South, with economic modeling projecting declines of 16% by 2070 under high warming scenarios (Lamica et al., 2025). Increasing climate change is expected to decrease species diversity, carbon sequestration capacity, and overall forest inventory and to favor species with lower merchantable value, which will also negatively impact the forestry sector with some models projecting billions of dollars lost annually (Van Houtven et al., 2019; Baker et al., 2023).

3. Water Resources

Climate change has and will continue to worsen droughts and shrink available snowpack across the western United States, and affect water quality (NASEM 2025). A hydrologic model constrained by observations show that the annual mean discharge in the Colorado River, which provides drinking water to roughly 40 million people, has been decreasing by 9.3% per ˚C of warming (1913 to 2017, Milly and Dunne 2020). The southwestern North America 2000 to 2021 drought, which reduced river flow and affected water resources for millions of Americans, was identified in the tree ring record to be the driest 22-year period since 800 CE, and anthropogenic trends in temperature and precipitation are estimated to have accounted for 42 to 46% of its severity (Williams et al., 2020, 2022). From 1980 to 2020, the western United States experienced a marked increase in evaporative demand, with at least 57% of this rise attributed to climate change (Albano et al., 2022). Current measurements of evapotranspiration already exceed the range of variability observed 20 to 40 years ago and drive drought conditions across the region (Albano et al., 2022).

Snowpack is generally considered to be the canary in the coalmine for declining water resources (Duffy et al., 2018, Mote et al., 2018, Cho et al., 2021, Musselman et al., 2021). An extended observational record of snowpack by Mote et al., (2018) found that 90% of snow monitoring sites with long records across the western United States now show evidence of decline, and the average decline in snow water equivalent on April 1st, the typical peak snowpack date, is roughly 15 to 30%. Snowpack melt is also observed to occur earlier each decade, which has detrimental implications for seasonal water storage (Musselman et al., 2021).

Other forms of water storage and other regions are also at risk. Recent satellite observations showed a decline in lake water storage across the conterminous United States from 1992 to 2020, predominately attributed to changes in temperature and precipitation (Yao et al., 2023). Furthermore, paleoclimate records show that the 2000 to 2010 drought in the upper Missouri River basin was potentially unprecedented over the last millennium and that recent warming has corresponded to decreasing runoff and increasing drought severities (Martin et al., 2020). Although trends towards increased aridity are clearest in observations from the American West, greater aridity is expected to reach eastward with increased warming, and even in areas with predicted increases in precipitation, aridity will increase (Overpeck and Udall, 2020).

Simulations predict this warming impact on water resources will continue and be enhanced under increased warming scenarios. Under 1.5˚C and 3˚C warming simulations, the increase in the water gap (where water consumption exceeds available resources) is expected to be the third largest in the Mississippi-Missouri basin out of all major river basins globally (Rosa and Sangiorgio 2025). Reduced rainfall under these scenarios is modeled to threaten 10 to 18 million hectares of United States cropland, which would have the potential to affect food supply for 157 million Americans (He and Rosa, 2023). Large reductions in extreme and average snow water equivalent in the western United States are projected by the middle of the century (Siirila-Woodburn et al., 2021) and increases in warm and dry snowpack droughts are predicted for the mountains and high latitudes of North America (Cowherd et al., 2023). This in turn is projected to pose a large risk to snow-melt fed irrigation in the American West (Qin et al., 2020). Terrestrial water storage more generally is predicted to decline by the late 21st century, with especially high confidence in declines in the eastern United States (Pokhrel et al., 2021).

Climate change is also predicted to impact water quality. Rising temperatures will directly alter the chemical composition of groundwater in many ways, including through warmer temperatures leading to increased stratification and nutrient release from sediments (Shukla et al., 2023, Dao et al., 2024). There are also many predicted indirect impacts of climate on water quality, such as increased flooding in high-precipitation areas leading to increased groundwater salinity and pollution levels (Dao et al., 2024). There is also evidence that increasingly frequent wildfires serve as a watershed-level contamination source for pollutants, including nitrate and arsenic, as well as an additional source of sedimentation (Pennino et al., 2022; Robinne et al., 2021). Higher temperatures enhance the growth of pathogens and harmful algal blooms (NASEM 2025), posing health and economic risks to people in places like Florida and elsewhere who are subjected to reoccurring blooms (van Vliet et al., 2023; Heil & Muni-Morgan, 2021).

4. Sea Level Rise and Coastal Areas

Global mean sea level has increased by approximately 1.2 millimeters per year over the twentieth century, a rate which accelerated to 3.0 millimeters per year in recent years (Hay et al., 2015) and in 2023 is about 4.5 millimeters per year (NASEM 2025). Most of this rise can be attributed to thermal expansion of water due to warming and glacier melt, with smaller contributions from Greenland and Antarctic ice melt (Frederikse et al., 2020). Ice sheet melt—the upper bounds of which are poorly constrained—is expected to play a much more prominent role in future sea level change (Chen et al., 2017), leading to a very likely total of 0.3 to 1.2 meters of global sea level rise by 2100, depending on concentration pathway and ice sheet physics (Kopp et al., 2014). Sea level change is highly spatially heterogeneous depending on the mechanism of change and can be exacerbated by local non-climate factors like land subsidence and groundwater depletion (NASEM 2025).

In North America, more frequent and intense flooding has been attributed to human influence on the climate (Kirchmeier-Young and Zhang, 2020). Sea level rise portends significant consequences for coastal communities which, as of 2020, comprised 40% of the United States population and the most economically productive areas in the country (Census Bureau 2020). Scientists warn that Americans' exposure to floods is inevitable over the next thirty years across the continental United States and that this risk may continue to increase depending on greenhouse gas emissions trajectories (Swain et al., 2020). Accounting for population changes, a sea level rise of 0.9 meters is predicted to put 4.2 million people at risk of inundation, and a rise of 1.8 meters would put 13.1 million people at risk (Hauer et al., 2016).

Flood risk maps are a tool that prospective homebuyers can use to assess their risk of flooding. Current estimates of flood risk are underestimated. The Federal Emergency Management Agency (FEMA) does not account for the effects of climate change in their flood risk maps (Marsooli et al., 2019). A 2018 analysis found that the total number of Americans exposed to flooding is between 2.6 to 3.1 times higher than FEMA's estimate, with 41 million Americans living within the 100-year floodplain (Wing et al., 2018).

Sea level rise has doubled the frequency of high-tide flooding in the continental U.S. over the past few decades (NASEM 2025). Globally, based on wave, tide, and storm surge models, coastal flooding is expected to double in the coming decades, and potentially as early as 2030 in much of the tropics (Vitousek et al., 2017). Along the coast of the United States, sea level is projected to rise by 0.25 to 0.3 meters by 2050. The Atlantic coast is particularly susceptible to sea level rise because of subsidence; between 58 to 100% of coastal marshes, which is the dominant land type on the Atlantic coast, are losing elevation relative to sea level (Ohenhen et al., 2023). By 2050 and even with flood mitigation infrastructure, sea level rise under a moderate climate change scenario (SSP2-4.5) would raise the flood risk of 55,000 to 273,000 people across thirty-two coastal cities, primarily along the Gulf and Atlantic coasts (Ohenhen et al. 2024). Minor high-tide flooding, already "routinely exceeded" along the Atlantic coast, will quickly increase on the Pacific coast; under an intermediate estimate of sea level rise, by the 2040s, the frequency of high-tide flooding is projected to increase eight-fold in Boston (from 6 to 46 days per year), 49-fold in La Jolla (from 1 to 49 days per year), and eleven-fold in St. Petersburg (from 6 to 67 days per year; Thompson et al., 2021). Some impacts of sea level rise are already being felt. In Miami Beach, for example, tide-induced flooding was more than 400% higher in the 2006 to 2013 period relative to the 1998 to 2006 period. Over these two periods, sea level rise in the region has also accelerated from 3 millimeters per year (mm/yr) to 9 ± 4 mm/yr (Wdowinski et al., 2016). Sea level rise along the United States southeast and Gulf coasts (>10 mm/yr since 2010) is faster than it has been in at least 120 years, and roughly 40% of this rise can be attributed to anthropogenic warming (Dangendorf et al., 2023).

However, it is not only residential flooding that poses a risk but flooding of essential services and infrastructure. Combining storm surge and road data, Tarabochia-Gast et al. (2022) find that 25 of 78 metropolitan statistical areas on the United States Atlantic and Gulf Coasts have half or more of their hospitals at risk of flooding from relatively weak hurricanes. With 0.82 meters of sea level rise, a measure well within the bounds of sea level rise expected within this century from climate change, the odds of hospital flooding increase by 22% (Tarabochia-Gast et al., 2022). Accounting for the risk of isolation (the inundation of transportation networks that isolates individuals from critical services like hospitals, supermarkets, and schools) increases the population exposed to rising sea levels by 30 to 90% (Logan et al., 2023), with disadvantaged groups being disproportionately exposed (Best et al., 2023).

Finally, frequent tidal flooding due to sea level rise will allow saltwater to intrude into freshwater coastal systems (Heiss et al. 2022; O'Donnell et al., 2024). Sea level rise is expected to convert at least 12,000 to 49,000 square kilometers of dry land into intertidal land (Haer et al., 2013). Saltwater intrusion has led to forest mortality (Kirwan and Gedan, 2019), crop failure (Tully et al., 2019), and drinking water degradation (Vineis et al., 2011). It also influences coastal infrastructure and may have played a role in the 2021 collapse of the Champlain Towers South condominium in Miami, Florida (Parkinson et al., 2021). Other impacts include coastal erosion under rising sea level. For example, in Hawaii, a doubling of coastal erosion is expected by 2050 (Anderson et al., 2015).

5. Extreme Precipitation and Storms

Human emissions have contributed to the rise in frequency and intensity of extreme precipitation events in North America (Kirchmeier-Young and Zhang, 2020; NASEM 2025). Extreme precipitation events have become the "new normal" which over three-fourths of Americans are likely to experience during their lifetimes (Kim et al., 2023). Rising average temperatures in the Gulf Coast have increased the intensity of extreme precipitation by 12 to 22% since 1880 (van

Oldenborgh et al., 2017). Up to one-third of Americans are now expected to experience a previously “once-in-a-lifetime" storm up to three times in their lifetimes (Kim et al., 2023). In the western United States, the effects of extreme precipitation are worsened by the alternation between drought and intense rainfall, a phenomenon referred to as whiplash events which can amplify hazards such as flash floods, wildfires, landslides and disease outbreak (Swain et al., 2025; NASEM 2025). In the winter of 2022 to 2023, after multiple years of drought, California experienced nine consecutive atmospheric rivers in three weeks, causing flooding, property damage, landslides, and prompting disaster declarations in forty counties (Swain et al., 2025). The southeastern United States is predicted to experience a 25 to 60% increase in whiplash events by the late twenty first century (Swain et al., 2025).

Researchers have also observed an increase in the probability of major hurricanes (Categories 3, 4, and 5) by 8% since 1979 (Kossin et al., 2020). The East Coast, Florida, and the coasts of Texas and Louisiana have been especially vulnerable to hurricanes in recent decades (Balaguru et al., 2023). Reed et al. (2022) estimated that extreme three-hour rainfall rates increased by 11% during the 2020 hurricane season due to anthropogenic climate change. Researchers have begun to determine how climate change has contributed to the devastation wrought by hurricanes. For example, Hurricane Harvey caused $90 billion in damages in 2017, with up to $67 billion of these attributable to anthropogenic climate change (Frame et al., 2020). Researchers estimate that climate change made Hurricane Harvey three times more likely (van Oldenborgh et al., 2017) and made Hurricane Harvey’s rainfall 15 to 20% more intense than it would have been otherwise (van Oldenborgh et al., 2017; Risser & Wehner 2017).

6. Energy, Infrastructure and Settlements

Rising temperatures, sea level rise, and changing hydrological regimes will further burden energy and infrastructure systems (NASEM 2025). Since 2018, a growing body of research documents these negative effects. Warming is projected to increase global energy demand in 2050 by 11 to 27% under moderate emissions scenarios (RCP4.5) and by 25 to 58% under high emissions scenarios (RCP8.5) (van Ruijven et al., 2019). Heat extremes further increase energy demands for cooling (NASEM 2025), while reducing heating demand, as observed in electricity trends across the United States (Amonkar et al., 2023). As energy demand rises, climate change is also increasingly impacting energy generation. For example, smoke from wildfires reduces solar photovoltaic output, and the 2020 wildfires were estimated to have cut monthly photovoltaic generation by nearly 8% during significant wildfire activity and increased energy reserve requirements by over 50% (Cai et al., 2023). New evidence indicates that drought conditions shift energy generation from hydropower to fossil fuel plants. In a retrospective analysis of the 2012 to 2016 California drought, the increased cooling demands cost nearly twice as much as the lost hydropower generation (Kern et al., 2020). Hydropower capacity is also declining. Two thirds of domestic hydropower plants show reductions in capacity, with changes in water availability explaining over 20% of the losses (Turner et al., 2024). Transmission and distribution systems are also vulnerable, and infrastructure costs are projected to increase by $6-13 billion this century under a moderate (RCP4.5) emissions scenario (Fant et al., 2020).

United States infrastructure also faces systematic threats from climate change (NASEM 2025). Rail, roads, and coastal property damages could reach tens of billions of dollars by 2050 under a moderate (RCP4.5) emissions scenario, though adaptation can reduce costs significantly (Neumann et al., 2021). Systematic reviews of literature document the widespread climate-driven risks of inundation, overflow, and corrosion to wastewater systems (Hyde-Smith et al., 2022; Li et al., 2023). Along the coasts of the United State, low-lying wastewater treatment plants are particularly vulnerable to sea level rise. In one estimate, the number of people at risk of losing wastewater services is over five times as high as the number of people at risk of direct flooding (Hummel et al., 2018). In Alaska, building and road losses from thawing permafrost are projected to cost $37 billion under a moderate (SSP2-4.5) emissions scenario (Manos et al., 2025). Beyond permafrost, rising urban temperatures can warm the subsurface and cause the deformation of construction materials, with the potential to undermine building stability in cities such as Chicago (Rotta Loria, 2023).

7. Terrestrial Ecosystems and Wildlife

A growing body of recent research reveals that terrestrial ecosystems and wildlife are already experiencing disruptions due to climate change. Rising temperatures, altered precipitation, and more frequent disasters are directly linked to observed global biodiversity loss (e.g., Habibullah et al., 2022). Recent studies have documented measurable population declines, local extinctions, and signals of ecosystem destabilization. Climate change is pushing individual species beyond their physiological limit, while ecosystems are simultaneously losing their capacity to buffer disturbance.

Globally, biodiversity declined by 2 to 11% during the 20th century (Pereira et al., 2024) with climate change projected to drive 14 to 32% of macroscopic species to extinction within the next 50 years even under moderate emissions scenarios (Wiens & Zelinka, 2023). Using a different method with ecological community-level data, climate change was predicted to cause almost 20% loss of species by 2070 under a moderate emissions scenario (Newbold, 2018), indicating that shifts in community composition are increasingly attributable to climate pressures whereas land-use change historically played a larger role (Newbold, 2018; Jaureguiberry et al., 2022). The number of vascular plant species expected to go extinct due to changes that have already happened, i.e., species “committed to extinction”, has increased by 60% globally over the past century, with the impact of climate change projected to surpass the impact of land-use change under all future scenarios (Di Marco et al., 2018).

Evidence also indicates that species’ adaptive capacity is limited. For example, observed adaptive responses in animals are generally insufficient to keep pace with current rates of warming (Radchuk et al., 2019). Globally, 57% of species will not be able to disperse quickly enough to track suitable climates under the RCP4.5 moderate emissions scenario (Román-Palacios & Wiens, 2020) and the loss of mammals and birds has “already reduced the capacity of plants to track climate change by 60%” via limited seed dispersal (Fricke et al., 2022). Rising temperatures are shifting the seasonal timing of animal life cycles globally, increasing risks of ecological mismatches that disrupt predator-prey, host-parasite, and pollination networks (Cohen et al., 2018).

Several recent studies have focused on the potential for nonlinear, abrupt change. Species are increasingly at risk of being exposed to temperatures that exceed their physiological thermal limit, with over 50% of the increase in species’ exposure is projected to occur in a single decade (Trisos et al., 2020; Pigot et al., 2023). Rising temperatures are a serious threat to species. By 2099 under intermediate emissions scenarios (SSP3-7.0 and SSP2-4.5), 15 to 29% of all land vertebrates will be exposed to extreme temperatures exceeding historical levels in over half of their geographic range (Murali et al., 2023). Likewise, 9% of freshwater fish globally will be exposed to extreme temperatures in over half of their geographic range when global warming reaches 2°C under moderate emissions scenarios (Barbarossa et al., 2021). Climate change is also driving synchronous decreases in ecosystem resilience, or the ability of a system to withstand disturbances without drastically changing, across terrestrial biomes which could lead to rapid ecosystem transitions (Rocha, 2022).

Within the United States, the decline and extinction of numerous species due to climate change is already underway and is most pronounced in the hotter and drier western regions (e.g., Riddell et al., 2019, 2021; Steel et al., 2022; Holzmann et al., 2023). Several examples are described below. Across the northern Rocky Mountains, warmer stream temperatures and decreased summer stream flow are reducing native trout habitat and driving the expansion of invasive trout species. Since 1993, the occupancy of native bull trout and cutthroat trout decreased by 18% and 6%, respectively, and are projected to decrease by another 39% and 16% by 2080 under a moderate emissions scenario (Bell et al., 2021). In the Mojave Desert, hotter temperatures and reduced rainfall are driving bird community collapse, with survey sites on average losing 43% of their species relative to the early 20th century (Iknayan & Beissinger, 2018). These local extinctions are linked to hotter and dryer climates, which require birds to expend greater amounts of energy to cool themselves, and thus are projected to worsen under future climate change (Riddell et al., 2019, 2021). In the mountains of Arizona, the local extinction rates for Yarrow’s Spiny Lizard have tripled in the past 7 years relative to the previous 42 years and are “among the fastest ever recorded” due to rapidly rising temperatures (Holzmann et al., 2023). Bumble bee populations in

North America have also declined due to temperatures reaching or exceeding the species’ thermal limit, and the probability of site occupancy decreased on average by 46% relative to 1901-1974 (Soroye et al., 2020). Across the southern Sierra Nevada, 30% of mature forest vegetation was lost between 2011 and 2020; drought, wildfires, and pest invasions reduced canopy cover and forest density, damaging ecosystems and exacerbating forest loss (Steel et al., 2022). Along the northern Pacific coastline from California to Alaska, common murre seabird populations experienced unprecedented mass mortality and 22 colonies failed to reproduce during with the 2014-2016 marine heatwave (Piatt et al., 2020) which has been linked to anthropogenic climate change (e.g., Wang et al., 2024).

III. ADDITIONAL SECTORS AND IMPACTS

1. Ocean Acidification, Deoxygenation, Marine Heatwaves, and Marine Ecosystem Impacts

The scientific community's understanding of the impacts of climate change on the ocean's physical, chemical, and biological systems has continued to increase. Three of the most observable phenomena that have been linked to climate change are ocean acidification, deoxygenation, and marine heatwaves, and each has subsequent impacts on the marine ecosystem.

Anthropogenic emissions have directly increased carbon uptake by the ocean, in turn decreasing the surface ocean pH by 0.1 pH units on average globally since 1770 in a phenomenon termed 'ocean acidification' (Garcia-Soto et al., 2021; NASEM 2025). In the last four decades, pH has declined globally at a rate of –0.0166 pH units per decade (Ma et al., 2023). Further observational records in the Pacific Ocean and California current system quantify acidification at roughly the same rate, with values of –0.0015 and –0.002 pH units per year, respectively (Wolfe et al., 2023; Feely et al., 2024). Ocean acidification dramatically changes the habitat range for marine calcifying organisms through promoting dissolution of their shells, and according to a 2025 review paper, by 2020, the suitable habitat worldwide declined by 43% for tropical and subtropical coral reefs and 13% since the pre-industrial for coastal bivalves (i.e., clams, oysters, mussels, and scallops) (Findlay et al., 2025). This in turn has impacts on aquaculture and fisheries, with losses of up to $400 million modeled for the United States economy by 2100 due to impacts on the bivalve industry (Doney et al., 2020). Notably, the average global ocean conditions have already crossed into the uncertainty range of the ocean acidification boundary, which is derived from a framework where unacceptable environmental change would occur (Findlay et al., 2025). Polar regions are the most rapidly acidifying (Feely et al., 2023), with observational evidence suggesting the Arctic Ocean is acidifying three to four times faster than other ocean basins (Findlay et al., 2025; Qi et al., 2022). As a result of this and warming, polar ecosystems may be the most heavily impacted by climate-induced ocean changes (Du Pontavice et al., 2022).

The ocean itself is also warming (NASEM 2025). The mean surface warming rate over the last 120 years is 0.062˚C per decade, and during the last decade (2009 to 2019), this accelerated to 0.280˚C (Garcia-Soto et al., 2021). Warmer water can hold less dissolved oxygen, so this in turn leads to deoxygenation of the ocean, and all studies summarized in a recent review have agreed that the ocean is losing oxygen at an alarming rate of roughly 2% per 50 years (Garcia-Soto et al., 2021). This is projected to continue; under a high warming scenario, 72% of the global ocean is expected to experience deoxygenation at all depths before 2080 (Gong et al., 2021). Oxygen is necessary for marine life, and deoxygenation can lead to ‘dead zones’, or low oxygen zones, compressing available habitat for marine species and changing fish distribution, which in turn impacts fisheries (Kim et al., 2023).

Furthermore, extreme warm ocean temperature events, often called marine heatwaves, have been increasing in frequency, with multiple studies finding a large increase in the frequency of occurrence of marine heatwaves over the 35-year satellite record (Hobday et al., 2018, Frölicher et al., 2018; NASEM 2025). Long-term warming trends have been found to be almost entirely responsible for these changes in frequency, as well as for observed increases in marine heat wave intensity (Capotondi et al., 2024; Laufkötter et al., 2020, Oliver, 2019). These marine heatwaves events have impacts on marine ecosystems, including fish and bird die-offs, impacts on foundational species like coral, sea grass, and kelp, and overall reductions in biodiversity (Smale et al., 2019; Capotondi et al., 2024). Examples of this include one study finding a two-to-fourfold increase in marine heatwaves in the North Atlantic coincided with high mortality in local kelp populations (Fillbee-Dexter et al., 2020). Marine heatwaves have a large impact on marine economic as well; modeled impacts on fish stocks are at least four times larger than decadal scale mean change, and there are significant projected impacts on fisheries revenues and biomass in climate-vulnerable areas, including up to a 30% decline in global fish biomass by 2021 (Cheung and Frolicher, 2020; Cheung et al., 2021, Carozza et al., 2021, Tittensor et al., 2021). There is also evidence of lagged ecosystem recovery after these marine heatwave events (Robertson et al., 2021), including an example from the 2014 to 2016 PNW heatwave suggesting that the response of ecosystems may persist for up to 5 years (Suryan et al., 2021).

Taken all together, these three major climate impacts on the ocean also have compounding effects on the marine ecosystems. Fish biomass maximum sustainable yield has had an observed 4.1% decline over the past eighty years (Free et al., 2019) and is projected to continue to decline under warming scenarios (Tittensor et al., 2021). There have been observed detrimental impacts on certain valuable species, including lobsters, oysters, salmon, and cod, which are all economically important to the seafood and shellfish industries in the United States (Le Bris, 2018; Oke et al., 2020, Sguotti et al., 2019; Welton et al., 2024).

2. Violence and Social Instability

Higher temperatures have historically been directly correlated with higher rates of violent crime (Corcoran and Zahnow, 2022), and previous work has estimated that each one-standard deviation increase in temperature or extreme weather events increases interpersonal violence by 4% and climate change related intergroup conflict by 14% (Hsiang et al., 2013). Building on this prior work, rising temperatures, changing precipitation patterns, and more frequent extreme weather events associated with the climate crisis have been observed and projected to alter patterns of violence and social instability through both individual and institutional factors.

On an individual behavior level, one recent meta-analysis documented a 9% rise in violent crime per 10ºC increase in daily temperatures (Choi et al., 2024), and a United States-specific study found that violent crime was 3% higher at high versus moderate temperatures across 44 cities and that risk was higher in cities with 90th percentile temperature anomalies deviating from the previous 30-year average (Heo et al., 2025). In addition, when seasonal cycles were removed, a different study found temperature residuals had a positive correlation with assault and robbery in all eight United States cities studied (Hu et al., 2024), and in a study focusing on 100 United States cities, estimated risk of shootings increased nearly monotonically with temperature (Lyons et al., 2022). Recent studies of Chicago and Cleveland also found that heat waves and high maximum daily temperatures, respectively, were correlated with an observed increase in crime (Hou et al., 2023, Cruz et al., 2020). There is also emerging evidence that drought may also be correlated with an increase in violent crime, particularly in agricultural regions of the country (Cohen 2025).

However, there are also more indirect ways that climate change can impact social instability. Here, like in national security frameworks, climate change acts as a threat multiplier, creating additional vulnerabilities and exacerbating hazards that already exist. For instance, climate change is especially likely to provoke instability and violence in regions that are dependent on agriculture or have high levels of political marginalization (Sellers et al., 2019, Koubi et al., 2019). Natural disasters, which have been increasingly tied to climate change, can also serve as threat multiplier and can lead to heightened negative impacts to mental health and increased levels of housing instability, especially among vulnerable populations even within the United States (Benevolenza and DeRigne, 2018). Increased levels of stress and PTSD that can be associated with natural disasters and other climate impacts also disrupts daily life and foster stress, which over time is linked in an increase in violent behavior (Amin 2025; Miles-Novelo and Anderson, 2019).

3. National Security

The assertion that "climate change is a direct threat to the national security of the United States" made by the 115th Congress remains true today (National Defense Authorization Act, 2018). Hazards driven by climate change threaten military infrastructure and hinder military readiness, while intensifying geopolitical competition, fueling migration and instability, and straining fragile states. Collectively, climate change is amplifying threats to United States national security at home and abroad.

These threats have been articulated and analyzed in numerous reports by the United States Department of Defense since 2018, with the most salient reports summarized below. In the 2022 National Defense Strategy, the Department of Defense recognized climate change as a transboundary challenge that is altering the security landscape by degrading readiness and installations, opening new strategic arenas such as the Arctic, driving greater demands for disaster response, and heightening instability and conflict risks that will increasingly tax United

States forces and partners (Department of Defense, 2022). The United States Army War College released a report in 2019 which detailed these threats, emphasizing regional instability due to reduced water and food security, increased geopolitical competition in the Arctic, and raised operational burdens, all of which elevate national security risks (Brosig et al., 2019). In the report "Climate Change and International Responses Increasing Challenges to United States National Security Through 2040", the National Security Council (NIC) concluded that climate change is likely to "exacerbate cross-border geopolitical flashpoints" and the effects of climate change will be most felt by developing countries with the least adaptation ability, thus increasing the "potential for instability and possibly internal conflict in these countries, in some cases creating additional demands on United States diplomatic, economic, humanitarian, and military resources" (NIC, 2021a). The NIC emphasizes these threats from climate change in their broader "Global Trends 2040" report (NIC, 2021b). Chapter 17 of the Fifth National Climate Assessment also states with high confidence that climate change can contribute to conflict abroad and that climate change "impacts the operations and missions of defense, diplomacy, and development agencies critical to United States national security" (Hellmuth et al., 2023). Alongside these official reports, an independent study revealed that "Department of Defense leadership considers climate change a security threat of strategic importance" and climate security researchers within the defense community "believe the United States Department of Defense prioritizes climate security as a near-term threat" (Burnett & Mach, 2021).

Since 2018, new research has substantially strengthened the evidence that climate change is impairing United States military readiness and degrading critical infrastructure. Epidemiological studies at Army installations reveal that rising temperatures have already translated into measurable impacts. A 1-degree Fahrenheit increase in average summertime temperature was associated with a 16% increase in heat stress rates among soldiers (Lewandowski et al., 2022), while there has been a marked increase in "black flag" hours when temperatures are high enough that all physical training is stopped at Basic Combat Training installations (Patton & Doyle, 2024). Overall, extreme heat has become a persistent "noncombat threat" to training and military operations which directly threatens preparedness (Moran et al., 2023). Coastal military installments face additional vulnerabilities from rising sea level. An assessment of readiness in the southwestern United States documented the near-term risk of "worsening erosion due to waves and high tides" at the Naval Base Coronado (Garfin et al., 2021). Tidal dynamics are expected to further exacerbate flooding risks for coastal infrastructure across the United States (Li et al., 2021). Abroad, Pacific atoll installations will cross thresholds of habitability and freshwater availability within decades, making annual wave-driven flooding a likely operational disruption (Storlazzi et al., 2018). Additional hazards compound these risks: wildfire-smoke exposure at Joint Base Lewis-McChord has significantly increased respiratory and behavioral health visits among service members (Robinson et al., 2025), while thawing permafrost in Alaska undermines runways, roads, and building foundations critical to defense missions (Douglas et al., 2021; Hjort et al., 2022).

Arctic sea ice has continued to decline since 2018, increasing geopolitical tension as the United States, China, and Russia vie for control over forthcoming shipping routes and new oil and gas extraction opportunities. The spring of 2025 set the record lowest sea ice maximum (NSIDC, 2025) and the first ice free day in the Arctic could now occurwithin 10 years (Heuzé & Jahn, 2024) with Arctic shipping routes projected to be navigable in all but the spring by 2065 (Zhao et al., 2024). Already, shipping in the Arctic has increased by 8.7% between 2013 and 2022 (Sander & Mikkelsen, 2025). China and Russia have begun increasing their military presence at a rapid pace, with the Kremlin placing the militarization of the Arctic as a state priority (Uryupova, 2023). These developments underscore that the United States must treat the Arctic as an emerging theater of strategic competition by investing in sustained military and coast guard presence to safeguard national security in an increasingly contested region.

As described in the previous section, climate change should also be viewed as a threat multiplier that exacerbates conditions already conducive to armed conflict and violence (e.g., Schleussner et al., 2016; Mach et al., 2019; Sellers et al., 2019; Koubi, 2019; Daoudy et al., 2022). Immigration from El Salvador, Guatemala, and Honduras to the United States between 2012 and 2018 increased 70.7% during growing seasons in Central America that were drier than the historical average (Linke et al., 2023). Droughts in Central America are projected to worsen under climate change (Anderson et al., 2023), making migration and its inherent instability a growing concern. There is also a growing link between climate change and terrorism, with climate change exacerbating existing social vulnerability that enables and drives terrorism (Asaka, 2021). From a hybrid warfare perspective, instability induced by climate change may also be leveraged by our adversaries to increase insurgency and conflict potential (Briggs, 2020). Taken together, this body of evidence demonstrates that climate change not only intensifies existing drivers of instability but also creates strategic openings that can be exploited by adversaries, thereby multiplying threats and amplifying risks to United States national security.

4. Economic Well-Being

Climate change drives substantial domestic and global economic losses related to damage across sectors—agriculture, crime, coastal storms, energy, human mortality, and labor (Hsiang et al., 2017). Warmer temperatures and lower precipitation, disproportionately impacting the Global South, increased global inequality by 25% from 1961 to 2010 (Diffenbaugh and Burke 2019).

The negative impact of anthropogenic warming on the United States economy has been found using seasonal data from 1957 to 2012, it is estimated average summer and fall temperatures will decrease United States gross state product growth by 0.2 to 0.4 % with the greatest effects in (hotter) southern states (Colacito et al. 2018).

Much of the body of literature linking economic damages to future climate relies on historical relationships between GDP and mean temperature. However, there is evidence that changes in variability or changes in other non-temperature variables also must be considered to arrive at an accurate damage estimate. Waidelich et al. (2024) used changes in the mean and variance of temperature and precipitation to predict that with 3°C warming, global average losses reach 10% of gross domestic product. Precipitation data also suggests that future hydrologic changes will drive more inequality in the United States (Palagi et al., 2022). There is also evidence that global climate models underestimate impacts from climate extremes, which could bias projections of future economic losses low (Schewe et al., 2019). Accounting for internal climate variability also substantially boosts future uncertainty, by 38% on average for near-term mortality, corn yields, and GDP projections in the continental United States (Schwarzwald and Lenssen, 2022). Sea level rise by itself may cause GDP to decline by $70-289 billion (Haer et al., 2013).

There is evidence that climate change is already causing economic damage. Since the 1970s, there has been a sevenfold increase in the reported disaster losses from extreme events, much of which is attributable to climate change; from 2000 to 2019, it has been estimated that anthropogenic warming—which changes the frequency and intensity of extreme events—added $2.86 trillion in global disaster costs (Newman and Noy 2023). From 1988-2017, it is estimated that one-third ($73 billion) of the cost of flood damages is a result of increased heavy precipitation (Davenport et al., 2021). From 1900 to 2018, it was estimated that the most damaging storms have increased by 330% per century, consistent with more frequent and stronger hurricanes due to anthropogenic warming in the Atlantic (Grinsted et all., 2019).

Another uncertainty is the human response to the economic damages inflicted by climate change, which could potentially exacerbate GDP losses. Lamperti et al. (2019) use an agent-based climate-macroeconomic model and find that climate change will increase the frequency of banking crises by between 26 to 248%, and that rescuing insolvent banks will cause an additional fiscal burden of approximately 5 to 15% of gross domestic product per year. The stability of the housing market could also be impacted, through overvaluations of residential properties exposed to flooding (Gourevitch et al., 2023).

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EPA Administrative History Appendix

EPA itself has consistently reaffirmed and further reinforced the scientific conclusions supporting the Endangerment Finding in its rulemakings and denials of petitions for reconsideration since 2009. Attached to EDF's submission are four memoranda synthesizing this administrative history, listed and summarized here:

1. Anthropogenic Greenhouse Gas Emissions: Human Activities Are Driving Accumulation of GHG in the Atmosphere

This memo lays out EPA's record and cited evidence on the claim that human activities are driving accumulation of GHG in the atmosphere and its relevance in guiding EPA's regulatory actions and policymaking. Section I summarizes how the Initial Endangerment Finding and corresponding Technical Support Document (TSD) define and support that GHG emissions are largely driven by anthropogenic sources. Section II identifies EPA rules and decisions to illustrate how EPA has reinforced that GHG emissions are driven by human activities through promulgation of industry standards over the past 15 years. Section III explains how EPA has continuously upheld these findings despite petitions for reconsideration from states, industry groups, and think tanks in 2009, 2017, and 2019.

2. Scientific Evidence: Unprecedented Rise in Atmospheric Concentration of GHGs

This memo lays out EPA's record and cited evidence on the claim that there is an "unprecedented rise" in atmospheric concentration of GHGs and is expected to continue and the relevance of this finding in guiding EPA's regulatory actions and policymaking. Section I summarizes how the Initial Endangerment Finding, corresponding Technical Support Document (TSD) and 2016 Endangerment Finding support that GHG emissions have been rising steadily through the years. Section II identifies EPA rules and decisions to illustrate how EPA has reinforced this finding in its promulgation of industry standards over the past 15 years. Section III explains how EPA has continuously upheld these findings in denying petitions for reconsideration from states, industry groups, and think tanks in 2009, 2017, and 2019.

3. Scientific Evidence: Warming Effect of GHGs and Other Climate Impacts

This memo lays out EPA's record and cited scientific evidence to show that the accumulation of GHGs exert a warming effect through increase in air and ocean temperature, sea level rise and melting of Arctic ice, and its relevance in guiding EPA's regulatory actions and policymaking. Section I summarizes how the Initial Endangerment Finding, corresponding Technical Support Document (TSD) and 2016 Endangerment Finding provide such scientific evidence. Section II identifies EPA rules and decisions to illustrate how EPA has reinforced that scientific evidence in its promulgation of industry standards over the past 15 years. Section III explains how EPA has continuously upheld these findings despite petitions for reconsideration from states, industry groups, and think tanks in 2009, 2017, and 2019.

4. Climate Change from GHG Endangers Public Health and Welfare

This memo lays out EPA's record and cited evidence on the claim that climate change endangers public health and welfare. Section I summarizes how the Initial Endangerment Finding and corresponding Technical Support Document (TSD) define and support that climate change endangers public health and welfare. Section II identifies EPA rules and decisions to illustrate how EPA has reinforced the conclusion that climate change endangers public health and welfare through promulgation of industry standards over the past 15 years. Section III explains how EPA has continuously upheld these findings despite petitions for reconsideration from states, industry groups, and think tanks in 2009, 2017, and 2019.

*   *   *

The Proposal fails to justify EPA's departure from these long-held, firmly-grounded agency positions.