National Air Quality and Health Impacts Along Truck Routes

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American Lung Association.

ICF

Background and Overview

In 2020, ICF conducted a comprehensive analysis for the American Lung Association on the potential health and climate benefits of a scenario for increasing on-road vehicle electrification across the United States.[1] ICF's analysis was the basis for the Lung Association's *Road to Clean Air* report.[2] The electrification scenario analyzed in that report included both light- and heavy-duty vehicles and two categories of emissions components:

- Downstream: tailpipe exhaust, evaporative, brake and tire wear
- Upstream: reduced fuel production, transport, and refining activities for internal combustion vehicles and increased electricity generation for electric vehicles

It assessed two potential cases for the nation's future electricity production. In early 2022, to support the Lung Association's Zeroing in on Healthy Air report,[3] ICF prepared an updated analysis of the potential benefits of a nationwide EV Scenario.[4] This analysis modernizes the findings from the 2020 study to address current trends and available data. Some of the key changes included:

- More aggressive adoption of EVs, including a more aggressive ZEV truck adoption schedule, [5] roughly in line with the final ACT Rule.
- A vehicle scheme that tracks the impacts of light-duty and heavy-duty vehicles separately.
- Consideration of a more aggressive transition to renewables on the electric grid, with resulting benefits to human health from both the base load on the grid and the additional load from new EVs, emphasizing the potential benefits of a cleaner electric grid. The non-combustion electricity case was determined through an optimization modeling approach using ICF's IPM model.

In addition to updating all modeling tools, updates were also made to the calculation function for avoided mortality estimates and cumulative health and climate benefit estimates for the entire period considered (2020-2050). The report also includes an analysis of demographic-specific impacts to provide insight into the effects of emissions on people of color.

Heavy-duty trucking is a major contributor to degraded air quality. Diesel exhaust – most heavy-duty vehicles are currently diesel fueled – includes nitrogen oxides (NOx) and particulate matter ($PM_{2.5}$) and is a toxic air contaminant. For this reason, truck corridors, which may concentrate large volumes of highly polluting vehicles, are of particular concern for air quality impacts. In fact, the U.S. Environmental Protection Agency (EPA) provides examples of projects of local air quality concern for particulate matter hotspots that would be covered by 40 CFR 93.123(b)(1), including:[6]

- Highways or expressways that serve a significant volume of diesel truck traffic, such as facilities where annual average daily traffic (AADT) is greater than 125,000 and 8% or more of this traffic consists of diesel trucks;

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[1] ICF. 2020. Health Benefits of Transition to Zero Emission Transportation Technologies. https://www.lung.org/getmedia/b9efc73e-aeba-4cd8-b789-942166c38ca6/EV_Technical_Documentation.pdf.

[2] https://www.lung.org/getmedia/99cc945c-47f2-4ba9-ba59-14c311ca332a/electric-vehicle-report.pdf

[3] American Lung Association. Zeroing in on Healthy Air: A National Assessment of the Health and Climate Benefits of Zero-Emission Transportation and Electricity. 2022. https://www.lung.org/clean-air/electric-vehicle-report

[4] American Lung Association, ICF. 2022. Updated Evaluation of the National Health Benefits from the Transition to Zero Emission Transportation Technologies. https://www.lung.org/getmedia/9b396179-40ff-4b3b-9426-9ceea288575d/prior-research-zero-emission-technologies-2022.pdf.

[5] As with the 2020 and 2022 studies, the scope of this analysis was determined to focus exclusively on battery electric vehicles (BEV) as a marker for all ZEVs.

[6] Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas, EPA-420-B-21-037, October 2021. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013C6A.pdf.

- Facilities connecting a highway or expressway to a major freight, bus, or intermodal terminal;
- Facilities that affect a congested intersection that has a significant increase in the number of diesel trucks;
- Highway projects that involve a significant increase in the number of diesel trucks or buses; and
- Major new or expanded bus or intermodal terminals.

These examples illustrate the impacts of heavy-duty vehicles on local air quality.

In this report, we examine the potential health and air quality benefits of a scenario for increasing on-road, heavy-duty vehicle electrification in counties across the United States that contain major trucking corridors. This report builds on the two previous reports. It does not contain new modeling analysis. Health and air quality results are taken from the county level outputs from the CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) modeling and related analyses in the March 2022 study for the heavy-duty vehicle class only. This analysis includes the same emission sectors as reported in the previous study. Although we focus on on-road emissions benefits from the downstream, heavy-duty vehicle class, we also include upstream benefits. For this, we report the upstream benefits from the *Non-Combustion* electrification case in the body of this report. Note that downstream-only health and air quality impacts are not available from the existing health benefits modeling.

The focus here is on national-scale impacts along major trucking routes. Our COBRA analysis is resolved at the county level. Thus, our analysis first identified counties with major trucking routes. This list of counties is the geography for which the current results are reported. Reported potential health benefits of vehicle electrification included here represent aggregate results for US counties hosting major truck routes, based on the existing county-level data. The following section describes how we identified the list of counties to include and how we collected and processed the existing data.

Following the methodology, we present our results. These summarize findings on:

- Monetized and numerated (cases) of **potential health benefits** achievable through electrification of trucking sector for counties that include major trucking routes, both for individual years and cumulative over the period
- Potential **emissions and air quality impacts** of particulate matter (PM) and PM precursors in these same areas
- National scale assessment of the **number of people currently living in counties along major trucking routes** and an estimate of the existing air quality conditions.

Finally, a note about the vehicle categories and pollutants incorporated here. These results rely on the COBRA-based analysis in the previous report, and thus employ the COBRA vehicle classes. That is, the national scale emissions reported previously considered the US vehicle fleet grouped into four vehicle categories for analysis:

- Passenger vehicles,
- Light heavy-duty trucks,
- Medium-heavy and heavy-trucks, and
- School buses.

These four categories were tracked through the emissions modeling but aggregated into two distinct vehicle classes in separate COBRA simulations. Thus, associated health and air quality benefits are reported for these vehicle classes:

- Light duty,
- Heavy-duty, and
- Total.

However, inputs to COBRA used the model's six vehicle schema. Table 21 in the report mapped the different vehicle schema. Since our emissions methodology included a mapping of emissions to COBRA categories, we also present changes in downstream emissions for the three heavy-duty categories in the COBRA inputs.

- Heavy-Duty Highway Vehicles fueled with Compressed Natural Gas (CNG)
- Heavy-Duty Highway Vehicles fueled with Diesel Fuel
- Heavy-Duty Highway Vehicles fueled with Gasoline

Note that we used a mapping approach (described in the previous report) to allocate emissions, so total vehicle emissions are preserved but attributed to categories with some subjectivity.

Also, as these emissions results are based on inputs to the COBRA model, GHG results attributable only to the determined truck corridor counties are not available. GHG impacts are not included here.

Methodology

Truck Flows and County Selection

We used Freight Analysis Framework Version 4 (FAF4)[7] data to define major trucking routes. The FAF4 dataset contains modeled freight flows with defined origin, destination, route, and magnitudes developed by FHWA and BTS based on a variety of sources, including the Commodity Flow Survey (CFS) and international trade data from the Census Bureau. FAF4 data provides base year estimates for 2012 and forecasted estimates for 2045. For our analysis, we interpolated the truck count data (volume/day/road section) to the year 2020 using the 2012 and 2045 estimates.[8]

We used two thresholds – at least 8,500 and 10,000 trucks per day (AADT) per road section, inclusive of both roadway directions – to define major truck routes in the continental United States. The 8,500 truck AADT threshold is the less conservative estimate for a major truck route. It is based on the FHWA's previously defined major freight corridor (highway segments carrying at least 8,500 trucks per day).[9] The 10,000 truck AADT threshold is the more conservative estimate of a major truck route. It is derived from US EPA's the first bulleted example for a new highway project that would likely be considered a "project of air quality concern," and require a PM "hot-spot assessment" (shown above).

We selected counties containing these major truck routes to define the study area. That is, counties containing at least one segment in FAF4 exceeding these thresholds are defined here as truck corridor counties. The major truck routes and analysis area used are shown in Figure 1 and Figure 2. Road segments are split at major intersections/interchanges or county borders. Note here and throughout that fewer counties include links with truck traffic meeting the higher threshold. Thus, the benefits are smaller, and thus more conservative estimates of potential national benefits in truck corridor counties, with the higher threshold. Note also that the thickness of the lines in Figure 1 and Figure 2 represent the truck AADT.

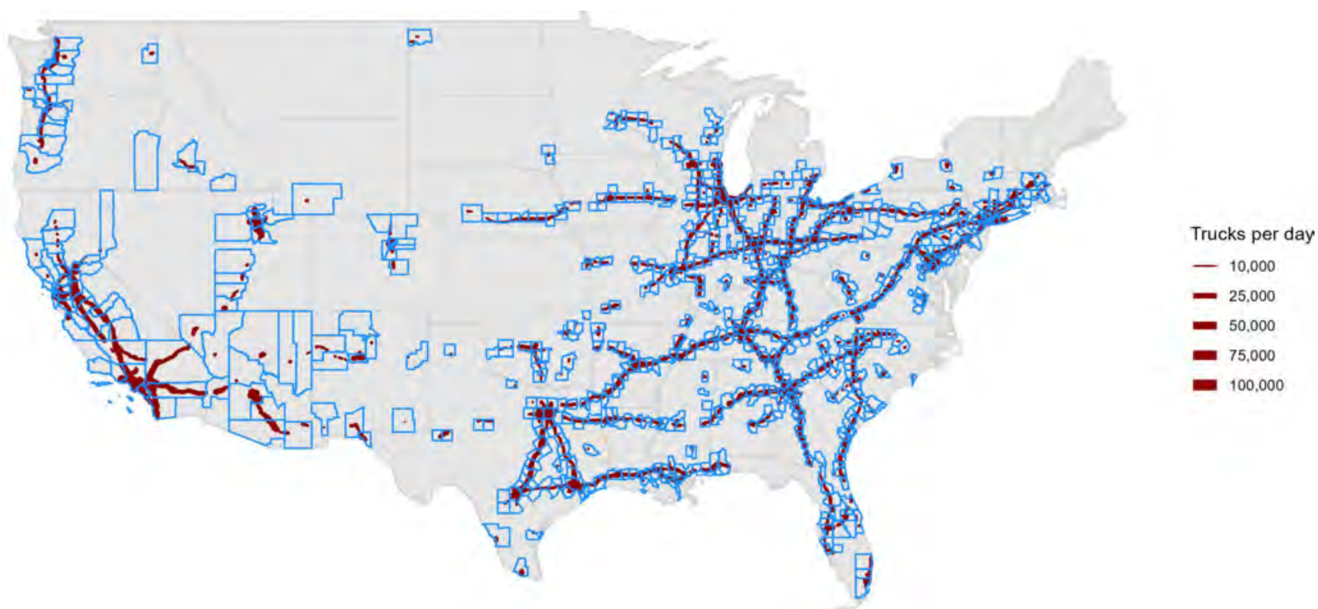
[7] Although a new version of the dataset, FAF5, was available as of February 2021, it was not possible to apply our definition for a "major truck route" due to data formatting changes from FAF4. Expressway and highway segment centerlines were split from one to two opposite-direction centerlines and, as a result, total freight flow in both directions was also distributed across these two segments.

[8] We interpolated 2020 values using variables AADTT12 (2012 baseline) and AADTT45 (2045 forecast) from the file FAF4DATA_V43.DBF for each roadway section. This file is available in the "assignment_results" zip file available at: https://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf4/netwkdbflow/index.htm.

[9] FHWA. 2008. Freight Story 2008. https://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm

Figure 1: Major Truck Routes and Corresponding Truck Route Counties, 8,500 Trucks per Day Threshold

Figure 2: Major Truck Routes and Corresponding Truck Route Counties, 10,000 Trucks per Day Threshold



Health and Air Quality Modeling

We did not conduct distinct health or air quality modeling for this analysis. All health and air quality results presented here are taken from the individual county-level outputs for the Heavy-Duty vehicle class COBRA simulations from the March 2022 report.[4] Section 5 of that report provides information on the modeling methodology.

To determine national changes in $PM_{2.5}$ concentration in truck corridor counties, we combined health and air quality metrics across counties using the same population-weighted approach for air quality and sum for health outcomes used to determine national and state-level changes in the March 2022 report.

In addition, we also provide summaries of existing air quality conditions from the Lung Association's 2022 State of the Air Report.[10] These are county-level design values representing long-term $PM_{2.5}$ concentrations, from 2018-2020. We provide these for context on the potential changes in PM concentrations available from the Scenario. However, we note that these are from a different period than the modeled results and thus should not be directly added to the predicted changes, as many factors other than those modeled here will affect future air quality.

Please note that there are no ZEV heavy-vehicle sales in 2020 in the Scenario. Thus, we do not report health, emissions, or air quality values for that year here.

Emissions Extraction

We extracted PM and PM precursor emissions from the COBRA inputs used in the March 2022 analysis. This provided us with emissions under both the business-as-usual and scenario for NO_2, SO_2, NH_3, $PM_{2.5}$, and VOC by county, emissions source, fuel type, and year. We extracted this information for the truck corridor counties under both thresholds (10,000 and 8,500 truck AADT). We then calculated the change in downstream emissions for each pollutant and modeled year for heavy-duty highway vehicles to isolate the truck emission changes in the identified counties. We also split out the Heavy-Duty Highway Vehicles COBRA inputs by fuel type.[11]

Population Demographics Extraction

Percent of the population identifying as a person of color was determined for each county in the US in the March 2022 report. It was defined using Annual County Resident Population Estimates by Age, Sex, Race, and Hispanic Origin for 2020 from the Census Bureau's Vintage 2020 Population Estimates.[12] "Person of color" is defined here as the sum of the male and female estimates of all racial and ethnic groups other than "not Hispanic, White alone." Additional details are provided in Section 5.3.3 of the March 2022 report. We use the same data here. We do not project changes in demographics for future years, and only report the value from the 2020 data.

Note that the population used as the denominator for this field differs from the population used by COBRA to calculate endpoint estimates. COBRA uses the US Census of Population and Housing 2010 and forecasting models developed by Woods & Poole (2015) to estimate the population of future years.[13]

Predicted Changes in Air Quality

We did not conduct distinct air quality modeling for this analysis. County-level estimates of changes in PM air concentrations under the Scenario are taken from the previous COBRA outputs.

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[10] Email from Will Barrett, Wed 8/17/2022 3:56 PM.

[11] We do not show total emissions changes due to complications with presenting Non-Combustion Case upstream emissions only in selected counties.

[12] Census Bureau County Population by Characteristics: 2010-2020 https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates/2020-evaluation-estimates/2010s-county-detail.html.

[13] For more information, see the COBRA user manual https://www.epa.gov/cobra/users-manual-co-benefits-risk-assessment-cobra-screening-model.

Results

Analysis Year Specific Impacts

Emissions

Table 1 shows the total, annual emissions changes consolidated over the truck corridor counties for $PM_{2.5}$ and PM precursor pollutants. Results are shown for the individual modeled years – 2030, 2040, and 2050. As noted earlier, no heavy-duty vehicle emissions changes occur in year 2020 in the modeled scenario.

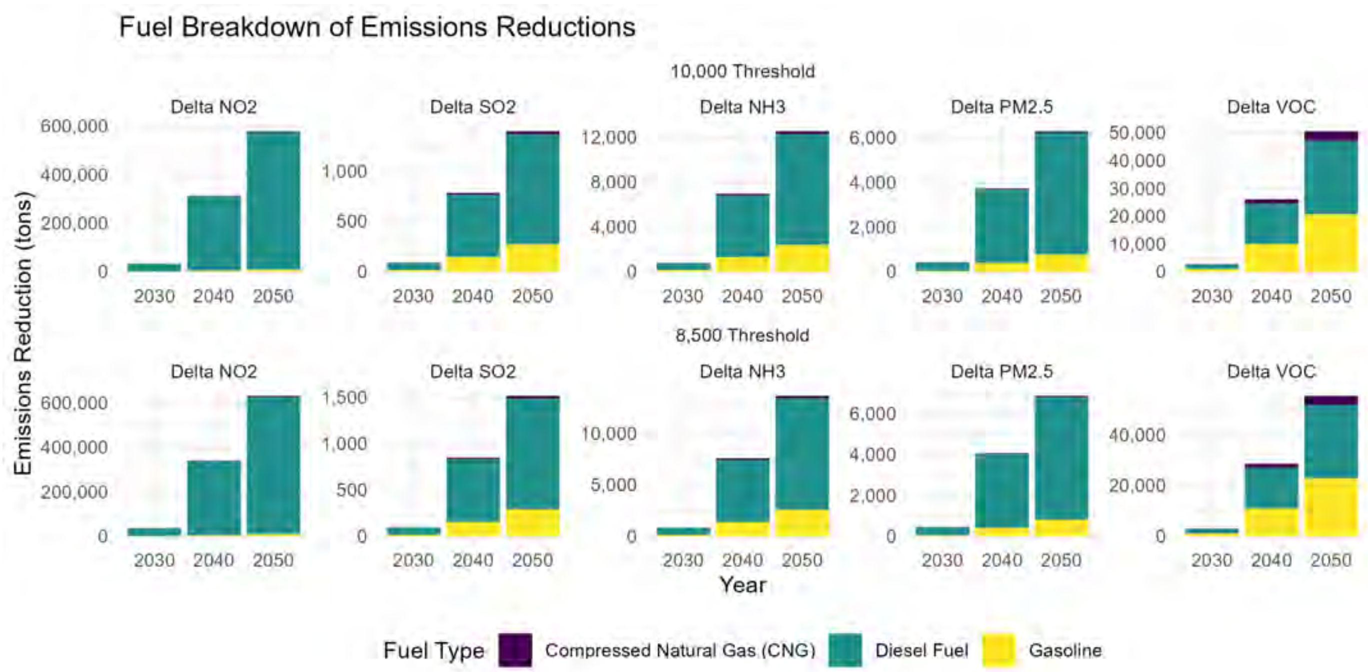
Table 1 shows the change in emissions (business-as-usual minus scenario) for on-highway sources, summed over all truck corridor counties for both truck AADT thresholds. These downstream emissions are identical in both electrification cases. These results consider heavy vehicles only. The top set of rows shows mass reductions in short tons. The lower set of rows show percent reductions, reflecting the level of emissions change from heavy vehicles relative to the business-as-usual case for emissions by pollutant.

Table 1. Total Emissions Reduction for Highway Sources in Truck Corridor Counties exceeding the 8,500- and 10,000-Truck per Day Thresholds, Short Tons per Year or Percent from Business as Usual.

	8,500 AADT Threshold			10,000 AADT Threshold		
Pollutant	2030	2040	2050	2030	2040	2050
NO_2	36,471	340,609	631,320	33,404	311,969	578,244
SO_2	97	850	1,517	89	782	1,395
NH_3	851	7,561	13,632	783	6,957	12,544
$PM_{2.5}$	456	4,064	6,863	418	3,722	6,287
VOC	2,979	28,544	55,382	2,717	26,039	50,535
NO_2	4.0%	48.0%	82.0%	4.0%	48.0%	82.0%
SO_2	1.5%	13.8%	23.3%	1.5%	13.7%	23.2%
NH_3	1.2%	10.3%	17.2%	1.2%	10.3%	17.1%
$PM_{2.5}$	1.4%	13.8%	22.2%	1.4%	13.7%	22.0%
VOC	0.7%	7.5%	14.9%	0.7%	7.5%	14.9%

COBRA includes Tiers that track highway vehicles by fuel. Figure 3 shows the results from Table 1 disaggregated by fuel type. This confirms that the largest portion of the emissions reductions in this category comes from diesel-fueled vehicles. Diesel exhaust is a mobile source air toxic.

Figure 3: Fuel Breakdown of the Highway Vehicle Emissions Reductions Under both AADT Thresholds



Changes in Health Outcomes and Air Quality by Year

Table 2 and Table *3* present total, national, annual estimates of the number of avoided adverse health effects and the economic value of these health risk reductions in truck corridor counties. Monetized values are shown for the 3% discount rate. Both tables show values for the Non-Combustion electricity Case.[14] Table 2 shows all modeled years for the 8,500 truck AADT threshold, while Table 3 presents the 10,000 truck threshold. Both represent the heavy-duty vehicle class simulation. These economic values reflect the US population's willingness to pay to reduce risks of premature mortality or certain illnesses.. As such, these economic values represent monetized US public health benefits. 2020 is not shown as there are no heavy-vehicle benefits in that year.

At a 3% discount, the estimate for total, monetized, annual public health benefits range from approximately $18 billion in 2030 (low) to $34.5 billion in 2050 (high) under the Non-Combustion Case considering heavy vehicle classes only in counties exceeding the 8,500-truck threshold. As EV penetration of heavy-duty vehicles begins in 2024 in this scenario, changes in health benefits do not appear in these decade-resolved, annual results until 2030.

Adult mortality is the main driver of benefits of emissions changes, with an estimated decrease in the number of premature deaths among adults between 2,770 and 2,950 in truck corridor counties nationally under the 2050 Non-Combustion Case with the lower truck count threshold.

On a national level, reductions are seen in population-weighted, annual $PM_{2.5}$ concentrations under the Non-Combustion Case for truck corridor counties. The annual average concentration reductions under the Non-Combustion Case are 0.13 μg/m^3 in 2030, 0.235 μg/m^3 in 2040, and 0.214 μg/m^3 in 2050 for the 8,500 truck

[14] The 3% discount rate reflects society's valuation of differences in the timing of benefits; the 7% discount rate reflects the opportunity cost of capital to society.

[15] For some health endpoints, the economic value estimates are based on the non-market valuation studies that estimate people's willingness to pay for reductions in these health risks. For other endpoints, non-market valuation studies are not readily available, and valuation is approximated using cost-of-illness methods that estimate medical costs and illness-related productivity losses.

AADT threshold. These values are only slightly smaller than the national average reductions seen for the Non-Combustion Case with the total vehicle scenario from the March 2022 study. All cumulative benefits are slightly lower for the 10,000-truck AADT threshold.

Table 2. Estimated health benefits under the Non-Combustion Electricity Case, considering heavy-duty vehicles only, for years 2030, 2040, and 2050, for counties Exceeding the 8,500-Trucks per Day Threshold

	2030		2040		2050	
Health Endpoint	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**
Mortality, low estimate[c,d]	1,750	$17,700,000,000	3,120	$33,200,000,000	2,770	$31,400,000,000
Mortality, high estimate[d,e]	1,790	$18,100,000,000	3,260	$34,700,000,000	2,950	$33,400,000,000
Infant Mortality	9.05	$91,400,000	15.7	$168,000,000	13.9	$158,000,000
Nonfatal Heart Attacks, low estimate[f]	199	$31,500,000	382	$60,400,000	359	$56,800,000
Nonfatal Heart Attacks, high estimate[g]	1,840	$292,000,000	3,540	$559,000,000	3,330	$527,000,000
Hospital Admits, All Respiratory	473	$17,500,000	927	$34,500,000	889	$33,200,000
Hospital Admits, Cardiovascular (except heart attacks)	465	$23,700,000	905	$46,200,000	863	$44,100,000
Acute Bronchitis	2,300	$1,410,000	4,520	$2,760,000	4,460	$2,720,000
Upper Respiratory Symptoms	41,700	$1,760,000	82,000	$3,470,000	80,800	$3,420,000
Lower Respiratory Symptoms	29,300	$783,000	57,500	$1,540,000	56,700	$1,510,000
Emergency Room Visits, Asthma	909	$512,000	1,760	$991,000	1,700	$957,000
Minor Restricted Activity Days	1,240,000	$108,000,000	2,440,000	$211,000,000	2,400,000	$208,000,000
Work Loss Days	210,000	$42,100,000	413,000	$82,700,000	407,000	$81,400,000
Asthma Exacerbation	43,500	$3,200,000	85,500	$6,280,000	84,200	$6,180,000
Total, low estimate		**$18,000,000,000**		**$33,800,000,000**		**$32,000,000,000**
Total, high estimate		**$18,700,000,000**		**$35,800,000,000**		**$34,500,000,000**
Population-Weighted Average Delta $PM_{2.5}$ (µg/m3)		0.130		0.235		0.214

Notes:
[a]The discount rate expresses future economic values in present terms. Not all health effects and associated economic values occur in the year of analysis.
[b]Adult mortality valuation is based on a Value of a Statistical Life (VSL; grown from EPA 1990 VSL using standard income growth data) calculated by ICF and is lagged 20 years (per COBRA Model guidance), not the default valuation in COBRA.
[c]Low estimate based on Krewski et al. (2009) (relative risk of 1.03 associated with a 10 µg/m^3 increase in $PM_{2.5}$), which applies to adults aged 30 to 99.
[d]Note: In some cases, the "low" estimate may be larger than the "high" estimate. This happens occasionally depending on county-specific population distribution and baseline health incidence.
[e]High estimate based on Di et al. (2017) (relative risk of 1.07 associated with a 10 µg/m^3 increase in $PM_{2.5}$), which applies to adults aged 65 to 99.
[f]Low estimate based on four acute myocardial infarction (AMI) studies.
[g]Low estimate based on Peter et al. (2001).

Table 3. Estimated health Benefits under the Non-Combustion Case, Considering Heavy-Duty Vehicles for Years 2020, 2030, 2040, and 2050, for Counties Exceeding the 10,000-Trucks per Day Threshold

	2030		2040		2050	
Health Endpoint	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**	**Change in the Number of Cases**	**Monetary Health Benefits (3% Discount, 2017$)[a,b]**
Mortality, low estimate[c,d]	1,600	$16,200,000,000	2,880	$30,600,000,000	2,590	$29,300,000,000
Mortality, high estimate[d,e]	1,640	$16,500,000,000	3,010	$32,000,000,000	2,760	$31,200,000,000
Infant Mortality	8.40	$84,900,000	14.8	$157,000,000	13.2	$149,000,000
Nonfatal Heart Attacks, low estimate[f]	181	$28,700,000	350	$55,500,000	333	$52,700,000
Nonfatal Heart Attacks, high estimate[g]	1,680	$267,000,000	3,250	$514,000,000	3,090	$489,000,000
Hospital Admits, All Respiratory	433	$16,000,000	854	$31,800,000	829	$30,900,000
Hospital Admits, Cardiovascular (except heart attacks)	425	$21,700,000	834	$42,600,000	804	$41,100,000
Acute Bronchitis	2,150	$1,310,000	4,250	$2,600,000	4,230	$2,580,000
Upper Respiratory Symptoms	38,900	$1,650,000	77,100	$3,260,000	76,600	$3,240,000
Lower Respiratory Symptoms	27,300	$730,000	54,100	$1,450,000	53,800	$1,440,000
Emergency Room Visits, Asthma	843	$475,000	1,640	$926,000	1,600	$901,000
Minor Restricted Activity Days	1,150,000	$100,000,000	2,280,000	$198,000,000	2,270,000	$197,000,000
Work Loss Days	196,000	$39,200,000	388,000	$77,600,000	385,000	$77,100,000
Asthma Exacerbation	40,600	$2,980,000	80,400	$5,900,000	79,900	$5,860,000
Total, low estimate		**$16,500,000,000**		**$31,200,000,000**		**$29,900,000,000**
Total, high estimate		**$17,000,000,000**		**$33,000,000,000**		**$32,200,000,000**
Population-Weighted Average Delta $PM_{2.5}$ (µg/m3)		0.129		0.235		0.217

Notes:
[a]The discount rate expresses future economic values in present terms. Not all health effects and associated economic values occur in the year of analysis.
[b]Adult mortality valuation is based on a Value of a Statistical Life (VSL; grown from EPA 1990 VSL using standard income growth data) calculated by ICF and is lagged 20 years (per COBRA Model guidance), not the default valuation in COBRA.
[c]Low estimate based on Krewski et al. (2009) (relative risk of 1.03 associated with a 10 µg/m^3 increase in $PM_{2.5}$), which applies to adults aged 30 to 99.
[d]Note: In some cases, the "low" estimate may be larger than the "high" estimate. This happens occasionally depending on county-specific population distribution and baseline health incidence.
[e]High estimate based on Di et al. (2017) (relative risk of 1.07 associated with a 10 µg/m^3 increase in $PM_{2.5}$), which applies to adults aged 65 to 99.
[f]Low estimate based on four acute myocardial infarction (AMI) studies.
[g]Low estimate based on Peter et al. (2001).

Existing Context

Existing Air Quality

Table 2 and Table 3 showed the predicted average changes in annual average $PM_{2.5}$ concentrations. Those values represent population-weighted changes across all truck corridor counties and are shown for years 2030, 2040, and 2050. For comparison, Table 4 shows an estimate of the current levels of PM air quality in these same counties. These values are determined from the Lung Association's State of the Air 2022 report and represent long-term average $PM_{2.5}$ concentrations. We determined these using available data. Many counties are listed as either Data Not Collected (DNC) or Incomplete Data Set (INC). These missing values are not included in the calculation.

Please note these values represent average, existing conditions for the 2018-2020 period. They should not be directly combined with the predicted changes in Table 2 and Table 3 since many sectors affect the ambient $PM_{2.5}$ concentration in these areas and baseline values are likely to change over the modeled period. They are shown here for reference only. Note also that the average PM concentrations present in these counties from Table 4 is higher than the most health-protective level (8.0 $\mu g/m^3$) under consideration by the US EPA for revised National Ambient Air Quality Standards for annual $PM_{2.5}$ concentrations.[16]

Table 4. Population-Weighted National Average $PM_{2.5}$ Concentrations (ug/m^3) in Counties Exceeding the Listed Threshold[17]

Trucks per Day Threshold	Population Weighted Average 2018-2020 $PM_{2.5}$ Design Value ($\mu g/m^3$)	Percent Missing Data	DNC	INC
10,000	9.26	64%	447	54
8,500	9.14	66%	545	62

Existing Affected Population

Also for reference, Table 5 shows the existing affected population in the truck corridor counties. The number of counties and total population is shown for both truck thresholds. Population is based on the 2020 Census. We also show the total percent of people of color (POC) considered in aggregate in these counties. This data is consistent with the values shown in the March 2022 report. For comparison, the national average POC share is 38.4%.[18]

[16] E.g., the Policy Assessment for the Reconsideration of the National Ambient Air Quality Standards for Particulate Matter, EPA-452/R-22-004, May 2022, concludes, "With regard to the primary annual $PM_{2.5}$ standard, all CASAC members agreed that the current level of the primary annual $PM_{2.5}$ standard is not sufficiently protective of public health and should be lowered. …. The majority of the CASAC members recommended revising the level of the primary annual $PM_{2.5}$ standard within the range of 8-10 $\mu g/m^3$, while the minority of the CASAC members recommended revision with the range of 10-11 $\mu g/m^3$." See. https://www.epa.gov/system/files/documents/2022-05/Final%20Policy%20Assessment%20for%20the%20Reconsideration%20of%20the%20PM%20NAAQS_May2022_0.pdf.
[17] Excludes all counties listed as "DNC" or "INC" in Lung Association's provided database.
[18] Calculated by subtracting percent white alone from 100%. https://www.census.gov/library/stories/2021/08/improved-race-ethnicity-measures-reveal-united-states-population-much-more-multiracial.html.

Table 5. Population and Demographics of Affected Counties by Threshold[19]

Threshold	Number of counties	Total Population[20]	Total Percent POC in the Counties[21]
10,000	782 counties (25% of all counties)	238 million people (72% of the population)	45.9% of population
8,500	921 counties (29% of all US counties)	255 million people (77% of the population).	44.8% of population

Cumulative Impacts

We also postprocessed health benefits in the truck corridor counties to show cumulative impacts of the proposed scenarios covering the entire period from 2020 to 2050. We calculated cumulative impacts using piecewise linear interpolation of the discounted monetized health benefits between the modeled years: 2020, 2030, 2040, and 2050. Under the heavy-duty vehicle scenario in which 2020 monetized health benefits were zero, we interpolated between zero-dollar values in 2020 and nonzero dollar values in 2030 to reflect nonzero heavy-duty zero emission vehicle sales that occur within the period.

Table 6 presents cumulative estimates of the total national number of avoided adverse health effects and the economic value of these health risk reductions at the 3% discount rates for the Non-Combustion Case. At a 3% discount, cumulative monetized public health benefits from 2020 to 2050 range from approximately $695 billion to $735 billion in the Non-Combustion Case at a 3% discount rate for the 8,500-truck threshold. Adult mortality is the main driver of benefits of emissions changes under all electricity generation and vehicle scenarios, with an estimated decrease in the number of premature deaths among adults between 64,000 and 66,800 under the Non-Combustion Case for the lower 8,500 truck threshold.

Figure 4 and Figure 5 show cumulative values from 2020 through the charted year. The values corresponding to 2030 in these charts represent cumulative impacts from 2020 through 2030. Both show cumulative results at the 3% discount rate, with Figure 4 showing the 8,500-truck threshold and Figure 5 the 10,000-truck threshold. Note that benefits for the Non-Combustion Case include changes to emissions from the baseline grid.

Note that although there are more trucks along certain routes in the counties exceeding the 10,000 AADT threshold than for the 8,500 threshold, it is not necessarily true that the total number of truck trips or total truck emissions in the county is greater. However, it is clear from these results that the higher populations included at the 8,500-truck threshold (Table 5) leads to greater potential benefits than using the 10,000-truck threshold. Thus, the higher (10,000 AADT) threshold is the more conservative estimate of available benefits in truck corridor counties across the US.

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[19] Excludes all counties listed as DNC or INC in Lung Association's provided database.
[20] As defined by the 2020 Decennial Census 94-171 Redistricting Data
[21] Percent of the population identifying as a person of color was calculated using the total population contained within the specified subset of counties as defined by the Annual County Resident Population Estimates by Age, Sex, Race, and Hispanic Origin for 2020 from the Census Bureau's Vintage 2020 Population Estimates. For further explanation about how this was calculated, see the "Population Demographics Extraction" section above.

Table 6. Estimated cumulative Health Benefits under the Non-Combustion Case from 2020 to 2050 for Heavy-Duty Vehicles.

	Counties exceeding the 8,500 trucks per day threshold		Counties exceeding the 10,000 trucks per day threshold	
Health Endpoint	Change in the Number of Cases	Monetary Health Benefits (3% Discount, 2017$)[a,b]	Change in the Number of Cases	Monetary Health Benefits (3% Discount, 2017$)[a,b]
2020-2050, Non-Combustion Case, Heavy-Duty Vehicle Class				
Mortality, low estimate[c]	64,000	$682,000,000,000	59,000	$629,000,000,000
Mortality, high estimate[d]	66,800	$712,000,000,000	61,600	$657,000,000,000
Infant Mortality	325	$3,460,000,000	304	$3,240,000,000
Nonfatal Heart Attacks, low estimate[e]	7,780	$1,230,000,000	7,150	$1,130,000,000
Nonfatal Heart Attacks, high estimate[f]	72,100	$11,400,000,000	66,300	$10,500,000,000
Hospital Admits, All Respiratory	18,900	$703,000,000	17,400	$648,000,000
Hospital Admits, Cardiovascular (except heart attacks)	18,400	$942,000,000	17,000	$869,000,000
Acute Bronchitis	92,800	$56,700,000	87,300	$53,300,000
Upper Respiratory Symptoms	1,680,000	$71,100,000	1,580,000	$66,900,000
Lower Respiratory Symptoms	1,180,000	$31,500,000	1,110,000	$29,700,000
Emergency Room Visits, Asthma	36,000	$20,300,000	33,700	$19,000,000
Minor Restricted Activity Days	49,900,000	$4,330,000,000	46,900,000	$4,070,000,000
Work Loss Days	8,470,000	$1,700,000,000	7,950,000	$1,590,000,000
Asthma Exacerbation	1,750,000	$129,000,000	1,650,000	$121,000,000
Total, low estimate		**$695,000,000,000**		**$641,000,000,000**
Total, high estimate		**$735,000,000,000**		**$678,000,000,000**

Notes:
[a]The discount rate expresses future economic values in present terms. Not all health effects and associated economic values occur in the year of analysis.
[b]Adult mortality valuation is based on a Value of a Statistical Life (VSL; grown from EPA 1990 VSL using standard income growth data) calculated by ICF and is lagged 20 years (per COBRA Model guidance), not the default valuation in COBRA.
[c]Low estimate based on Krewski et al. (2009) (relative risk of 1.03 associated with a 10 μg/m^3 increase in $PM_{2.5}$), which applies to adults aged 30 to 99.
[d]High estimate based on Di et al. (2017) (relative risk of 1.07 associated with a 10 μg/m^3 increase in $PM_{2.5}$), which applies to adults aged 65 to 99.
[e]Low estimate based on four acute myocardial infarction (AMI) studies.
[f]Low estimate based on Peter et al. (2001).

Figure 4. Estimated cumulative Health Benefits at 3% Discount Rate under the Non-Combustion Case from 2020 to 2050

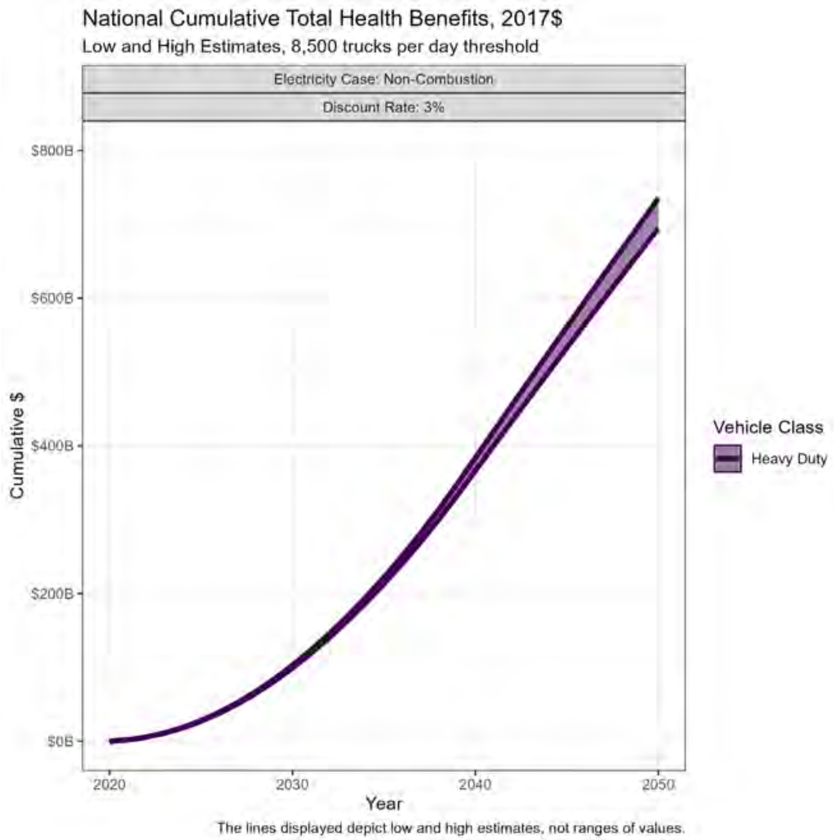
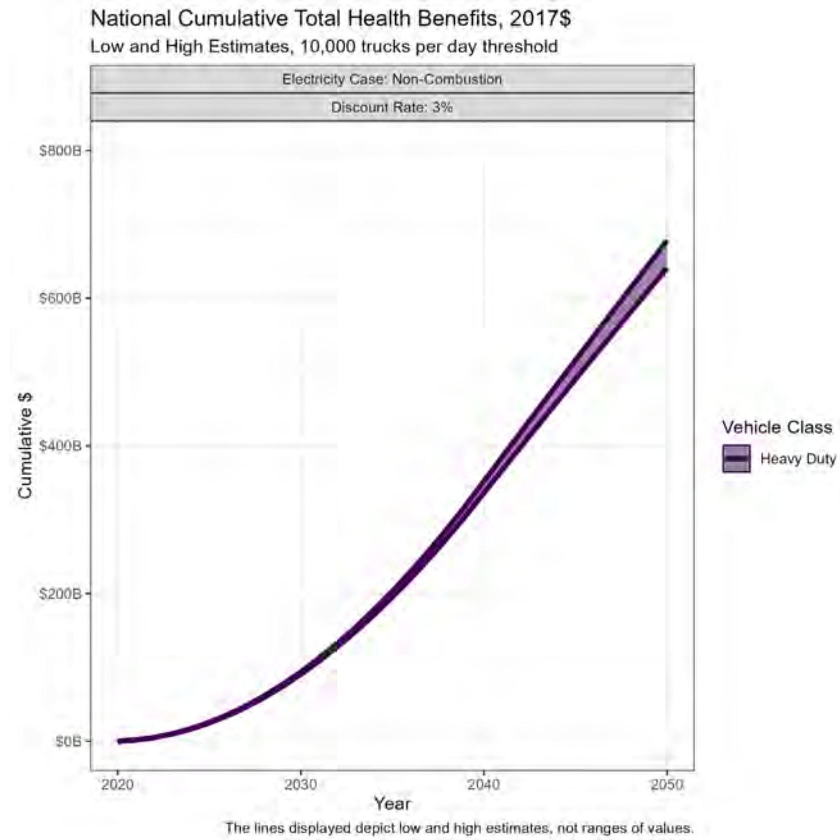


Figure 5. Estimated Cumulative Health Benefits at 3% Discount Rate under the Non-Combustion Case from 2020 to 2050



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