Appendix A: Methodology

Emissions model and scope

We projected annual CO_2 and nitrogen oxide (NO_x) emissions through 2050 using ICCT's Roadmap model 1.9.0.[1] We modeled Class 4–8 vehicles in the United States by segment. Segments were defined for each source type and regulatory class combination in the EPA's MOVES model.[2] Vehicle sales, powertrain shares, survival curves, mileage, and emissions data were sourced from the latest version, MOVES3, with some adjustments as described here. Vehicle sales data were set such that the maximum vehicle stock of a given model year in MOVES3 occurs in the same calendar year in Roadmap. Prior year sales data were back calculated using survival curves. The share of zero-emission powertrains by vehicle segment were separately defined for each ZEV scenario, which is described in more detail in the following section. Average annual vehicle mileages were calibrated such that model-estimated historical CO_2 emissions align with the EPA's greenhouse gas emissions inventory in 2019.[3] We additionally apply mileage degradation factors sourced from MOVES, such that annual mileage decreases over the lifetime of the vehicle but lifetime average mileage remains unchanged. In practice, this means that age 0 mileage for buses is roughly 1.3–1.4 times the lifetime average mileage; 1.5 times for short-haul tractors, 1.8 times for long-haul tractors, 2.0 times for refuse trucks, and roughly 1.5–1.6 times for other rigid trucks.

Vehicle emission factors were sourced directly from MOVES3 for CO_2. For NO_x, average zero-mile emission factors under current policies were sourced directly from MOVES3 but were adjusted to align with proposed NO_x standards and ZEV crediting schemes, described in more detail below. We applied a degradation factor to account for deterioration of NO_x emission control technology over time. The rate of deterioration was determined by current and proposed warranty and useful life requirements following MOVES methodology. We included well-to-wheel CO_2 emissions from fuel production and use but excluded those emissions associated with vehicle and infrastructure manufacturing and end-of-life. In 2019, CO_2 accounted for 97.9% of heavy-duty vehicle greenhouse gas emissions on a CO_2-equivalent basis.[4] All ZEVs are modeled as battery electric vehicles, with upstream well-to-tank emissions that depend

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[1] International Council on Clean Transportation, *Roadmap Model Documentation*, version 1.9.0, 2022, https://theicct.org/transportation-roadmap.
[2] U.S. Environmental Protection Agency, *MOVES and Other Mobile Source Emissions Models*, version MOVES3, 2021, 3, https://www.epa.gov/moves.
[3] US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020," February 3, 2022, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.
[4] US EPA, "U.S. Transportation Sector Greenhouse Gas Emissions: 1990–2019," December 2021, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013NR3.pdf.

purely on the carbon intensity of the electricity grid. Grid carbon intensity was sourced from the International Energy Agency's stated policies scenario.

Scenarios

ZEV pathways

We modeled six ZEV pathways that cover a wide range of possible heavy-duty ZEV deployment in the United States. These pathways are summarized in Figure A1 and described in detail below.

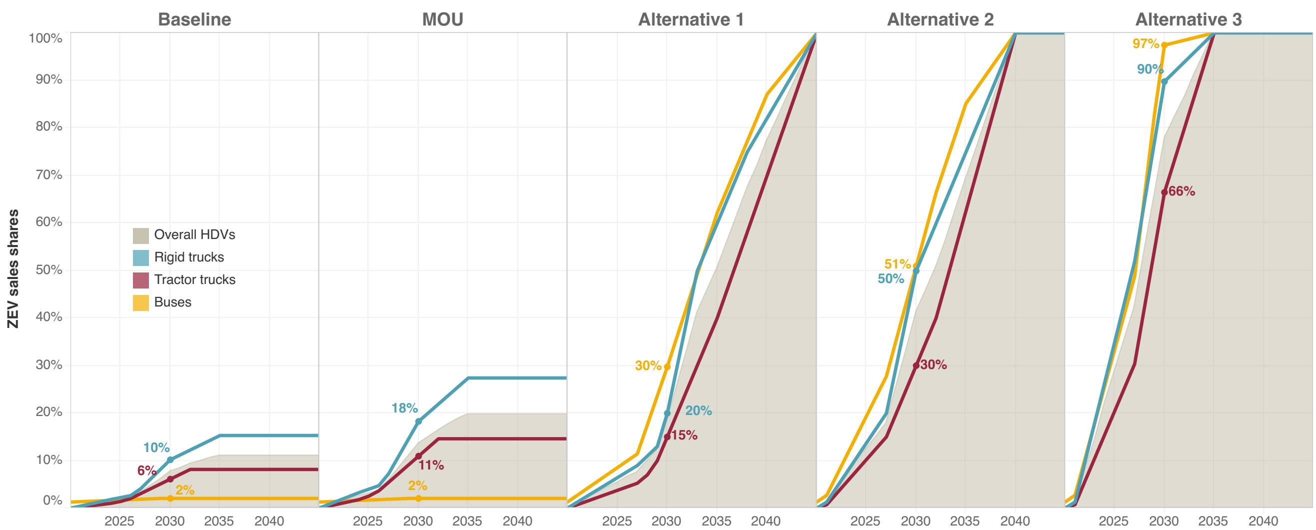

Figure A1. Sales share of heavy-duty ZEVs overall and by vehicle group for each ZEV pathway.

<u>No ZEVs:</u> No heavy-duty ZEVs are sold from 2020 on.

<u>Baseline:</u> The six states that have adopted the ACT regulation, representing 20% of the market, achieve its ZEV sales requirements for trucks. For transit buses, the ZEV sales required in the Innovative Clean Transit (ICT) regulation are achieved in California, assuming a 77% share of large fleets.[5] All other buses maintain current national-average sales shares.

<u>MOU:</u> The 17 states and District of Columbia that have signed the multi-state memorandum of understanding, representing 36.5% of the market, achieve the sales requirements set out in the ACT regulation. Buses follow the Baseline scenario.

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[5] Federal Transit Administration, "National Transit Database 2020 Vehicles," accessed January 4, 2022, https://www.transit.dot.gov/ntd/data-product/2020-vehicles.

Alternate 1: The sales requirements set out in the ACT regulation are achieved nationwide with a 3-year lag, such that requirements in 2024 are first achieved in 2027. ZEV sales shares increase linearly to 100% by 2045 after the lagged ACT requirements end in 2038 for rigid trucks and after 2035 for tractors. For transit buses, sales requirements set out in the ICT are achieved nationwide with a 3-year lag in 2027 and 2030, then increase linearly to 100% by 2035. For school and other buses, ZEV sales shares of 10% are achieved in 2027 and increase linearly to 100% by 2045 (school buses) or 2040 (other buses).

Alternate 2: The sales requirements set out in the ACT regulation are achieved nationwide. ZEV sales shares increase linearly to 100% by 2040 after the ACT requirements end in 2035 for rigid trucks and after 2032 for tractors. For transit buses, sales requirements set out in the ICT are achieved nationwide in 2027, then increase linearly to 100% by 2032. For school and other buses, ZEV sales shares of 25% are achieved in 2027 and increase linearly to 100% by 2040 (school buses) or 2035 (other buses).

Alternate 3: The purchase, stock, and drayage registration requirements set out in the draft Advanced Clean Fleets regulation are achieved nationwide.[6] If not achieved by these requirements, ZEV sales shares increase linearly to 100% by 2035, except for transit and non-school buses. For these segments, ZEV sales shares increase linearly to 100% by 2030.

We modeled these ZEV pathways by defining segment-specific sales trajectories. ZEV sales trajectories were informed by a literature review of market readiness and feasibility assessments, as described in the main text and Appendix B. Because long-haul tractors require significant infrastructure investments before large-scale electrification is feasible, we assumed most tractor ZEV sales would be fulfilled by short-haul tractors. This assumption leads to much faster short-haul tractor electrification than predicted solely based on market readiness.

Figure A2 shows these trajectories for each vehicle segment we modeled. Figure A3 shows these trajectories in greater detail for model years 2027–2030.

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[6] California Air Resources Board, “Public Workshop on Draft Regulatory Language and Updated Cost Assumptions for the Advanced Clean Fleets Regulation,” September 9, 2021.

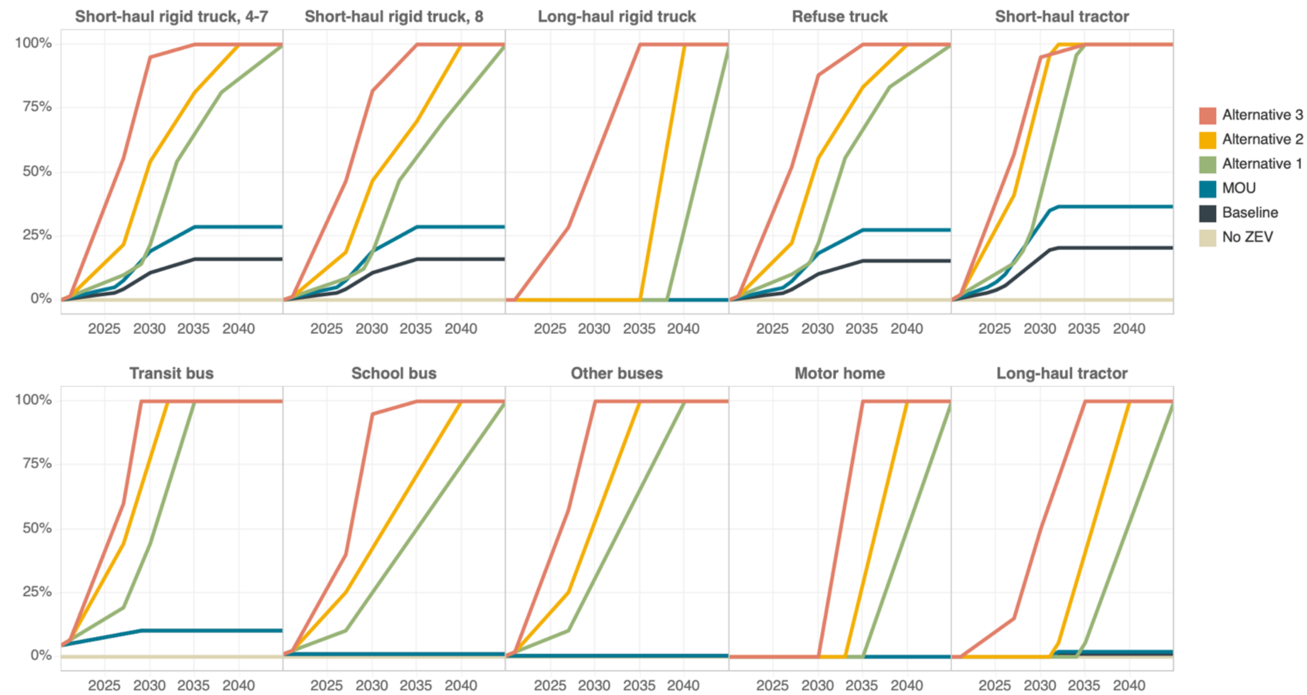

Figure A2. Sales share of heavy-duty ZEVs by vehicle segment for each ZEV pathway.

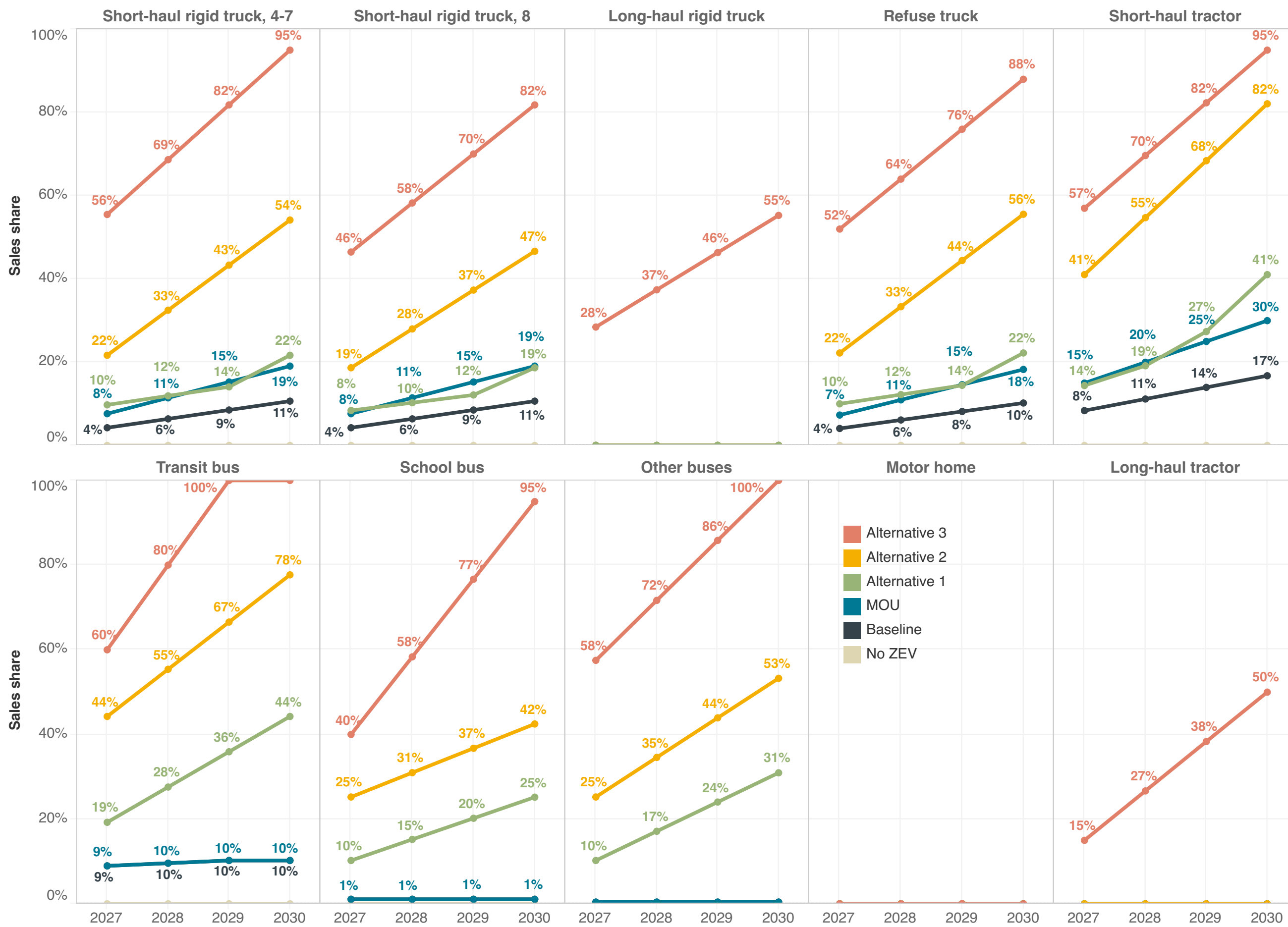

Figure A3. Sales share of heavy-duty ZEVs by vehicle segment for each ZEV pathway in model years 2027–2030.

In the EPA's proposal, no ZEV deployment was considered within the NO_x portion of the rulemaking. In this case, our No ZEV pathway is representative of EPA's consideration in proposing the NO_x standard. Within the greenhouse gas portion, the EPA considered only 1.5% ZEV deployment in model years 2027–2029 for key market segments. With state-level adoption of the ACT, however, our Baseline ZEV pathway has overall heavy-duty ZEV deployment at 3.3% in model year 2027, increasing to 7.7% by model year 2030. The sales share is slightly higher in the key market segments that EPA targeted in the proposal, at 3.8% in model year 2027, increasing to 8.8% by model year 2030.

NO_x standards and crediting

We modeled six regulatory options for federal NO_x standards. To do so, we mapped the three weight-class categories for diesel engines defined in the EPA proposal to MOVES vehicle segments. We assumed that federal standards would apply to all states except those that have adopted the California omnibus regulation.[7] As of writing, three U.S. states have adopted this regulation–California, Massachusetts, and Oregon–though more states may follow suit. We considered the following regulatory options.

EPA 2010: All vehicles outside omnibus-adopting states are subject to the current NO_x standards. Under these standards, ZEVs are not credited toward emissions compliance. The three omnibus-adopting states are subject to California's omnibus regulation.

EPA Option 1: New federal NO_x standards are adopted as proposed by the EPA in Option 1. These new standards would strengthen NO_x limits, as well as warranty and useful life requirements. ZEV are credited towards emissions compliance. The three omnibus-adopting states continue to follow California's omnibus regulation, as it is more stringent that EPA's proposed Option 1.

EPA Option 1 with lower FEL caps: This scenario is the same as EPA Option 1 but the FEL cap is lowered to 30 mg/bhp-hr above the emissions limit for all years and vehicle segments.

EPA Option 1 without ZEV crediting: This scenario is the same as EPA Option 1 but ZEVs can no longer be credited toward NOx emissions compliance.

EPA Option 2: New federal NO_x standards are adopted as proposed by the EPA in Option 2. These new standards would strengthen NO_x limits, as well as warranty and useful life requirements, but all to a lesser degree than Option 1. ZEV are credited towards emissions compliance. The three omnibus-adopting states continue to follow California's omnibus regulation, as it is more stringent that EPA's proposed Option 2.

Federal omnibus: New federal NO_x standards are adopted in alignment with California's omnibus regulation such that all U.S. states follow the same standards. These new standards would in effect enforce the current emissions limits for 2031 starting in 2027. ZEVs are not credited towards emissions compliance.

For all regulatory options, we set NO_x emission factors based on changes in emissions limits, useful life, and warranty provisions. We did not account for emissions changes due to any other differences, including inducements, in-use testing requirements, or compliance cycles.

We calculated zero-mile NO_x emissions rates (ZMERs) by multiplying the current MOVES ZMER for a vehicle segment by the ratio of the new emissions limit (or FEL cap) to the old limit. Historically, real-world reductions in NO_x emissions have been

[7] Sara Kelly and Benjamin Sharpe, "California's Heavy-Duty Omnibus Regulation: Updates to Emission Standards, Testing Requirements, and Compliance Procedures" (Washington, D.C.: International Council on Clean Transportation, January 4, 2022), https://theicct.org/publication/california-us-hdv-omnibus-reg-jan22/.

smaller than the reduction in regulatory emissions limits would imply [8]. Since we assume the same reduction in real-world NO_x emissions as the reduction in regulatory limits, our modeling shows a best-case scenario for emissions reductions due to these policies, unless updated compliance testing methods improve this relationship.

We calculated NO_x emission control degradation factors over the lifetime of the vehicle following MOVES methodology[9]. Under this methodology, NO_x emissions rates remain constant until the end of the warranty period and then increase at a constant rate to 158% of their initial value between the end of the warranty period and the end of the useful life. For vehicle weight classes with intermediate useful life emissions limits, NO_x emissions rates increase in two steps before reaching a value 158% higher than the full useful life emissions rate.

Under EPA Option 1, and in omnibus-adopting states from 2024–2026, ZEVs are allowed to generate credits toward compliance with NO_x emissions standards. Manufacturers can start generating ZEV credits in model year 2024 but may not trade them until model year 2027. We assumed manufacturers would use these ZEV credits to certify a portion of their diesel fleet at the FEL cap, rather than the emissions limit. For simplicity, it was assumed that all ZEV credits would be used in the first model year they became eligible. If ZEV credits remained after all diesel engines had been certified at the FEL cap, they were applied to the next model year.

In all scenarios, ZEVs sold in omnibus-adopting states are not eligible to generate credits toward compliance with the federal regulation. Under the Baseline and MOU ZEV pathways, we assumed all ZEV deployment would occur in ACT or MOU states, respectively. In Alternatives 1–3, we did not differentiate ZEV deployment by U.S. state.

Greenhouse gas standards and crediting

We modeled three regulatory options representing greenhouse gas standards and ZEV crediting schemes. To do so, we mapped the 33 regulatory categories defined in the Phase II rulemaking to MOVES vehicle segments. We considered the following regulatory options.

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[8] Huzeifa Badshah, Francisco Posada, and Rachel Muncrief, “Current State of NOx Emissions from In-Use Heavy-Duty Diesel Vehicles in the United States” (Washington, D.C.: International Council on Clean Transportation, November 26, 2019), https://theicct.org/publication/current-state-of-nox-emissions-from-in-use-heavy-duty-diesel-vehicles-in-the-united-states/.

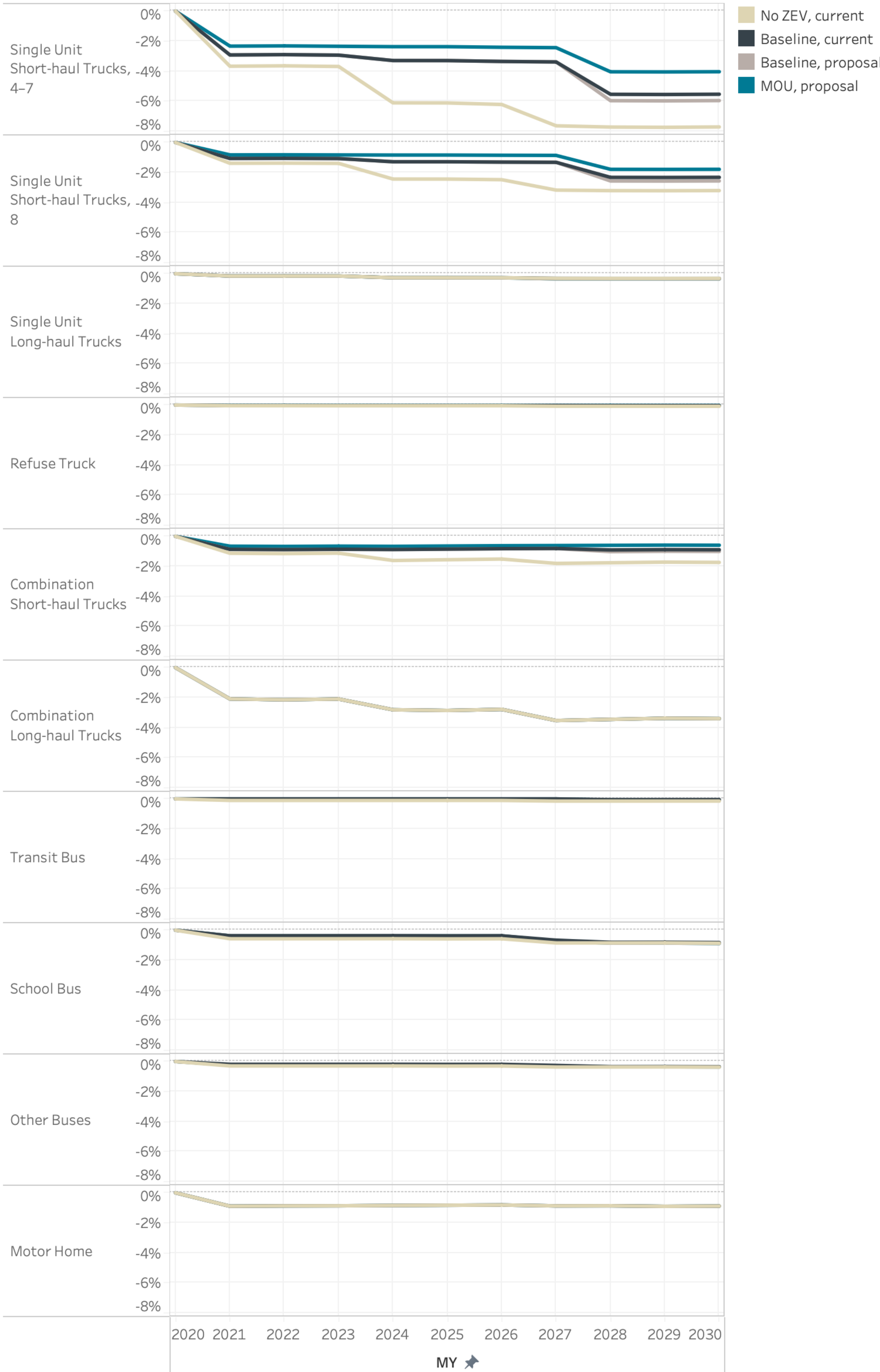
[9] Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards NPRM. U.S. Environmental Protection Agency, Washington, D.C, https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryID=347135&Lab=OTAQ.

Current: All vehicles are subject to the original Phase II greenhouse gas standards. Under these standards, ZEVs generate supercredits – credits that represent more than their emission savings – based on a given advanced technology multiplier. For battery electric vehicles, the multiplier is 4.5 through model year 2027. The multiplier drops to 1 in model year 2028 such that no supercredits can be generated after model year 2027.

Proposal: The Phase II greenhouse gas standards are updated as proposed by the EPA. These updates would increase the stringency of the standards by 1.5% for certain vehicle segments, including transit buses, school buses, delivery trucks, and short-haul tractors. The ZEV supercrediting scheme is unchanged.

ICCT: Internal combustion engine vehicles are subject to the original Phase II greenhouse gas standards, without ZEV crediting. ZEV deployment is required independently and corresponds to the ZEV pathways defined above.

Due to differences in ZEV crediting between these regulatory options, the effective greenhouse gas emissions standard for ICE vehicles depends on the ZEV pathway. We assumed that per-vehicle ICE emissions would not increase over time, regardless of ZEV crediting, also known as backsliding. Figure A4 shows how greater ZEV deployment in the Baseline pathway decreases the stringency of the original rule, and similarly how additional ZEV deployment in the MOU pathway undermines the stringency of the proposed rule.



No ZEV, current
Baseline, current
Baseline, proposal
MOU, proposal
Single Unit Short-haul Trucks, 4–7
Single Unit Short-haul Trucks, 8
Single Unit Long-haul Trucks
Refuse Truck
Combination Short-haul Trucks
Combination Long-haul Trucks
Transit Bus
School Bus
Other Buses
Motor Home
0%
-2%
-4%
-6%
-8%
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
MY

Figure A4. Percent change in greenhouse gas emissions standards under select policy scenarios and ZEV pathways relative to a model year 2017 baseline.

Health impacts analysis in communities meeting environmental justice criteria

Overview

We developed NO_x emissions inventories by vehicle segment and modeled $PM_{2.5}$ concentrations to evaluate the health benefits in communities meeting various environmental justice criteria. The methodology is summarized below in Figure A5. In developing the NO_x inventories, we primarily used spatial traffic activity data supplemented by road length and population data to allocate national NO_x emissions estimates from the EPA and from the ICCT's Roadmap model to a variable resolution grid. We used the Intervention Model for Air Pollution (InMAP), a reduced complexity model, to estimate changes in $PM_{2.5}$ concentrations.[10] From these results, we estimated health impacts for various population groups defined using environmental justice factors related to diesel truck emissions and their associated health impacts.

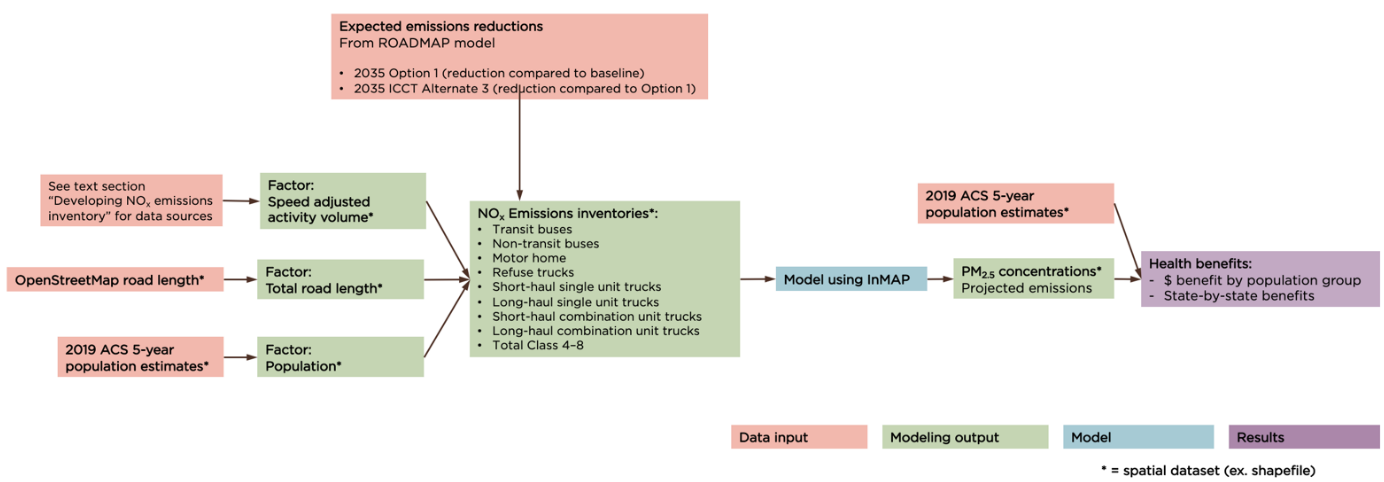


Figure A5. Overview of data sources and health impacts modeling methodology.

10 Christopher W. Tessum, Jason D. Hill, and Julian D. Marshall, "InMAP: A Model for Air Pollution Interventions," *PLOS One* 12, no. 4 (April 19, 2017): e0176131, https://doi.org/10.1371/journal.pone.0176131.

Developing NO_x emissions inventory

We used a variable resolution grid to model emissions at a high spatial resolution in densely populated areas while minimizing computational intensity. The grid has the same geometry as used for the InMAP Source Receptor Matrix (ISRM), with grid resolutions of 48, 24, 12, 4, 2, and 1 km.[11] The population threshold was set at 4,000 and the population density threshold was set at 0.004, and grids exceeding either of these thresholds were divided into the next level if not already at 1 x 1 km.

Due to bounds of the air quality model, this analysis focused on the 48 contiguous states plus Washington, D.C., accounting for 99.3% of the national population and representing a minimum of 99.0% of the NO_x emissions for each heavy-duty vehicle segment.

Activity data from FHWA's Highway Performance Monitoring System (HPMS) spatial dataset were used to allocate most national NO_x emissions to the variable resolution grid.[12] The dataset reports single unit truck annual average daily traffic (AADT), which includes bus activity, and combination unit truck AADT for each road segment. The single unit activity corresponds to this analysis's vehicle groups of buses and other trucks (transit bus, non-transit bus, motor homes, refuse truck) and rigid trucks. The combination unit activity corresponds to this analysis's tractor truck vehicle group. Although the dataset captures a large portion of activity, some activity, particularly on smaller roadways, is not included. Additionally, the data are reported by individual state DOTs, leading to variations in the spatial completeness. To account for this, emissions were allocated on a state-by-state basis with weight factors for each state.

The activity in the HPMS dataset were compared to FHWA's state summaries (from Tables vm-2 and vm-4 in the references), which were combined to get total VMT by vehicle group (bus, rigid truck, and tractor truck) by road classification (interstate, other arterial, other).[13,14] In total, 74% of single unit activity is captured in the HPMS dataset and 88% of combination unit activity when comparing the totals to the FHWA state summaries.

We considered the variations in each vehicle group's spatial activity patterns and typical speeds by road type. We calculated emissions for four different road classifications used in MOVES: rural restricted, rural unrestricted, urban restricted, and urban unrestricted. Urban and rural areas were defined using FHWA's classifications, with

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[11] Andrew Goodkind et al., *InMAP Source-Receptor Matrix (ISRM) dataset* (Zenodo, March 11, 2019), https://doi.org/10.5281/zenodo.3590127.
[12] Federal Highway Administration, Highway Performance Monitoring System (HPMS) shapefiles, accessed March 2022, https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm
[13] "Functional system travel 2018 annual vehicle miles", Federal Highway Administration, accessed March 2022, https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm2.cfm
[14] "Distribution of annual vehicle distance traveled 2018", Federal Highway Administration, accessed March 2022, https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm4.cfm

small urban areas (population <25,000) classified as rural. Restricted roads are defined as interstates, freeways, and expressways; unrestricted roads are defined as all other road types, including other arterials, collectors, and local roads.

To account for higher emissions at low-speed operation, we adjusted emission factors based on road classification. First, we used heavy-duty in-use testing (HDIUT) data to develop adjustment factors for three 25-mph speed bins (Table A1).[15] Separate adjustment factors were developed for buses and rigid trucks and tractor trucks to reflect that tractor trucks have a larger increase in emissions at low speeds (11.6 times higher than highway operation compared to 6.55 times higher for buses and rigid trucks).

Table A1. Distance-specific emission factors and adjustment factors for 25-mph speed bins based on HDIUT data.

Speed bins	Buses and rigid trucks		Tractor trucks	
	g/mi emissions	Adjustment factor *normalized by highway EF*	g/mi emissions	Adjustment factor *normalized by highway EF*
Urban (1-25 mph)	2.03	**6.55**	6.96	**11.6**
Suburban (25-50 mph)	0.70	**2.26**	2.43	**4.0**
Highway (>50 mph)	0.31	**1.0**	0.60	**1.0**

The adjustment factors were combined with typical speed profiles for more specific vehicle segments to calculate multipliers by road classification. MOVES reports hourly speed profiles for weekdays and weekends for each vehicle segment. These speed profiles were aggregated into vehicle groups. Then, the profiles were combined with average hourly activity profiles and estimates of percentage of activity in weekdays/weekends for urban and rural roads from NEI technical support documentation.[16] The overall distribution of activity in each speed bin by vehicle segment and road classifications were applied to calculate a weighted average of the speed adjustment factors. Table A2 shows the speed multipliers for each vehicle group, which were normalized by the rural restricted multiplier, the lowest in all cases due to higher speed operation.

[15] Huzeifa Badshah, Francisco Posada, and Rachel Muncrief, *Current state of NOx emissions from in-use heavy-duty diesel vehicles in the United States,* (ICCT: Washington, DC, 2019), https://theicct.org/publications/nox-emissions-us- hdv-diesel-vehicles.

[16] U.S. EPA, 2015. "Technical Support Document, Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform", Office of Air Quality Planning and Standards, https://www.epa.gov/sites/default/files/2015-10/documents/2011v6_2_2017_2025_emismod_tsd_aug2015.pdf.

Table A2. Speed multipliers for each vehicle segment by road classification.

Vehicle segment	Vehicle group	Rural restricted	Rural unrestricted	Urban restricted	Urban unrestricted
Transit bus	Buses and other trucks	1.00	2.12	1.65	4.11
Non-transit bus					
Motor home					
Refuse truck					
Short-haul single unit truck	Rigid trucks	1.00	1.87	1.45	3.52
Long-haul single unit truck					
Short-haul combination unit truck	Tractor trucks	1.00	2.06	1.54	4.42
Long-haul combination unit truck					

These multipliers were used to estimate the share of emissions in each state. We applied these multipliers to the VMT by vehicle segment and road classification state data developed from FHWA state summaries. Table A3 shows the percent breakdown of national NO_x emissions by state for the three vehicle groups.

Table A3. Percent of national emissions by state for each vehicle group.

U.S. state	% Share of national emissions		
	Buses and other trucks	Rigid trucks	Tractor trucks
AL	1.8%	1.8%	1.8%
AR	1.2%	0.9%	0.8%
AZ	4.6%	3.0%	2.8%
CA	13.2%	10.7%	10.5%
CO	1.3%	1.0%	0.9%
CT	1.2%	1.2%	1.3%
DC	0.3%	0.1%	0.1%
DE	0.7%	0.5%	0.5%
FL	6.2%	7.2%	7.5%
GA	5.4%	5.0%	5.1%
IA	0.3%	0.7%	0.7%
ID	0.3%	0.6%	0.6%
IL	4.0%	3.9%	3.9%
IN	3.2%	3.6%	3.7%
KS	0.3%	0.7%	0.7%
KY	1.9%	1.7%	1.6%
LA	1.8%	2.4%	2.5%
MA	2.8%	2.3%	2.3%
MD	2.4%	1.8%	1.8%
ME	0.5%	0.4%	0.4%
MI	1.1%	1.5%	1.5%
MN	3.6%	2.1%	1.9%

MO	1.9%	2.6%	2.7%
MS	1.0%	1.1%	1.1%
MT	0.3%	0.2%	0.2%
NC	4.3%	3.4%	3.2%
ND	0.2%	0.4%	0.4%
NE	0.2%	0.2%	0.2%
NH	0.4%	0.4%	0.4%
NJ	0.8%	2.1%	2.3%
NM	0.5%	0.6%	0.6%
NV	2.0%	0.7%	0.5%
NY	5.7%	3.7%	3.4%
OH	2.1%	3.1%	3.2%
OK	1.4%	2.3%	2.4%
OR	2.6%	2.1%	2.0%
PA	3.6%	3.7%	3.7%
RI	0.4%	0.4%	0.4%
SC	1.1%	1.3%	1.3%
SD	0.0%	0.1%	0.2%
TN	0.6%	1.7%	1.9%
TX	4.0%	7.4%	7.9%
UT	0.8%	2.5%	2.7%
VA	2.6%	1.2%	1.0%
VT	0.2%	0.2%	0.2%
WA	1.0%	2.0%	2.1%
WI	2.3%	1.8%	1.7%
WV	0.7%	0.7%	0.7%
WY	0.1%	0.2%	0.2%

Once each state's total emissions were calculated, NO_x emissions were allocated to the variable resolution grid based on a combination of activity patterns, population, and road length. We captured variation in spatial trends by vehicle segment by allocating spatial activity data by road type. This accounts for the higher share of long-haul trucks on interstates and highways compared to short-haul trucks and other trends that differ by vehicle segment. The share of total vehicle group AADT attributable to each vehicle segment was calculated using MOVES3 population and activity data (from Table 7-2 in the reference) and overall VMT by source type for Class 4–8 vehicles in 2020 from MOVES3.[17] These percentages are shown below in Table A4. We calculated the VMT associated with each vehicle segment for all roads in the HPMS activity shapefile by multiplying the AADT by road length and by the percent vehicle activity assigned to each vehicle segment based on the road classification.

[17] U.S. Environmental Protection Agency, "Population and activity of onroad vehicles in MOVES3" (2021), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1011TF8.pdf.

Table A4. Fraction of vehicle activity assigned to each vehicle segment by road classification.

Vehicle group	Vehicle segment	Rural restricted	Rural unrestricted	Urban restricted	Urban unrestricted
Buses and rigid trucks	Transit bus	0.04850	0.04346	0.05937	0.05755
	School bus	0.06345	0.06491	0.05554	0.06656
	Refuse truck	0.01248	0.01236	0.01315	0.01192
	Other bus	0.11218	0.09871	0.10914	0.12767
	Motor home	0.03748	0.03587	0.03133	0.03320
	Short-haul single unit	0.68282	0.69774	0.68659	0.65609
	Long-haul single unit	0.04310	0.04695	0.04488	0.04702
	Total	**1.00000**	**1.00000**	**1.00000**	**1.00000**
Tractor trucks	Short-haul combination	0.10994	0.24831	0.18784	0.27344
	Long-haul combination	0.89006	0.75169	0.81216	0.72656
	Total	**1.00000**	**1.00000**	**1.00000**	**1.00000**

Due to the state-by-state variation and spatial incompleteness of the HPMS dataset, data on population and road length were also used to allocate emissions to the variable resolution grid. Population counts were derived from 2019 ACS 5-year estimates.[18] Road length used OpenStreetMap shapefiles, which includes road segments of all types, including small local roads not captured in the FHWA HPMS dataset.[19]

Weight factors for allocation based on activity (from HPMS), population, and road length were determined based on the percentage of VMT in the HPMS dataset compared to the VMT in FHWA's state summary, with the remaining percentage allocated to a combination of population and road length. Thus, states with only a low percentage of activity captured in the HPMS dataset were given a higher weight factor to population and road length.

Some states reported higher VMT in the HPMS dataset compared to FHWA's state summary. Maximum activity weight factors were applied based on national trends to address these cases. Tractor trucks were given maximum weights of 80% to activity in urban areas and 100% in rural areas, while single unit trucks were given maximum weights of 70% to activity in urban areas and 80% to activity in rural areas.

After assigning each state's weight factor for activity data, the remaining percentage was assigned to population and road length. These differed by vehicle segment, as shown in Table A5. These percentages were determined following methodology from a

[18] "TIGER/Line with selected demographic and economic data," U.S. Census Bureau (2019), accessed April 2022, https://www.census.gov/ geographies/mapping-files/time-series/geo/tiger-data.2019.html.
[19] OpenStreetMap contributors, United States road segment shapefiles, accessed April 2022, https://download.geofabrik.de/north-america/us.html.

past study of global emissions.[20] These percentages were adjusted to reflect trends in vehicle activity aligning more with population centers (such as transit buses and refuse trucks) versus aligning more with roadways (such as long-haul trucks).

Table A5. Weight factors assigned to the fraction of emissions not captured by HPMS activity data, shown for each vehicle segment.

Vehicle segment	% population	% road length
Transit buses	75%	25%
Non-transit buses	50%	50%
Motor home	50%	50%
Refuse trucks	75%	25%
Short-haul rigid trucks	50%	50%
Long-haul single unit trucks	25%	75%
Short-haul combination trucks	50%	50%
Long-haul combination trucks	25%	75%

For each grid cell, the percentage of total emissions was calculated by applying the three weight factors to the percentage of activity, population, and road length. From this, a gridded emissions inventory was created for each of the 48 contiguous states and Washington, D.C., which were then combined into a single national emissions inventory. National NO_x emissions were allocated for the following two scenarios and health impacts were compared for the year 2035.

EPA Option 1: National total emissions by vehicle segment were calculated using EPA's estimate from the draft regulatory impact analysis. The published estimate of emissions reductions compared to the 2035 baseline is 315 metric tons. This was combined with the distribution of emissions by vehicle segment in ICCT's Roadmap model to calculate emissions by vehicle segment.

Federal omnibus with Alternative 3 ZEV pathway: Emissions estimates in metric tons per vehicle segment were used from the most ambitious NO_x standard (Federal omnibus) and ZEV pathway (Alternative 3) modeled in Roadmap, as described above. The total national emissions reduction compared to EPA's Option 1 is 46.4 metric tons.

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[20] Susan Anenberg et al., *Impacts and mitigation of excess diesel NOx emissions in 11 major vehicle markets,* (ICCT: Washington, DC, 2017), https://theicct.org/publication/impacts-and-mitigation-of-excess-diesel-nox-emissions-in-11-major-vehicle-markets/.

Modeling $PM_{2.5}$ and health impacts

We modeled the changes in $PM_{2.5}$ concentration using InMAP, inputting the spatial inventory of changes in NO_x emissions. We use the same variable resolution grid for the resulting $PM_{2.5}$ concentrations. Note that InMAP relies on underlying data of pollutant concentrations that may experience significant changes before 2035, which would influence the atmospheric interactions. However, these estimates are still helpful to understand the magnitude of benefits and relative impacts across the United States.

To assess the impact by population group, we assigned $PM_{2.5}$ concentrations to each census tract based on the location of its centroid. From this, we calculated estimated premature mortality and the associated monetary value. We use a concentration-response function of a 6% increase in mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration.[21] The analysis uses a value of a statistical life (VSL) of $10.6 million (in 2017 U.S. dollars) for 2035, adjusted from EPA's value of $11 million in 2045.

We use EPA's environmental justice screening tool to evaluate the impacts for select population groups.[22] Additionally, we evaluate impacts on populations in census tracts with higher percentage of people of color. The population groups are defined as follows:

1. **Disadvantaged**: Communities designated as disadvantaged communities, meaning those that are both overburdened in terms of environmental or climate indicators and underserved socioeconomically. This is not limited to impacts from transportation.
2. **High diesel particulate exposure (diesel PM)**: Communities at or above the 90th percentile for diesel particulate matter exposure, or the top 10% that are adversely impacted by diesel particulate matter exposure in the U.S., and above the threshold for socioeconomic indicators.
3. **High traffic (traffic)**: Communities at or above the 90th percentile for traffic proximity and volume and above the threshold for socioeconomic indicators.
4. **High ambient $PM_{2.5}$ exposure (PM)**: Communities at or above the 90th percentile for $PM_{2.5}$ in the air on an annual average basis and above the threshold for socioeconomic indicators.
5. **High rates of air pollution related diseases (disease)**: Communities at or above the 90th percentile for asthma OR diabetes OR heart disease OR low life expectancy and above the threshold for socioeconomic indicators.
6. **High proportion of low-income households (income)**: Communities at or above the 65th percentile for low income versus all others, and low income is

[21] Daniel Krewski et al., "Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality" (Health Effects Institute, 2009), https://www.healtheffects.org/system/ files/Krewski140.pdf.
[22] "Climate and economic justice screening tool," U.S. EPA (2022), https://screeningtool.geoplatform.gov/en.

defined as 'Percent of a census tract's population in households where household income is at or below 200% of the Federal poverty level'.

7. **High proportion of people of color (POC)**: Communities at or above the 65th percentile for percent people of color, people of color defined as Latinos of any race and non-Latino, non-white people.
8. **Meets any criteria (any)**: Communities that meet any of the criteria above. They represent 47.3% of total population as shown in the table below.