APPENDIX F

Air Quality Modeling and Health Impacts Assessment for the MY 2012-2016 NHTSA CAFE Standards

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Revised Draft Report

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 Introduction

This report summarizes the application of air quality modeling tools to examine the air quality impacts and related health benefits associated with selected alternatives for the Corporate Average Fuel Economy (CAFE) Standards Draft Environmental Impact Statement (DEIS).

1.1 BACKGROUND AND OBJECTIVES

The National Highway Transportation Safety Administration (NHTSA) and the U.S. Environmental Protection Agency (EPA) are preparing to establish new standards for passenger cars and light trucks that will improve fuel efficiency and reduce the emission of greenhouse gases and other air pollutants. The Corporate Average Fuel Economy (CAFE) standards proposed by NHTSA apply to passenger cars and light trucks, for model years 2012 through 2016. The vehicle categories that would be subject to the new CAFE standards include cars, sport utility vehicles, minivans, and pick-up trucks used for personal transportation. The standards are designed to achieve an average 34.1 miles per gallon (mpg) fuel efficiency under NHTSA's preferred alternative for the combined classes of vehicles by model year (MY) 2016. Although the changes to the fleet required by the CAFE standards are expected to result in improved fuel efficiency, the lower cost of fuel consumed per mile driven might create an incentive for additional driving that would partially offset the fuel savings. This "rebound effect" could limit any direct emissions reductions from increased fuel efficiency. However, the proposed CAFE standards would also lead to reductions in "upstream" emissions, which are emissions associated with petroleum extraction, refining, storage, and distribution of transportation fuels, due to the reduction in total fuel consumption. The net effect of the CAFE standards is an overall reduction in emissions on the national scale.

Different regions of the country could experience either a net increase or a net decrease in emissions due to the proposed CAFE standards, depending on the relative magnitudes of the changes in emissions due to increased fuel efficiency, increased vehicle use, and reduced fuel production and distribution. The regional differences are taken into account in this study through the use of grid-based air quality modeling and analysis techniques, which account for local and regional differences in emissions as well as many of the other factors that affect air quality and the resulting health impacts at any given location, such as meteorology and atmospheric chemistry processes.

The objective of this study is to use air quality modeling and health-related benefits analysis tools to examine the air quality related consequences of the proposed CAFE standards and, specifically, to quantify the air quality and health-related benefits associated with those standards and the alternative standards that NHTSA considered in its DEIS. To support this objective, estimates of air quality changes and health-related benefits were calculated for the national scale, based on a detailed analysis of the air quality and health effects on a grid cell-by-grid cell basis.

1.2 OVERVIEW OF THE METHODOLOGY

To examine and quantify the air quality and health-related benefits associated with implementation of the proposed CAFE standards for MY 2012-2016, a national-scale photochemical air quality modeling and health risk assessment was conducted. Key components of this assessment included:

- Emission inventory preparation,
- Air quality model application, and
- Benefits/health impacts assessment.

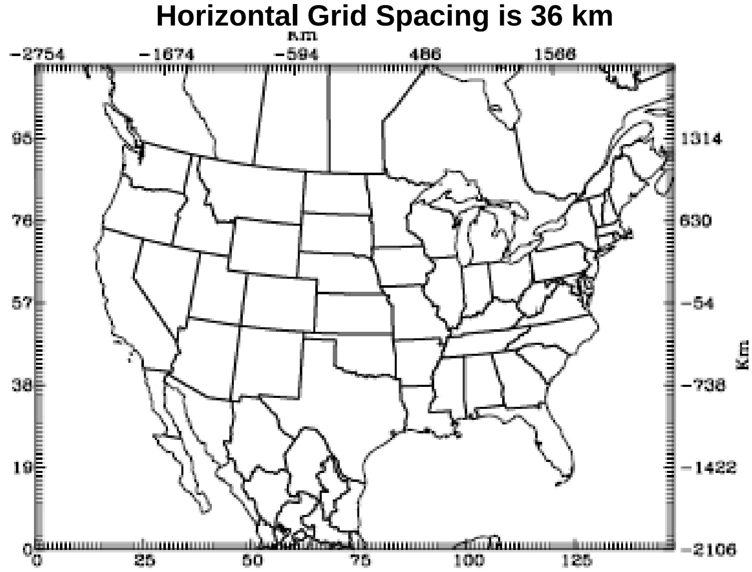
The primary tools that were used for this assessment include:

- Sparse-Matrix Operator Kernel Emissions (SMOKE) processing tool (version 2.5) for the preparation of model-ready emissions;
- Community Multiscale Air Quality (CMAQ) model (version 4.6) for quantifying the air quality changes for the different fuel efficiency alternatives; and
- Environmental Benefits Mapping and Analysis Program (BenMAP) tool (version 3.0.14) to assess the health-related impacts of the simulated changes in air quality.

These tools are widely used for conducting air quality and health effects analysis.

The national-scale modeling analysis utilized CMAQ's standard continental U.S. modeling domain shown in Figure 1.2-1. The horizontal resolution of this modeling domain is 36 kilometers (km). Air quality impacts and health effects were calculated for each grid cell, selected sub-regions, and the conterminous United States.

Figure 1.2-1. CMAQ Modeling Domain for the NHTSA CAFE Standards Modeling Analysis; Horizontal Grid Spacing is 36 km



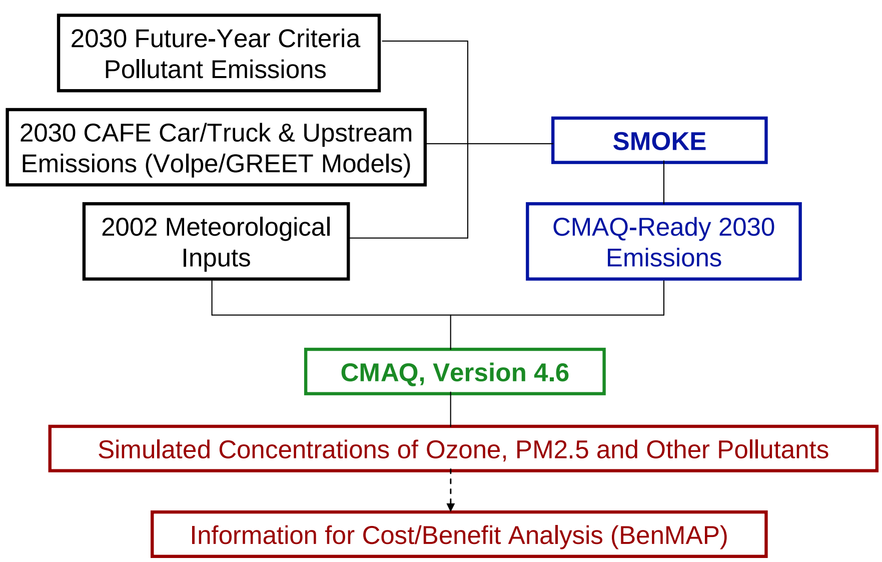
The CMAQ model was applied for an annual simulation period, using meteorological inputs for a base year of 2002. The meteorological inputs were originally prepared by EPA and have been used for a number of past and recent air quality modeling studies (Douglas et al. 2008).

The modeling was conducted for 2030 and used to examine the proposed CAFE standard (the Preferred or 3-Percent Alternative), as well as several alternative proposed CAFE standards that were considered in the DEIS. The emissions for 2030 are expected to reflect the combined impacts of the proposed CAFE standards for all model years covered by the proposed standards. This year was chosen for analysis because almost all passenger cars and light trucks in operation are expected to meet at least the MY 2012-2016 standards by 2030. Emissions for 2030 were obtained from the latest projected 2030 national-scale emission inventory released by EPA and processed for the 36-km modeling domain using SMOKE. The resulting model-ready inventories contain emissions for all criteria pollutants (as required for photochemical modeling) for 10 source category sectors, including on-road mobile sources, non-road mobile sources (construction equipment, locomotives, ships, aircraft, etc.), electric generating unit (EGU) point sources, non-EGU point sources, area sources, biogenic sources, etc. Following preparation of the baseline 2030 emissions inventory, the baseline data for the on-road mobile (passenger cars and light trucks only) and relevant upstream emissions categories were replaced with data provided by NHTSA, reflecting the CAFE alternatives analyzed in the MY 2012-2016 DEIS. National emissions estimates for all passenger cars and light trucks projected to be in use in 2030 were derived by NHTSA using the Volpe model (NHTSA 2009). Upstream emissions associated with the fuels used by these vehicle classes were estimated using emission factors provided by EPA, based on the Greenhouse Gas, Regulated Emissions, and Energy Used in Transportation (GREET) model (Argonne 2002 in Abt Associates 2008).

Following the application of CMAQ for each alternative, the CMAQ outputs were processed for input to the BenMAP health effects analysis tool, and BenMAP was used to estimate the health impacts and monetized health-related benefits associated with the changes in air pollution simulated by CMAQ for each of the modeled alternative CAFE standards. The BenMAP tool includes health impact functions, which relate a change in the concentration of a pollutant with a change in the incidence of a health endpoint. BenMAP also calculates the economic value of health impacts. For this study, the health effects analysis considered the effects of ozone and fine particulate matter ($PM_{2.5}$). The health effects were calculated for the national scale and for selected sub-regions.

Figure 1.2-2 summarizes the components of the NHTSA air quality modeling and health-related benefits analysis.

Figure 1.2-2. Schematic Diagram of the NHTSA CAFE Standards Air Quality Modeling and Health-Related Benefits Analysis



1.3 MODELING SCENARIOS

Eight annual CMAQ simulations comprised this study. Four of the simulations focus on the environmental consequences (EC) (direct and indirect effects) outcome (referred to in the remainder of this report as the EC scenario) and four focus on the cumulative impacts outcome (referred to in the remainder of this report as the CI scenario). The environmental consequences alternatives assume no increase in fuel economy after 2016, and post-2016 model year vehicles are assumed to meet the proposed CAFE standards for model year 2016. The cumulative impacts alternatives assume continued increases in fuel economy after 2016. The EC and CI scenarios represent DEIS alternatives and the assumptions defining them are the same as in the DEIS and the Volpe model emissions datasets (NHTSA 2009). For both the EC and CI scenarios, a subset of the DEIS alternatives was chosen for the modeling analysis that represents the full range of potential impacts. For each simulation, emissions were adjusted to reflect a selected CAFE standard alternative, as presented in the DEIS. The modeling includes the following MY 2012-2016 DEIS alternatives:

- Alternative 1, or No Action Alternative. This is the baseline that assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agency's collective market forecast or the manufacturer's required level of average fuel economy for MY 2011.
- Alternative 2, or the 3-Percent Alternative. This alternative requires a 3-percent average annual increase in mpg, resulting in an estimated achieved MY 2016 fleetwide 36.0 mpg for passenger cars and 26.5 mpg for light trucks. Alternative 2 results in a combined estimated achieved fleetwide 32.0 mpg in MY 2016.
- Alternative 4, or the Preferred Alternative. This alternative requires approximately a 4.5-percent on average annual increase in mpg, resulting in an estimated achieved MY 2016 fleetwide 37.8 mpg for passenger cars and 28.1 mpg for light trucks. Alternative 4 results in a combined estimated achieved fleetwide 33.8 mpg in MY 2016.
- Alternative 8, or the 7-Percent Alternative. This alternative requires a 7-percent average annual increase, resulting in an estimated achieved MY 2016 fleetwide 42.1 mpg for passenger cars and 31.7 mpg for light trucks. Alternative 8 results in a combined estimated achieved fleetwide 37.8 mpg in MY 2016.

Chapter 2 Emission Inventory Preparation

This section summarizes the data, methods, and procedures followed in preparing modeling emission inventories for use in the air quality modeling analysis of the proposed CAFE standards for passenger cars and light trucks. The analysis examined the expected changes in criteria pollutant emissions from on-road mobile sources for the alternatives, and from the effects those alternatives would also have on emissions associated with various “upstream” activities associated with extraction of oil (feedstock recovery), feedstock transportation, fuel refining, and fuel transportation, storage, and distribution. The emissions changes were incorporated into a national air quality modeling database originally developed by EPA and the impacts were assessed for an annual simulation period. Although the DEIS (NHTSA 2009) evaluated changes in emissions for a number of future years, the emissions preparation and modeling analysis discussed herein focuses on 2030 in simulating the effects on air quality.

2.1 EMISSIONS DATA AND METHODS

The Community Multiscale Air Quality (CMAQ) model requires as input hourly, gridded criteria pollutant emissions of both anthropogenic and biogenic sources that have been spatially allocated to the appropriate grid cells and chemically speciated for the applicable chemical mechanism used in the model. The modeling inventories were processed and prepared for CMAQ using EPA’s Sparse-Matrix Operator Kernel Emissions (SMOKE) software (version 2.5) (CEMPD 2007). The emissions inventories prepared for the NHTSA CAFE modeling analysis were derived, in part, from information developed by EPA for 2030 based on the 2002 modeling platform database (EPA 2008). The SMOKE emissions input files include the following categories:

- Area fugitive dust;
- Agricultural sources;
- Aircraft, locomotive and commercial marine vessels;
- Fires;
- Non-point (area) sources;
- Non-road sources;
- On-road sources;
- Electric generating unit (EGU) sources (estimated using the Integrated Planning Model [IPM] and referred to as IPM point sources); and
- Non-EGU (Non-IPM) point sources.

The SMOKE emissions input files for 2030 were obtained from the following EPA FTP site: ftp://ftp.epa.gov/EmisInventory/2002v3CAP. These files provided emissions data and related information for the 50 states and Washington, D.C. In addition, biogenic emissions for the modeling domain were obtained for 2002 (the meteorological base year) and emissions for the portions of Canada, Mexico, and offshore areas included in the modeling domain were obtained for 2020 (the latest year available) from EPA. The modeling inventories include the following pollutants: volatile organic compounds (VOC), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), fine particulates ($PM_{2.5}$), coarse particulates (PM_{10}), and ammonia (NH_3).

In addition to the modeling inventory information obtained from EPA for 2030, NHTSA provided information regarding the expected changes in on-road mobile emissions (for passenger cars and light trucks) and upstream emissions associated with these vehicle classes (NHTSA 2009). For each pollutant, a total emissions value for all states and Washington, D.C. was provided for passenger car and light truck "tailpipe" emissions and for the upstream emissions associated with fuel production for these vehicle classes for the No Action and CAFE standard alternatives. These emissions assume that emission rates for vehicles are the same across the U.S. Emissions factors provided by EPA were used to define the makeup of the fuels, and specifically the gasoline to ethanol proportions. The Energy Information Administration's (EIA) *Annual Energy Outlook* (AEO) ethanol proportions (EIA 2007) were assumed. NHTSA also provided estimates of vehicle miles traveled (VMT) by county for 2030 for these vehicle classes. As part of the emissions processing, this information was incorporated into the EPA modeling input files for each simulation, as detailed in the following section.

2.2 EMISSIONS PROCESSING PROCEDURES

As noted previously, SMOKE Version 2.5 was used to process the emissions and prepare CMAQ-ready inputs for the various CAFE alternatives using source sector files provided by EPA and other emission information provided by NHTSA. The preparation of the various modeling inventories included (1) processing of all source sectors using various SMOKE programs and inputs, (2) substitution of the NHTSA on-road mobile and upstream emissions to reflect the No Action and CAFE standard alternatives, and (3) review and quality assurance checks.

2.2.1 Preparation of On-Road Mobile Emission Inputs

The SMOKE on-road mobile input files obtained from EPA for 2030 contain monthly, county-level emissions for criteria pollutants by vehicle type and roadway type. The vehicle types are listed in Table 2.2.1-1.

Table 2.2.1-1

Vehicle Types Contained in EPA's SMOKE Input Files for On-road Mobile Sources

Class #	Vehicle Class	Description
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0 - 6,000 lbs. GVWR, 0 - 3,750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0 - 6,000 lbs. GVWR, 3,751 - 5,750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001 - 8,500 lbs. GVWR, 0 - 5,750 lbs. ALVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001 - 8,500 lbs. GVWR, > 5,751 lbs. ALVW)
6	HDGV2b	Class 2b Heavy-Duty Gasoline Vehicles (8,501 - 10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001 - 14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001 - 16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001 - 19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501 - 26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001 - 33,000 lbs. GVWR)
12	HDGV8a	Class 8a Heavy-Duty Gasoline Vehicles (33,001 - 60,000 lbs. GVWR)
13	HDGV8b	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1 and 2 (0 - 6,000 lbs. GVWR)
16	HDDV2b	Class 2b Heavy-Duty Diesel Vehicles (8,501 - 10,000 lbs. GVWR)
17	HDDV3	Class 3 Heavy-Duty Diesel Vehicles (10,001 - 14,000 lbs. GVWR)
18	HDDV4	Class 4 Heavy-Duty Diesel Vehicles (14,001 - 16,000 lbs. GVWR)
19	HDDV5	Class 5 Heavy-Duty Diesel Vehicles (16,001 - 19,500 lbs. GVWR)
20	HDDV6	Class 6 Heavy-Duty Diesel Vehicles (19,501 - 26,000 lbs. GVWR)
21	HDDV7	Class 7 Heavy-Duty Diesel Vehicles (26,001 - 33,000 lbs. GVWR)
22	HDDV8a	Class 8a Heavy-Duty Diesel Vehicles (33,001 - 60,000 lbs. GVWR)
23	HDDV8b	Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Buses (School, Transit, and Urban)
26	HDDBT	Diesel Transit and Urban Buses
27	HDDBS	Diesel School Buses
28	LDDT34	Light-Duty Diesel Trucks 3 and 4 (6,001 - 8,500 lbs. GVWR)

The various roadway types are listed in Table 2.2.1-2.

Table 2.2.1-2

Roadway Types Contained in EPA's SMOKE Input Files for On-road Mobile Sources

Area Type	Description
Rural	Interstate
Rural	Other Principal Arterial
Rural	Minor Arterial
Rural	Minor Collector
Rural	Major Collector
Rural	Local
Urban	Interstate
Urban	Other Principal Arterial
Urban	Minor Arterial
Urban	Minor Collector
Urban	Major Collector
Urban	Local

The SMOKE on-road mobile emissions files include emissions for exhaust, evaporative, tires, and brakes. Exhaust emissions are provided for VOC, NO_x, CO, SO_2, $PM_{2.5}$, PM_{10}, and NH_3. Evaporative emissions are provided for VOC. For tires and brakes, emissions are provided for $PM_{2.5}$ and PM_{10}.

As noted above, the proposed CAFE standards apply only to passenger cars and light trucks. From the list above and as defined in EPA's MOBILE6 motor vehicle emission factor model, the passenger-car category is made up of the following vehicle classes – Class #1: light-duty gas vehicle (LDGV) and #14: light-duty diesel vehicle (LDDV). The light-duty truck category comprises various vehicle classes depending on size – Class #2: light-duty gas truck (LDGT1); #3: LGDT2; #4: LDGT3; and #5: LDGT4; and two light-duty diesel truck categories: Class #15: LDDT12 and #28: LDDT34.

To incorporate the NHTSA emission estimates for each proposed CAFE standard alternative into the EPA emissions input files, the EPA SMOKE mobile source input files were modified such that the NHTSA-generated emissions were substituted for the EPA emissions to create modified SMOKE input files. The steps involved in this process included the following:

Step 1 – Calculate the county-level car and light-truck tailpipe emissions for the alternatives

- With the total U.S. emissions for passenger cars and light trucks for NO_x, VOC, CO, SO_2 and $PM_{2.5}$ for each alternative and the VMT fractions for all U.S. counties provided by NHTSA, allocate county-level emissions for each pollutant.

Step 2 – Calculate the county-level total emissions based on the EPA 2030 SMOKE input files for on- road sector

- With the utility program mb_cty_sum, calculate the monthly total county-level passenger-car and light-truck emissions for the EPA files.
- With the utility program cty_ann_ems, calculate the annual county-level passenger-car and light-truck emissions based on the monthly totals.

Step 3 – Calculate adjustment factors for passenger cars and light trucks for the alternatives

- With the utility program cal_fac, calculate the ratio of county-level emissions from a specified CAFE alternative to 2030 EPA emissions.

Step 4 – Apply the adjustment factors to the EPA SMOKE input files alternatives

- With the utility program adj_ems, apply the county-level adjustment factors for passenger cars and light trucks for a specified CAFE alternative to the EPA SMOKE input files to prepare updated SMOKE input files.

2.2.2 Preparation of Upstream Emission Inputs

As noted above, the proposed CAFE standards for passenger cars and light trucks are also expected to affect the "upstream" emissions associated with the extraction of oil (feedstock recovery), feedstock transportation, fuel refining, and fuel transportation, storage, and distribution. The upstream emissions are associated with a variety of equipment, processes, and activities involved in the production of fuel, including oil field extraction equipment (drills, pumps, etc.); oil refining (boilers, heaters, etc.); and the transportation, storage, and distribution of the fuel. For this analysis, EPA provided a list of Source Category Codes (SCC) associated with these activities/equipment types and a complete list of refineries operating in the United States. For each alternative, NHTSA provided estimates of upstream emissions, by pollutant, for passenger cars and light trucks only. The EPA SMOKE input files for 2030, however, contain emissions for all vehicle types, not just passenger cars and light trucks. To utilize and incorporate the NHTSA upstream emissions estimates into the EPA SMOKE files, it was assumed that 50 percent of the total upstream emissions are associated with the production of fuel for passenger cars and light trucks (EPA pers. comm. 2009a). Using the refinery list and SCC codes provided by EPA for all assumed sources/source types associated with upstream emissions, the emission estimates provided by NHTSA were substituted for the EPA emissions for the alternatives to prepare modified SMOKE inputs for the non-point and non-IPM point files.

The upstream emissions for each alternative considered only emissions occurring domestically and did not consider emissions from the transport of crude oil or refined gasoline to the United States. The upstream emissions estimates from the GREET model assumed that 1) 50 percent of the fuel savings with the alternatives would reduce imports of refined gasoline, and therefore would reduce domestic emissions only during fuel transportation, storage and distribution and would not reduce emissions from feedstock recovery, feedstock transportation, and fuel refining and 2) 90 percent of the reduction in domestic fuel refining would reduce imports of crude petroleum (and therefore would not reduce domestic emissions from feedstock recovery and feedstock transportation), and 3) 10 percent of the reduction in domestic fuel refining would reduce domestic production of crude petroleum (which would reduce domestic emissions from feedstock recovery and feedstock transportation). NHTSA estimated these percentages using several scenarios from EIA's AEO 2008. (EIA 2008).

2.2.3 SMOKE Emission Processing and Quality Assurance Procedures

Once the modified mobile source and upstream-related SMOKE input files reflecting the CAFE alternatives estimates were developed, the modified files were processed by SMOKE and merged with the other source category input files to prepare model-ready inputs for CMAQ. The general procedures followed in preparing the modeling inventories, using various programs included with SMOKE, are as follows:

- Modify EPA mobile source and upstream-related SMOKE input files using emissions data and related information provided by NHTSA;
- Chemically speciate input criteria pollutants into the Carbon Bond 2005 (CB-05) chemical mechanism species, as required by CMAQ (default speciation profiles were applied);
- Temporally distribute the input annual/monthly emissions into hourly emissions;
- Spatially distribute input emissions to the modeling grid;
- Merge emissions from all source categories into the CMAQ model-ready files; and
- Review and quality assure the inventory processing procedures and results

The emissions inventory processing quality assurance (QA) procedures included the development and examination of tabular emissions summaries and graphical display products.

Tabular summaries were prepared to examine emissions totals for various steps of the emissions processing. Summaries for input emissions are based on the input inventory data: monthly emissions for the on-road and non-road mobile sectors, and annual emissions for other sectors for criteria pollutants. Summaries for output emissions are based on the SMKMERGE reports: daily emissions for each species included in the chemical mechanism for each sector. The output daily emissions are summed over all days in the year and the species are summed for the criteria pollutants. The emissions were summarized for each alternative by state and sector, and comparisons were made between the input emissions and output emissions for each sector to assure consistency.

In addition to the tabular summaries, various graphical displays were prepared for one day of each month (the 15th of each month was randomly selected) to examine the spatial distribution and temporal variation for each sector and the final merged emissions using the Package for Analysis and Visualization of Environmental (PAVE) data graphical plotting package, which is available from the University of North Carolina Institute for the Environment web site at: http://www.ie.unc.edu/cempd/EDSS.

2.3 EMISSIONS SUMMARIES

Four CAFE standard alternatives from the DEIS were chosen for the air quality modeling analysis under the two (EC and CI) scenarios. As noted earlier, the EC scenario assumes no further increases in fuel economy from 2016 to 2030, while the CI scenario assumes increases in fuel economy to meet the 35 mpg by 2020 requirement and further increases at the rate predicted by EPA until 2030. The DEIS alternatives simulated under these scenarios include the No Action Alternative (Alternative 1), and Alternatives 2, 4, and 8, which required eight modeling emission inventories. Using the original and modified inputs, the SMOKE emissions processing system was used to prepare the CMAQ model-ready hourly emission inventory inputs for each simulation for the 36-km resolution national grid. Although the processed emission inventories were prepared for the full list of species given in Section 2.2.1, most of the presentation and discussion that follows focuses on the VOC, NO_x, SO_2, and $PM_{2.5}$ emissions species, which are important precursor species for ozone and $PM_{2.5}$.

Table 2.3-1 presents national (48-state) annual emissions totals for each pollutant by sector for each alternative and scenario simulated. Table 2.3-2 presents annual emission totals for all sectors combined for these alternatives and scenarios.

Table 2.3-1

National (48-State) Emissions Totals (thousands tons/year) by Sector for the NHTSA Modeling Scenarios

Pollutant	Sector	No Action EC	No Action CI	Alternative 2 EC	Alternative 2 CI	Alternative 4 EC	Alternative 4 CI	Alternative 8 EC	Alternative 8 CI
VOC	EGU	49	49	49	49	49	49	49	49
	Non-EGU Point	1,175	1,170	1,165	1,157	1,160	1,156	1,146	1,143
	Nonpoint	8,165	8,133	8,101	8,044	8,063	8,035	7,972	7,950
	Nonroad	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048
	On-road	1,504	1,505	1,507	1,510	1,508	1,509	1,500	1,501
NO_x	EGU	1,992	1,992	1,992	1,992	1,992	1,992	1,992	1,992
	Non-EGU Point	2,182	2,178	2,174	2,166	2,170	2,166	2,169	2,165
	Non-point	1,742	1,735	1,729	1,717	1,723	1,717	1,721	1,715
	Non-road	3,087	3,087	3,087	3,087	3,087	3,087	3,087	3,087
	On-road	1,565	1,568	1,572	1,580	1,571	1,575	1,503	1,507
CO	EGU	736	736	736	736	736	736	736	736
	Non-EGU Point	3,152	3,151	3,149	3,147	3,148	3,147	3,148	3,147
	Non-point	15,588	15,586	15,584	15,580	15,582	15,580	15,582	15,580
	Non-road	17,792	17,792	17,792	17,792	17,792	17,792	17,792	17,792
	On-road	19,060	19,114	19,176	19,308	19,134	19,200	17,895	17,954
SO_2	EGU	4,532	4,532	4,532	4,532	4,532	4,532	4,532	4,532
	Non-EGU Point	2,101	2,095	2,089	2,077	2,083	2,077	2,083	2,077
	Non-point	1,299	1,299	1,299	1,299	1,299	1,299	1,299	1,299
	Non-road	378	378	378	378	378	378	378	378
	On-road	38	37	35	33	34	33	31	30
PM_{10}	EGU	740	740	740	740	740	740	740	740
	Non-EGU Point	595	594	592	590	591	590	591	590
	Non-point	11,019	11,019	11,019	11,019	11,019	11,019	11,019	11,019
	Non-road	203	203	203	203	203	203	203	203
	On-road	168	168	168	168	168	169	169	169
$PM_{2.5}$	EGU	605	605	605	605	605	605	605	605
	Non-EGU Point	378	376	375	372	374	372	373	372
	Non-point	3,556	3,556	3,556	3,556	3,556	3,556	3,556	3,556
	Non-road	181	181	181	181	181	181	181	181
	On-road	89	89	89	90	90	90	90	90
NH_3	EGU	44	44	44	44	44	44	44	44
	Non-EGU Point	158	158	158	158	158	158	158	158
	Non-point	3,674	3,674	3,674	3,674	3,674	3,674	3,674	3,674
	Non-road	4	4	4	4	4	4	4	4
	On-road	417	417	417	417	417	417	417	417

Table 2.3-2

National (48-State) Emissions Totals (thousands tons/year) for All Sectors Combined for the NHTSA Modeling Scenarios

	No Action		Alternative 2		Alternative 4		Alternative 8	
Pollutant	EC	CI	EC	CI	EC	CI	EC	CI
VOC	12,940	12,906	12,870	12,809	12,828	12,797	12,716	12,692
NO_x	10,567	10,560	10,554	10,542	10,543	10,537	10,471	10,466
CO	56,328	56,378	56,437	56,563	56,392	56,455	55,152	55,209
SO_2	8,349	8,341	8,333	8,319	8,327	8,319	8,323	8,316
PM_{10}	12,725	12,724	12,723	12,721	12,722	12,721	12,722	12,721
$PM_{2.5}$	4,809	4,808	4,807	4,805	4,806	4,805	4,806	4,805
NH_3	4,297	4,297	4,297	4,297	4,297	4,297	4,297	4,297

To illustrate and check the reasonableness of the spatial distribution of emissions throughout the modeling domain, daily emission density plots for selected days were prepared and examined. Emissions associated with the No Action Alternative were used to check the reasonableness of the spatial distribution of emissions. Figure 2.3-1 presents daily emissions for a representative summer day (July 15) for VOC, NO_x, SO_2, and $PM_{2.5}$ for the 36-km national grid. A summer day was selected because it is included in both the ozone season and the annual simulation period. The plots show the spatial distribution of the 2030 EC No Action Alternative emissions, with higher emissions in the more populated areas of the eastern United States and California, and lower emissions in the less-populated areas of the interior western United States and areas of Canada and Mexico. The VOC emission plots also include biogenic emissions, with higher emissions associated with the more forested regions of the southeastern United States and Canada. The $PM_{2.5}$ emissions are associated with various anthropogenic mobile and industrial sources, but the high values noted in southwestern Oregon are associated with wildfires that were burning on July 15, 2002.

Figure 2.3-1a. Daily VOC Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

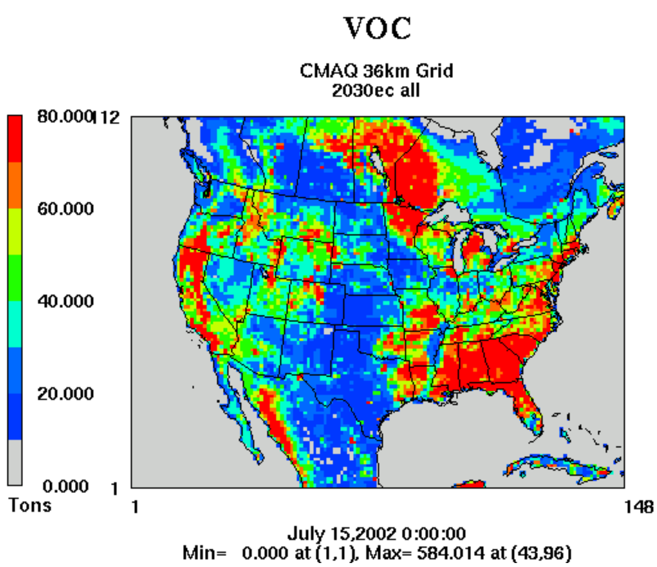


Figure 2.3-1b. Daily NO_x Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

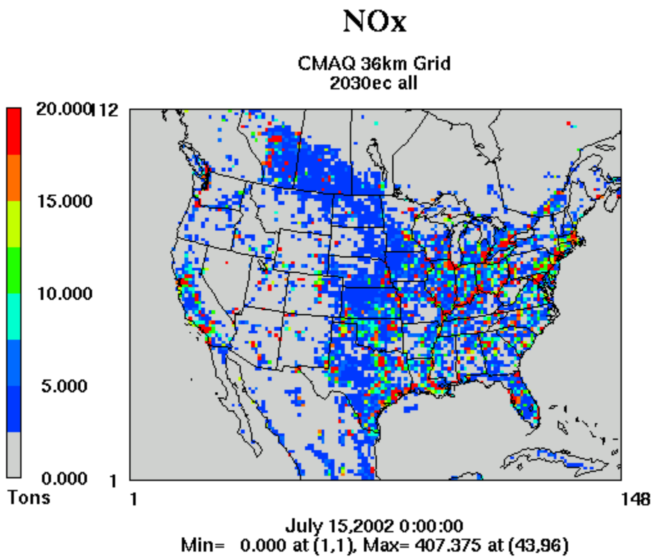


Figure 2.3-1c. Daily SO_2 Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

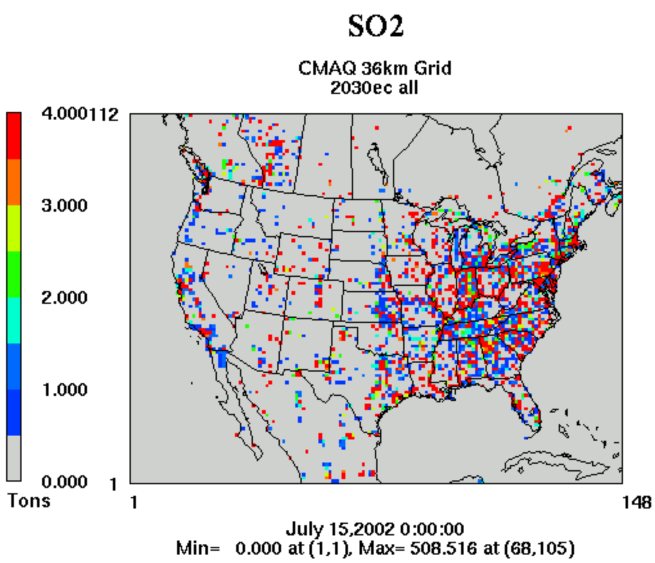


Figure 2.3-1d. Daily $PM_{2.5}$ Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

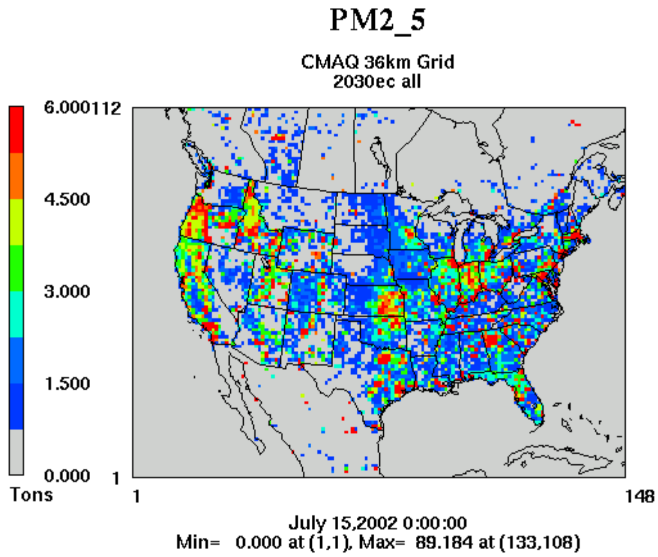


Figure 2.3-2 illustrates the spatial distribution of differences (or changes) in the emissions for the CAFE standard alternatives compared to the No Action (baseline) alternative. The figure presents difference plots for VOC, NO_x, SO_2, and $PM_{2.5}$, comparing the emissions for EC Alternative 8 (7%/year) with the emissions for the EC No Action alternative. The difference plots for these two alternatives were selected for presentation because they show the greatest differences between any of the alternatives and the baseline and are best suited to illustrate the spatial distribution of the differences (or changes). The difference plots illustrate where the expected reductions in emissions will occur throughout the 36-km resolution modeling domain. The green area outside of the United States indicates no emissions change.

Figure 2.3-2a. Difference in Daily VOC Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC Alternative 8 Minus the No Action Alternative

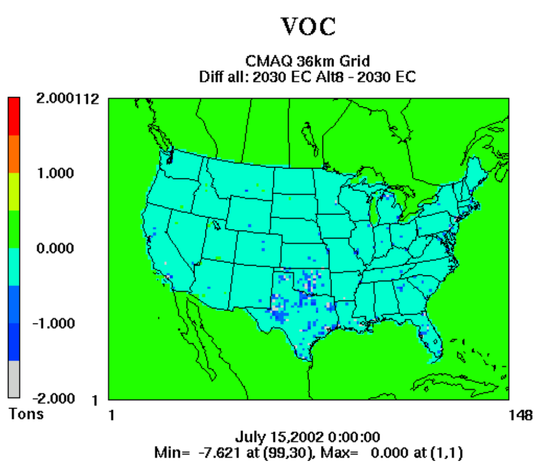


Figure 2.3-2b. Difference in Daily NO_x Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC Alternative 8 Minus the No Action Alternative

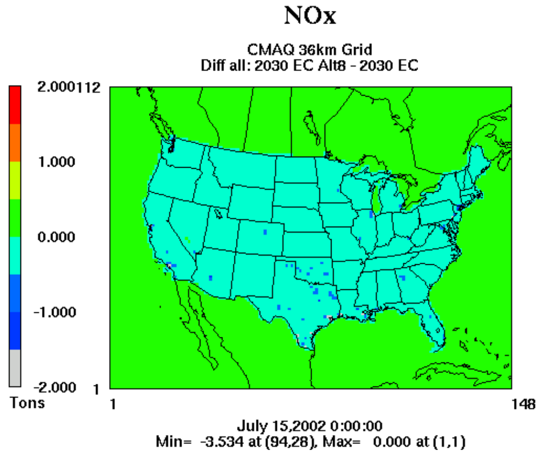


Figure 2.3-2c. Difference in Daily SO_2 Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC Alternative 8 Minus the No Action Alternative

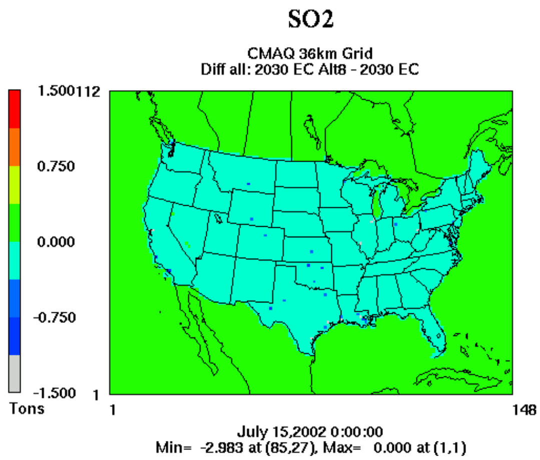
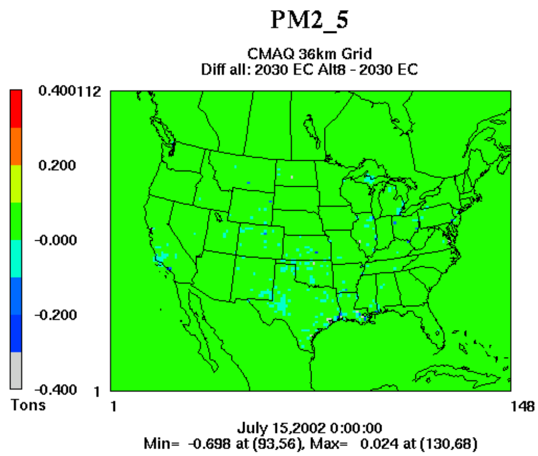


Figure 2.3-2d. Difference in Daily $PM_{2.5}$ Emissions for 15 July 2030: NHTSA Proposed CAFE Standards EC Alternative 8 Minus the No Action Alternative



The figures indicate overall reductions in VOC, NO_x and SO_2 emissions throughout the United States, associated with the on-road mobile emissions (from passenger cars and light trucks), and larger but more localized reductions in VOC, NO_x, SO_2 and $PM_{2.5}$ emissions in certain areas, associated with point-source emissions (from upstream sources).

Figure 2.3-3 presents national emissions estimates by source sector for the No Action Alternative and Alternatives 2, 4, and 8 for the EC and CI scenarios for VOC, NO_x, SO_2, and $PM_{2.5}$.

Figure 2.3-3a. National Emissions Totals for VOC for 2030 for the NHTSA Modeling Analysis Alternatives

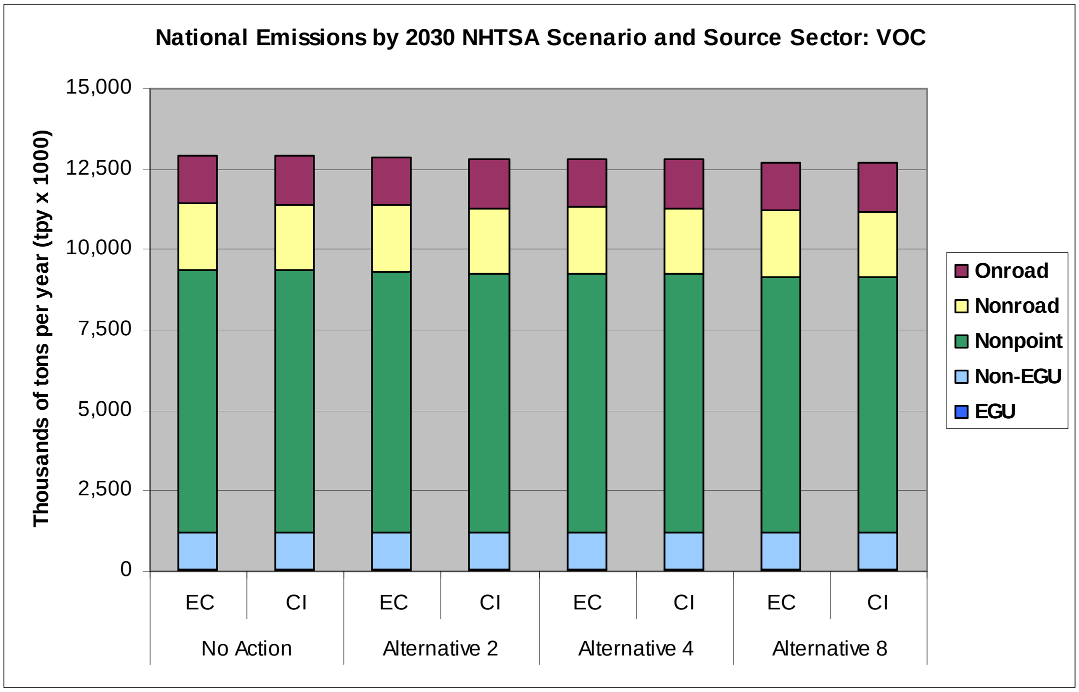


Figure 2.3-3b. National Emissions Totals for NO_x for 2030 for the NHTSA Modeling Analysis Alternatives

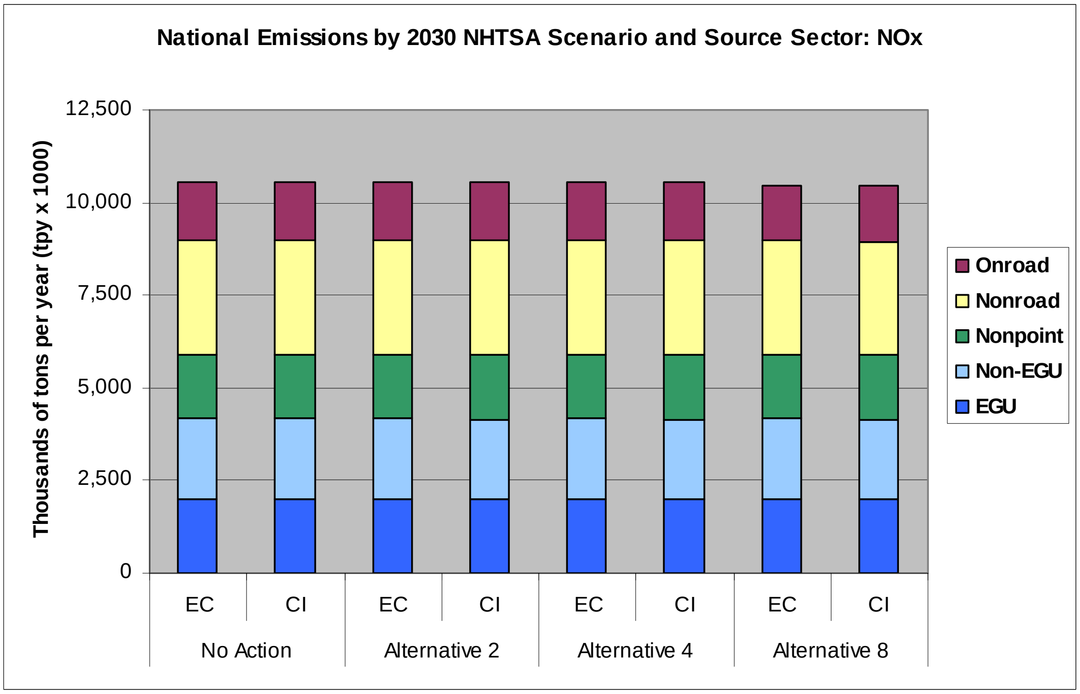


Figure 2.3-3c. National Emissions Totals for SO_2 for 2030 for the NHTSA Modeling Analysis Alternatives

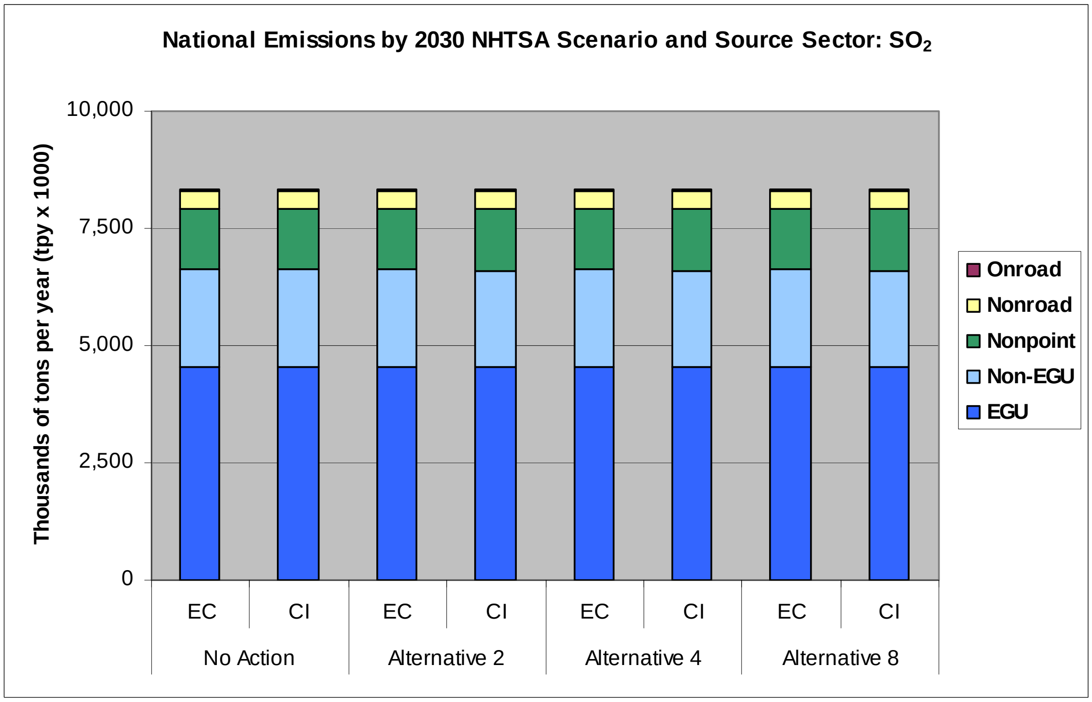
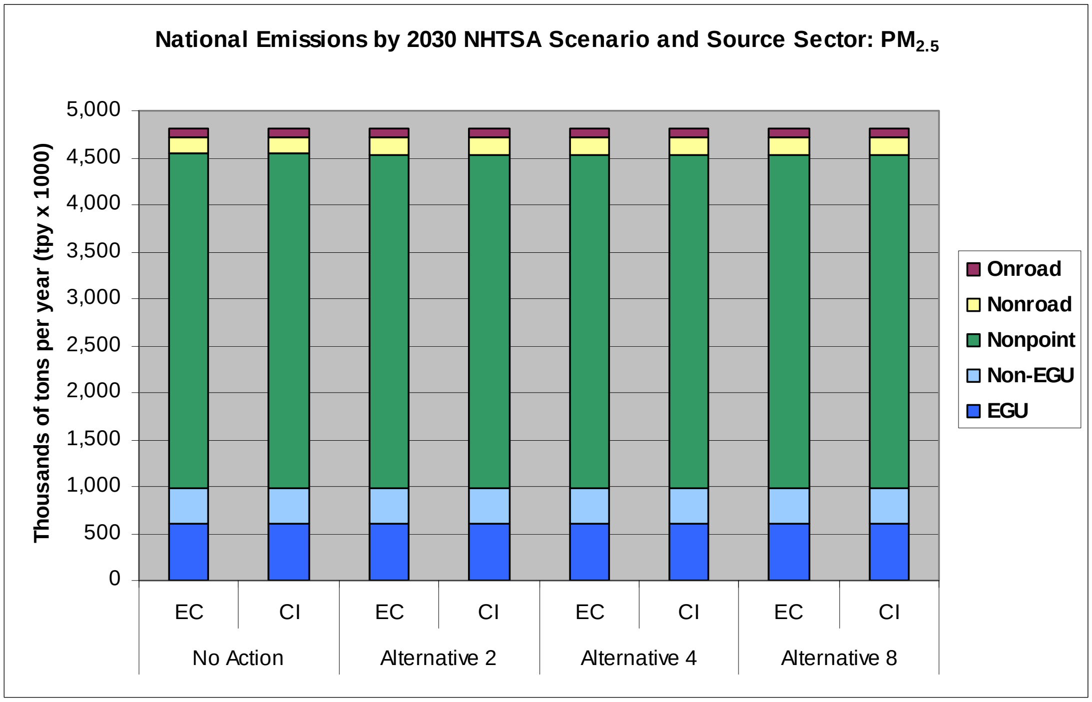


Figure 2.3-3d. National Emissions Totals for $PM_{2.5}$ for 2030 for the NHTSA Modeling Analysis Alternatives



On a national scale, anthropogenic VOC emissions are primarily from on-road mobile, non-road mobile, and area (non-point) sources; NO_x emissions come from all source categories; SO_2 emissions primarily derive from EGU and non-EGU point sources; and $PM_{2.5}$ emissions come primarily from area (non-point) sources. For the various CAFE alternatives, the expected changes in emissions for passenger cars and light duty trucks are reflected in the on-road mobile source category, while the expected changes in upstream emissions are reflected in the non-point (area) and non-EGU point source categories. The estimated decreases in mobile emissions are distributed nationwide while most of the decreases in upstream emissions are located in petroleum development/fuel production states including Texas, Louisiana, and California. Comparing the No Action Alternative to Alternative 4 (the Preferred or 3-Percent Alternative), national-scale VOC emissions are expected to decrease by approximately 1 percent and NO_x, SO_2, and $PM_{2.5}$ emissions are expected to decrease by less than 1 percent. Comparing the No Action Alternative to the most stringent alternative simulated in the study, Alternative 8, national-scale VOC emissions are expected to decrease by 2 percent, NO_x emissions are expected to decrease by 1 percent, and SO_2 and $PM_{2.5}$ emissions are expected to decrease by less than 1 percent. On a local scale, depending on source makeup, distribution, and population, the expected decreases in emissions could be larger or smaller than these national averages.

Chapter 3 Air Quality Modeling

The air quality modeling methods and results are presented in this section. The CMAQ model was used in this study to simulate the air quality impacts of the proposed CAFE standards. The model was applied at the national scale for an annual simulation period. The CMAQ model requires information on the emissions, meteorology, and land-use characteristics of the modeling domain. Information about the emissions changes associated with selected alternative proposed CAFE standards were incorporated into the model through the emission input files for the modeled year 2030. Because air quality impacts are calculated at the grid-cell level, the CMAQ model can account for regional differences in the relative magnitudes of the changes in emissions due to increased fuel efficiency, increased vehicle use, and reduced fuel production and distribution potentially resulting from the proposed CAFE standards. The CMAQ modeling results provide the basis for the health effects and benefits modeling.

3.1 OVERVIEW OF THE CMAQ MODELING SYSTEM

The CMAQ model is a state-of-the-science, regional air quality modeling system that can be used to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching 1999). The CMAQ tool was designed to improve the understanding of air quality issues (including the physical and chemical processes that influence air quality) and to support the development of effective emission control strategies on both the regional and local scale. The CMAQ model was designed as a "one-atmosphere" model. This concept refers to the ability of the model to dynamically simulate ozone, particulate matter, and other species (such as mercury) in a single simulation. In addition to addressing a variety of pollutants, CMAQ can be applied to a variety of regions (with varying geographical, land-use, and emissions characteristics) and for a range of space and time scales.

Numerous recent applications of the model, for both research and regulatory air quality planning purposes, have focused on the simulation of ozone and $PM_{2.5}$. The CMAQ model was used by EPA to support the development of the Clean Air Interstate Rule (CAIR) (EPA 2005). It was also used by EPA to support the second prospective analysis of the costs and benefits of the Clean Air Act (CAA) (Douglas et al. 2008).

The CMAQ model numerically simulates the physical processes that determine the magnitude, temporal variation, and spatial distribution of the concentrations of ozone and particulate species in the atmosphere and the amount, timing, and distribution of their deposition to Earth's surface. The simulation processes include advection, dispersion (or turbulent mixing), chemical transformation, cloud processes, and wet and dry deposition. The CMAQ science algorithms are described in detail by Byun and Ching (1999).

The CMAQ model requires several different types of input files. Gridded, hourly emission inventories characterize the release of anthropogenic, biogenic, and, in some cases, geogenic emissions from sources within the modeling domain. The emissions represent both low-level and elevated sources and a variety of source categories (including, for example, point, on-road mobile, non-road mobile, area, and biogenic). The amount and spatial and temporal distribution of each emitted pollutant or precursor species are key determinants to the resultant simulated air quality values.

The CMAQ model also requires hourly, gridded input fields of several meteorological parameters including wind, temperature, mixing ratio, pressure, solar radiation, fractional cloud cover, cloud depth, and precipitation. A full list of the meteorological input parameters is provided in Byun and Ching (1999). The meteorological input fields are typically prepared using a data-assimilating prognostic meteorological model, the output of which is processed for input to the CMAQ model using the Meteorology-Chemistry Interface Processor (MCIP). The prescribed meteorological conditions influence the transport, vertical mixing, and resulting distribution of the simulated pollutant concentrations. Certain of the meteorological parameters, such as mixing ratio, can also influence the simulated chemical reaction rates. Rainfall and near-surface meteorological characteristics govern the wet and dry deposition, respectively, of the simulated atmospheric constituents.

Initial and boundary condition (IC/BC) files provide information on pollutant concentrations throughout the domain for the first hour of the first day of the simulation, and along the lateral boundaries of the domain for each hour of the simulation. Photolysis rates and other chemistry-related input files supply information needed by the gas-phase and particulate chemistry algorithms.

CMAQ version 4.6 was used for this study. This version of the model supports several options for the gas-phase chemical mechanism, particle treatment, aerosol deposition, and cloud treatment. All simulations conducted as part of this study used the CB-05 chemical mechanism. For particles, the AERO4 particle treatment, which includes sea salt, was applied. For one run, the CMAQ Particle and Precursor Tagging Methodology (PPTM) as described by Douglas et al. (2007) was used for quality assurance purposes to quantify the contribution of the emissions from major source categories to the simulated $PM_{2.5}$ concentrations.

3.2 CMAQ APPLICATION PROCEDURES FOR THE NHTSA MODELING ANALYSIS

The application of CMAQ, including the modeling domain, simulation period, input files (with the exception of the emission inventories), and post-processing and quality assurance procedures are discussed in this section. Preparation of the emission inventories for the application of CMAQ was discussed in detail in the previous section. Model performance evaluation for CMAQ for this simulation period was conducted as part of a recent study for EPA (Douglas and Myers 2009) and the results were found to be acceptable for use in benefits analysis.

3.2.1 Modeling Domain and Simulation Period

The modeling domain used for this analysis was presented in Figure 1.2-1. The 36-km resolution modeling domain includes 148 x 112 grid cells. The tick marks (refer to Figure 1.2-1) denote the 36-km grid cells. For this domain, the model was run for an entire calendar year. The base-year meteorological conditions are for 2002 and the emissions represent 2030. In running the model, the annual simulation period was divided into two parts covering January through June and July through December, respectively. Each part of the simulation also included an additional five start-up simulation days, which was intended to reduce the influence of uncertainties in the initial conditions on the simulation results.

3.2.2 Meteorological and Other Input Files

All input files for the application of the CMAQ model, with the exception of the certain components of the emission inventories, were obtained from EPA.

The 36- km resolution meteorological input files for the base year 2002 were prepared using the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Fifth Generation Mesoscale Model (MM5). The MM5 outputs were post-processed by EPA for input to CMAQ using the Meteorology-Chemistry Interface Processor (MCIP) program. The meteorological input preparation methodology and some information on MM5 model performance are discussed by Dolwick et al. (2007).

Existing initial condition, boundary condition, land-use, and photolysis rate input files were used, as prepared by EPA for CMAQ modeling for the selected modeling domain and simulation period.

3.2.3 Post-processing and Quality Assurance Procedures

Quality assurance of the CMAQ runs included the following steps:

- Scripts were routinely checked to ensure that the correct input files and output file names were used. Any error messages generated by CMAQ were checked and reconciled.

- Plots of ozone, $PM_{2.5}$, and selected particulate species were prepared for the 15^{th} day of each month, for each simulation. These were examined and compared with the results for other runs. The concentration patterns and values were checked for reasonableness. The results for each month and each alternative were compared to ensure that differences in the CMAQ results were consistent with the emissions changes.

- The CMAQ modeling results were then incorporated into an Access database tool, referred to as an Access Database for Visualizing and Investigating Strategies for Ozone Reduction (ADVISOR) tool. The ADVISOR tool is an interactive database tool that contains information for review, comparison, and assessment of the CMAQ simulations. The database contains the simulation results (as represented by several different metrics) for the full domain, selected geographical sub-regions (EPA regions), and selected monitoring site locations. For ozone, the ADVISOR metrics include daily maximum 1-hour ozone concentration (in parts per billion, or ppb), daily maximum 8-hour ozone concentration (ppb), and several ozone exposure metrics. For $PM_{2.5}$, the ADVISOR metrics include annual and quarterly average $PM_{2.5}$ concentration (microgram per cubic meter, or μgm^{-3}), and several $PM_{2.5}$ exposure metrics. The results for all metrics can be displayed in an absolute or relative manner (as differences or percent differences). The ADVISOR tool was used to review and compare the CMAQ results, primarily on a seasonal and annual basis.

Following the quality assurance of the modeling results, the CMAQ results were post-processed for input to the health impacts and benefits modeling, as discussed in Section 4 of this report.

3.3 CMAQ MODELING RESULTS

For both the EC and CI scenarios, results for the No Action alternative are presented first, followed by the differences between each CAFE alternative and the No Action alternative for that scenario. The modeling results for ozone and $PM_{2.5}$ were used to calculate health effects and monetized health-related benefits in Section 4 of this report.

3.3.1 Environmental Consequences Scenario

Results for the EC scenario are presented and compared in this section. The results for ozone are presented first, followed by the results for $PM_{2.5}$.

3.3.1.1 Ozone

Figure 3.3.1-1 displays simulated daily maximum 8-hour ozone concentration (ppb) for the EC No Action alternative for the 15^{th} of July. This day was selected as an example ozone-season day for display of the ozone concentrations (for all simulations), primarily because of relatively higher ozone concentrations on this day compared to other days comprising the simulation period but also because the meteorological conditions are typical of the ozone season. The date and time given on this and all subsequent figures refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum values for any location within the domain are also provided, along with their grid cell (x,y) locations.

Figure 3.3.1-1. Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for 15 July 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

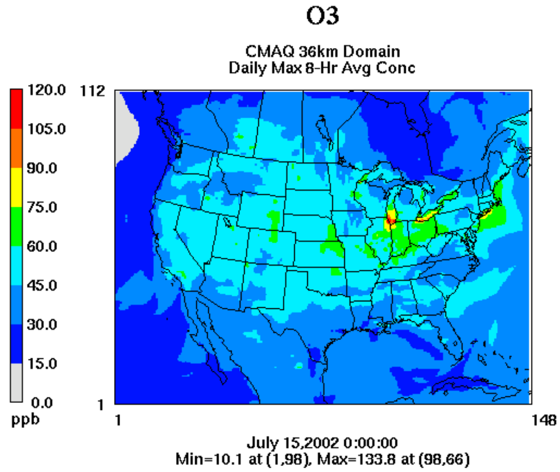


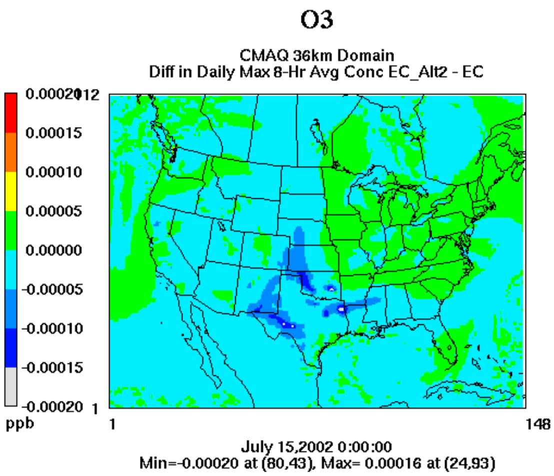
Figure 3.3.1-1 indicates that daily maximum ozone concentrations for this day are generally less than 75 ppb (the current 8-hour ozone NAAQS level). There are few areas with higher ozone concentrations, especially in the Midwest and along the Northeast Corridor. This finding is representative of the ozone results for 2030, which show that most areas would be in attainment of the current 8-hour ozone standard. From a meteorological perspective, the ozone concentration pattern for this day reflects a typical summertime meteorological pattern, with an upper-level high pressure ridge over the continental United States and surface high pressure systems over northern Illinois and the southwestern United States. The meteorological inputs are for 2002 and, on this day in 2002, the eastern part of the Nation had seasonal normal maximum temperatures around 90 degrees Fahrenheit (°F), while the Southwest, Great Basin, and Upper Plains experienced higher-than-normal temperatures, with maxima reaching from the mid-90s to more than 100 °F in parts of Montana. The winds aloft over much of the United States were light and variable.

Figure 3.3.1-2 illustrates the differences in daily maximum 8-hour ozone between each modeled alternative and the EC No Action Alternative (Alternative 2 minus No Action, Alternative 4 minus No Action, and Alternative 8 minus No Action). Again the results for July 15th are displayed. The very small increases and decreases in ozone concentration are characteristic of all simulation days.

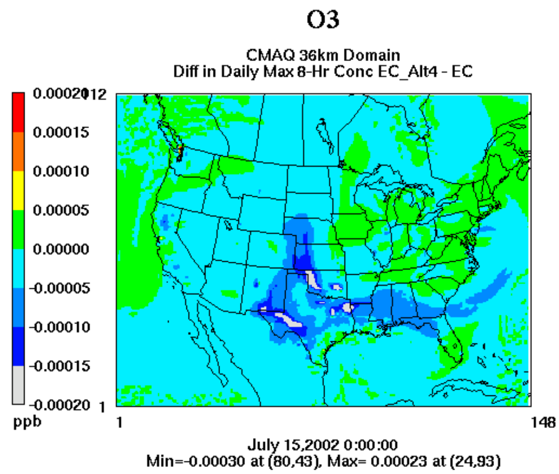
The differences in ozone concentration are projected to be very small and too small to be meaningful relative to the current ozone standard (75 ppb) and (as will be shown later) health effects. Although the effects on ozone are negligible, the extent and magnitude of the decreases in ozone increase with each more stringent alternative and are, as expected, greatest for Alternative 8. A combination of increases and decreases in for Alternatives 2 and 4 are replaced by mostly decreases for Alternative 8.

Figure 3.3.1-2. Difference in Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for 15 July: NHTSA Proposed CAFE Standards EC Alternatives 2, 4 and 8 Minus the No Action Alternative

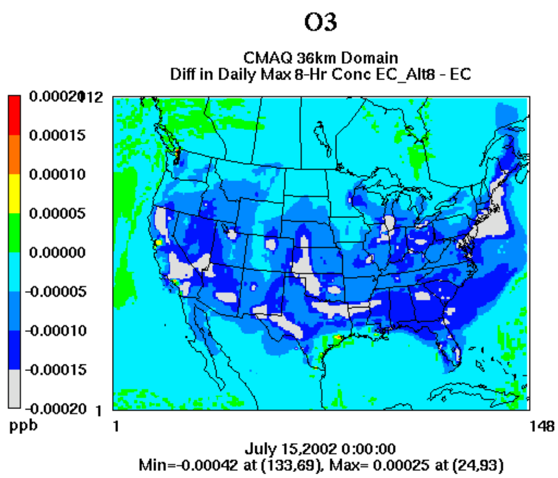
(a) Alternative 2



(b) Alternative 4



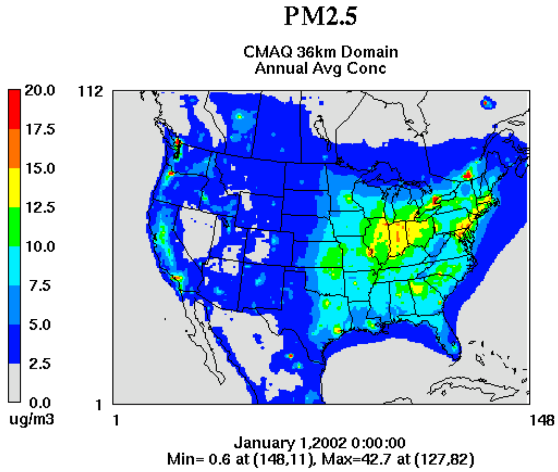
(c) Alternative 8



3.3.1.2 $PM_{2.5}$

Figure 3.3.1-3 displays simulated annual average $PM_{2.5}$ concentration (μgm^{-3}) for the EC No Action alternative. This plot indicates areas of higher $PM_{2.5}$ in the eastern United States and in California, with localized peak concentrations in several, mostly western and midwestern, urban areas. Only a few areas are characterized by annual average concentrations greater than the current annual NAAQS of 15 μgm^{-3}. The date and time given on the figures refer to the meteorological base year and start hour for the selected day or averaging period. The minimum and maximum values for any location within the domain are also provided, along with their grid cell (x,y) locations.

Figure 3.3.1-3. Simulated Annual Average $PM_{2.5}$ Concentration (μgm^{-3}) for 2030: NHTSA Proposed CAFE Standards EC No Action Alternative.



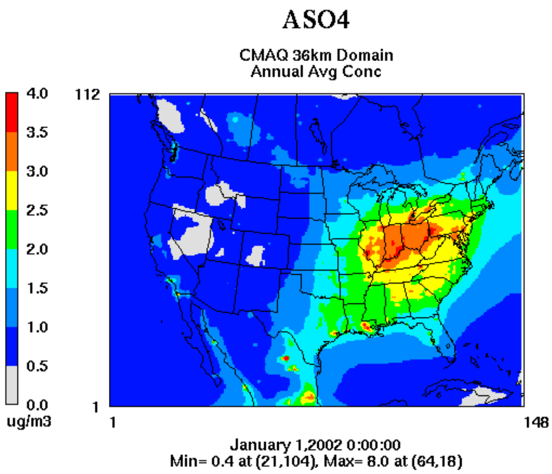
$PM_{2.5}$ is comprised of various components including sulfate, nitrate, organic carbon, and elemental carbon. Precursor emissions for all four component species would be affected by the proposed CAFE standards, from both the tailpipe and upstream emissions. Simulated concentrations of these component species are plotted in Figure 3.3.1-4.

Figure 3.3.1-5 displays the difference in simulated annual average $PM_{2.5}$ concentration (μgm^{-3}) for each modeled alternative compared to the EC No Action alternative (Alternative 2 minus No Action, Alternative 4 minus No Action, and Alternative 8 minus No Action).

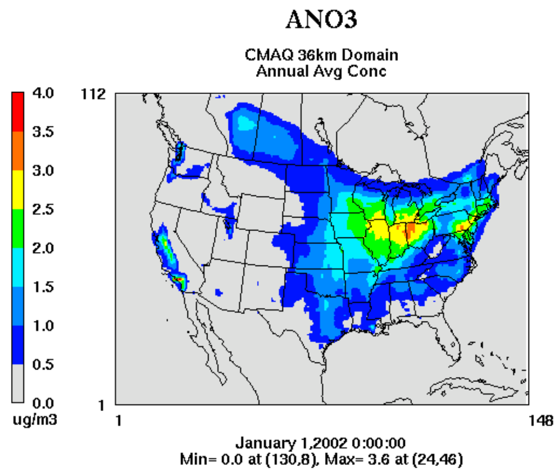
The absolute and relative differences are projected to be larger for $PM_{2.5}$ than for ozone. The differences associated with Alternative 2 are a mix of small decreases and even smaller increases. The maximum simulated decrease in annual average $PM_{2.5}$ for any grid cell in the domain is approximately 0.2 μgm^{-3}, while the maximum increase is 0.003 μgm^{-3}. The extent and magnitude of the decreases become larger with each, more stringent alternative. A combination of increases and decreases for Alternative 2 are replaced by mostly decreases for Alternatives 4 and 8, with a maximum decrease of approximately 0.3 μgm^{-3} in both cases. Some of the largest decreases occur in areas associated with oil and gas production and refining, such as the Gulf Coast, Oklahoma, and California. This pattern suggests that the some of the decreases in $PM_{2.5}$ are attributable to reductions in the upstream emissions.

Figure 3.3.1-4. Simulated Annual Average $PM_{2.5}$ Concentration (μgm^{-3}) for 2030: NHTSA Proposed CAFE Standards EC No Action Alternative

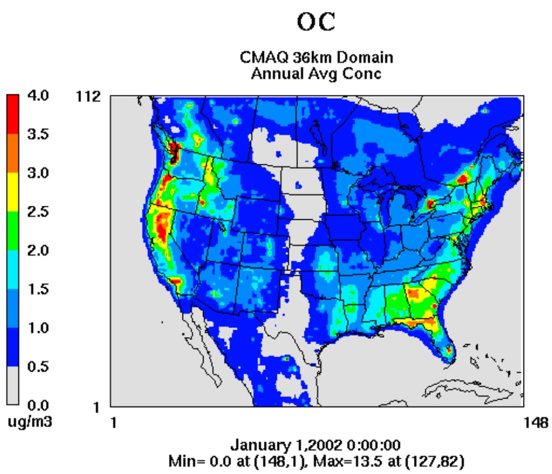
(a) Sulfate



(b) Nitrate



(c) Organic Carbon



(d) Elemental Carbon

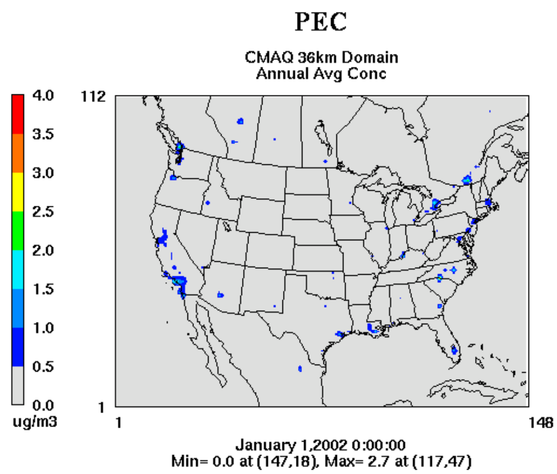
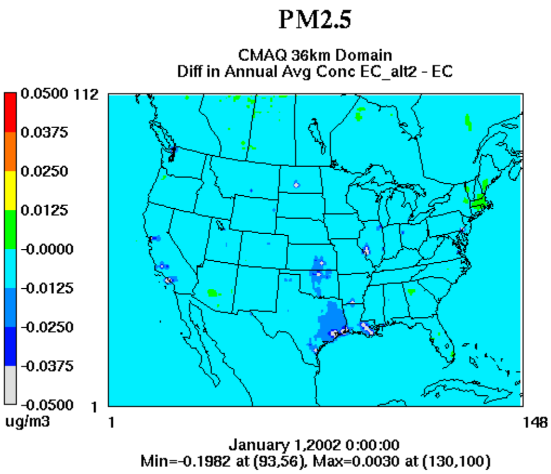
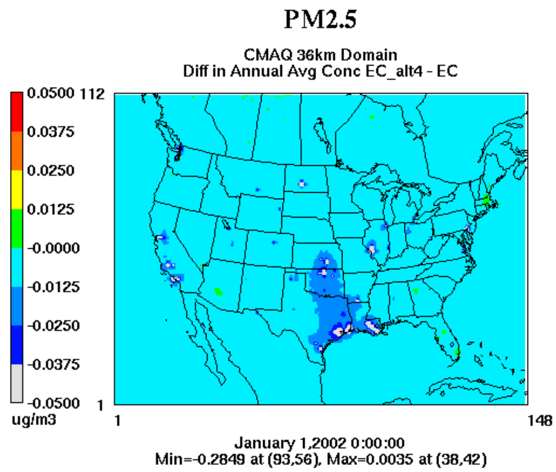


Figure 3.3.1-5. Difference in Annual Average $PM_{2.5}$ Concentration (μgm^{-3}): NHTSA Proposed CAFE Standards EC Alternatives 2, 4 and 8 Minus the No Action Alternative

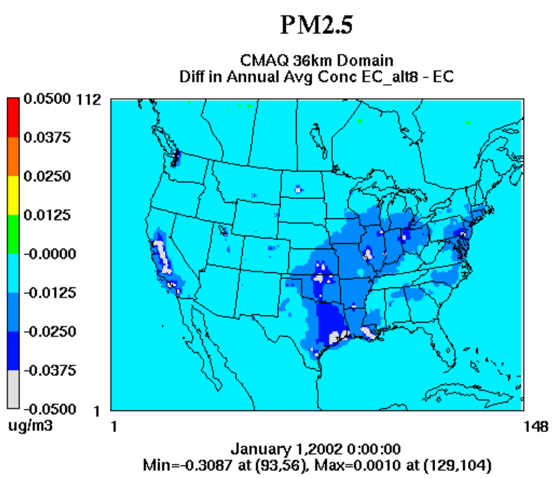
(a) Alternative 2



(b) Alternative 4



(c) Alternative 8



3.3.2 Cumulative Impacts Scenario

Results for the CI scenario are presented and compared in this section.

3.3.2.1 Ozone

Figure 3.3.2-1 displays simulated daily maximum 8-hour ozone concentration (ppb) for the CI No Action alternative for the 15^{th} of July. The simulated ozone concentrations are very similar to those presented for the EC scenario, reflecting the small differences in emissions between the EC and CI scenarios for 2030.

Figure 3.3.2-1. Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for 15 July 2030: NHTSA Proposed CAFE Standards CI No Action Alternative

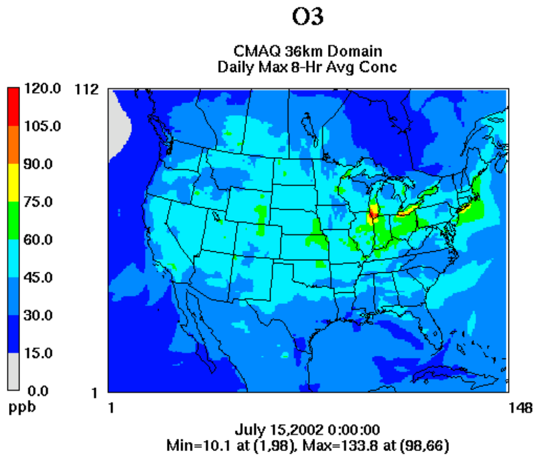


Figure 3.3.2-2 illustrates the differences in daily maximum 8-hour ozone between each modeled alternative and the CI No Action alternative (Alternative 2 minus No Action, Alternative 4 minus No Action, and Alternative 8 minus No Action). Again the results for July 15th are displayed. The very small increases and decreases in ozone concentration are characteristic of all simulation days.

Similar to the EC scenario, the differences in simulated ozone concentration are too small to be considered meaningful.

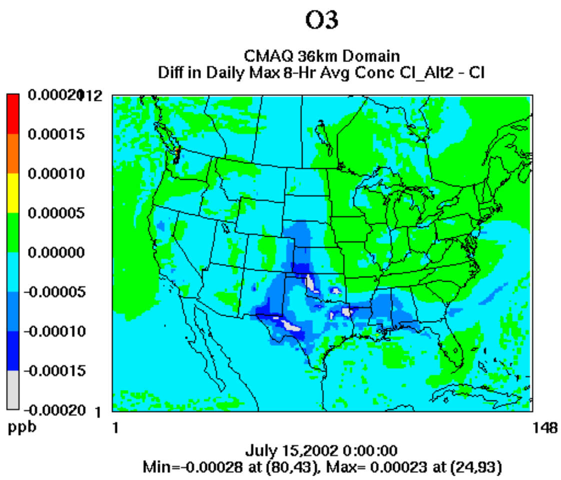
3.3.2.2 $PM_{2.5}$

Figure 3.3.2-3 displays simulated annual average $PM_{2.5}$ concentration (μgm^{-3}) for the CI No Action alternative. The simulated $PM_{2.5}$ concentrations are very similar to those presented for the EC scenario. Simulated concentrations of the component species for the CI No Action alternative (not shown) are also very similar.

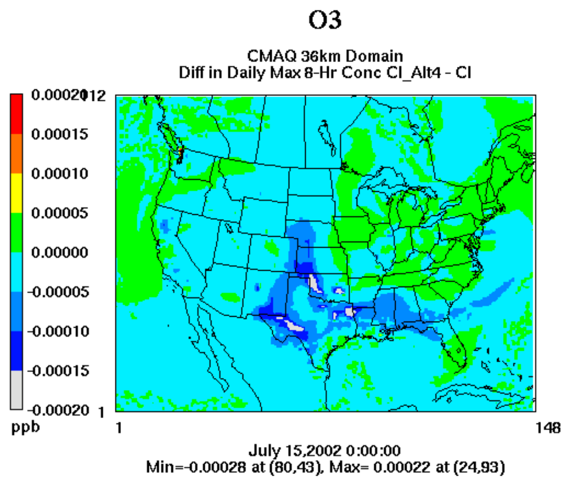
Figure 3.3.2-4 displays the difference in simulated annual average $PM_{2.5}$ concentration (μgm^{-3}) for each modeled alternative compared to the CI No Action alternative (Alternative 2 minus No Action, Alternative 4 minus No Action, and Alternative 8 minus No Action).

Figure 3.3.2-2. Difference in Simulated Daily Maximum 8-Hour Ozone Concentration (ppb) for 15 July: NHTSA Proposed CAFE Standards CI Alternatives 2, 4 and 8 Minus the No Action Alternative

(a) Alternative 2



(b) Alternative 4



(c) Alternative 8

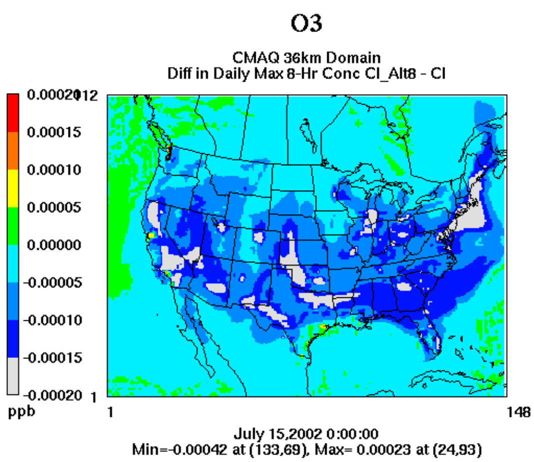


Figure 3.3.2-3. Simulated Annual Average $PM_{2.5}$ Concentration (μgm^{-3}) for 2030: NHTSA Proposed CAFE Standards CI No Action Alternative

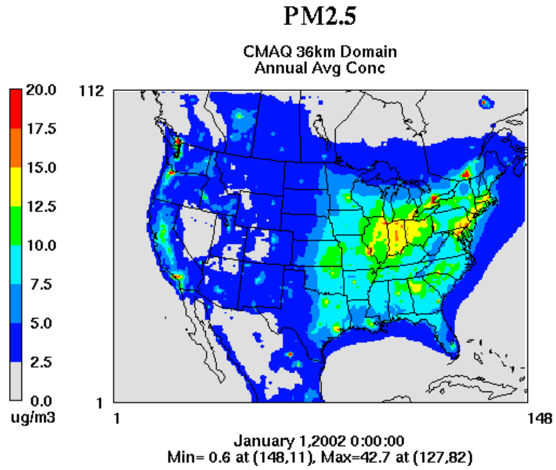
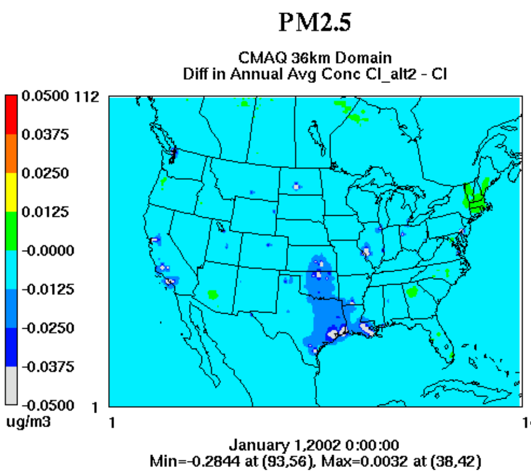
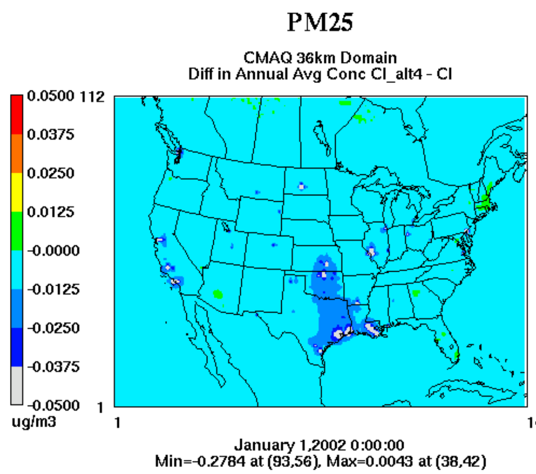


Figure 3.3.2-4. Difference in Annual Average $PM_{2.5}$ Concentration (μgm^{-3}): NHTSA Proposed CAFE Standards CI Alternatives 2, 4 and 8 Minus the No Action Alternative

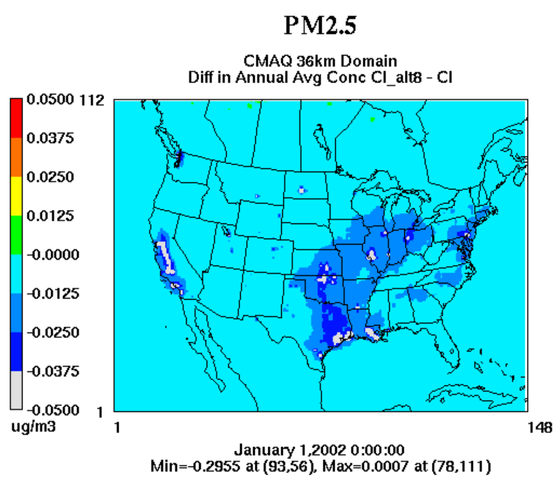
(a) Alternative 2



(b) Alternative 4



(c) Alternative 8



Again, the simulated absolute and relative differences are larger for $PM_{2.5}$ than for ozone. The differences associated with Alternatives 2 and 4 are very similar and are a mix of small decreases and very small increases. For Alternative 8, the differences are mostly decreases. The maximum decrease in annual average $PM_{2.5}$ for any grid cell in the domain is approximately 0.3 μgm^{-3} for all three alternatives. Again, some of the largest decreases occur in areas associated with oil and gas production and refining and appear to be attributable to reductions in the upstream emissions.

3.3.3 Discussion of Attributes, Limitations and Uncertainties

The CMAQ air quality modeling system provides a reliable platform for evaluating the expected responses to changes in precursor emissions at the national and regional scale. The detailed, quantitative modeling results provide an excellent basis for comparing the effects of the various CAFE alternatives and provide the requisite input for the health effects and benefits modeling.

CMAQ can account for differences in emissions as well as other factors that affect air quality and the resulting health impacts at any given location, such as meteorology, topography, land-use, and atmospheric chemistry processes. Accordingly, CMAQ can simulate regional differences in the response of the model to the emissions changes. This is important because different regions of the country could experience either a net increase or a net decrease in emissions due to the proposed CAFE standards, depending on the relative magnitudes of the changes in emissions due to increased fuel efficiency, increased vehicle use, and reduced fuel production and distribution. Regional differences in the response of the model to changes in emissions are also important in the calculation of health effects, because the air quality changes are matched to gridded population estimates.

All air quality modeling exercises are affected by inherent uncertainties that derive from model formulation (including numerical approximations and the parameterization of physical and chemical processes), and inaccuracies in the input fields (including the meteorological inputs and emission inventory estimates). A number of key limitations and uncertainties, both general and specific to this analysis, are discussed below.

One limitation of this application of CMAQ is the use of 36-km horizontal grid resolution. Although this grid resolution is consistent with current EPA modeling guidance and practice for annual and seasonal modeling for $PM_{2.5}$, it is coarser than that typically used for ozone. This grid resolution might not be sufficiently detailed to resolve certain sub-grid scale processes in portions of the modeling domain and this could introduce biases or uncertainties into the simulated concentration fields. Use of 36-km grid resolution might limit the response of the model to small changes in precursor emissions, especially for ozone.

Pollutants such as ozone and $PM_{2.5}$ are secondary pollutants that are formed through atmospheric chemical processes. There are many different reaction pathways and there are uncertainties associated with each pathway as represented in the CMAQ model.

The emission estimates for cars and light duty trucks and the affected upstream emission sources provided by NHTSA were provided as total emissions for all states and Washington, D.C. These were spatially allocated to each state and county using VMT. These emissions assume that emission rates for vehicles are the same across the U.S. As a result, the modeling does not account for such factors as impacts of temperature on emissions, differences in age distribution of the fleet, and differences in fuels (especially with regard to ethanol fraction).

Another source of uncertainty in the emission inventories involves the hydrocarbon speciation profiles, which are used in the air quality modeling emission pre-processor, SMOKE, to break total hydrocarbons down into individual constituent compounds. Given the complexity of the atmospheric chemistry, the hydrocarbon speciation can influence the air quality modeling results. For some sources, these profiles are based on limited data. Recent analyses indicate that profiles for vehicles meeting Tier 2 emission standards differ from profiles for older technology vehicles (EPA 2009b); speciation profiles specific to Tier 2 vehicles were not used for this analysis.

Many of the national-scale databases used for this application, including the meteorological and other input databases (for 2002) and the projected baseline criteria pollutant emissions data for 2030, were originally prepared by EPA for use in past modeling exercises conducted to support national rulemaking. However, it is expected that there are errors and uncertainties in the inputs that contribute to biases in the CMAQ results, as revealed for the base-year modeling by Douglas and Myers (2009). This is especially true for the future-year modeling. For example, the meteorological conditions for 2002 might be representative of current conditions but would not reflect any effects of potential climate change in 2030. Similarly, the 2030 emissions are based on future estimates of population and economic and industrial activity and contain uncertainties due to potential unknown social, political, and/or economic factors that could affect growth/activity and future emissions.

Chapter 4 Health Effects and Benefits Modeling

The methods and results of the health effects and benefits modeling are presented in this section. Following the application of CMAQ for each CAFE alternative, the CMAQ-derived air quality estimates were processed for input to the BenMAP health effects analysis tool, and BenMAP was used to estimate the health impacts and monetized health-related benefits associated with the changes in air pollution simulated by CMAQ for each modeled CAFE alternative. The BenMAP tool includes health impact functions, which relate a change in the concentration of a pollutant with a change in the incidence of a health endpoint. BenMAP also calculates the economic value of health impacts. For this study, the health affects analysis considered the effects of ozone and fine particulate matter ($PM_{2.5}$).

4.1 OVERVIEW OF THE BENMAP MODELING SYSTEM

BenMAP is a computer program developed by EPA that uses interpolation functions, population projections, health impact functions, and valuation functions to translate simulated changes in air pollution concentration into changes in health-related incidences and monetized health-related benefits. BenMAP is primarily intended as a tool for estimating the human health effects and economic benefits associated with changes in ambient air pollution. EPA originally developed this tool to analyze national-scale air quality regulations. The health benefits and monetary values derived using BenMAP are intended to inform policy makers by enabling the comparison of the benefits and costs of various regulatory measures (Abt Associates 2008).

BenMAP relies on the input of air quality information that can be used to calculate the change in ambient air pollution associated with a change in emissions. Typically, the results from two air quality modeling simulations (with different emission inputs) are used. In some cases, measured ambient air quality data can also be used.

BenMAP calculates health effects based on expected relationships between the change in concentration and certain health effects (also known as health endpoints), using concentration-response (C-R) functions from epidemiology studies (Abt Associates 2008). The response functions are used together with population data to estimate health effects. For a model-based application, health effects are calculated on a grid cell-by-grid cell basis and then summed to obtain regional and national-scale estimates. In its most basic form, the health effect for a given health endpoint is a function of the change in air concentration, concentration-response estimates, and population. Primary health endpoints include premature mortality, heart attacks, and chronic respiratory illnesses.

After estimating the change in adverse health effects associated with a given change in air quality, BenMAP calculates the monetary benefits associated with those changes (Abt Associates 2008). Simply, the economic value is based on the change in the incidence of a certain adverse health effect multiplied by the value of the health effect (on a per-incident or per-case basis). For example, the value associated with avoided premature mortality is typically calculated using the Value of Statistical Life (VSL), which is the monetary amount that people are willing to pay to slightly reduce the risk of premature death. For other health effects, the medical costs of the illness are typically used to estimate value. The BenMAP database includes several different valuation functions for VSL and other health endpoints.

4.2 BENMAP APPLICATION PROCEDURES FOR THE NHTSA MODELING ANALYSIS

Prior to the application of BenMAP, the CMAQ model output files were reformatted for input into the BenMAP tool. The analysis period for ozone for the application of BenMAP is a subset of the CMAQ simulation period and includes only May through September. The input files for ozone contain 154 days of hourly average ozone concentrations for each grid cell in the CMAQ modeling domain. The analysis period for $PM_{2.5}$ for the application of BenMAP is the full annual CMAQ simulation period. The input files for $PM_{2.5}$ contain 365 days of 24-hour average $PM_{2.5}$ concentration for each grid cell. The area covered by the BenMAP analysis is the continental United States. BenMAP includes population data at the census-tract level and algorithms for characterizing demographic changes (age distribution) over time. For this analysis, population estimates for 2030 were used. This is consistent with the CMAQ simulation year of 2030. BenMAP was applied separately for ozone and $PM_{2.5}$.

BenMAP calculates the changes in health effects and monetized health-related benefits by comparing the results of two simulations. For this study, BenMAP was used to calculate the change in health effects and monetized health-related benefits for each CAFE standard alternative compared to the No Action alternative. This was done separately for the EC and CI scenarios and resulted in six BenMAP applications using the CMAQ results for:

- EC Alternative 2 and the EC No Action alternative;
- EC Alternative 4 and the EC No Action alternative;
- EC Alternative 8 and the EC No Action alternative;
- CI Alternative 2 and the CI No Action alternative;
- CI Alternative 4 and the CI No Action alternative; and
- CI Alternative 8 and the CI No Action alternative.

Difference plots of the CMAQ-derived ozone and $PM_{2.5}$ concentrations for each pair of simulations were presented in Figures 3.3.1-2, 3.3.1-5, 3.3.2-2, and 3.3.2-4.

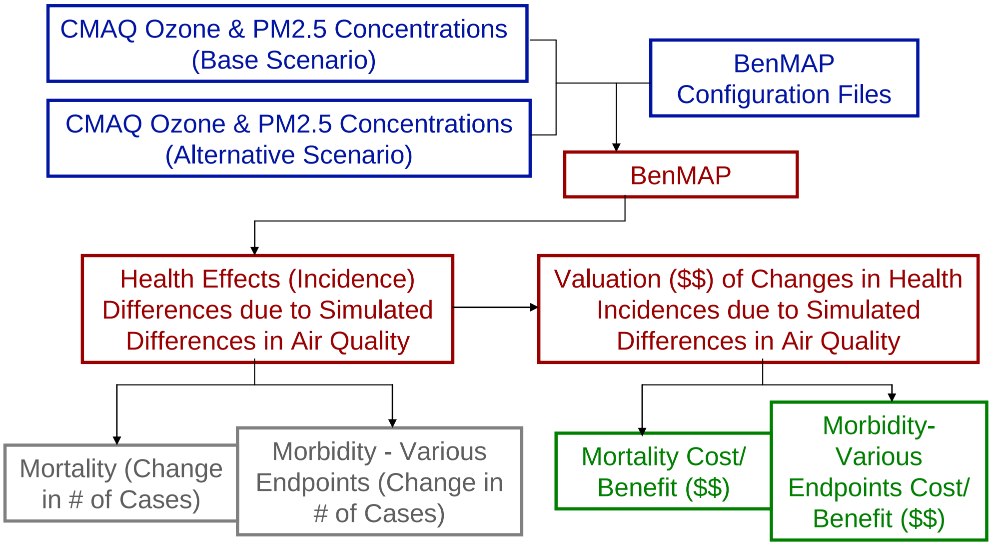
For each pollutant and simulation couple, the application of BenMAP included four steps:

- Incorporation of the CMAQ modeling results into the air quality grid files required by BenMAP (air quality grid creation);
- Calculation of the change in the incidence of adverse health effects based on the differences in the CMAQ-derived ozone and $PM_{2.5}$ concentrations between the two simulations;
- Aggregation of the incidence results and calculation of the economic value of the aggregated incidences; and
- Preparation of tabular and graphical summaries; quality assurance and analysis of the results.

In the air quality grid creation step, the CMAQ model results were used directly. An option to use the model results together with observed data (the relative monitor and model method) was tested and the outcome was confirmed to be very similar to that for the chosen approach.

Figure 4.2-1 illustrates the steps and components of the BenMAP application procedure.

Figure 4.2-1. Schematic Diagram of the NHTSA CAFE Standards BenMAP Health Effects and Benefits Analysis



4.2.1 Health Impact Functions

BenMAP was used to calculate reductions in both mortality and a range of non-fatal health effects (morbidity), based on epidemiological studies of a number of U.S. and non-U.S. (Canadian) populations.

BenMAP can estimate changes in a wide range of health impact "endpoints" associated with changes in ozone and $PM_{2.5}$ exposure. The endpoints are grouped broadly as "mortality" and "morbidity." Mortality endpoints include changes in "all-cause" mortality, as well as mortality due to specific causes, such as cardiopulmonary disease. Morbidity endpoints include specific illnesses and symptoms ("asthma exacerbations"); events requiring medical care (emergency room visits and hospital admissions); and adverse effects that involve lost work or restricted activity days.

EPA has evaluated the literature related to the adverse effects of ozone and particulate exposures and identified a set of endpoints for which the associations are considered to be well established, and for which reliable exposure-response relationships have been developed (Abt Associates 2008). For this analysis, a recommended set of health endpoints to be used with the latest version of BenMAP was provided by EPA (EPA pers. comm. 2009c). These endpoints are listed in Table 4.2.1-1 and 4.2.1-2 for ozone and $PM_{2.5}$, respectively. The endpoints include changes in mortality (for both adults and infants), as well as a range of morbidity endpoints related to respiratory and cardiovascular diseases and symptoms, hospital admissions, and lost work or lost activity days. The age range for each endpoint, if available, is provided in the tables.

Table 4.2.1-1

Health Impact Functions Used in NHTSA Proposed CAFE Standards BenMAP Application to Estimate Ozone-Related Health Effects

Endpoint	Author/Study/Location	Age Range	Notes
Mortality, Non-Accidental	Ito et al. (2005)	0-99	a, b
Mortality, Non-Accidental	Schwartz (2005) (14 U.S. cities)	0-99	a,c
Mortality, Non-Accidental	Bell et al. (2004) (95 U.S. Cities)	0-99	a,b
Mortality, All Cause	Levy et al. (2005) (US & non-U.S.)	0-99	a,c
Mortality, All Cause	Bell et al. (2005) (US & non-U.S.)	0-99	a,b
Mortality, Cardiopulmonary	Huang et al. (2005) (19 U.S. cities)	0-99	a,b
Emergency Room Visits, Asthma	Jaffe et al. (2003) (Ohio cities)	5-34	a
Emergency Room Visits, Asthma	Peel et al. (2005) (Atlanta, GA)	0-99	a
Emergency Room Visits, Asthma	Wilson et al. (2005) (Portland, ME)	0-99	a
Emergency Room Visits, Asthma	Wilson et al. (2005) (Manchester, NH)	0-99	a
Hospital Admissions, All Respiratory	Burnett et al. (2001) (Toronto, CAN)	0-1	a,c
Hospital Admissions, All Respiratory	Schwartz ((New Haven, CT)	65-99	a,b
Hospital Admissions, All Respiratory	Schwartz (Tacoma, WA)	65-99	a,b
Hospital Admissions, Chronic Lung Disease	Moolgavkar et al. (1997) (Minneapolis, MN)	65-99	a,d
Hospital Admissions, Pneumonia	Moolgavkar et al. (1997) (Minneapolis, MN)	65-99	a,d
Hospital Admissions, Pneumonia	Schwartz (1994) (Detroit, MI)	65-99	a,d
Hospital Admissions, Pneumonia	Schwartz (1994)(Minneapolis, MN)	65-99	a,d
Hospital Admissions, Chronic Lung Disease (less Asthma)	Schwartz (1994) (Detroit, MI)	65-99	a,d
School Loss Days, All	Chen et al. (2000) (Washoe Co, NV)	5-17	a,f
School Loss Days, All	Gilliland et al. (2001) (So. CA)	5-18	a,e
Worker Productivity	Crocker & Horst (Nationwide)	18-64	a,d
Minor Restricted Activity Days	Ostro & Rothschild (1989) (Nationwide)	18-64	a,g

a/ Metric is daily maximum 8-hour ozone.
b/ Metric is daily maximum 8-hour ozone. Warm season. 8-hour max from 24-hour mean.
c/ Metric is daily maximum 8-hour ozone. Warm season. 8-hour max from 1-hour mean.
d/ Metric is daily maximum 8-hour ozone. All year. 8-hour max from 24-hour mean.
e/ Metric is daily maximum 8-hour ozone. All year. 8-hour max from 8-hour mean.
f/ Metric is daily maximum 8-hour ozone. All year. 8-hour max from 1-hour mean.
g/ Metric is daily maximum 8-hour ozone. 8-hour max from 1-hour mean.

Pooled estimates for ozone include: emergency room visits for asthma (Jaffe et al. 2003, Peel et al. 2005 and Wilson et al. 2005), and hospital admissions for respiratory symptoms (Schwartz and Schwartz).

Table 4.2.1-2

Health Impact Functions Used in NHTSA Proposed CAFE Standards BenMAP Application to Estimate PM2.5-Related Health Effects

Endpoint	Author/Study/Location	Age Range	Notes
Mortality, All Cause	Laden et al. (2006) (6 cities)	25-99	
Mortality, All Cause	Pope et al. (2002) (51 cities)	30-99	
Mortality, All Cause	Woodruff et al. (2006) (204 counties)	0-1	
Mortality, All Cause	Pope et al. (2002) (51 cities)	30-99	a
Mortality, All Cause	Pope et al. (2002) (51 cities)	30-99	b
Mortality, All Cause	Pope et al. (2002) (51 cities)	30-99	c
Mortality, All Cause	Pope et al. (2002) (51 cities)	30-99	d
Mortality, All Cause	Expert Elicitation (2006)	30-99	e
Mortality, All Cause	Expert Elicitation (2006)	30-99	f
Mortality, All Cause	Expert Elicitation (2006)	30-99	g
Mortality, All Cause	Expert Elicitation (2006)	30-99	h
Mortality, All Cause	Expert Elicitation (2006)	30-99	i
Mortality, All Cause	Expert Elicitation (2006)	30-99	j
Mortality, All Cause	Expert Elicitation (2006)	30-99	k
Chronic Bronchitis	Abbey et al. (1995) (SF,SD, South Coast Air Basin)	27-99	
Acute Bronchitis	Dockery et al. (1996) (24 communities)	8-12	
Acute Myocardial Infarction, Nonfatal	Peters et al. (2001) (Boston, MA)	18-24	
Acute Myocardial Infarction, Nonfatal	Peters et al. (2001) (Boston, MA)	25-44	
Acute Myocardial Infarction, Nonfatal	Peters et al. (2001) (Boston, MA)	45-54	
Acute Myocardial Infarction, Nonfatal	Peters et al. (2001) (Boston, MA)	55-64	
Acute Myocardial Infarction, Nonfatal	Peters et al. (2001) (Boston, MA)	65-99	
Hospital Admissions, Chronic Lung Disease	Moolgavkar (2003) (Los Angeles, CA)	65-99	
Hospital Admissions, Chronic Lung Disease	Ito (2003) (Detroit, MI)	65-99	
Hospital Admissions, Chronic Lung Disease (less Asthma)	Moolgavkar (2000) (Los Angeles, CA)	18-64	
Hospital Admissions, Pneumonia	Ito	65-99	
Hospital Admissions, Asthma	Sheppard (2003) (Seattle, WA)	0-64	
Hospital Admissions, All Cardiovascular (less Myocardial Infarctions)	Moolgavkar	18-64	
Hospital Admissions, All Cardiovascular (less Myocardial Infarctions)	Moolgavkar	65-99	
Hospital Admissions, Ischemic Heart Disease (less Myocardial Infarctions)	Ito (2003) (Detroit, MI)	65-99	
Hospital Admissions, Dysrhythmia	Ito (2003) (Detroit, MI)	65-99	
Hospital Admissions, Congestive Heart Failure	Ito (2003) (Detroit, MI)	65-99	
Emergency Room Visits, Asthma	Norris et al. (1999) Seattle, WA	0-17	
Minor Restricted Activity Days	Ostro and Rothschild (1989) (Nationwide)	18-64	
Lower Respiratory Symptoms	Schwartz and Neas (2000) (6 U.S. Cities)	7-14	
Asthma Exacerbation, Cough	Ostro et al. (2001) (Los Angeles)	6-18	

Table 4.2.1-2

Health Impact Functions Used in NHTSA Proposed CAFE Standards BenMAP Application to Estimate PM2.5-Related Health Effects

Endpoint	Author/Study/Location	Age Range	Notes
Asthma Exacerbation, Wheeze	Ostro et al. (2001) (Los Angeles)	6-18	
Asthma Exacerbation, Shortness of Breath	Ostro et al. (2001) (Los Angeles)	6-18	
Work Loss Days	Ostro (1987) (Nationwide)	18-64	
Upper Respiratory Symptoms	Pope et al. (1987) (Utah Valley)	9-11	

a/ Adjusted Coefficient With 10 µg Threshold
b/ Adjusted Coefficient With 12 µg Threshold
c/ Adjusted Coefficient With 15 µg Threshold
d/ Adjusted Coefficient With 7.5 µg Threshold
e/ Full Range
f/ Range from > 10 to 30 µg
g/ Range from >16 to 30 (no threshold)
h/ Range from >7 to 30
i/ Range from 4 to 7 µg
j/ Range from 4 to 10 µg
k/ Range from 4 to 16 µg (no threshold)

Pooled estimates for $PM_{2.5}$ include: hospital admissions for respiratory symptoms (Moolgavkar 2003 and Ito 2003), and hospital admissions for cardiovascular (Moolgavkar 2003 and Ito 2003). In the health incidence calculation step, no threshold value was specified, consistent with EPA guidance. The optional use of a threshold value can be used to examine the sensitivity of PM-related health impact estimates to different assumed thresholds. The results options for this study include the mean value, incremental percentile values, and the standard deviation.

4.2.2 Valuation Metrics

BenMAP was also used to estimate reductions in monetized health-related benefits (based on value of statistical life studies, lost wages, and health care expenses) associated with the health impacts. These estimates are derived using a set of monetary surrogates for the various health effects developed by EPA and public health researchers. BenMAP also tracks changes over time in willingness-to-pay for reductions in health risks, and includes adjustment factors that incorporate the effect of inflation on health-related costs.

The assessment of monetized health-related benefits involves assigning monetary values to each health endpoint, and totaling the overall benefits associated with changes in pollutant exposures. Different valuation methods are used for the various health endpoints. The monetary surrogate value for mortality is derived using a Value of Statistical Life (VSL) approach, that is, the monetary cost of a single "statistical" death (Abt Associates 2008). The VSL used for this analysis was $6.3 million (in 2000-equivalent dollars).

Valuation methods for morbidity endpoints (non-fatal health effects) include approaches referred to as cost-of-illness (COI), willingness-to-pay (WTP), and lost wages or productivity (Abt Associates 2008). COI estimates comprise a range of approaches, which account for the costs of medical care, and in some cases lost wages. WTP approaches refer to methods where voluntary payments to avoid disease are directly or indirectly estimated and used to estimate monetized health-related benefits. Finally, lost productivity methods value the time lost to illness using wage rates or the estimated value of leisure or school time (Abt Associates 2008). For all endpoints, the total monetized health-related benefit for a given endpoint is estimated by multiplying the monetary values for that endpoint by the estimated change in the number of "cases" of the endpoint. For most studies, morbidity values are small compared to the mortality values. Thus, the specific valuation methods used for morbidity have only a small effect on the overall monetized health-related benefits estimates.

For this analysis, a recommended set of valuation methods to be used with the latest version of BenMAP was provided by EPA (EPA pers. comm. 2009c). The endpoints and methods for the valuation portion of the analysis are listed in Table 4.2.2-1 and 4.2.2-2 for ozone and $PM_{2.5}$, respectively. The endpoints include monetized health-related benefits associated with changes in mortality, as well as a range of morbidity endpoints. All monetized health-related benefits results for this analysis are presented in 2006-equivalent dollars.

Table 4.2.2-1

Valuation Functions Used in NHTSA Proposed CAFE Standards BenMAP Application to Estimate Ozone-Related Monetized Health-Related Benefits

Endpoint	Author/Study/Location	Valuation Method	Notes
Mortality, Non-Accidental	Ito et al. (2005)	VSL	a,c
Mortality, Non-Accidental	Schwartz (2005) (14 U.S. cities)	VSL	a,c
Mortality, Non-Accidental	Bell et al. (2004) (95 U.S. Cities)	VSL	a,c
Mortality, All Cause	Levy et al. (2005) (US & non-U.S.)	VSL	a,c
Mortality, All Cause	Bell et al. (2005) (US & non-U.S.)	VSL	a,c
Mortality, Cardiopulmonary		VSL	a,c
Hospital Admissions, Respiratory		COI	b,d
Hospital Admissions, Respiratory		COI	b,e
Emergency Room Visits, Respiratory	Smith et al. (1997)	COI	c
Emergency Room Visits, Respiratory	Stanford et al. (1999)	COI	c
School Loss Days			f
Worker Productivity			g
Acute Respiratory Symptoms	CV studies	WTP: 1day	h

a/ Based on 26 value-of life studies.
b/ Med costs + wage loss
c/ 0-99
d/ 65-99
e/ 0-2
f/ 0-17
g/18-65
h/ 18-99

Table 4.2.2-2

Valuation Functions Used in NHTSA Proposed CAFE Standards BenMAP Application to Estimate PM2.5-Related Monetized Health-Related Benefits

Endpoint	Author/Study/Location	Valuation Method	Notes
Mortality	Laden et al. (2006) (6 cities)	VSL	a, i
Mortality	Pope et al. (2002) (51 cities)	VSL	a, i
Mortality	Woodruff et al. (1997) (86 cities)	VSL	a, i
Chronic Bronchitis	Abbey et al. (1995) (SF, SD, So Coast Air Basin)	WTP	b, k
Acute Myocardial Infarction	Peters et al. (2001) (Boston, MA)	COI	c,j,q
Hospital Admissions, Chronic Lung Disease	Ito (2003) (Detroit, MI)	COI	d,i
Hospital Admissions, Pneumonia	Ito (2003) (Detroit, MI)	COI	d,i
Hospital Admissions, Respiratory	Ito (2003) (Detroit, MI)	COI	d,p
Hospital Admissions, Cardiovascular	Moolgavkar (2000) (Los Angeles)	COI	d,p
Hospital Admissions, Cardiovascular	Moolgavkar (2000) (Los Angeles)	COI	d,i
Emergency Room Visits, Respiratory	Norris et al (1999) (Seattle, WA)	COI	i,s
Acute Bronchitis	Dockery et al. (1996) (24 communities)	WTP	e,f,m
Lower Respiratory Symptoms	Schwartz and Neas (2000) (6 U.S. cities)	WTP	e,f,m
Upper Respiratory Symptoms	Pope et al. (1991) (Utah Valley)	WTP	e,f,m
Acute Respiratory Symptoms	Ostro (2001) (Los Angeles)	WTP	e,f,n
Work Loss Days	Ostro (1987) (Nationwide)		g,o
Asthma Exacerbation	Ostro (2001) (Los Angeles)	WTP	h,m,r
Mortality, All Cause	Expert Elicitation (2006)	VSL	a,j

a/ Based on 26 value-of-life studies.
b/ Average severity
c/ 5 yrs med, 5 yrs wages, 3% DR
d/ med costs + wage loss
e/1 day illness
f/ CV studies
g/ Median daily wage, county-specific
h/ bad asthma day
i/ 0-99
j/ 30-99
k/ 0-24
l/ 65-99
m/ 0-17
n/ 18-99
o/ 18-65
p/ 20-64
q/ Russell (1998)
r/ Rowe Chestnut (1986)
s/ Stanford (1999)

In the aggregation and valuation step, the results were aggregated for the national scale as well as for three regions (eastern United States, western United States, and California). Default options were applied in the aggregation and pooling of the results. Similarly, EPA standard inflation values (defaults) were used for the valuation. The results are given in 2006-equivalent dollars, but the use of 2000-equivalent dollars was also tested.

4.2.3 Post-processing and Quality Assurance Procedures

As a first step in the quality assurance of the BenMAP application procedures and results, a protocol document outlining each step in the application of BenMAP was prepared. This was subsequently used as a checklist for each application and for quality assurance. Following the application of BenMAP for each pair of simulations, a subset of the BenMAP runs was duplicated by a second modeler using another computer and the results were confirmed to be the same. Finally, the results for each simulation pair were checked for consistency with emissions and the CMAQ modeling results.

Tabular and graphical summaries of the results were then prepared, as presented in the following sections. The contents of the tables and charts were systematically checked by comparing the values with the raw BenMAP report files.

4.3 BENMAP RESULTS

As noted earlier, BenMAP was used to estimate the reduction in the incidence of various health-related endpoints, as well as a monetized estimate of the health-related benefits for each CAFE alternative. The incidence and valuation results are presented in the remainder of this section. The health incidence results presented in this section are the BenMAP-derived mean values. The valuation estimates reflect both an income growth adjustment and a time lag between exposure and $PM_{2.5}$ mortality.

The income growth adjustment accounts for expected growth in real income over time. Economic theory suggests that WTP for most goods and services (such as environmental protection) will increase if income increases. To account for growth in income through 2030, the BenMAP-derived reductions were multiplied by 1.23 for long-term mortality, 1.27 for chronic health impacts, and 1.08 for minor health impacts (EPA pers. comm. 2010).

The valuation results for $PM_{2.5}$ assume that there is a time lag between changes in $PM_{2.5}$ concentration and changes in $PM_{2.5}$ mortality. To account for this, monetized health-related benefits occurring in the future are discounted. For this analysis, the BenMAP-derived reductions were multiplied by 0.91 to achieve a 3% discount rate and by 0.82 to achieve a 7% discount rate (EPA pers. comm. 2010). Similar adjustments do not exist for ozone.

All of the incidence and valuation results are rounded to two significant figures.

4.3.1 Environmental Consequences Scenario

The environmental consequences (EC) scenario assumes no increase in required fuel economy after the 2016 model year. The emissions associated with the CAFE alternatives under the EC scenario are presented in Tables 2.3-1 and 2.3-2.

4.3.1.1 Ozone

BenMAP results for ozone mortality for the EC alternatives are presented in Table 4.3.1-1. The reductions in premature mortality incidence are for the entire continental United States. There are no results for the No Action alternative because this is the baseline to which the CMAQ results under the action alternatives were compared within the BenMAP tool (see list of simulation pairs in Section 4.2). The baseline values presented in this table are a standard output from BenMAP and provide a point of reference for assessing the meaningfulness of the incidence results. The BenMAP baseline values (based on the BenMAP 2020 mortality incidence dataset for the mortality endpoints and on BenMAP 2000 incidence and prevalence dataset for the morbidity endpoints) represent deaths or health effects due to all causes, not just those related to air pollution, and these vary depending on the health impact function used for the referenced study.

Table 4.3.1-1

BenMAP-Aggregated Incidence Results for Ozone-Related Mortality: Estimated Nationwide Reduction in Premature Mortality for the CAFE Alternatives Under the EC Scenario

	Reduction in No. of Cases			
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**	**Baseline Values**
Mortality, Non-Accidental (Ito et al.)	8	20	140	3,336,233
Mortality, Non-Accidental (Schwartz)	3	7	48	3,336,233
Mortality, Non-Accidental (Bell et al.)	2	4	32	3,336,233
Mortality, All Cause (Levy et al.)	8	20	140	3,518,886
Mortality, All Cause (Bell et al.)	6	14	100	3,518,886
Mortality, Cardiopulmonary (Huang et al.)	3	7	54	1,832,204

The results vary slightly by epidemiology study and among the CAFE alternatives. The estimated mortality reductions increase with each successively more stringent CAFE alternative. Note that the number of premature deaths avoided is small compared to the baseline values.

BenMAP results for other ozone-related health effects and associated endpoints (morbidity) are presented in Table 4.3.1-2. The studies cover different age groups, as indicated. The reductions in incidence for all endpoints are for the entire continental United States.

Table 4.3.1-2

BenMAP Aggregated Incidence Results for Ozone-Related Morbidity: Estimated Nationwide Reduction in Various Morbidity Endpoints for the CAFE Alternatives Under the EC Scenario

	Reduction in No. of Cases			
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**	**Baseline Values**
Emergency room visits for asthma (age 5-34)	10	23	150	1,331,279
Emergency room visits for asthma (all ages)	5	12	79	2,272,043
Hospital admissions for respiratory symptoms (infant)	11	26	180	557,743
Hospital admissions for respiratory symptoms (age 65-99)	24	60	430	3,552,024
Hospital admissions for chronic lung disease (age 65-99)	6	14	95	536,289
Hospital admissions for pneumonia (age 65-99)	9	23	170	1,608,131
School loss days (Chen) (age 5-17)	3,800	8,900	59,000	9,923,739,648
School loss days (Gilliland) (age 5-17)	9,100	21,000	140,000	477,336,832
Minor restricted-activity days (age 18-65)	11,000	25,000	160,000	1,674,888,832

For all endpoints considered here, the reductions increase with each successively more stringent CAFE alternative. However, the estimated reductions are very small compared to the baseline values.

BenMAP valuation results for ozone mortality for the EC scenario CAFE alternatives are presented in Table 4.3.1-3. The monetized health-related benefits represent nationwide changes in millions of U.S. 2006-equivalent dollars.

Table 4.3.1-3 BenMAP-Derived Nationwide Monetized Health-Related Benefits for Ozone-Related Mortality: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the EC Scenario			
	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Non-accidental (Ito et al.)	71	180	1,300
Non-accidental (Bell et al. (U.S. cities))	16	40	290
Non-accidental (Schwartz et al.)	24	61	440
All causes (Levy et al.)	72	180	1,300
All causes (Bell et al.)	51	130	920
Cardiopulmonary	27	68	490

The monetized health-related benefits increase with each successively more stringent CAFE alternative. The calculated monetized health-related benefits for Alternative 4 (the Preferred or 3-Pecent Alternative) range from 40 to 180 million dollars for the non-accidental valuation estimates, and from 130 to 180 million for the all-cause valuations. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 290 million to 1.3 billion dollars for the non-accidental valuation estimates, and from 920 million to 1.3 billion dollars for the all-cause valuations.

BenMAP valuation results for other ozone-related health effects and associated endpoints (morbidity) are presented in Table 4.3.1-4.

Table 4.3.1-4 BenMAP-Derived Nationwide Monetized Health-Related Benefits for Ozone-Related Morbidity: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Various Morbidity Endpoints for the CAFE Alternatives Under the EC Scenario			
	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Emergency room visits for respiratory symptoms (all ages)	<1	<1	<1
Hospital admissions for respiratory symptoms (age 0-2)	<1	<1	2
Hospital admissions for respiratory symptoms (age 65-99)	<1	1	6
School loss days (age 0-17)	<1	1	6
Acute respiratory symptoms (age 18-99)	1	2	10

For the endpoints considered here, the monetized health-related benefits are similar for Alternatives 2 and 4, and larger for Alternative 8. The monetized health-related benefits for Alternative 4 are less than or approximately equal to one million dollars for most of the endpoints considered here, and two million for acute respiratory symptoms. The monetized health-related benefits for Alternative 8 range from less than one million dollars for emergency room visits for respiratory symptoms to 10 million dollars for acute respiratory symptoms.

4.3.1.2 $PM_{2.5}$

BenMAP results for $PM_{2.5}$ mortality for the EC scenario CAFE alternatives are presented in Table 4.3.1-5. The mortality estimates are based on both epidemiology literature and expert elicitation in which experts were asked to develop estimates of the increment in mortality that would be associated with increments of $PM_{2.5}$ exposures, based on their understanding of the epidemiological literature taken as a whole (Abt Associates 2008).

Table 4.3.1-5 BenMAP Aggregated Incidence Results for PM2.5-Related Mortality: Estimated Nationwide Reduction in Premature Mortality for the CAFE Alternatives Under the EC Scenario				
	Reduction in No. of Cases			Baseline Values
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**	
Harvard six-city study (Laden et al.)	300	440	910	3,462,126
ACS study (Pope et al.)	120	170	350	3,438,489
Infant mortality study (Woodruff et al.)	0	1	1	9,660
Expert Elicitation				
Expert A	320	460	970	3,438,489
Expert B	250	360	760	3,438,641
Expert C	260	380	800	3,438,489
Expert D	170	260	530	3,438,489
Expert E	400	580	1,200	3,438,489
Expert F	220	320	660	3,438,678
Expert G	200	290	610	3,438,489
Expert H	170	250	520	3,438,489
Expert I	250	360	760	3,438,489
Expert J	220	320	660	3,438,489
Expert K	140	200	420	3,438,603
Expert L	190	270	570	3,438,602

The results vary slightly by study and among the CAFE alternatives. There is general consensus among the experts and among the studies, but differences due to the use of different study populations and exposure-response relationships are apparent. The estimated mortality reductions increase with each successively more stringent CAFE alternative. Note that the estimated number of premature deaths avoided is small compared to the baseline values.

BenMAP results for other $PM_{2.5}$-related health effects and associated endpoints (morbidity) are presented in Table 4.3.1-6.

Table 4.3.1-6 BenMAP Aggregated Incidence Results for $PM_{2.5}$-Related Morbidity: Estimated Nationwide Reduction in Various Morbidity Endpoints for the CAFE Alternatives Under the EC Scenario				
	Reduction in No. of Cases			Baseline Values
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**	
Chronic bronchitis (age>=25)	73	110	220	866,145
Emergency room visits for asthma (age<19)	95	140	280	901,983
Acute bronchitis (age 8-12)	170	260	520	1,062,017
Asthma exacerbation (age 6-18)	4,800	7,000	14,000	518,129,056
Lower respiratory symptoms (age 7-14)	2,100	3,000	6,100	17,297,550
Upper respiratory symptoms (asthmatic children age 9-18)	1,600	2,300	4,600	104,679,720
Minor restricted-activity days (age 18-65)	79,000	120,000	230,000	1,674,888,832
Work loss days (age 18-65)	13,000	20,000	39,000	456,440,704
Nonfatal myocardial infarction (age>17)	180	270	580	1,332,501
Hospital admissions - respiratory (all ages)	53	78	170	3,179,487
Hospital admissions - cardiovascular (age>17)	59	87	180	6,806,413

For all endpoints considered here, the reductions increase with each successively more stringent CAFE alternative. The reductions are small compared to the baseline values.

BenMAP valuation results for $PM_{2.5}$ related mortality for the EC scenario alternatives with a 3% discount rate are presented in Table 4.3.1-7. The monetized health-related benefits represent nationwide changes, in millions of U.S. 2006-equivalent dollars.

Table 4.3.1-7

BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Mortality with a 3% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the EC Scenario

	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Harvard six-city study (Laden et al.)	2,400	3,600	7,500
ACS study (Pope et al.)	950	1,400	2,900
Infant mortality study (Woodruff et al.)	4	5	10
Expert Elicitation			
Expert A	2,600	3,800	8,000
Expert B	2,000	3,000	6,300
Expert C	2,100	3,200	6,600
Expert D	1,400	2,100	4,300
Expert E	3,300	4,800	10,000
Expert F	1,800	2,600	5,500
Expert G	1,100	1,700	3,500
Expert H	1,400	2,100	4,300
Expert I	2,000	3,000	6,200
Expert J	1,800	2,600	5,500
Expert K	320	470	970
Expert L	1,400	2,000	4,300

The calculated monetized health-related benefits increase with each successively more stringent CAFE alternative. The monetized health-related benefits for Alternative 4 range from 1.4 to 3.6 billion dollars for the premature mortality (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates) and from 470 million to 4.8 billion for the expert elicitation estimates. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 2.9 billion to 7.5 billion dollars for the premature mortality values (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates), and from 970 million to 10 billion for the expert elicitation estimates.

BenMAP valuation results for $PM_{2.5}$ related mortality with a 7% discount rate for the EC scenario alternatives are presented in Table 4.3.1-8.

Table 4.3.1-8

BenMAP-Derived Nationwide Health Costs for $PM_{2.5}$-Related Mortality with a 7% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the EC Scenario

	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Harvard six-city study (Laden et al.)	2,200	3,200	6,800
ACS study (Pope et al.)	860	1,300	2,600
Infant mortality study (Woodruff et al.)	3	5	9
Expert Elicitation			

Table 4.3.1-8 BenMAP-Derived Nationwide Health Costs for $PM_{2.5}$-Related Mortality with a 7% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the EC Scenario			
	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Expert A	2,300	3,400	7,200
Expert B	1,800	2,700	5,700
Expert C	1,900	2,800	6,000
Expert D	1,300	1,900	3,900
Expert E	3,000	4,300	9,000
Expert F	1,600	2,400	4,900
Expert G	1,000	1,500	3,200
Expert H	1,300	1,900	3,900
Expert I	1,800	2,700	5,600
Expert J	1,600	2,400	4,900
Expert K	290	420	870
Expert L	1,300	1,800	3,900

For this case, the monetized health-related benefits for Alternative 4 range from 1.3 to 3.2 billion dollars for the premature mortality (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates) and from 420 million to 4.3 billion for the expert elicitation estimates. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 2.6 billion to 6.8 billion dollars for the premature mortality values (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates), and from 870 million to 9 billion for the expert elicitation estimates.

BenMAP valuation results for other $PM_{2.5}$-related health effects and associated endpoints (morbidity) are presented in Table 4.3.1-9.

Table 4.3.1-9 BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Morbidity: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Various Morbidity Endpoints for the CAFE Alternatives Under the EC Scenario			
	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Chronic bronchitis (age>=30)	37	54	110
Emergency room visits for asthma (all ages)	<1	<1	<1
Acute bronchitis (age 0-17)	<1	<1	<1
Asthma exacerbation (age 0-17)	<1	<1	<1
Lower respiratory symptoms (age 0-17)	<1	<1	<1
Upper respiratory symptoms (age 0-17)	<1	<1	<1
Minor restricted-activity days (age >=18)	5	7	15
Work loss days (age 18-65)	2	3	6
Nonfatal myocardial infarction (all ages)	10	14	30
Hospital admissions - respiratory (all ages)	1	2	3
Hospital admissions - cardiovascular (age>17)	2	3	6

The greatest reductions in monetized health-related benefits are associated with fewer incidences of chronic bronchitis and non-fatal myocardial infarctions. The monetized health-related benefits increase with each successively more stringent CAFE alternative.

4.3.2 Cumulative Impacts Scenario

The cumulative impacts (CI) scenario assumes continued increases in fuel economy after 2016. The emissions associated with the CAFE alternatives under the CI scenario were also presented in Tables 2.3-1 and 2.3-2.

4.3.2.1 Ozone

BenMAP results for ozone mortality for the CI alternatives are presented in Table 4.3.2-1. The reductions in premature mortality incidence are for the entire United States. The baseline values (from BenMAP) represent deaths due to all causes, not just those related to air pollution, and these vary based on the health impact function used for the referenced study.

Table 4.3.2-1

BenMAP Aggregated Incidence Results for Ozone-Related Mortality: Estimated Reduction in Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in No. of Cases			Baseline Values
Epidemiology Study	Alternative 2	Alternative 4	Alternative 8	
Mortality, Non-Accidental (Ito et al.)	8	17	140	3,336,233
Mortality, Non-Accidental (Schwartz)	3	6	47	3,336,233
Mortality, Non-Accidental (Bell et al.)	2	4	31	3,336,233
Mortality, All Cause (Levy et al.)	8	17	140	3,518,886
Mortality, All Cause (Bell et al.)	6	12	99	3,518,886
Mortality, Cardiopulmonary (Huang et al.)	3	7	53	1,832,204

Similar to the EC alternatives, the results vary slightly by study and among the CAFE alternatives. The calculated mortality reductions increase with each successively more stringent CAFE alternative. In all cases the reductions are small compared to the baseline values.

BenMAP results for other ozone-related health effects and associated endpoints (morbidity) are presented in Table 4.3.2-2.

Table 4.3.2-2

BenMAP-Aggregated Incidence Results for Ozone-Related Morbidity: Estimated Reduction in Various Morbidity Endpoints for the CAFE Alternatives Under the CI Scenario

	Reduction in No. of Cases			Baseline Values
Epidemiology Study	Alternative 2	Alternative 4	Alternative 8	
Emergency room visits for asthma (age 5-34)	11	20	140	1,331,279
Emergency room visits for asthma (all ages)	6	11	78	2,272,043
Hospital admissions for respiratory symptoms (infant)	12	23	170	557,743
Hospital admissions for respiratory symptoms (age 65-99)	25	53	420	3,552,024
Hospital admissions for chronic lung disease (age 65-99)	6	12	93	536,289
Hospital admissions for pneumonia (age 65-99)	10	20	160	1,608,131
School loss days (Chen) (age 5-17)	4,100	7,800	58,000	9,923,739,648
School loss days (Gilliland) (age 5-17)	9,700	19,000	140,000	477,336,832
Minor restricted-activity days (age 18-65)	11,000	22,000	160,000	1,674,888,832
Work loss days (age 18-65)	2.5.E+10	6.4.E+10	5.6.E+11	7.5.E+15

For the endpoints considered here, the reductions increase with each more stringent CAFE alternative. The reductions are very small compared to the baseline values.

BenMAP valuation results for ozone mortality for the CI scenario alternatives are presented in Table 4.3.2-3. The monetized health-related benefits represent nationwide changes, in millions of U.S. $2006.

Table 4.3.2-3

BenMAP-Derived Nationwide Monetized Health-Related Benefits for Ozone-Related Mortality: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Non-accidental (Ito et al.)	72	160	1,300
Non-accidental (Bell et al. (U.S. cities))	16	35	280
Non-accidental (Schwartz et al.)	25	53	430
All causes (Levy et al.)	73	160	1,300
All causes (Bell et al.)	52	110	900
Cardiopulmonary	27	59	480

The monetized health-related benefits for Alternative 4 range from 35 to 160 million dollars for the non-accidental valuation estimates, and from 59 to 160 million dollars for all causes. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 280 million to 1.3 billion dollars for the non-accidental valuation estimates, and from approximately 480 million to 1.3 billion dollars for the all-cause valuations.

BenMAP valuation results for other ozone-related health effects and associated endpoints (morbidity) are presented in Table 4.3.2-4.

Table 4.3.2-4

BenMAP-Derived Nationwide Monetized Health-Related Benefits for Ozone-Related Morbidity: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Various Morbidity Endpoints for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Emergency room visits for respiratory symptoms (all ages)	<1	<1	<1
Hospital admissions for respiratory symptoms (age 0-2)	<1	<1	2
Hospital admissions for respiratory symptoms (age 65-99)	<1	1	6
School loss days (age 0-17)	<1	1	6
Acute respiratory symptoms (age 18-99)	1	1	10

For the endpoints considered here, the monetized health-related benefits are similar for Alternatives 2 and 4, and larger for Alternative 8. The monetized health-related benefits for Alternative 4 are less than or approximately equal to one million dollars for all endpoints considered here. The monetized health-related benefits for Alternative 8 range from less than one million dollars for emergency room visits for respiratory symptoms to 10 million dollars for acute respiratory symptoms.

4.3.2.2 $PM_{2.5}$

BenMAP results for $PM_{2.5}$ mortality for the CI alternatives are presented in Table 4.3.2-5. The mortality estimates are based on both epidemiology literature and expert elicitation.

Table 4.3.2-5

BenMAP Aggregated Incidence Results for PM2.5-Related Mortality: Estimated Reduction in Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in No. of Cases			Baseline Values
Epidemiology Literature				
Harvard six-city study (Laden et al.)	410	410	870	3,462,126
ACS study (Pope et al.)	160	160	340	3,438,489
Infant mortality study (Woodruff et al.)	1	1	1	9,660
Expert Elicitation				
Expert A	440	440	920	3,438,489
Expert B	340	340	730	3,438,641
Expert C	360	360	770	3,438,489
Expert D	240	240	510	3,438,489
Expert E	550	550	1,200	3,438,489
Expert F	300	300	640	3,438,678
Expert G	270	270	580	3,438,489
Expert H	240	240	500	3,438,489
Expert I	340	340	730	3,438,489
Expert J	300	300	630	3,438,489
Expert K	190	190	400	3,438,603
Expert L	260	260	550	3,438,602

The results vary slightly by study and among the CAFE alternatives. There is general consensus among the experts and among the studies. The calculated mortality reductions increase with each successively more stringent CAFE alternative. Note that number of premature deaths avoided is small compared to the baseline values.

BenMAP results for other $PM_{2.5}$-related health effects and associated endpoints (morbidity) are presented in Table 4.3.2-6.

Table 4.3.2-6

BenMAP Aggregated Incidence Results for PM2.5-Related Morbidity: Estimated Reduction in Various Morbidity Endpoints for the CAFE Alternatives Under the CI Scenario

	Reduction in No. of Cases			
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**	**Baseline Values**
Chronic bronchitis (age>=25)	100	100	210	866,145
Emergency room visits for asthma (age<19)	130	130	270	901,983
Acute bronchitis (age 8-12)	240	240	500	1,062,017
Asthma exacerbation (age 6-18)	6,600	6,600	14,000	518,129,056
Lower respiratory symptoms (age 7-14)	2,900	2,900	5,900	17,297,550
Upper respiratory symptoms (asthmatic children age 9-18)	2,200	2,200	4,400	104,679,720
Minor restricted-activity days (age 18-65)	110,000	110,000	220,000	1,674,888,832
Work loss days (age 18-65)	19,000	19,000	38,000	456,440,704
Nonfatal myocardial infarction (age>17)	260	260	550	1,332,501
Hospital admissions - respiratory (all ages)	73	73	160	3,179,487

For all endpoints considered here, the calculated reductions increase with each successively more stringent CAFE alternative. The reductions are very small compared to the baseline values.

BenMAP valuation results for $PM_{2.5}$-related mortality for the CI scenario alternatives with a 3% discount rate are presented in Table 4.3.2-7.

Table 4.3.2-7

BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Mortality with a 3% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Harvard six-city study (Laden et al.)	3,400	3,400	7,200
ACS study (Pope et al.)	1,300	1,300	2,800
Infant mortality study (Woodruff et al.)	5	5	10
Expert Elicitation			
Expert A	3,600	3,600	7,600
Expert B	2,800	2,800	6,000
Expert C	3,000	3,000	6,300
Expert D	2,000	2,000	4,100
Expert E	4,500	4,500	9,600
Expert F	2,500	2,500	5,300
Expert G	1,600	1,600	3,400
Expert H	1,900	2,000	4,100
Expert I	2,800	2,800	5,900
Expert J	2,500	2,500	5,200
Expert K	440	440	930
Expert L	1,900	1,900	4,100

The valuation results for Alternatives 2 and 4 are very similar. The monetized health-related benefits for Alternative 4 range from 1.3 to 3.4 billion dollars for the premature mortality estimates (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates 2008), and from 440 million to approximately 4.5 billion for the expert elicitation estimates. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 2.8 to 7.2 billion dollars for the premature mortality estimates (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates 2008), and from 930 million to 9.6 billion for the expert elicitation estimates.

BenMAP valuation results for $PM_{2.5}$-related mortality a 7% discount rate for the CI scenario alternatives are presented in Table 4.3.2-8.

Table 4.3.2-8

BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Mortality with a 7% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Harvard six-city study (Laden et al.)	3,100	3,100	6,500
ACS study (Pope et al.)	1,200	1,200	2,500
Infant mortality study (Woodruff et al.)	5	5	9

Table 4.3.2-8

BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Mortality with a 7% Discount Rate: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Premature Mortality for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Literature	**Alternative 2**	**Alternative 4**	**Alternative 8**
Expert Elicitation			
Expert A	3,200	3,200	6,900
Expert B	2,500	2,500	5,400
Expert C	2,700	2,700	5,700
Expert D	1,800	1,800	3,700
Expert E	4,100	4,100	8,700
Expert F	2,200	2,200	4,700
Expert G	1,400	1,400	3,000
Expert H	1,800	1,800	3,700
Expert I	2,500	2,500	5,300
Expert J	2,200	2,200	4,700
Expert K	400	400	830
Expert L	1,700	1,700	3,700

The monetized health-related benefits for Alternative 4 range from 1.2 to 3.1 billion dollars for the premature mortality estimates (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates 2008), and from 400 million to approximately 4.1 billion for the expert elicitation estimates. The monetized health-related benefits are greatest for Alternative 8, with values ranging from 2.5 to 6.5 billion dollars for the premature mortality estimates (not including infant mortality) based on epidemiological studies (Pope et al. 2002 and Laden et al. 2006 in Abt Associates 2008), and from 830 million to 8.7 billion for the expert elicitation estimates.

BenMAP valuation results for other $PM_{2.5}$-related health effects and associated endpoints (morbidity) are presented in Table 4.3.2-9.

Table 4.3.2-9

BenMAP-Derived Nationwide Monetized Health-Related Benefits for $PM_{2.5}$-Related Morbidity: Estimated Monetized Benefits (Millions U.S. Dollars/Year) Related to Various Morbidity Endpoints for the CAFE Alternatives Under the CI Scenario

	Reduction in Millions $2006		
Epidemiology Study	**Alternative 2**	**Alternative 4**	**Alternative 8**
Chronic bronchitis (age>=30)	51	51	110
Emergency room visits for asthma (all ages)	<1	<1	<1
Acute bronchitis (age 0-17)	<1	<1	<1
Asthma exacerbation (age 0-17)	<1	<1	<1
Lower respiratory symptoms (age 0-17)	<1	<1	<1
Upper respiratory symptoms (age 0-17)	<1	<1	<1
Minor restricted-activity days (age >=18)	7	7	14
Work loss days (age 18-65)	3	3	6
Nonfatal myocardial infarction (all ages)	13	13	29
Hospital admissions - respiratory (all ages)	2	2	3
Hospital admissions - cardiovascular (age>17)	2	2	5

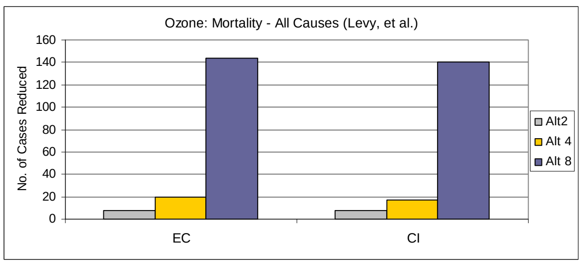
Rounded to the nearest million dollars, the results for Alternatives 2 and 4 are identical and the results for Alternative 8 are greater than both of these by about a factor of 2. The greatest monetized health-related benefits are associated with fewer incidences of chronic bronchitis and non-fatal myocardial infarctions.

4.3.3 Summary of BenMAP Results

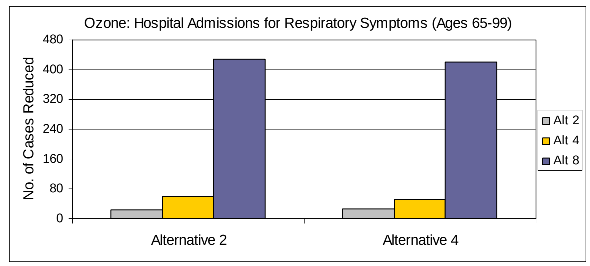
One of the goals of this application was to compare the health effects and monetized health-related benefits across the range of EC and CI scenario alternatives. Figure 4.3.3-1 graphically displays the nationwide reduction in the number of cases associated with selected health endpoints for ozone and $PM_{2.5}$. For ozone, the endpoints are mortality (Levy et al. 2005 in Abt Associates 2008), hospital admissions for respiratory symptoms, emergency room visits for asthma, and minor restricted activity days. For $PM_{2.5}$, the endpoints are mortality (Laden et al. 2006 in Abt Associates 2008), hospital admissions for respiratory symptoms, asthma exacerbation, and minor restricted activity days. Note that the scales are different for each plot.

Figure 4.3.3-1a. BenMAP-Derived Changes in Selected Health Outcomes for the NHTSA Proposed CAFE Standards EC and CI Scenarios: Ozone

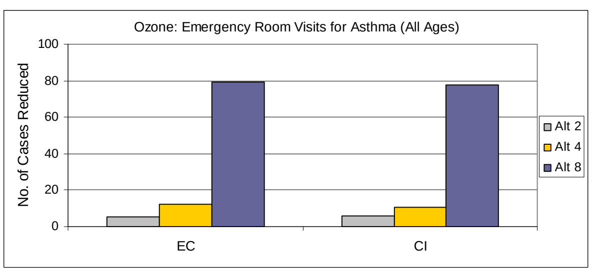
(a) Mortality (Levy et al.)



(b) Hospital Admissions for Respiratory Symptoms



(c) Emergency Room Visits for Asthma



(d) Minor Restricted Activity Days

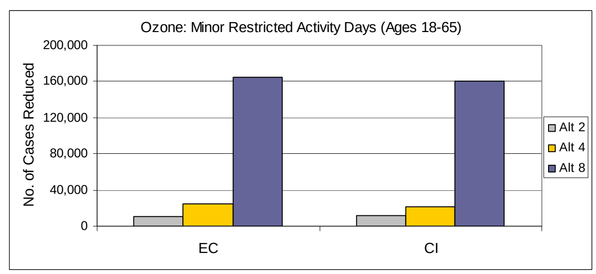
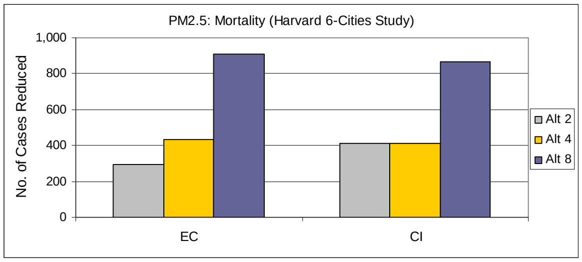
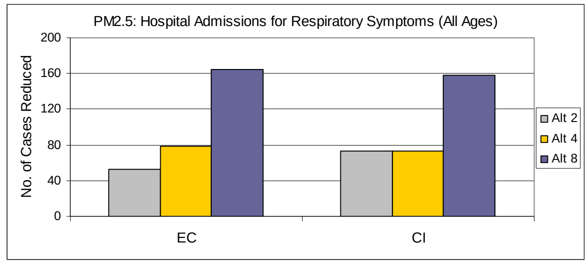


Figure 4.3.3-1b. BenMAP-Derived Changes in Selected Health Outcomes for the NHTSA Proposed CAFE Standards EC and CI Scenarios: $PM_{2.5}$

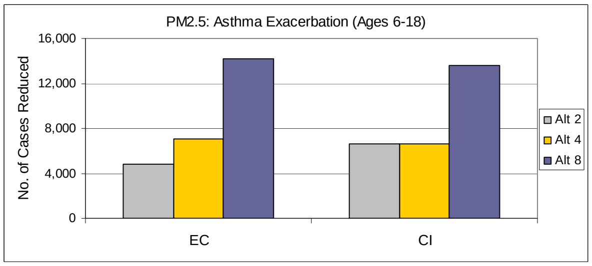
(a) Mortality (Laden et al.)



(b) Hospital Admissions for Respiratory Symptoms



(c) Asthma Exacerbation



(d) Minor Restricted Activity Days

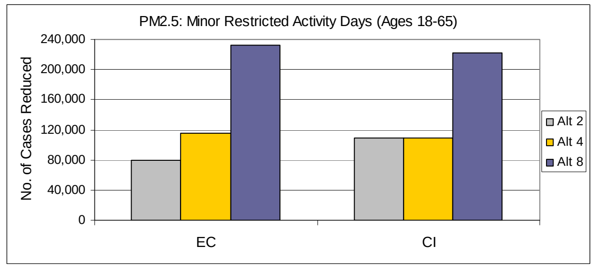
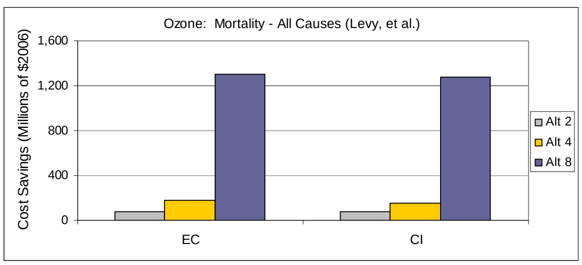


Figure 4.3.3-2 graphically displays the nationwide monetized health-related benefits associated with selected health endpoints for ozone and $PM_{2.5}$. For both ozone and $PM_{2.5}$, the monetized health-related benefits are displayed for mortality and combined respiratory symptoms. For ozone, the combined symptoms include emergency room visits for respiratory symptoms, hospital admissions for respiratory symptoms, and acute respiratory symptoms. For $PM_{2.5}$, the combined symptoms include chronic bronchitis, acute bronchitis, asthma exacerbation, emergency room visits for asthma, lower and upper respiratory symptoms, and hospital admissions for respiratory symptoms. Again, to accommodate differences in the results, the scales are different for each plot.

Figure 4.3.3-2a. BenMAP-Derived Monetized Health-Related Benefits for the NHTSA Proposed CAFE Standards EC and CI Scenarios: Ozone

(a) Mortality (Levy et al.)



(b) Combined Respiratory Symptoms

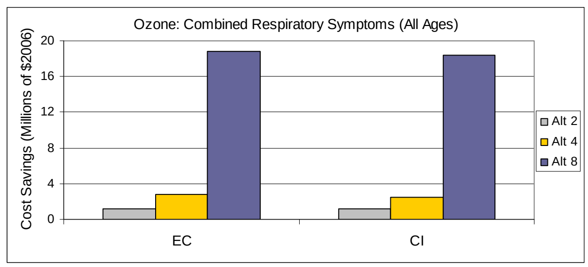
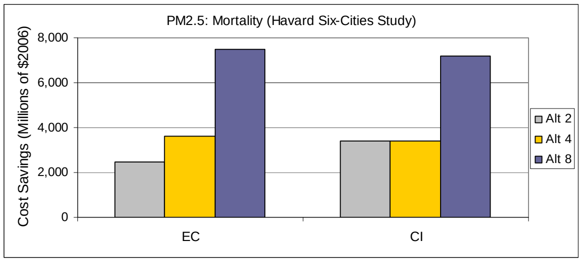
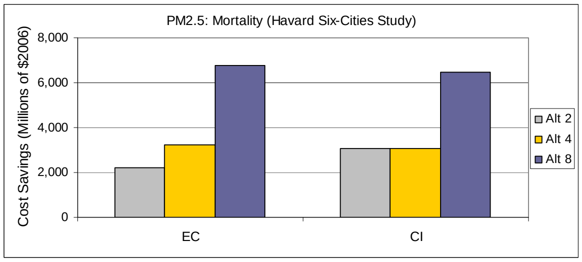


Figure 4.3.3-2b. BenMAP-Derived Monetized Health-Related Benefits for the NHTSA Proposed CAFE Standards EC and CI Scenarios: $PM_{2.5}$

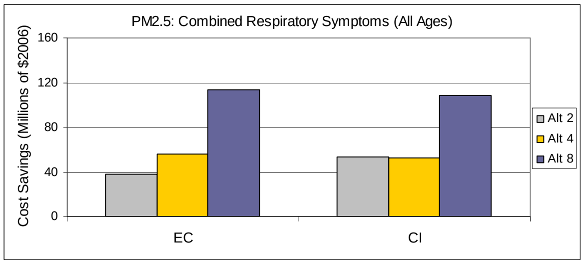
(a) Mortality (Laden et al.) with 3% Discount



(b) Mortality (Laden et al.) with 7% Discount



(c) Combined Respiratory Symptoms



In summary:

- For both the EC and CI scenarios, the relative changes in health effects incidences and monetized health-related benefits among the alternatives are consistent with the changes in emissions for the CAFE alternatives.
- The estimated reduction in health effects and the monetized health-related benefits for CAFE Alternatives 2 and 4 are similar in magnitude; those for Alternative 8 are greater (by about a factor of 10 for ozone and about a factor of 2 for $PM_{2.5}$).
- For Alternative 2 the calculated health-related benefits are greater for the CI scenario; for Alternatives 4 and 8 the calculated health-related benefits are greater for the EC scenario. This result is consistent with the emissions changes and is due to the differences between the EC and CI scenarios in the interaction of VMT, car/truck shares, and gas/diesel shares.
- Similar to other studies the estimated health-related benefits associated with mortality are greater than those associated with the morbidity endpoints and the health-related benefits associated with $PM_{2.5}$ are greater than those associated with ozone.

4.3.4 Discussion of Attributes and Limitations

The BenMAP tool incorporates a wide variety of recent studies that can be used to quantify and monetize health effects. The epidemiological studies address a variety of different health endpoints and, in some cases, multiple studies (involving different populations or concentration-response functions) are available allowing for some comparison. BenMAP includes up-to-date valuation methods and data for the monetization of health impacts. BenMAP also incorporates advanced statistical methods for aggregating and weighting the results to obtain both mean values as well as information about the likelihood (probability) that the value will be within a given range. A primary advantage of BenMAP is that it can incorporate the change in air quality directly from air quality model output files and thus takes into account spatial and temporal differences in the changes in air quality, and relates these to population. For this analysis, selection of the health effects studies and valuation methods were based on the latest BenMAP (configuration and aggregation, pooling and valuation) input files provided by EPA (which reference the studies and methods that EPA considers to be the most relevant and applicable to the U.S. population as a whole.)

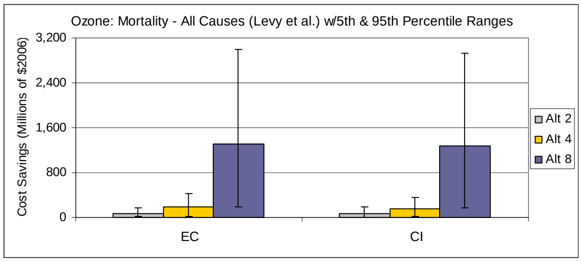
Nevertheless, there are uncertainties associated with the estimation of changes in health effects and monetized health-related benefits associated with changes in ozone and $PM_{2.5}$ air quality. For the health incidence calculations, BenMAP includes an option to generate an average incidence estimate, as well as a range of results that assume there is variability in the inputs to the health impact functions. Variability is incorporated into most of the BenMAP exposure-response algorithms by prescribing a dose-response parameter that assumes a Gaussian or bell-shaped distribution about the mean value. In calculating the health effects, BenMAP samples this distribution to develop a probability distribution of effect. The result is expressed as the mean value of the distribution. For the $PM_{2.5}$ mortality expert elicitation functions, variability is accounted for in a variety of ways.

For the valuation calculation, the valuation function is also specified as a probability distribution, accounting for different methods of estimating health costs and willingness to pay. BenMAP samples from probability distributions from single or multiple cost estimation models, and combines the results through Monte Carlo simulation. The valuation function for morbidity used for this analysis is a Weibull distribution with a mean of $6.3 million (in year 2000 dollars).

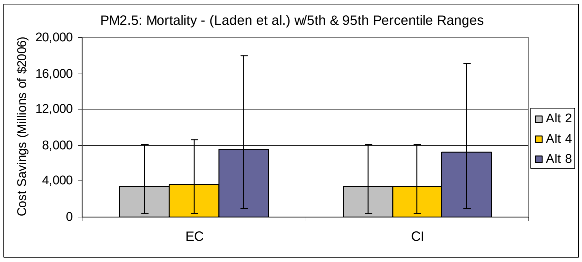
The resulting monetized benefit distributions therefore include contributions both from the uncertainty in the exposure-response relationships and in the valuation functions. Tables 4.3.1-1 through 4.3.1-8 and 4.3.2-1 through 4.3.2-8 present the expected value (mean) estimates generated by BenMAP. The BenMAP-generated overall distributions in monetized health-related benefits (represented by 5^{th}- and 95^{th}- percentile intervals) for mortality for both ozone, as determined by Levy et al. (2005) in Abt Associates (2008) and $PM_{2.5}$, as determined by Laden et al. (2006) in Abt Associates (2008), are presented in Figure 4.3.4-1. Mortality is used here to illustrate the uncertainty because the majority of quantified and monetized health-related benefits are associated with mortality.

Figure 4.3.4-1. BenMAP-Derived Monetized Health-Related Benefits for the NHTSA Proposed CAFE Standards EC and CI Scenarios, with 5^{th}- and 95^{th}- Percentile Ranges

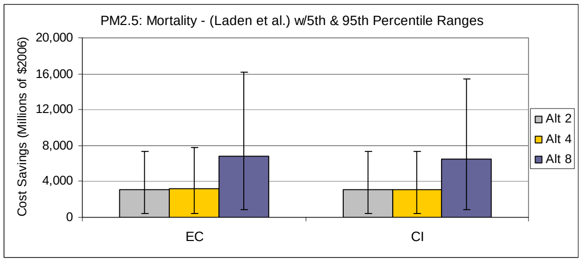
(a) Ozone Mortality (Levy et al.)



(b) $PM_{2.5}$ Mortality (Laden et al.) with 3% Discount



(c) $PM_{2.5}$ Mortality (Laden et al.) with 7% Discount

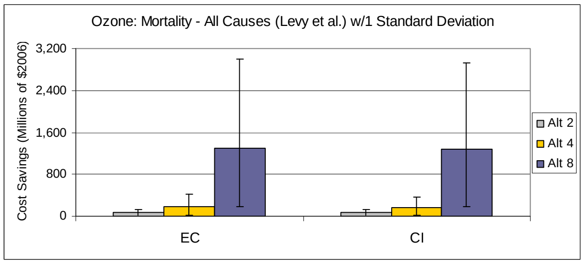


In general, the differences between the 5th- and 95th- percentile values and the mean are quite large and similar in magnitude to the mean value. For EC Alternative 4 for $PM_{2.5}$ with a 7% discount rate, for example, the mean value is 3,200 million dollars. The 5th- and 95th-percentile values are 430 and 7,800 million dollars, respectively. Thus there is a 90 percent probability that the monetized health-related benefits would be between 430 and 7,800 million dollars.

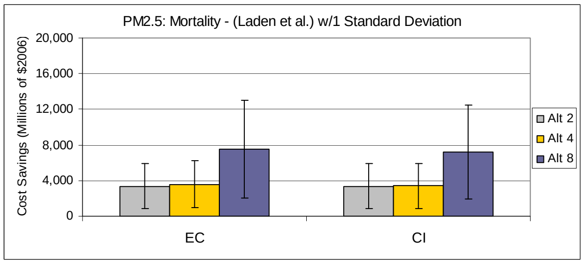
The BenMAP-generated mean and standard deviations in monetized health-related benefits for mortality for both ozone, as determined by Levy et al. (2005) in Abt Associates (2008) and $PM_{2.5}$, as determined by Laden et al. (2006) in Abt Associates (2008) are presented in Figure 4.3.4-2.

Figure 4.3.4-2. BenMAP-Derived Monetized Health-Related Benefits for the NHTSA Proposed CAFE Standards EC and CI Scenarios, with One Standard Deviation

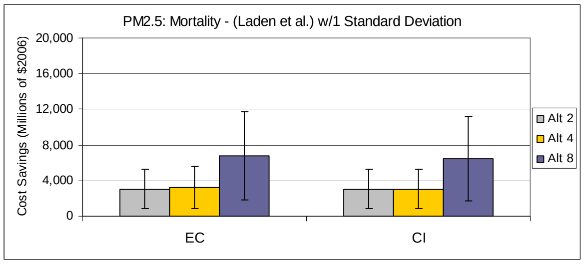
(a) Ozone Mortality (Levy et al.)



(b) $PM_{2.5}$ Mortality (Laden et al.)with 3% Discount



(c) $PM_{2.5}$ Mortality (Laden et al.)with 7% Discount



The standard deviation values indicate considerable variability in the distributions leading to uncertainty in the results. For EC Alternative 4 for $PM_{2.5}$ with a 7 % discount rate, for example, the mean value is 3,200 million dollars and the standard deviation is 2,400.

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