Final Environmental Impact Statement

Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2012-2016

February 2010

National Highway Traffic
Safety Administration

NHTSA

www.nhtsa.gov

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

Administrator

1200 New Jersey Avenue SE
Washington, DC 20590

February 22, 2010

Dear NEPA Contact:

I am pleased to enclose a copy of the National Highway Traffic Safety Administration's (NHTSA) Final Environmental Impact Statement (FEIS) to address the potential environmental impacts of new Corporate Average Fuel Economy (CAFE) standards required by the Energy Independence and Security Act of 2007.

NHTSA recently proposed standards for model years (MYs) 2012-2016 passenger cars and light trucks (Notice of Proposed Rulemaking; 74 *Federal Register* 49454 (Sep. 28, 2009)). NHTSA's proposed action is part of a joint proposed rulemaking with the U.S. Environmental Protection Agency (EPA). Together, these proposed actions call for a strong and coordinated federal greenhouse gas (GHG) and fuel economy program for passenger cars, light-duty trucks, and medium-duty passenger vehicles. NHTSA proposed Corporate Average Fuel Economy standards under the Energy Policy and Conservation Act, as amended, and EPA proposed GHG emissions standards under the Clean Air Act. These joint proposed rules address the urgent and closely intertwined challenges of energy independence, energy security, and global warming. The joint proposed rulemaking is consistent with the National Fuel Efficiency Policy announced by President Obama on May 19, 2009, calling for harmonized federal standards regulating both fuel economy and GHG emissions, to provide a predictable regulatory framework for the automotive industry.

In connection with NHTSA's proposed CAFE standards, NHTSA prepared the enclosed FEIS, which analyzes the environmental impact of the proposed standards for MYs 2012-2016. The FEIS compares the environmental impacts of the agency's Preferred Alternative and reasonable alternatives, including a "No Action" Alternative, pursuant to the National Environmental Policy Act (NEPA), 42 U.S.C. § 4321 *et seq.*, and implementing regulations issued by the Council on Environmental Quality (CEQ) and the Department of Transportation. The FEIS analyzes direct, indirect, and cumulative impacts to inform decisionmakers and the public of the environmental impacts of the various alternatives.

In developing the proposed standards and possible alternatives, NHTSA considered four factors underlying maximum feasibility, as required by the Energy Policy and Conservation Act (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the United States to conserve energy), as well as relevant environmental and safety considerations.

Under the proposed standard for passenger cars, the required average fuel economy (in miles per gallon, or mpg) would range from 33.4 mpg in MY 2012 to 37.8 mpg in MY 2016. Under the proposed standard for light trucks, the required average fuel economy would range from 25.3 mpg in MY 2012 to 28.7 mpg in MY 2016. The combined industry-wide required average fuel economy for all passenger cars and light trucks under the proposed standard would range from 29.7 mpg in MY 2012 to 34.1 mpg in MY 2016.

NHTSA is mailing this FEIS to approximately 300 interested parties, including Federal, State, and local agencies, elected officials, environmental and public interest groups, Native American tribes, and other interested individuals.

Chapter 1 of the enclosed FEIS describes the public comment process. Comments on the Draft Environmental Impact Statement (DEIS) and NHTSA's responses to those comments are provided in Chapter 10 of this FEIS. The transcript from the public hearing and written comments submitted to the agency are a part of the administrative record, and are available on the Federal Docket, which can be found on the web at http://www.regulations.gov, Reference Docket No. NHTSA-2009-0059.

No sooner than 30 days after the EPA publishes a Notice of Availability of the FEIS in the *Federal Register*, NHTSA will publish a final CAFE rule and Record of Decision. The Record of Decision will state and explain NHTSA's decision, and describe NHTSA's consideration of applicable environmental laws and policies.

The FEIS has been placed in NHTSA's public files and is available for public inspection at:

DOT Library, W12-300
1200 New Jersey Avenue, SE
West Building
Washington, DC 20590

A limited number of hard copies of the DEIS and this FEIS are available from the DOT Library. The DEIS and this FEIS are also available for public viewing on the CAFE website at http://www.nhtsa.gov/portal/fueleconomy.jsp.

Additional information about the project is available from NHTSA's Fuel Economy Division, Office of International Policy, Fuel Economy and Consumer Programs, at 202-366-0846 or on the NHTSA CAFE website identified above. For assistance, please contact NHTSA through the following website: https://www.nhtsa.dot.gov/email.cfm or toll free at 1-888-327-4236 (for TTY, contact 1-800-424-9153). The NHTSA CAFE website also provides access to the texts of formal NHTSA documents, such as orders, notices, and rulemakings.

Sincerely yours,

David L. Strickland

Enclosure

FINAL ENVIRONMENTAL IMPACT STATEMENT

CORPORATE AVERAGE FUEL ECONOMY STANDARDS, PASSENGER CARS AND LIGHT TRUCKS, MYS 2012-2016

FEBRUARY 2010

LEAD AGENCY:
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

COOPERATING AGENCY:
U.S. ENVIRONMENTAL PROTECTION AGENCY

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List of Acronyms and Abbreviations

+/-	plus or minus
°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
APA	Administrative Procedures Act
AEO	Annual Energy Outlook
AER	Annual Energy Review
AAM	Alliance of Automobile Manufacturers
AMFA	Alternative Motor Fuels Act
AMOC	Atlantic Meridional Overturning Circulation
AMT	Automated Shift Manual Transmission
AOGCM	atmospheric-ocean general circulation models
ATVM	Advanced Technology Vehicles Manufacturing Loan Program
BTU	British thermal unit
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CBD	Center for Biological Diversity
CCSP	Climate Change Science Program
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CMAQ	Congestion Mitigation and Air Quality Improvement
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of the Parties
DEIS	Draft Environmental Impact Statement
DHHS	U.S. Department of Health and Human Services
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPM	diesel particulate matter
DRIA	Draft Regulatory Impact Assessment
EA	environmental assessment
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act
ENSO	El Niño Southern Oscillation
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
EU	European Union
EU ETS	European Union Greenhouse Gas Emission Trading System
EV	electric vehicle
FAO	Food and Agriculture Organization (United Nations)
FEIS	Final Environmental Impact Statement
FEOW	Freshwater Ecoregions of the World project
FFV	flexible fuel vehicle
FONSI	Finding of No Significant Impact
FHWA	Federal Highway Administration

FMCSA	Federal Motor Carrier Safety Administration
FR	Federal Register
FRIA	Final Regulatory Impact Analysis
FTA	Federal Transit Administration
g/mi	gram per mile
GAO	General Accounting Office
GDP	Gross Domestic Product
GHG	greenhouse gases
GIS	Greenland ice sheet
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GtC/year	gigaton carbon per year
GWP	global warming potential
HEV	hybrid electric vehicle
HFC	hydrofluorocarbon
HOP	high oil price
IARC	International Agency for Research on Cancer
IEO	International Energy Outlook
IGSM	Integrated Global System Model
IPCC	Intergovernmental Panel on Climate Change
IRIS	Integrated Risk Information System
K	kelvin
ka	kiloannum
LNG	liquefied natural gas
LTCCS	Large Truck Crash Causation Study
LTV	light trucks and vans
MA	Millennium Ecosystem Assessment
MAGICC	Model for Assessment of Greenhouse Gas-induced Climate Change
mg/L	milligram per liter
mg/m^3	milligram per cubic meter
MGA	Midwestern Governors Association
MHTs	Major Habitat Types
mm	millimeter
$MMTCO_2$	million metric tons of carbon dioxide
MNB	Maximum Net Benefits
MOC	Meridional Overturning Circulation
MOP	moderate oil price
MOVES	Motor Vehicle Emission Simulator (U.S. EPA)
mpg	mile per gallon
MSATs	mobile source air toxics
MTBE	methyl tertiary butyl ether
MY	model year
N_2	nitrogen
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NADA	National Automobile Dealers Association
NATA	National-scale Air Toxics Assessment
NCD	National County Database
NCI	National Cancer Institute
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NERA	National Environmental Research Associates
NF_3	nitrogen trifluoride
NGO	non-governmental organization
NHTSA	National Highway Traffic Safety Administration

NMIM	National Mobile Inventory Model
NO	nitric oxide
NO_2	nitrogen dioxide
NOI	Notice of Intent
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
Non-EGU	Sources other than electric generating units (power plants).
NPRM	Notice of Proposed Rulemaking
NRDC	Natural Resources Defense Council
NYSDOT	New York State Department of Transportation
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
OMB	Office of Management and Budget
PAH	polycyclic aromatic hydrocarbon
PFC	perfluorocarbon
PHEV	Plug-In Hybrid Electric Vehicle
POM	polycyclic organic matter
PM	particulate matter
PM_{10}	particulate matter 10 microns diameter or less
$PM_{2.5}$	particulate matter 2.5 microns diameter or less
ppm	parts per million
ppmv	parts per million by volume
PPR	Prairie Pothole Region
PRIA	Preliminary Regulatory Impact Analysis
RCP	Representative Concentration Pathway
RFS	Renewable Fuels Standard
RGGI	Regional Greenhouse Gas Initiative
RIA	Regulatory Impact Analysis
RPE	retail price equivalent
SAP	Synthesis and Assessment Product
SAB	Science Advisory Board
SCC	social cost of carbon
SCC	source category code
SF_6	sulfur hexafluoride
SIP	State Implementation Plan
SO	sulfur oxide
SO_x	sulfur oxides
SO_2	sulfur dioxide
SRES	Special Report on Emission Scenarios
SUV	sport utility vehicle
TS&D	Transportation, Storage, and Distribution
TB	total benefits
TCTB	Total Costs Equal Total Benefits
TC	total cost
TgC/yr	teragram carbon per year (1,000,000,000,000 grams carbon per year)
THC	thermohaline circulation
TLAAS	Temporary Lead-time Allowance Alternative Standards
U.S.C.	United States Code
UCS	Union of Concerned Scientists
UMD	University of Maryland
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USCCSP	United States Climate Change Science Program
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey

VMT	vehicle-miles traveled
VOC	volatile organic compound
VSL	value of statistical life
Volpe Center	Volpe National Transportation Systems Center
WAIS	Western Antarctic ice sheet
WCI	Western Climate Initiative
WGI	IPCC Work Group I
WGII	IPCC Work Group II
WHO	World Health Organization
WMO	World Meteorological Organization
WWF	World Wildlife Fund

Glossary

To help readers more fully understand this Environmental Impact Statement, NHTSA has provided the following list of definitions for technical and scientific terms, as well as plain English terms used differently in the context of this EIS.

Term	Definition
Adaptation	Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, including anticipatory and reactive, private and public, and autonomous and planned.
Afforestation	Planting of new forests on lands that historically have not contained forests (for at least 50 years).
Anthropogenic	Resulting from or produced by human beings.
Aquaculture	Farming of plants and animals that live in water.
Benthic	Describing habitat or organisms occurring at the bottom of a body of water.
Biosphere	The part of the Earth system comprising all ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including dead organic matter, such as litter, soil organic matter, and oceanic detritus.
Carbon sink	Any process, activity, or mechanism that removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere.
Coral bleaching	The paling in color that results if a coral loses its symbiotic, energy providing, organisms.
Criteria pollutants	Carbon monoxide (CO), airborne lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and fine particulate matter (PM).
Cryosphere	The portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.
Dansgaard-Oeschger events	Very rapid climate changes – up to 7 °C in some 50 years – during the Quaternary geologic period, and especially during the most recent glacial cycle.
Ecosystem	A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, all of Earth.

Term	Definition
El Niño-Southern Oscillation	The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basinwide warming of the tropical Pacific east of the international dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño-Southern Oscillation, or ENSO. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds.
Emission rates	Rate at which contaminants are discharged from a particular source, usually in weight unit per time period.
Endemic	Restricted to a region.
EPCA factors for setting "maximum feasible" CAFE standards	Technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the Nation to conserve energy.
Eutrophication	Enrichment of a water body with plant nutrients.
Evapotranspiration	The combined process of water evaporation from Earth's surface and transpiration from vegetation.
Expected Value Model Inputs	Model input scenario that uses the Energy Information Administration's April 2009 Reference Case fuel price forecast, a 10-percent rebound effect, a domestic social cost of carbon of $20.00 per ton, a 3-percent discount rate, and a value of $0.17 per gallon for oil import externalities
GREET model	Model developed by Argonne National Laboratory that provides estimates of the energy and carbon contents of fuels as well as energy use in various phases of fuel supply.
Hydrology	The science dealing with the occurrence, circulation, distribution, and properties of Earth's water.
Hydrosphere	The component of the climate system comprising liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, and underground water.
Kiloannum	A unit of time equal to 1000 years. Abbreviation is "ka."
Lake stratification	The layering of warmer, less dense water over colder, denser water.
Lifetime fuel consumption	Total volume of fuel used by a vehicle over its lifetime.
Maximum lifetime of vehicles	The age after which less than 2 percent of the vehicles originally produced during a model year remains in service.
NEPA scoping process	An early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.

Term	Definition
Nonattainment area	Regions where concentrations of criteria pollutants exceed federal standards. Nonattainment areas are required to develop and implement plans to comply with the National Ambient Air Quality Standards within specified time periods.
Ocean acidification	A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.
Optimized standards	Standards set at levels such that the cost of the last technology application (using the Volpe model) equals the benefits of the improvement in fuel economy resulting from that application, thereby maximizing net benefits (benefits minus costs).
Overexploitation of species	Exploitation of species to the point of diminishing returns.
Paleoclimatology	The study of climate change through the physical evidence left on Earth of historical global climate change (prior to the widespread availability of records to temperature, precipitation, and other data).
Pathways of fuel supply	Imports to the United States of refined gasoline and other transportation fuels, domestic refining of fuel using imported petroleum as a feedstock, and domestic fuel refining from crude petroleum produced within the United States.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below zero degrees Celsius for at least two consecutive years.
Phenology	The study of natural phenomena in biological systems that recur periodically (development stages, migration) and their relationship to climate and seasonal changes.
Rebound effect	A situation in which improved fuel economy reduces the fuel cost of driving and leads to additional use of passenger cars and light trucks and thus increased emissions of criteria pollutants by passenger cars and light trucks.
Reformed CAFE Program	Consists of two basic elements: (1) a process that sets fuel economy targets for different values of vehicle footprint; and (2) a Reformed CAFE standard for each manufacturer, which is equal to the production-weighted harmonic average of the fuel economy targets corresponding to the footprint values of each light truck model it produces.
Saltwater intrusion	Displacement of fresh surface water or groundwater by the advance of saltwater due to its greater density. This process usually occurs in coastal and estuarine areas due to reducing land-based influence (either from reduced runoff and associated groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (relative sea-level rise).
Silviculture	The management of forest resources.
Survival rate	The proportion of vehicles originally produced during a model year that are expected to remain in service at the age they will have reached during each subsequent year.

Term	Definition
Technologies	Engine technologies, transmission, vehicle, electrification/accessory and hybrid technologies that influence fuel economy.
Thermohaline circulation	This term refers to the physical driving mechanism of ocean circulation, resulting from fluxes of heat and fresh water across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources.
Tipping point	A situation where the climate system reaches a point at which is there is a strong and amplifying positive feedback from only a moderate additional change in a driver, such as CO_2 or temperature increase.
Total vehicle miles	Total number of miles a vehicle will be driven over its lifetime.
Track width	The lateral distance between the centerlines of the base tires at ground, including the camber angle.
Transpiration	Water loss from plant leaves.
Turbidity	A decrease in the clarity of water due to the presence of suspended sediment.
Vehicle footprint	The product of track width times wheelbase divided by 144.
Vehicle miles traveled	Total number of miles driven.
Volpe model	CAFE Compliance and Effects Model developed by the U.S. Department of Transportation's Volpe Center, that, for any given year, applies technologies to the manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration.
Wheelbase	The longitudinal distance between front and rear wheel centerlines.

Summary

Foreword

The National Highway Traffic Safety Administration (NHTSA) prepared this Environmental Impact Statement (EIS) to analyze and disclose the potential environmental impacts of the proposed model years (MYs) 2012–2016 Corporate Average Fuel Economy (CAFE) standards for the total fleet of passenger and non-passenger automobiles (hereinafter referred to as passenger cars and light trucks, respectively) and reasonable alternative standards for the NHTSA CAFE program pursuant to Council on Environmental Quality (CEQ) regulations implementing the National Environmental Policy Act (NEPA), U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations.[1] This EIS compares the potential environmental impacts of alternative mile-per-gallon (mpg) levels NHTSA will consider for the final rule, including the Preferred Alternative (*i.e.*, the proposed standards) and a No Action Alternative. It also analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance.

Background

The Energy Policy and Conservation Act of 1975 (EPCA) established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and separate standards for light trucks.[2] As part of that Act, the CAFE program was established to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. The Act directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States. The Secretary delegated responsibility for implementing the CAFE program to NHTSA.[3]

In December 2007, Congress passed the Energy Independence and Security Act of 2007 (EISA),[4] amending the EPCA CAFE program requirements and providing DOT additional rulemaking authority and responsibilities. Pursuant to EPCA, as amended by EISA, on April 22, 2008, NHTSA proposed CAFE standards for MYs 2011–2015 passenger cars and light trucks in a Notice of Proposed Rulemaking (NPRM).[5]

On October 10, 2008, NHTSA submitted to the U.S. Environmental Protection Agency (EPA) its Final Environmental Impact Statement, Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011–2015.[6] On March 30, 2009, NHTSA issued a final rule adopting CAFE standards for MY 2011.[7]

On April 1, 2009, NHTSA published a Notice of Intent (NOI) to prepare an EIS for proposed MYs 2012–2016 CAFE standards.[8] The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping by requesting public input on the scope of the environmental analysis to be conducted.[9]

On May 19, 2009, President Obama announced a National Fuel Efficiency Policy aimed at both increasing fuel economy and reducing greenhouse gas (GHG) emissions for all new cars and trucks sold in the United States, while also providing a predictable regulatory framework for the automotive industry. The policy seeks to set harmonized federal standards to regulate both fuel economy and GHG emissions. The policy covers MY 2012 to MY 2016 and ultimately requires the equivalent of an average fuel economy of 35.5 mpg in 2016, if all carbon dioxide (CO_2) reductions were achieved through fuel economy improvements. In conjunction with the President's announcement, on May 19, 2009, DOT and EPA issued a Notice of Upcoming Joint Rulemaking to propose coordinated fuel economy and GHG standards for MYs 2012–2016 light-duty vehicles.

On September 28, 2009, NHTSA and EPA announced in the *Federal Register* the Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards. The proposed rule calls for a strong and coordinated federal GHG and fuel economy program for passenger cars, light-duty trucks, and medium-duty passenger vehicles (hereinafter light-duty vehicles), referred to in this rulemaking as the National Program. The proposed rules would achieve substantial improvements in fuel economy and reductions of GHG emissions from light-duty vehicles, based on technology that is already being commercially applied in most cases and that can be incorporated at a reasonable cost. These joint proposed rules address the closely intertwined challenges of energy independence, energy security, and global warming.

The proposed National Program makes it possible for the standards of two different federal agencies to act in a unified fashion, providing nationwide environmental and energy benefits, cost savings, and administrative efficiencies. [10] Establishing a harmonized approach to regulating light-duty vehicle GHG emissions and fuel economy is critically important, given the interdependent goals of addressing climate change and ensuring energy independence and security.

NEPA directs that "to the fullest extent possible," federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action).[11] To inform its development of the new MYs 2012–2016 CAFE standards, NHTSA prepared this EIS to analyze and disclose the potential environmental impacts of a proposed Preferred Alternative and other proposed alternative standards, including the No Action Alternative.

Section 1501.6 of CEQ regulations emphasizes agency cooperation early in the NEPA process and allows a lead agency (in this case, NHTSA) to request the assistance of other agencies that either have jurisdiction by law or have special expertise regarding issues considered in an EIS.[12] NHTSA invited EPA to become a cooperating agency, pursuant to CEQ regulations, because of its special expertise in the areas of climate change and air quality. On May 12, 2009, EPA agreed to become a cooperating agency. The EPA environmental analysis of its proposed rulemaking is summarized and referenced in the appropriate sections of this EIS.

Purpose and Need for the Proposed Action

For purposes of this EIS, the Proposed Action is NHTSA's action to set passenger car and light truck CAFE standards for MYs 2012–2016 in accordance with EPCA, as amended by EISA. NEPA requires that alternatives to a proposed action be developed based on the action's purpose and need.

EPCA and EISA set forth extensive requirements for the rulemaking, and those requirements form the purpose of and need for the standards. The requirements also were the basis for establishing the range of alternatives considered in this EIS. Specifically, the statute requires the Secretary of Transportation to establish average fuel economy standards for each model year at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year."[13]

When setting maximum feasible fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[14] NHTSA interprets the statutory factors as including environmental issues and permitting the consideration of other relevant societal issues, such as safety.[15]

EPCA and EISA further direct the Secretary of Transportation, after consultation with the Secretary of Energy and the Administrator of EPA, to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with MY 2011 "to achieve a combined fuel economy average for MY 2020 of at least 35 miles per gallon for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year."[16] In so doing, the Secretary of Transportation is to adopt "annual fuel economy standard increases," but in any single rulemaking, standards may be established for not more than five model years.[17] NHTSA also is acting pursuant to President Obama's memorandum to DOT on January 26, 2009, as described in Section 1.1 of this EIS.

The purpose of this EIS is to identify proposed CAFE standards and regulatory alternatives, and to analyze and disclose the potential environmental impacts of the proposed standards and alternatives for consideration by NHTSA decisionmakers.

Alternatives

NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives. The EPCA fuel economy requirements, including the four statutory factors NHTSA must consider in determining maximum feasible CAFE levels—technological feasibility, economic practicability, the need of the United States to conserve energy, and the effect of other motor vehicle standards of the Government on fuel economy—form the purpose of and need for the MYs 2012–2016 CAFE standards and, therefore, inform the range of alternatives for consideration in this NEPA analysis. The NHTSA decision process balances the four statutory EPCA factors, along with considerations such as environmental impacts and safety. In developing a reasonable range of alternatives, NHTSA identified alternative stringencies that represent the spectrum of potential actions the agency could take. The environmental impacts of these alternatives, in turn, represent the spectrum of potential environmental impacts that could result from NHTSA's action of setting CAFE standards. This EIS analyzes the impacts of eight "action" alternatives as well as the impacts if the CAFE standards imposed no new requirements (the No Action Alternative).

The specific alternatives NHTSA examined, described below and shown in Table S-1 and Table 2.3-1, encompass a reasonable range of alternative actions (*i.e.*, CAFE standards) for which to evaluate the potential environmental impacts under NEPA, in view of EPCA requirements. At one end of this range is the No Action Alternative (Alternative 1), which assumes no action would occur under the National Program.[18] The No Action Alternative 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 manufacturers' required level of average fuel economy for MY 2011. NHTSA also considers eight action alternatives, including NHTSA's Preferred Alternative (Alternative 4), which requires approximately a 4.3-percent average annual increase in mpg from 2012 to 2016. This alternative and the EPA proposed rulemaking together comprise the National Program described in the NPRM.

Alternatives 2, 3, 4, 5, 7, and 8 require average annual increases in mpg ranging from 3 percent (Alternative 2) to 7 percent (Alternative 8) from year to year. [19]

NHTSA added three alternatives to the list first proposed in the NOI: the agency's Preferred Alternative (Alternative 4), an alternative that maximizes net benefits (MNB) (Alternative 6), and an alternative under which the total costs equal the total benefits (TCTB) (Alternative 9). The agency's Preferred Alternative represents the required fuel economy level that NHTSA has tentatively determined to be the maximum feasible level under EPCA, based on balancing the four statutory factors and other relevant considerations. For a detailed explanation of the alternatives, *see* Section 2.3 of this EIS.

The other two alternatives, the MNB and TCTB, represent fuel economy levels that depend on the agency's best estimate of relevant economic variables (*e.g.*, gasoline prices, social cost of carbon, discount rate, and rebound effect). For further discussion of the economic assumptions, *see* Section 2.2.4 of this EIS. The MNB Alternative and TCTB Alternative provide the decisionmaker and the public with useful information about where the standards would be set if costs and benefits were balanced in two different ways.

The 6-Percent Alternative results in a required CAFE level in 2016 that is equal to the required CAFE level under the MNB Alternative, but the required CAFE levels in 2012 through 2015 under the 6-Percent Alternative are actually slightly lower than under the MNB Alternative. In general, the net result is that there is very little substantive difference in the required CAFE level under the 6-Percent and MNB Alternatives. The TCTB Alternative results in a required CAFE level in 2016 that is slightly lower than the required CAFE level under the 7-Percent Alternative, but the required CAFE levels in 2012 through 2015 under the TCTB Alternative are slightly higher than under the 7-Percent Alternative. In general, the net result is that there is very little substantive difference in the required CAFE level under the 7-Percent and TCTB Alternatives.

As discussed in Sections 1.2.2.2 and 2.2 of this EIS, the CAFE levels required under an attribute-based standard depend on the mix of vehicles produced for sale in the United States.[20] The average fuel economy levels actually achieved by passenger cars and light trucks in a given model year may differ from the required CAFE levels for that model year. This occurs because some manufacturers' average fuel economy levels for their vehicles are projected to exceed the applicable CAFE standards during certain model years,[21] while other manufacturers' fuel economy levels are projected to fall short of either the passenger car or light truck CAFE standards during some model years.[22] Table S-1 shows the MY 2016 required fuel economy levels for each alternative. Table 2.3-1 of this EIS shows the required fuel economy levels for each alternative in each model year, from MY 2012 to MY 2016. For additional detail and discussion of how NHTSA considers the EPCA statutory factors and other considerations that guide the agency's determination of "maximum feasible" standards and inform an evaluation of the alternatives, *see* Section IV.F of the NPRM. For detailed calculations and discussions of manufacturer cost impacts and estimated benefits for each of the alternatives, *see* Sections VII and VIII of the NHTSA Preliminary Regulatory Impact Analysis.

Table S-1 also shows the MY 2016 estimated[23] *achieved* fuel economy levels for each alternative. Table 2.3-2 of this EIS shows the estimated achieved fuel economy levels for each alternative in each model year, from MY 2012 to MY 2016. Comparing the MY 2016 achieved levels with the MY 2016 required levels in Table S-1 shows that estimated achieved mpg in 2016 would actually exceed the average required CAFE level under the No Action Alternative, indicating that some manufacturers would increase average mpg levels under the No Action Alternative.

Table S-1: Required and Achieved MPG by Alternative									
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action*	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
2016 – Required MPG									
Passenger Cars	30.5	35.5	37.2	37.8	39.1	40.9	40.9	42.9	42.3
Light Trucks	24.4	26.9	28.2	28.7	29.6	31.0	31.0	32.6	31.8
Combined	28.1	32.0	33.6	34.1	35.2	36.9	36.9	38.7	38.0
2016 – Achieved MPG									
Passenger Cars	32.4	35.7	37.3	37.7	38.8	40.2	40.3	41.3	41.0
Light Trucks	24.7	26.8	28.0	28.4	29.3	30.5	30.5	31.4	31.1
Combined	29.3	32.1	33.5	33.9	34.9	36.3	36.3	37.2	37.0

*The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agency's vehicle market forecast or the manufacturers' required level of average fuel economy for MY 2011. The numbers listed under Required MPG are representative of this scenario, but would not be implemented as CAFE standards under this alternative.

Under most of the action alternatives, the estimated achieved mpg levels in 2016 would be somewhat lower than the required mpg levels because some manufacturers are not expected to comply fully with passenger car or light truck standards.

Potential Environmental Consequences

This section describes how the proposed action and alternatives could affect energy use, air quality, and climate, which are the resources for which NHTSA performed a quantitative assessment. This EIS describes potential additional impacts on water resources, vegetation, wildlife, land use and development, safety, hazardous materials and regulated wastes, noise, and environmental justice. NHTSA assesses those resource areas qualitatively.[24]

The effects on energy use, air quality, and climate described in this section include *direct*, *indirect*, and *cumulative* effects. Direct effects occur at about the same time and place as the action. Indirect effects occur later in time or are farther removed in distance. Cumulative effects are the incremental impacts resulting from the action added to those of other past, present, and reasonably foreseeable future actions.

When comparing direct and indirect effects with cumulative effects, it is important to understand that the methodology for evaluating direct effects compares the alternatives against a base case in which no further increases in average new passenger car or light truck mpg occur after 2016, whereas the evaluation of cumulative effects assumes that all the alternatives reach the EISA-mandated minimum level of 35 mpg by the year 2020 and ongoing gains in average new passenger car and light truck mpg through 2030.

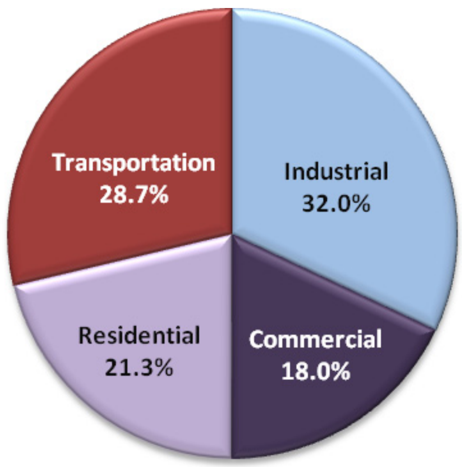
Energy Use

Energy intensity in the United States (energy use per dollar of gross domestic product) has declined steadily at about 2 percent per year since 1973. Despite this continuing improvement in economy-wide energy efficiency, transportation fuel consumption has grown steadily through annual increases, and now represents the major use of petroleum in the U.S. economy.

The transportation sector is the second largest consumer of energy in the United States (after the industrial sector), and as shown in Figure S-1, represents 28.7 percent of U.S. total energy use.[25] This pattern of the industrial and transportation sectors being the first and second largest sectors by energy use, respectively, is also found globally, though at a slightly lower level, with transportation constituting 17.3 percent of non-U.S. world energy use. According to estimates from the U.S. Department of Energy (DOE) Energy Information Administration (EIA), this pattern will continue in the future with U.S. transportation use stabilizing as a percentage of total energy use and non-U.S. consumption increasing as a percentage of total energy use.[26]

Passenger cars and light trucks account for more than half of U.S. energy consumption in this sector, with the remaining consumption spread among heavy trucks, aviation, public transportation, and rail and marine transportation.

Figure S-1. U.S. Energy Consumption by Sector, 2007



Source: http://www.eia.doe.gov/emeu/aer/txt/ptb0201a.html.

As shown in Figure S-2, about 69 percent of the petroleum used in the United States is consumed by the transportation sector. While most U.S. gasoline and diesel is produced domestically, increasing volumes of crude oil are imported for processing in U.S. refineries as domestic crude oil production is steadily declining. Crude oil imports surpassed 10 million barrels per day in 2007, with a high proportion coming from volatile and unstable regions.[27] Despite efforts to increase the use of non-fossil fuels in transportation, fuel use remains largely petroleum based. Biofuels comprise slightly more than 2 percent of fuel use in the U.S. transportation sector and this component is expected to rise to 10 percent by 2030.

To calculate fuel savings for each alternative, NHTSA subtracted fuel consumption under that alternative from the No Action Alternative level. Fuel consumption estimates for 2012 to 2016 are based on the annual mpg increases specified by each alternative.

For 2017 to 2060, the estimates for the direct and indirect effects analysis assume all new vehicles meet the MY 2016 CAFE standards for each action alternative. NHTSA's cumulative effects analysis forces alternatives that are not at least 35 mpg in 2016 to continue to increase so that those alternatives meet the EISA-mandated minimum of 35 mpg by 2020. Once the EISA target is met, the estimates assume the same percent increases in new vehicle mpg for all alternatives through the year 2030. These percent increases are based on average annual mpg projections by the EIA's Annual Energy Outlook (AEO). The AEO forecasts are regarded as the official U.S. government energy projections by both the public and the private sector. The projected mpg increases result from consumer demand and technology advances associated with ongoing projected increases in fuel prices.[28] *See* Sections 3.1.4, 3.2.2, 4.1.3, and 4.2.2 of this EIS for further details about the methodology used for NHTSA's fuel savings calculations.

Key Findings for Energy Use

The fuel consumption figures below are shown for 2060, the year when nearly the entire U.S. fleet is likely to be composed of MY 2016 and later vehicles.

Direct and Indirect Effects

Combined Passenger Cars and Light Trucks

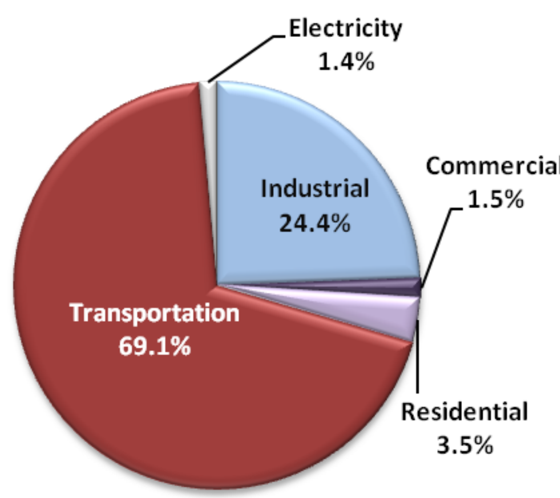
- Total annual fuel savings in 2060 range from **25.5 billion gallons** for Alternative 2 (3-Percent Alternative) **to 59.6 billion gallons** for Alternative 8 (7-Percent Alternative), compared with fuel consumption under the No Action Alternative (Alternative 1).

Passenger Cars

- Annual fuel savings in 2060 range from **17.2 billion gallons** (Alternative 2) **to 39.0 billion gallons** (Alternative 8), compared with fuel consumption under the No Action Alternative.

- Fuel consumption under the No Action Alternative (Alternative 1) is 205.5 billion gallons in 2060. Consumption under the other alternatives ranges from 188.4 billion gallons for Alternative 2 (3-Percent Alternative) to 166.5 billion gallons for Alternative 8 (7-Percent Alternative).

Figure S-2. U.S. Petroleum Consumption by Sector, 2007



Source: http://www.eia.doe.gov/emeu/aer/petro.html.

- Fuel consumption under the Preferred Alternative (Alternative 4) is 179.4 billion gallons in 2060, representing a savings of 26.2 billion gallons, compared with fuel consumption under the No Action Alternative.

Light Trucks

- Annual fuel savings in 2060 range from **8.3 billion gallons** (Alternative 2) **to 20.6 billion gallons** (Alternative 8), compared with fuel consumption under the No Action Alternative.
- Fuel consumption under the No Action Alternative is 113.0 billion gallons in 2060. Fuel consumption under the other alternatives ranges from 104.6 billion gallons for Alternative 2 (3-Percent Alternative) to 92.4 billion gallons for Alternative 8 (7-Percent Alternative).
- Fuel consumption under the Preferred Alternative is 99.4 billion gallons in 2060, representing a savings of 13.5 billion gallons, compared with fuel consumption under the No Action Alternative.

Cumulative Effects

Combined Passenger Cars and Light Trucks

- Total annual fuel savings in 2060 range from **37.5 billion gallons** for Alternative 2 (3-Percent Alternative) to **56.0 billion gallons** for Alternative 8 (7-Percent Alternative), compared with fuel consumption under the No Action Alternative.

Passenger Cars

- Annual fuel savings in 2060 range from **26.0 to 36.9 billion gallons.**
- Fuel consumption under the No Action Alternative is 193.2 billion gallons in 2060. Under the other alternatives, it ranges from 167.3 billion gallons for Alternative 2 (3-Percent Alternative) to 156.3 billion gallons for Alternative 8 (7-Percent Alternative).
- Fuel consumption under the Preferred Alternative is 167.2 billion gallons in 2060, representing a savings of 26.0 billion gallons compared with fuel consumption under the No Action Alternative.

Light Trucks

- Annual fuel savings in 2060 range from **11.5 billion gallons** (Alternative 2) **to 19.1 billion gallons** (Alternative 8).
- Fuel consumption under the No Action Alternative is 103.8 billion gallons in 2060. Under the other alternatives it ranges from 92.2 billion gallons for Alternative 2 (3-Percent Alternative) to 84.6 billion gallons for Alternative 8 (7-Percent Alternative).
- Fuel consumption under the Preferred Alternative is 91.2 billion gallons in 2060, representing a savings of 12.6 billion gallons.

Figure S-3 illustrates each of the alternatives' *direct and indirect effects* on annual fuel savings for passenger cars and light trucks in 2020, 2040, and 2060. For readers interested in additional details about the alternatives' *direct and indirect* effects on annual fuel consumption, *see* Tables 3.2.3-1 and 3.2.3-2 in this EIS and the accompanying discussion. Figure S-4 illustrates each of the alternatives' *cumulative* effects on annual fuel savings for passenger cars and light trucks in 2020, 2040, and 2060. For readers interested in additional details about the alternatives' *cumulative* effects on annual fuel consumption, *see* Tables 4.2.3-1 and 4.2.3-2 in this EIS and the accompanying discussion.

Air Quality

Air pollution and air quality can affect public health, public welfare, and the environment. The alternative MYs 2012–2016 CAFE standards under consideration would affect air pollutant emissions and air quality. This EIS air quality analysis assesses the impacts of the action alternatives in relation to emissions of pollutants of concern from mobile sources and the resulting health effects and monetized health benefits.

Under the authority of the Clean Air Act and its amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six relatively common air pollutants—known as "criteria" pollutants because EPA regulates them by developing human-health-based and/or environmentally based criteria for setting permissible levels. The criteria pollutants are carbon monoxide, nitrogen dioxide (NO_2), ozone, sulfur dioxide (SO_2), particulate matter (PM_{10} and $PM_{2.5}$), and lead. Ozone is not emitted directly from vehicles, but is formed from emissions of the ozone precursor pollutants nitrogen oxides (NO_x) and volatile organic compounds (VOCs).

In addition to criteria pollutants, motor vehicles emit some substances defined as hazardous air pollutants by the 1990 Clean Air Act Amendments. Hazardous air pollutants include certain VOCs, compounds in PM, pesticides, herbicides, and radionuclides that present tangible hazards, based on scientific studies of human (and other mammal) exposure.

Figure S-3. Annual Fuel Savings of Passenger Cars and Light Trucks by Alternative, Direct and Indirect Impacts

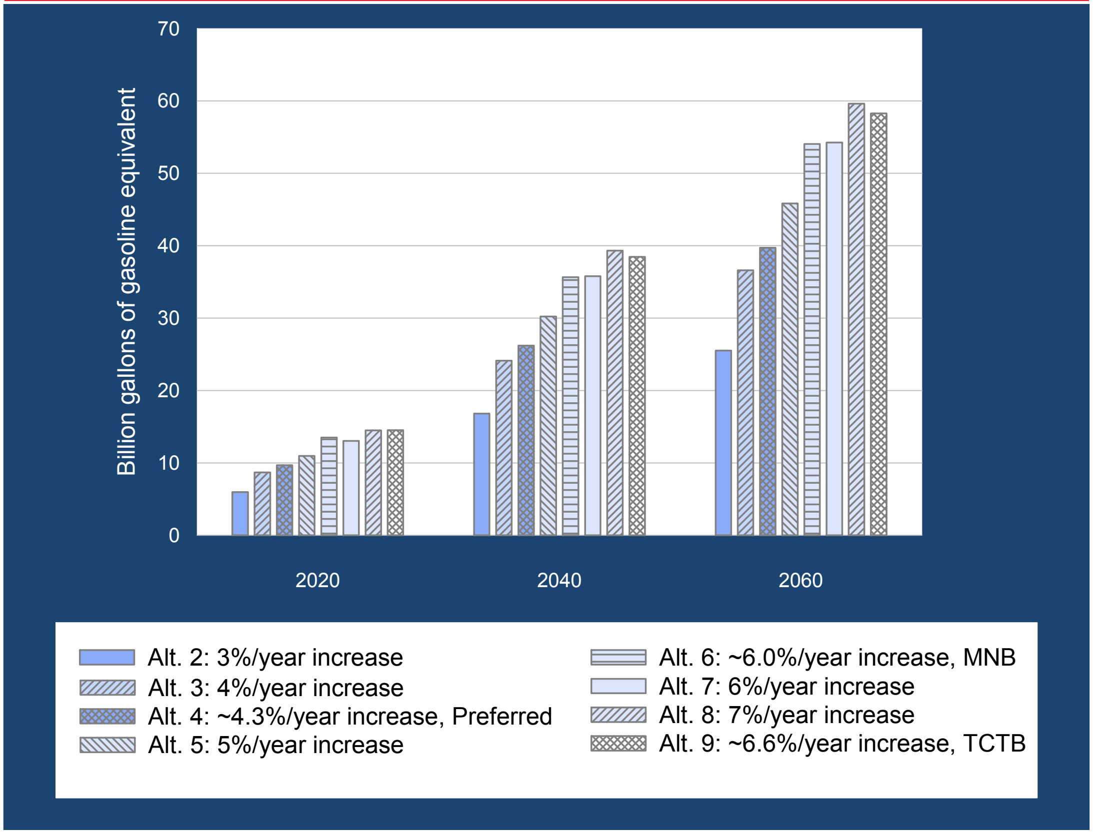
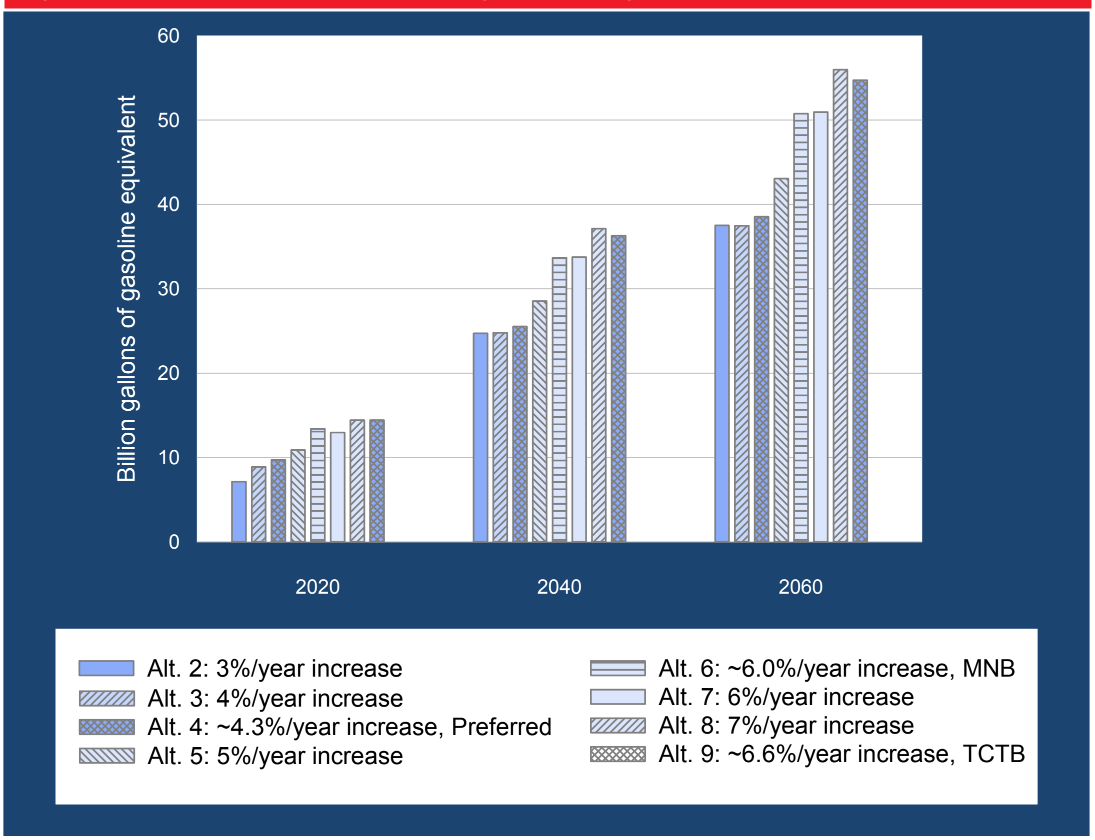


Figure S-4. Annual Fuel Consumption of Passenger Cars and Light Trucks by Alternative, Cumulative Impacts



Hazardous air pollutants from vehicles are known as mobile source air toxics (MSATs). The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde. EPA and the Federal Highway Administration (FHWA) have identified these air toxics as the MSATs that typically are of greatest concern for impacts of highway vehicles. DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class.

Health Effects of the Pollutants

The criteria pollutants assessed in this EIS have been shown to cause a range of health effects at various concentrations and exposures, including:

- Damage to lung tissue (*e.g.*, ozone, particulate matter);
- Reduced lung function (*e.g.*, ozone, nitrogen dioxide, sulfur dioxide, particulate matter);
- Exacerbation of existing respiratory and cardiovascular diseases (*e.g.*, ozone, nitrogen dioxide, particulate matter, sulfur dioxide);
- Difficulty breathing (*e.g.*, ozone, nitrogen dioxide, particulate matter, sulfur dioxide);
- Irritation of the upper respiratory tract (*e.g.*, ozone, nitrogen dioxide, sulfur dioxide);
- Bronchitis and pneumonia (*e.g.*, nitrogen dioxide);
- Reduced resistance to respiratory infections (*e.g.*, nitrogen dioxide);
- Alterations to the body's defense systems against foreign materials (*e.g.*, particulate matter);
- Reduced delivery of oxygen to the body's organs and tissues (*e.g.*, carbon monoxide);
- Impairment of the brain's ability to function properly (*e.g.*, carbon monoxide); and
- Cancer (*e.g.*, particulate matter) and premature death (*e.g.*, ozone, sulfur dioxide).

MSATs are also associated with health effects. For example, acetaldehyde, benzene, 1-3 butadiene, formaldehyde, and certain components of DPM are all classified by EPA as either known or probable human carcinogens. In addition, many MSATs are also associated with noncancer health effects, such as respiratory irritation.

Contribution of the U.S. Transportation Sector to Air Pollutant Emissions

The U.S. transportation sector is a major source of emissions of certain criteria pollutants or their chemical precursors. Emissions of these pollutants from on-road mobile sources (passenger cars and light trucks) have declined dramatically since 1970 as a result of pollution controls on vehicles and regulation of the chemical content of fuels.

Passenger cars and light trucks remain responsible for about 50 percent of total U.S. emissions of carbon monoxide, 4 percent of $PM_{2.5}$ emissions, and 1 percent of PM_{10} emissions. They also contribute about 21 percent of total nationwide emissions of volatile organic compounds and 32 percent of NO_x, both of which are chemical precursors of ozone. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors. Passenger cars and light trucks contribute only 1 percent of SO_2, but SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere. With the elimination of lead in gasoline, lead is no longer emitted from motor vehicles in more than negligible quantities, and thus is not assessed in this analysis.

Key Findings for Air Quality

The findings for direct and indirect effects are shown for the year 2030 when most of the fleet in operation would meet at least the MYs 2012–2016 standards. Findings for cumulative effects are shown for the year 2050 when most of the fleet would achieve the average fuel economy levels the agency projects in 2030 based on AEO fuel economy forecasts. The No Action Alternative results in the highest emissions of most criteria pollutants. For hazardous air pollutants (MSATs), some of the alternatives result in slightly higher emissions of some hazardous air pollutants, when compared with emission levels under the No Action Alternative.

With a few exceptions, cumulative emissions reductions are higher than noncumulative emissions reductions for the same combination of pollutant, year, and alternative, due to differences in vehicle miles traveled and fuel consumption under the cumulative case compared with the noncumulative case.

Monetized $PM_{2.5}$-related health benefits, and related incidence of reduced health effects from the emissions reductions, were estimated by multiplying direct $PM_{2.5}$ and $PM_{2.5}$ precursor emission reductions (NO_x, SO_x, and VOCs) by the pollutant-specific benefit-per-ton estimates supplied by EPA. Health outcomes include premature mortality, chronic bronchitis, respiratory emergency room visits, and work-loss days. The economic benefits associated with reductions in health outcomes reflect a valuation of human health, as determined by EPA.

EPA used the Value of Statistical Life (VSL) metric to calculate the economic benefits associated with reducing the risk of premature mortality. An estimated VSL of $6.3 million (in year 2000 dollars), as established by EPA in 2009, was used for this study. For other health-related effects, EPA used Willingness-to-Pay estimates derived from the valuation literature, estimated health care expenses, and lost wages in the valuation of economic benefits.

Direct and Indirect Effects

Criteria Pollutants

- Emissions of $PM_{2.5}$, SO_x, NO_x, and VOCs in 2030 are highest in the No Action Alternative, and **generally decline as fuel economy standards increase** across the alternatives.

- Emissions of carbon monoxide are slightly higher under Alternatives 2 through 4 than under the No Action Alternative, but generally decline as fuel economy standards increase under Alternatives 5 through 9.

- Emissions of carbon monoxide, NO_x, and VOCs in 2030 are lowest under Alternative 8, emissions of SO_x are lowest under Alternative 9, and emissions of $PM_{2.5}$ are lowest under Alternative 4.

Hazardous Air Pollutants

- The changes in toxic air pollutant emissions, whether positive or negative, are **generally small in relation to emission levels under the No Action Alternative.**

- Emissions of acetaldehyde in 2030 increase with each successive alternative from the No Action Alternative to Alternative 4, decline from Alternative 5 to Alternative 8, and then increase slightly with Alternative 9. Acetaldehyde emissions in 2030 are highest under Alternative 4 and lowest under Alternative 8.

- Emissions of acrolein and formaldehyde in 2030 generally increase under each successive alternative from the No Action Alternative to Alternative 9, except for a slight decrease in formaldehyde emissions from the No Action Alternative to Alternative 2.

- Emissions of benzene and diesel particulate matter in 2030 generally decrease under each successive alternative from the No Action Alternative to Alternative 9. Emissions are highest under the No Action Alternative and lowest under Alternative 8.

- Emissions of 1,3-butadiene increase under each successive alternative from the No Action Alternative to Alternative 3 and then generally decrease from Alternative 4 to Alternative 9. Emissions of 1,3-butadiene are lowest under Alternative 8.

Health and Health Benefits

- Alternatives 2 through 9 would **reduce adverse health effects nationwide** compared with the No Action Alternative. Reductions become larger as fuel economy standards increase.

- The monetized benefits also follow the same patterns as reductions in adverse health effects. When estimating quantified and monetized health impacts, EPA relies on results from two $PM_{2.5}$-related premature mortality studies it considers co-equal (Pope *et al.*, 2002 and Laden *et al.*, 2006). EPA recommends that monetized benefits be shown using incidence estimates derived from each of these studies and valued using both a 3-percent and 7-percent discount rate to account for an assumed lag in the occurrence of mortality after exposure (EPA assumes a 20-year distributed "cessation lag"), for a total of four analyses. *See* Sections 3.3.2.4.2, 3.3.3.3.3 of this EIS. Estimated **benefits** in annual health costs **range from $1.2 billion for Alternative 2** (lowest of the four analyses) **to $5.6 billion for Alternative 9** (highest of the four analyses).

Cumulative Effects

Criteria Pollutants

- As with the direct effects, cumulative emissions of $PM_{2.5}$, SO_x, NO_x, and VOCs in 2050 are highest under the No Action Alternative and generally decline (with some exceptions) as fuel economy standards increase across alternatives. **In every case, emissions of these pollutants remain below those of the No Action Alternative.**

- Cumulative emissions of carbon monoxide in 2050 under Alternatives 2 through 4 are slightly higher than those of the No Action Alternative, and are lower than the No Action Alternative under Alternatives 5 through 9.

- Cumulative emissions of carbon monoxide, NO_x, and VOC in 2050 are lowest under Alternative 8, emissions of SO_x are lowest under Alternative 9, and emissions of $PM_{2.5}$ are lowest under Alternative 4.

Hazardous Air Pollutants

- The changes in toxic air pollutant emissions, whether positive or negative, are **generally small in relation to emission levels under the No Action Alternative.**
- Annual cumulative emissions of acetaldehyde in 2050 increase with each successive alternative from the No Action Alternative to Alternative 3 and then decline, though not consistently, from Alternative 4 to Alternative 9. Acetaldehyde emissions in 2050 are highest under Alternative 4 and lowest under Alternative 8.
- Annual cumulative emissions of acrolein and formaldehyde in 2050 generally increase under each successive alternative from the No Action Alternative to Alternative 6, and then decline, though not consistently, from Alternative 6 to Alternative 9. Acrolein emissions are highest under Alternative 8 and lowest under the No Action Alternative. Formaldehyde emissions are highest under Alternative 8 and lowest under Alternative 2.
- Annual cumulative emissions of benzene and diesel particulate matter in 2050 decrease, though not consistently, across the alternatives, and are lowest under Alternative 8.
- Annual cumulative emissions of 1,3-butadiene in 2050 increase from the No Action Alternative to Alternative 2 and then decrease, though not consistently, under each successive alternative from Alternative 3 to Alternative 9.

Health and Health Benefits

- As with the direct effects, Alternatives 2 through 9 would reduce adverse health effects nationwide compared with the No Action Alternative.
- Estimated monetized health benefits range from **$3.36 billion for Alternative 2 to $10.32 billion for Alternative 9** (lowest and highest of the four monetized health benefit analyses as explained above).

For readers interested in additional detail, Tables 3.3.3-1, 3.3.3-3, 3.3.3-4, 3.3.3-6, and 3.3.3-9 of this EIS provide data on direct effect criteria pollutant and hazardous air pollutant emissions, as well as monetized health benefits for the alternatives. Tables 4.3.3-1 through 4.3.3-4 of this EIS provide cumulative effects data on criteria pollutant and hazardous air pollutant emissions. Table 4.3.3-9 of this EIS provides cumulative effects data on monetized health benefits from the alternatives.

Climate

The Earth's natural greenhouse effect makes the planet habitable for life as we know it. *See* Figure S-5. Carbon dioxide (CO_2) and other GHGs trap heat in the troposphere (the layer of the atmosphere that extends from Earth's surface up to about 8 miles above the surface), absorb heat energy emitted by Earth's surface and lower atmosphere, and reradiate much of it back to the surface. Without GHGs in the atmosphere, most of this heat energy would escape back to space.

The amount of CO_2 and other natural GHGs in the atmosphere, such as methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone, has fluctuated over time, but natural emissions of GHGs are largely balanced by natural sinks, such as vegetation (which, when buried and compressed in the Earth over long periods of time, becomes fossil fuel) and the oceans, which remove the gases from the atmosphere.

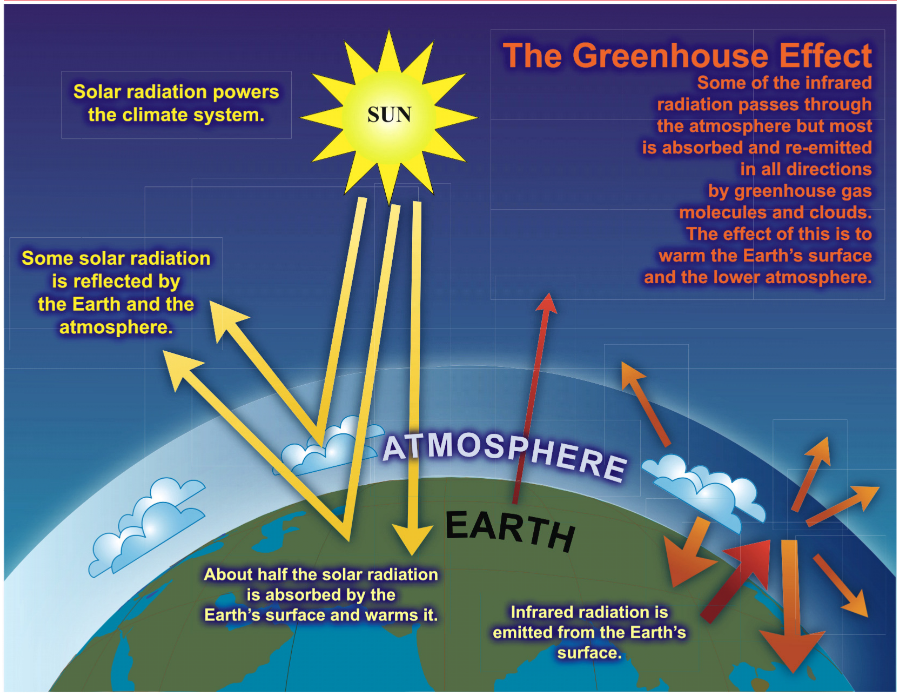
Since the industrial revolution, when fossil fuels began to be burned in increasing quantities, concentrations of GHGs in the atmosphere have increased. CO_2 has increased by more than 38 percent since pre-industrial times, while methane's concentration is now 149 percent above pre-industrial levels.[29]

This buildup of GHGs in the atmosphere is upsetting Earth's energy balance and causing the planet to warm, which in turn affects sea levels, precipitation patterns, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientists refer to this phenomenon as "global climate change."

During the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (0.74 °Celsius), and sea levels have risen 6.7 inches (0.17 meter), with a maximum rate of about 0.08 inch (2 millimeters) per year over the past 50 years on the northeastern coast of the United States.[30]

Most scientists now agree that climate change is very likely due to GHG emissions from human activities.[31] Human activities, such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees, can contribute to increased concentrations of these gases in the atmosphere.

Figure S-5. The Greenhouse Effect[32]



Throughout this EIS, NHTSA has relied extensively on findings of the United Nations Intergovernmental Panel on Climate Change (IPCC), the U.S. Climate Change Science Program (CCSP), and EPA. Our discussion relies heavily on the most recent, thoroughly peer reviewed, and credible assessments of global and U.S. climate change – the IPCC Fourth Assessment Report (*Climate Change* 2007), the EPA Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act and the accompanying Technical Support Document (TSD), and CCSP and National Science and Technology Council reports that include *Scientific Assessment of the Effects of Global Change on the United States* and Synthesis and Assessment Products. [33] This EIS frequently cites these sources and the studies they review.

Impacts of Climate Change

Climate change is expected to have a wide range of impacts on temperature, sea level, precipitation patterns, severe weather events, and water resources, which in turn could affect human health and safety, infrastructure, food and water supplies, and natural ecosystems.

- Impacts to **freshwater resources** could include changes in precipitation patterns; decreasing aquifer recharge in some locations; changes in snowpack and timing of snowmelt; saltwater intrusion from sea-level changes; changes in weather patterns resulting in flooding or drought in certain regions; increased water temperature; and numerous other changes to freshwater systems that disrupt human use and natural aquatic habitats.
- Impacts to **terrestrial ecosystems** could include shifts in species range and migration patterns, potential extinctions of sensitive species unable to adapt to changing conditions, increases in the occurrence of forest fires and pest infestation, and changes in habitat productivity due to increased atmospheric concentrations of CO_2.
- Impacts to **coastal ecosystems** could include the loss of coastal areas due to submersion and erosion, additional impacts from severe weather and storm surges, and increased salinization of estuaries and freshwater aquifers.
- Impacts to **land use** could include flooding and severe-weather impacts to coastal, floodplain, and island settlements; extreme heat and cold waves; increases in drought in some locations; and weather- or sea-level-related disruptions of the service, agricultural, and transportation sectors.
- Impacts to **human health** could include increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water and food-borne diseases, changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition.

In addition to its role as a GHG in the atmosphere, CO_2 is transferred from the atmosphere to water, plants, and soil. In water, CO_2 combines with water molecules to form carbonic acid. When CO_2 dissolves in seawater, a series of well-known chemical reactions begins that increases the concentration of hydrogen ions and make seawater more acidic, which has adverse effects on corals and some other marine life.

Increased concentrations of CO_2 in the atmosphere can also stimulate plant growth to some degree, a phenomenon known as the CO_2 fertilization effect. The available evidence indicates that different plants respond in different ways to enhanced CO_2 concentrations.

Contribution of the U.S. Transportation Sector to Climate Change

Contributions to the build-up of GHG in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity. Emissions from the United States account for about 17.2 percent of total global CO_2 emissions. As shown in Figure S-6, the U.S. transportation sector contributed 31.5 percent of total U.S. CO_2 emissions in 2007, with passenger cars and light trucks accounting for 60.6 percent of total U.S. CO_2 emissions from transportation.[34] Thus, 19.1 percent of total U.S. CO_2 emissions come from passenger cars and light trucks. Viewed globally, passenger cars and light trucks in the United States account for roughly 3.3 percent of total global CO_2 emissions.

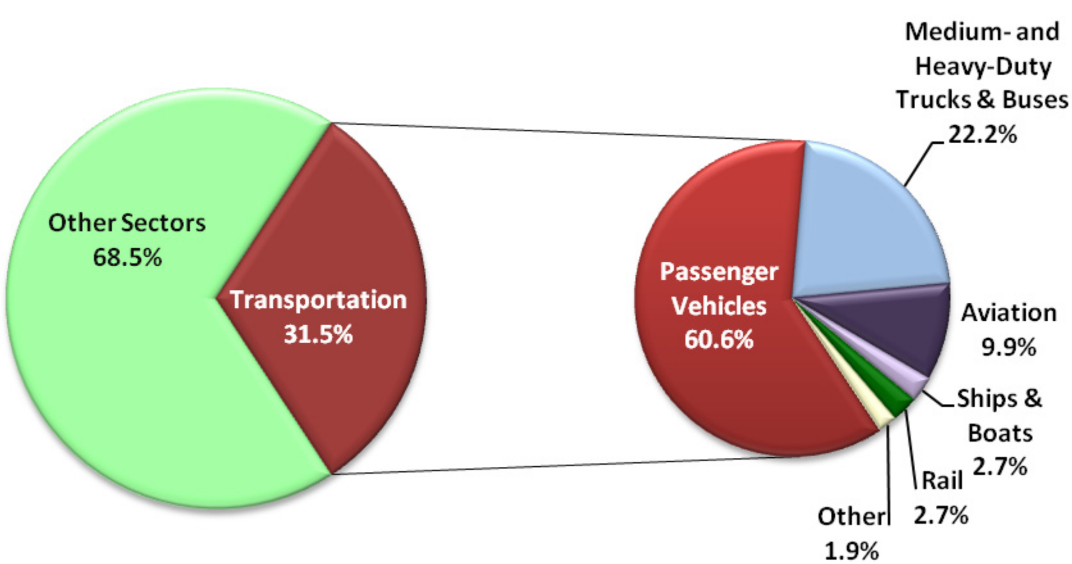
Key Findings for Climate

The proposed action and alternatives have the potential to substantially decrease the growth in GHG emissions, resulting in reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level that are otherwise projected to occur. They would also, to a small degree, reduce the impacts and risks of climate change.

Note that under all of the alternatives analyzed in this EIS, growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use (annual vehicle miles traveled per vehicle), is projected to result in growth in total passenger car and light truck travel. This growth in travel outpaces improvements in fuel economy for each of the action alternatives, resulting in projected increases in total fuel consumption by U.S. passenger cars and light trucks (*see* Figure S-7).

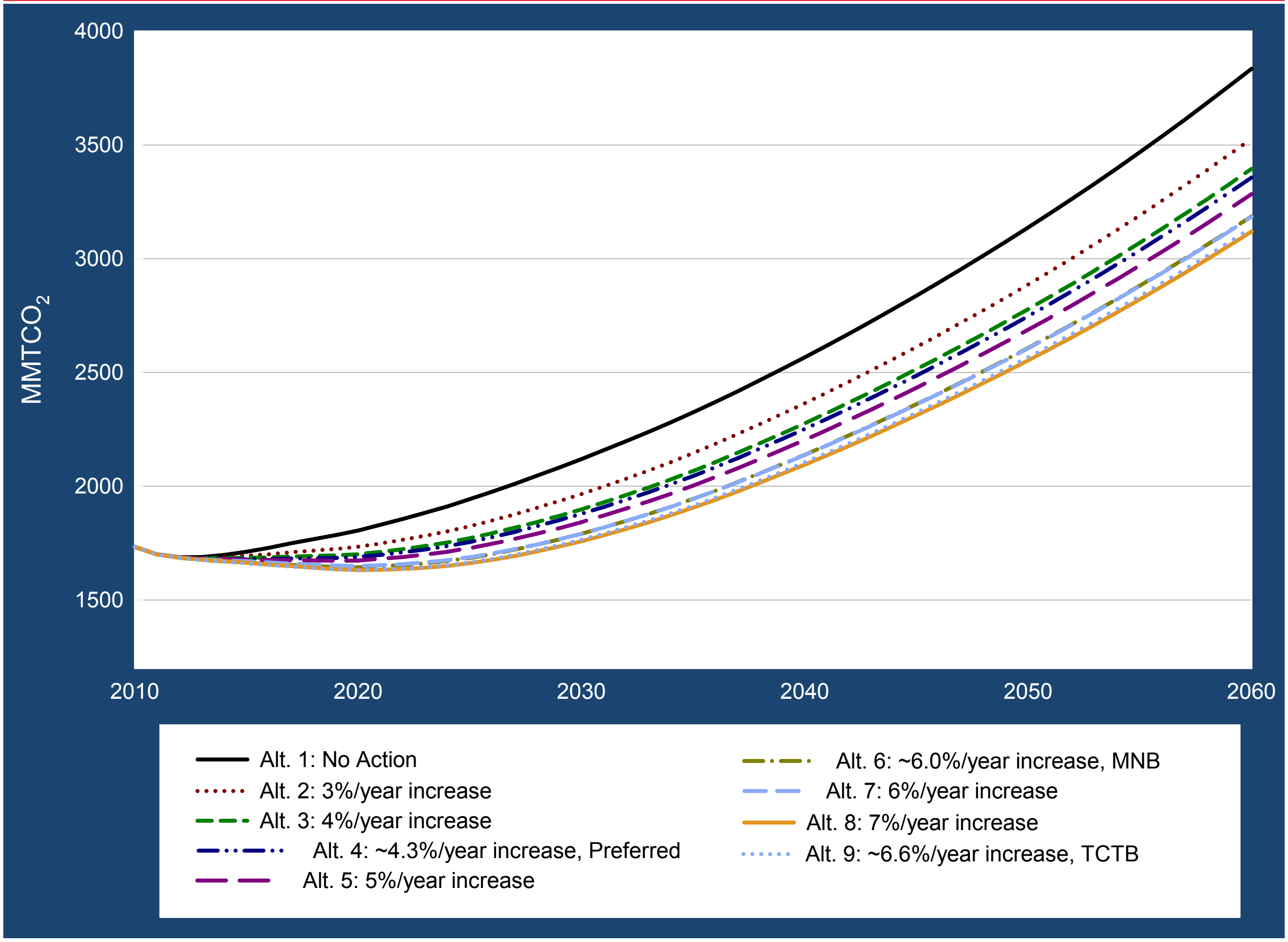
Because CO_2 emissions are a direct consequence of fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks. NHTSA estimates that the proposed CAFE standards will reduce fuel consumption and CO_2 emissions from what they otherwise are estimated to be in the absence of the CAFE program (*i.e.*, fuel consumption and CO_2 emissions under the "no action" alternative).

Figure S-6. U.S. Transportation Sector's Contribution to U.S. Greenhouse Gas Emissions



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007.

Figure S-7. Projected Annual Greenhouse Gas Emissions by Alternative, Direct and Indirect Impacts



The global emissions scenario used in the cumulative effects analysis (and described in Chapter 4 of this EIS) differs from the global emissions scenario used for the climate change modeling for direct and indirect effects. In the cumulative analysis, the Reference Case climate change scenario used in the modeling analysis reflects reasonably foreseeable actions in global climate change policy; the global emissions scenario used for the analysis of direct and indirect effects assumes that no significant global controls on GHG emissions are adopted. *See* Section 4.4.3.3 of this EIS for additional explanation of the cumulative effects methodology.

The figures for GHG emissions and reductions below are summed for the period 2012 through 2100 under each of the nine alternatives.

Direct and Indirect Effects

Greenhouse Gas Emissions

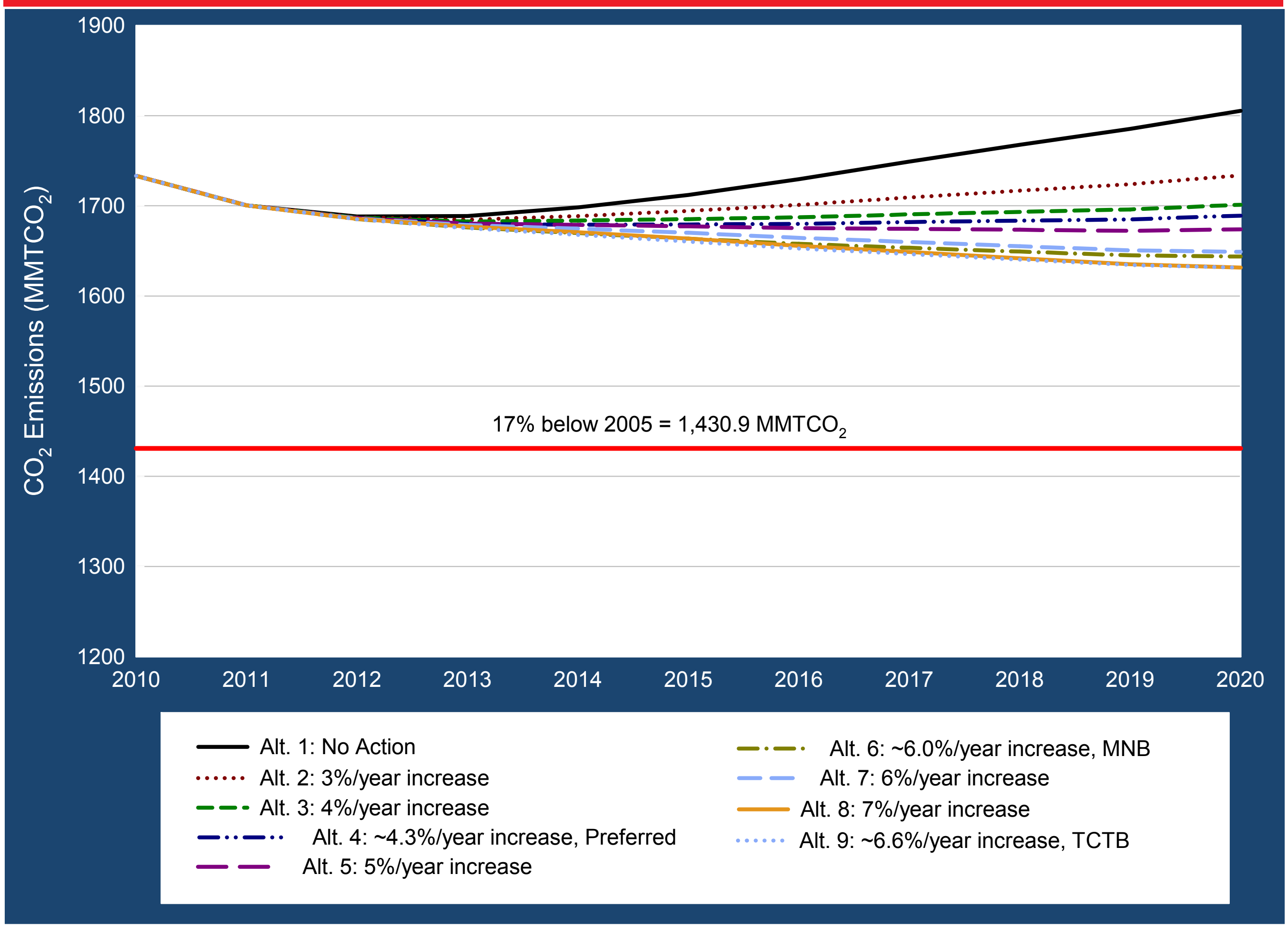
- Compared with total projected U.S. CO_2 emissions in 2100 of 7,886 million metric tons of carbon dioxide equivalent ($MMTCO_2$), the action alternatives would **reduce annual U.S. CO_2 emissions by 3.9 to 9.1 percent in 2100**. *See* Figure S-7.
- Compared with cumulative global emissions of 5,293,896 MMTCO2 over this period, the action alternatives are expected to reduce annual global CO_2 emissions by between 0.4 percent (Alternative 2) and 0.9 percent (Alternative 9).
- Average annual CO_2 emission reductions from the CAFE alternatives range from 232 to 543 $MMTCO_2$ over 2012–2100, **equivalent to the annual CO_2 emissions of 60 to 141 coal-fired power plants.**[35]

- The emissions reductions from the alternatives are equivalent to **the annual emissions of between 3.60 million cars (Alternative 2) and 9.70 million cars (Alternative 9)** in 2016, compared with the No Action Alternative. Emissions reductions in 2016 from the Preferred Alternative (Alternative 4) are equivalent to the annual emissions of 6.26 million cars.

- President Obama recently submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020,[36] in association with the Copenhagen Accord, and in conformity with anticipated U.S. energy and climate legislation. While this rulemaking contributes to meeting that goal, the alternatives would **result in projected CO_2 emissions from the light duty vehicle sector in 2020 in the range of 0.6 percent above (Alternative 2) to 5.4 percent below (Alternative 9) 2005 levels.** Thus, no alternative would reduce 2020 emissions from cars and light trucks to 17 percent below 2005 levels, due to the fact that total vehicles miles traveled (VMT) increase under all scenarios.[37] *See* Figure S-8.

The President's stated policy goal outlined above does not specify that every emitting sector of the economy must contribute equally proportional emissions reductions. Significantly, the action of setting fuel economy standards does not directly regulate total emissions from passenger cars and light trucks. NHTSA's authority to promulgate new fuel economy standards is limited and does not allow regulation of other factors affecting emissions, including society's driving habits. *See* Section 3.4.4.1 of this EIS for additional discussion relating NHTSA's action to this policy goal.

Figure S-8. Projected Annual CO_2 Emissions by Alternative Compared with 17% below 2005 Levels, Direct and Indirect Impacts



CO_2 Concentration, Global Mean Surface Temperature, Sea-Level Rise, and Precipitation

CO_2 emissions affect the concentration of CO_2 in the atmosphere, which in turn affects global temperature, sea level, and precipitation patterns. The impacts of the proposed action and alternatives on temperature, precipitation, or sea-level rise are small in absolute terms, because the action alternatives result in a small proportional change to the emissions trajectories in the reference scenario to which the alternatives were compared. Although these effects are small, they occur on a global scale and are long-lived.

- Estimated CO_2 concentrations in the atmosphere for the year 2100 range from **778.4 parts per million (ppm) under Alternative 8 to 783.0 ppm under the No Action Alternative.**
- For 2100, the reduction in temperature **for the action alternatives, as compared to the No Action Alternative, ranges from 0.01 °F (0.007 °C) to 0.03 °F (0.018 °C).** *See* Figure S-9.
- Projected sea-level rise in 2100 ranges from 14.96 inches (38.00 centimeters) under the No Action Alternative to 14.89 inches (37.84 centimeters) under the TCTB Alternative. Thus, the action alternatives will result in a **maximum reduction of sea-level rise equal to 0.06 inches (0.16 centimeters) by 2100** from the level projected under the No Action Alternative.

Cumulative Effects

Greenhouse Gas Emissions

- Compared with projected global emissions of 3,919,462 $MMTCO_2$ from 2012 through 2100, the incremental impact of this rulemaking is expected to **reduce global CO_2 emissions by about 0.8 to 1.2 percent** from their projected levels under the No Action Alternative. *See* Figure S-10.
- Projections of emissions reductions over the 2012 through 2100 period due to the MYs 2012–2016 CAFE standards and other reasonably foreseeable future actions (i.e., forecasted fuel economy increases resulting from projected demand for fuel economy) ranged from **30,200 to 45,600 $MMTCO_2$**.

Figure S-9. Reduction in Global Mean Temperature Compared with the No Action Alternative, Direct and Indirect Impacts

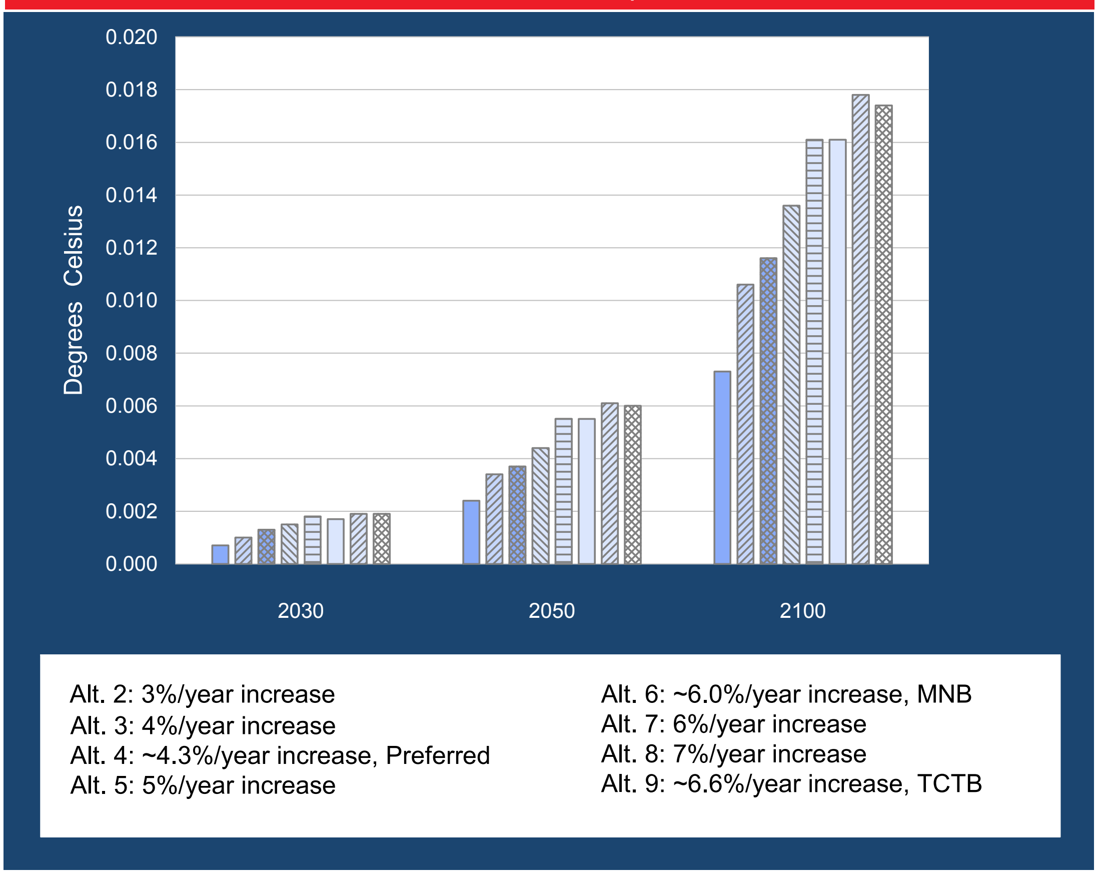
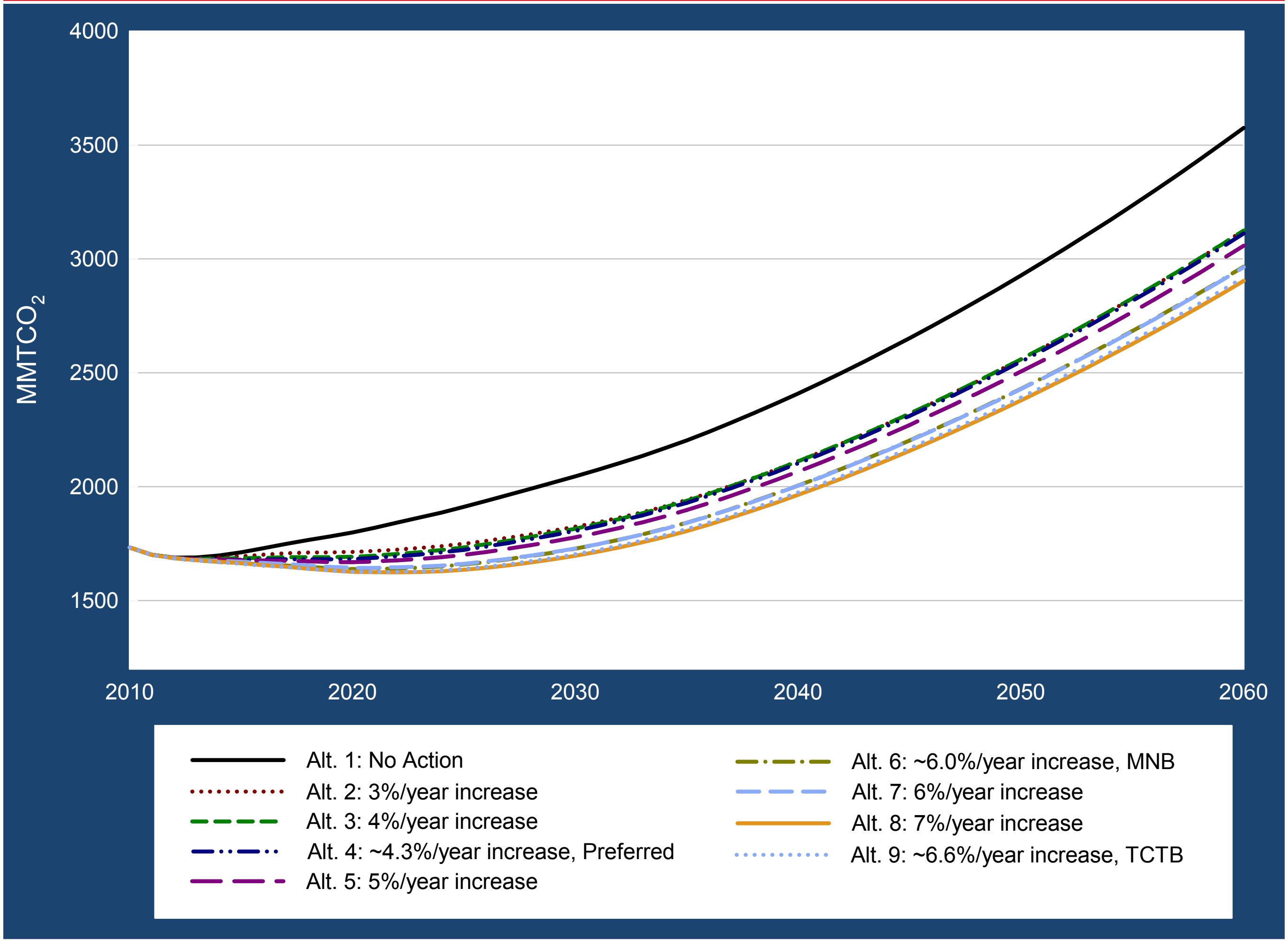


Figure S-10. Projected Greenhouse Gas Emissions by Alternative, Cumulative Impacts



- This action contributes to meeting the President's goal of returning GHG emissions to 17 percent below 2005 levels by 2020. The alternatives would **reduce projected CO_2 emissions from the light duty vehicle sector in 2020 by 0.7 percent (Alternative 2) to 5.7 percent (Alternative 9) below 2005 levels.** *See* Figure S-11.

CO_2 Concentration, Global Mean Surface Temperature, Sea-Level Rise, and Precipitation

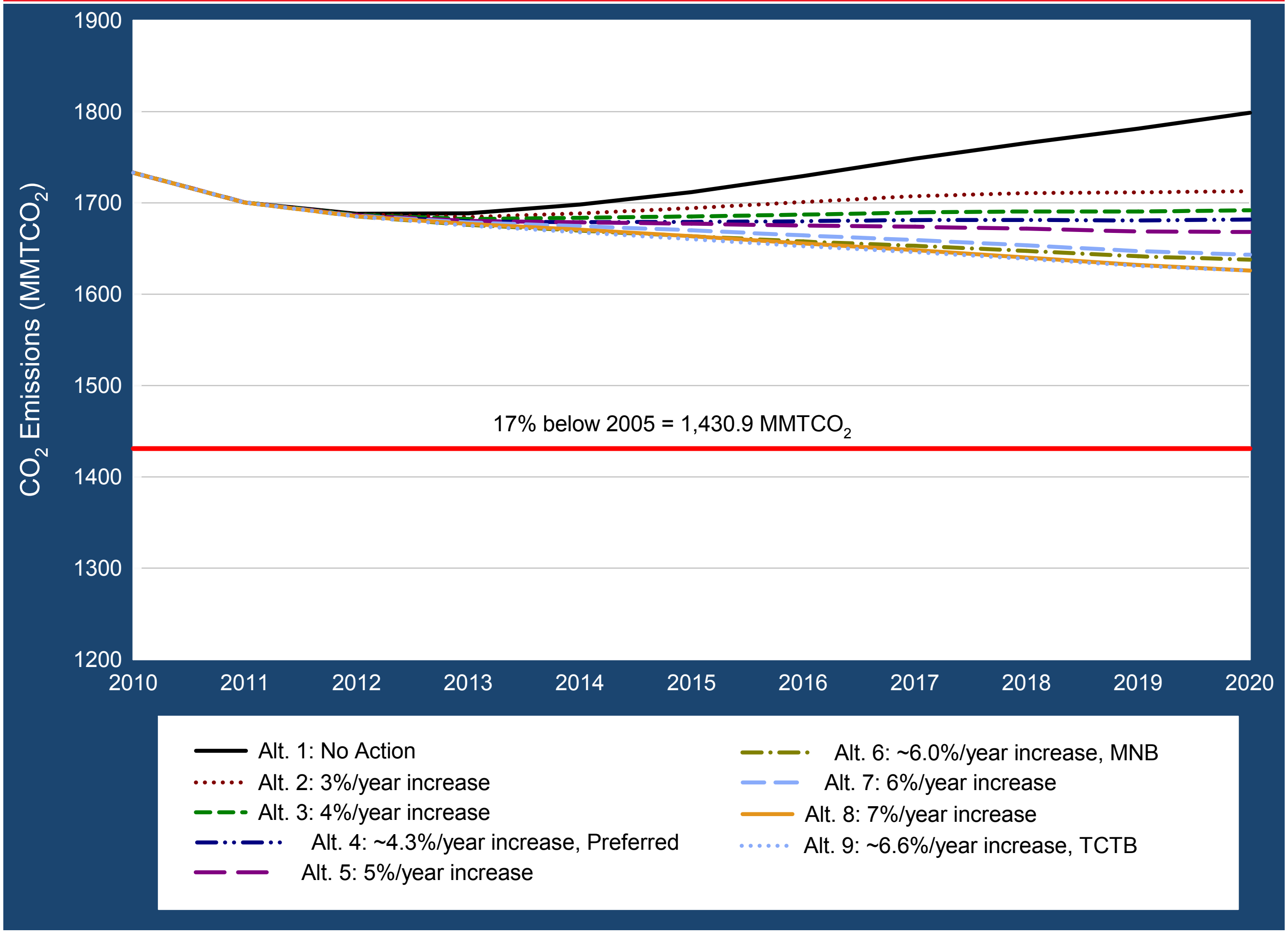
- Estimated CO_2 concentrations in the atmosphere for the year 2100 range from **653.4 ppm under Alternative 8 to 657.4 ppm under the No Action Alternative.**
- For 2100, **the reduction in temperature increase for the action alternatives in relation to the No Action Alternative is about 0.02 to 0.04° F (0.01 to 0.02 °C).** *See* Figure S-12.
- Projected sea-level rise in 2100 ranges from 12.93 inches (32.84 centimeters) under the No Action Alternative to 12.87 inches (32.68 centimeters) under the TCTB Alternative (Alternative 9). Thus, the CAFE action alternatives will result in a maximum **reduction of sea level rise equal to 0.06 inches (0.16 centimeters) by 2100** from the level that would occur under the No Action Alternative.

Readers interested in further details about the direct, indirect, and cumulative climate impacts should consult Sections 3.4 and 4.4 of this EIS.

Health, Societal, and Environmental Impacts of Climate Change

The magnitude of the changes in climate effects that the alternatives would produce (4 ppm of CO_2, a few hundredths of a degree difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 millimeters of sea-level rise) are

Figure S-11. Projected Annual CO_2 Emissions by Alternative Compared with 17% below 2005 Levels, Cumulative Impacts



too small to address quantitatively in terms of their impacts on health, society, and the environment. Given the enormous resource values at stake, these distinctions could be important, but they are too small for current quantitative techniques to resolve. For detailed discussion of climate change's impacts on various resource sectors, *see* Section 4.5 of this EIS.

The changes in non-climate impacts (such as ocean acidification by CO_2) associated with the alternatives are also difficult to assess quantitatively. However, it is clear that a reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce the ocean acidification effect and the CO_2 fertilization effect. For additional discussion of non-climate environmental impacts, *see* Section 3.5 of this EIS.

Mitigation

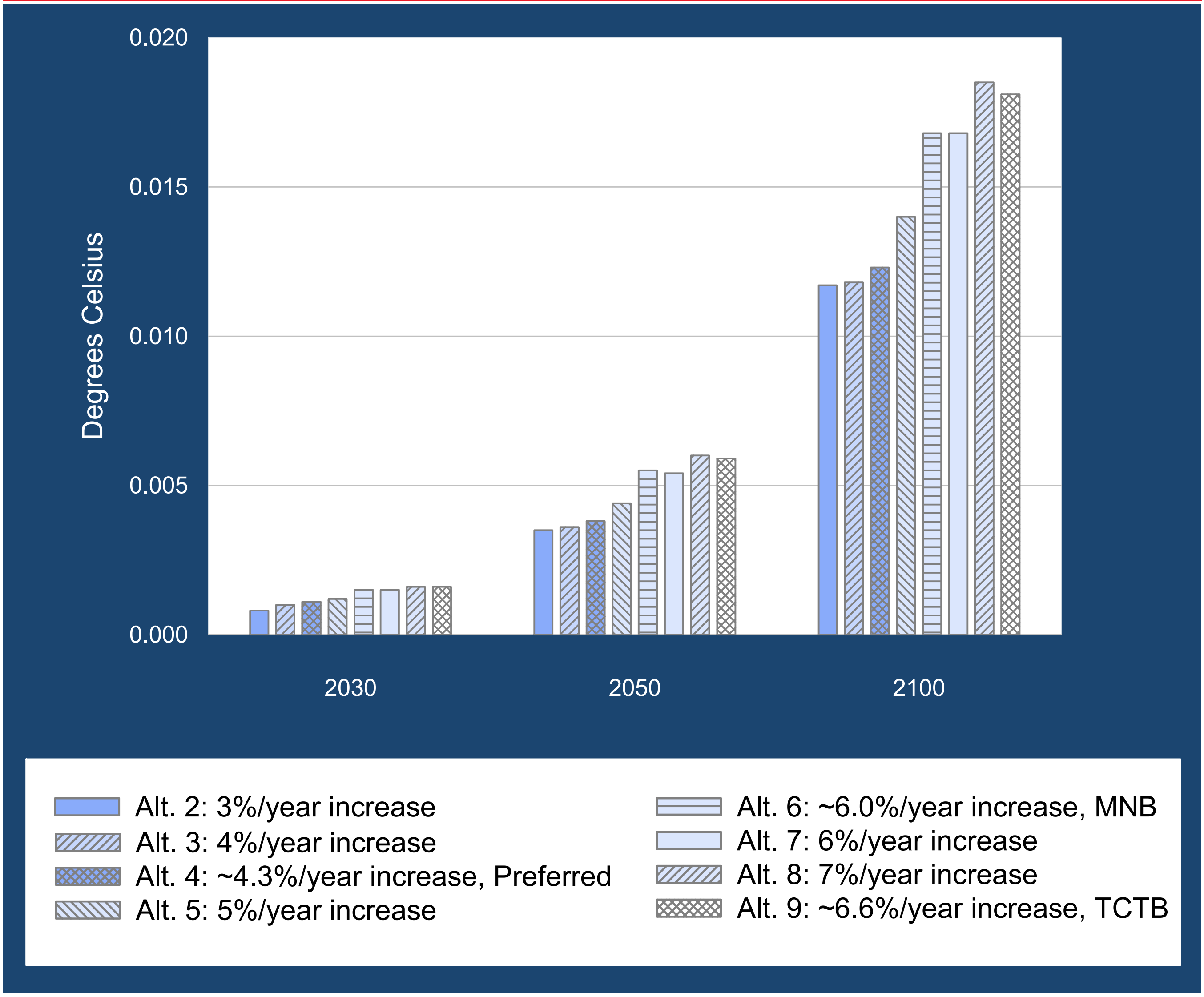
CEQ regulations for implementing the procedural requirements of NEPA require that the discussion of alternatives in an EIS "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives."[38] In particular, an EIS should discuss the "[m]eans to mitigate adverse environmental impacts."[39]

Under NEPA, an agency does not have to formulate and adopt a complete mitigation plan, but should analyze possible measures that could be adopted. An agency should state in its Record of Decision whether all practicable means to avoid or reduce environmental harm have been adopted into the selected alternative.[40]

Energy and Climate

Each of the action alternatives would reduce energy consumption and GHG emissions from vehicles sold in the United States compared with the No Action Alternative, resulting in a net beneficial effect. Although an agency typically does not propose mitigation measures for an action resulting in a net beneficial effect, NHTSA would like to highlight

Figure S-12. Cumulative Effects on Global Mean Temperature (Reduction Compared with the No Action Alternative)



several other federal programs, which in conjunction with NHTSA CAFE standards, can make significant contributions in further reducing energy consumption and GHG emissions.

The programs described below present the potential for future developments and advances that could provide further beneficial environmental effects.

- EPA administers Renewable Fuel Standards under Section 211(o) of the Clean Air Act. EPA estimates that the greater volumes of biofuel mandated by proposed standards would reduce GHG emissions from transportation by approximately 160 MMTCO$_2$ equivalent per year.
- DOT, in coordination with EPA and the U.S. Department of Housing and Urban Development, announced six livability principles around which the agencies will coordinate agency policies. One of the principles is focused on increasing transportation options, which aims to decrease energy consumption, improve air quality, and reduce GHG emissions.
- DOT is one of more than a dozen agency members of the U.S. Climate Change Technology Program, led by DOE, which is aimed at the development and adoption of technologies designed to reduce the U.S. carbon footprint.[41]
- In furtherance of DOT's high-speed rail initiative, President Obama recently announced DOT's American Recovery and Reinvestment Act High-Speed Intercity Passenger Rail grants to 31 states and the District of Columbia to jump-start high-

speed rail development in the United States. High-speed rail development will help reduce vehicle miles traveled, a critical factor for reducing GHG emissions from the transportation sector.

- The Federal Transit Administration is actively supporting the DOT Livability Initiative and the Federal Sustainable Communities Partnership with its programs to expand mass transit, another travel alternative that will reduce U.S. transportation sector GHG emissions.
- Also within DOT, the Federal Aviation Administration is a sponsor of the Commercial Aviation Fuels Initiative (CAAFI), which is a coalition of the U.S. commercial aviation community that acts as a focal point for engaging the emerging alternative fuels industry. The CAAFI seeks to enhance energy security, and thereby reduce GHG emissions, in the transportation sector by promoting the development of alternative fuel options for use in aviation.
- DOE's Clean Cities Program develops government-industry partnerships designed to reduce petroleum consumption.[42]
- DOE administers the Vehicle Technologies Program, which creates public-private partnerships that enhance energy efficiency and productivity and can bring clean technologies to the marketplace.[43]
- Pursuant to Executive Order (EO) 13514 on Federal Sustainability, DOT and other federal agencies will be working to implement the President's recently announced goal of federal government GHG emissions reductions of 28 percent by 2020. The federal government is the single largest energy consumer in the U.S. economy. As such, the EO 13514 environmental performance goals for federal agencies focus on reducing GHG reductions from government operations and, thereby, leading by example.

Air Pollution

Generally, NHTSA's analysis forecasts emissions from criteria pollutants and mobile source air toxics to decline under the action alternatives, although emissions of carbon monoxide, acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde could increase under certain alternatives and analysis years, compared with the No Action Alternative. While carbon monoxide emissions are projected to increase in some cases, the associated harm might not increase measurably. There have been fewer than three violations of the carbon monoxide National Ambient Air Quality Standards per year since 2002, owing to the success of regulations governing fuel composition and vehicle emissions. Also, vehicle manufacturers can choose which technologies to employ to meet the new CAFE standards. Some of their choices result in higher or lower impacts for these emissions.

There could be increases in criteria and toxic air pollutant emissions in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives. These increases would represent a slight decline in the rate of reductions achieved by implementation of Clean Air Act standards.

There are several federal programs available to mitigate such impacts. Federal transportation funds administered by the Federal Highway Administration (FHWA) could be available to assist in funding projects to reduce increases in emissions. FHWA provides funding to states and localities specifically to improve air quality under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program. The FHWA and the Federal Transit Administration also provide funding to states and localities under other programs that have multiple objectives, including air quality improvement. Specifically, the Surface Transportation Program provides flexible funding that states may use for projects on any federal-aid highway. As state and local agencies recognize the need to reduce emissions of carbon monoxide, acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde (or other emissions eligible under the CMAQ Program, including the criteria pollutants and mobile source air toxics analyzed in this EIS), they have the ability to apply CMAQ funding to reduce impacts in most areas. Further, under the Clean Air Act, EPA has the authority to continue to improve vehicle emissions standards, which could result in future reductions as EPA promulgates new regulations.

Notes

[1] NEPA is codified at 42 U.S.C. §§ 4321-4347. CEQ NEPA implementing regulations are codified at 40 CFR Parts 1500-1508. NHTSA NEPA implementing regulations are codified at 49 CFR Part 520.

[2] 49 U.S.C. § 32901-32919.

[3] 49 CFR §§ 1.50, 501.2(a)(8).

[4] Pub. L. No. 110-140, 121 Stat. 1492 (Dec. 19, 2007). EISA amends and builds on EPCA by setting out a comprehensive energy strategy for the 21st Century addressing renewable fuels and CAFE standards.

[5] Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011–2015, 73 *Federal Register* (*FR*) 24352 (May 2, 2008). At the same time, NHTSA requested updated product plan information from the automobile manufacturers. *See* Request for Product Plan Information, Passenger Car Average Fuel Economy Standards—Model Years 2008–2020 and Light Truck Average Fuel Economy Standards—Model Years 2008–2020, 73 *FR* 21490 (May 2, 2008).

[6] EPA published a Notice of Availability of the Final Environmental Impact Statement (FEIS) in the *Federal Register* on October 17, 2008. Environmental Impact Statements; Notice of Availability, 73 FR 61859 (Oct. 17, 2008).

[7] Final Rule, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196 (Mar. 30, 2009). On January 7, 2009, DOT announced that the Bush Administration would not issue the final rule. The DOT January 7, 2008 statement can be found at: http://www.dot.gov/affairs/dot0109.htm (last accessed Feb. 2, 2009). President Obama issued a memorandum on January 26, 2009, to the Secretary of Transportation and the NHTSA Administrator requesting that NHTSA issue a final rule adopting CAFE standards for MY 2011 only, and to reconsider the standards for years after 2011. Memorandum for the Secretary of Transportation and the Administrator of the National Highway Traffic Safety Administration, 74 *FR* 4907 (Jan. 26, 2009).

[8] *See* Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 74 *FR* 14857 (Apr. 1, 2009).

[9] Scoping, as defined under NEPA, is an early and open process for determining the scope of issues to be addressed in an EIS and for identifying the significant issues related to a proposed action. *See* 40 CFR § 1501.7.

[10] This would also achieve levels of emissions that would satisfy California's standards.

[11] 42 U.S.C. § 4332.

[12] 40 CFR § 1501.6.

[13] 49 U.S.C. § 32902(a).

[14] 49 U.S.C. § 32902(f).

[15] *See, e.g.*, *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)); and 73 *FR* 24352, 24364 (May 2, 2008).

[16] 49 U.S.C. § 32902(b)(2)(A).

[17] 49 U.S.C. §§ 32902(b)(2)(C), 32902(b)(3)(B).

[18] Although EISA's recent amendments to EPCA direct NHTSA to increase the stringency of CAFE standards and do not permit the agency to take no action on fuel economy, CEQ regulations mandate analysis of a no action alternative. *See* 40 CFR § 1502.14(d). CEQ has explained that "the regulations require the analysis of the no action alternative *even if the agency is under a court order or legislative command to act*." *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 *FR* 18026 (1981) (emphasis added).

[19] Alternative 2 requires a 3% average annual increase in mpg. Alternative 3 requires a 4% average annual increase in mpg. Alternative 5 requires a 5% average annual increase in mpg. Alternative 7 requires a 6% average annual increase in mpg. Alternative 8 requires a 7% annual increase in mpg.

[20] In this rulemaking, NHTSA and EPA have chosen vehicle footprint as the most appropriate attribute on which to base fuel economy and GHG emissions standards as discussed in the NPRM. Thus, vehicles with larger footprints (*i.e.*, generally larger vehicles) would be subject to less stringent standards than vehicles with smaller footprints (*i.e.*, generally smaller vehicles).

[21] In NHTSA's analysis, "overcompliance" occurs through multi-year planning: manufacturers apply some "extra" technology in early model years to carry that technology forward and thereby facilitate compliance in later model years.

[22] Consistent with EPCA, NHTSA has not accounted for manufacturers' ability to earn CAFE credits for selling flex-fuel vehicles (FFVs), to carry credits forward and back between model years, and to transfer credits between the passenger car and light truck fleets when setting standards. 49 U.S.C. § 32902(h). However, to assist in understanding the extent to which use of credits might reduce manufacturers' compliance costs and the benefits of new CAFE standards, NHTSA does analyze the potential effects of FFV credits. *See* Section 3.1.4.1 of this EIS.

[23] The CAFE level required under an attribute-based standard depends on the mix of vehicles produced for sale in the United States. NHTSA has developed the average mpg levels under each alternative based on the vehicle market forecast that NHTSA and EPA have used to develop and analyze new CAFE and GHG emissions standards.

[24] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last accessed July 22, 2009) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

[25] U.S. Energy Information Administration, 2009. Annual Energy Review 2008. Report No. DOE/EIA-0384(2008), *available at* http://www.eia.doe.gov/emeu/aer/petro.html

[26] *Id.*

[27] U.S. Energy Information Administration, 2009. Annual Energy Review 2008. Washington, D.C. DOE/EIA-0384(2008). 408 pgs.

[28] The AEO projections anticipate an average annual percentage gain of 0.51 percent in passenger car mpg and 0.86 percent in light truck mpg from 2019 through 2030.

[29] U.S. EPA, Recent Atmospheric Changes page, Climate Change Site, http://www.epa.gov/climatechange/science/recentac.html (last accessed December 17, 2009).

[30] Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson, and M. Prather. 2007. Historical Overview of Climate Change. Pgs. 93–128. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, New York. 996 pgs.

[31] EPA (U.S. Environmental Protection Agency). 2009. Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act. Office of Atmospheric Programs Climate Change Division. U.S. Environmental Protection Agency, Washington, District of Columbia. December 7. 210 pgs.

[32] *See* Note 30.

[33] Synthesis and assessment reports are issued by expert panels that have assessed numerous individual studies in order to draw general conclusions about the state of the science, have been reviewed and formally accepted by, commissioned by, or in some cases authored by U.S. government agencies and individual government scientists and provide assurances that the material has been well vetted by both the climate change research community and the U.S. government.

[34] EPA (U.S. Environmental Protection Agency). 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks. Washington, D.C. EPA 430-R-09-004. 441 pgs. Last Revised: July 14, 2009. *Available at*: http://www.epa.gov/climatechange/emissions/usinventoryreport.html (last accessed February 17, 2010).

[35] Estimated using EPA's Greenhouse Gas Equivalencies Calculator, *available at*: http://www.epa.gov/cleanenergy/energy-resources/calculator.html (last accessed Feb. 17, 2010).

[36] On January 28, 2010, the United States submitted this target to the U.N. Framework Convention on Climate Change as part of a January 31, 2010 deadline negotiated in Copenhagen in December 2009. *See* http://unfccc.int/home/items/5264.php (last accessed Feb. 1, 2010).

[37] NHTSA may propose more stringent CAFE standards for MYs 2017-2020 that may help to achieve the President's target.

[38] 40 CFR § 1502.14(f).

[39] 40 CFR § 1502.16(h).

[40] 40 CFR § 1505.2(c).

[41] Office of Policy and International Affairs, Department of Energy, *Climate Overview*, *available at* http://www.pi.energy.gov/climateoverview.html (last accessed Jul. 15, 2009).

[42] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Clean Cities: Fact Sheet (2009).

[43] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, *About the Program*, *available at* http://www1.eere.energy.gov/ vehiclesandfuels/about/index.html (last accessed Jul. 15, 2009).

Chapter 1 Purpose and Need for the Proposed Action

1.1 INTRODUCTION

The Energy Policy and Conservation Act of 1975 (EPCA)[1] established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and light trucks.[2] As part of that Act, the Corporate Average Fuel Economy (CAFE) Program was established to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States.[3] The National Highway Traffic Safety Administration (NHTSA) is delegated responsibility for implementing EPCA fuel economy requirements assigned to the Secretary of Transportation.[4]

In December 2007, the Energy Independence and Security Act of 2007 (EISA)[5] amended EPCA's CAFE program requirements, providing the U.S. Department of Transportation (DOT) additional rulemaking authority and responsibilities. Pursuant to EISA, on April 22, 2008, NHTSA proposed CAFE standards for model years (MYs) 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking (NPRM).[6] On March 21, 2008, NHTSA issued a Notice of Intent (NOI) to prepare an EIS for the MYs 2011-2015 CAFE standards.[7] On October 10, 2008, NHTSA submitted to the U.S. Environmental Protection Agency (EPA) its Final Environmental Impact Statement, Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MYs 2011-2015. EPA published a Notice of Availability of the Final Environmental Impact Statement (FEIS) in the *Federal Register* (*FR*) on October 17, 2008.[8] On January 7, 2009, DOT announced that the Bush Administration would not issue the final rule.[9]

In the context of calls for the development of new national policies to prompt sustained domestic and international actions to address the closely intertwined issues of energy independence, energy security, and climate change, President Obama issued a memorandum on January 26, 2009 to the

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[1] EPCA was enacted for the purpose of serving the Nation's energy demands and promoting conservation methods when feasibly obtainable. EPCA is codified at 49 U.S.C. § 32901 *et seq.*

[2] 49 U.S.C. §§ 32901-32919.

[3] 49 CFR § 1.50. In addition, the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each automobile manufacturer that sells vehicles in the United States. 49 U.S.C. § 32904.

[4] Accordingly, the Secretary of Transportation, DOT, and NHTSA are used interchangeably in this section of the DEIS.

[5] EISA amends and builds on the Energy Policy and Conservation Act by setting out a comprehensive energy strategy for the 21st Century addressing renewable fuels and CAFE standards. Pub. L. No. 110-140, 121 Stat. 1492 (Dec. 19, 2007).

[6] Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 *FR* 24352 (May 2, 2008). At the same time, NHTSA requested updated product plan information from the automobile manufacturers. *See* Request for Product Plan Information, Passenger Car Average Fuel Economy Standards—Model Years 2008-2020 and Light Truck Average Fuel Economy Standards—Model Years 2008-2020, 73 *FR* 21490 (May 2, 2008).

[7] Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 *FR* 16615 (Mar. 28, 2008).

[8] Environmental Impact Statements; Notice of Availability, 73 *FR* 38204 (Jul. 3, 2008).

[9] The January 7, 2008 statement from the U.S. Department of Transportation can be found at: http://www.dot.gov/affairs/dot0109.htm (last accessed Jun. 9, 2009).

Secretary of Transportation and the NHTSA Administrator.[10] The memorandum requested that NHTSA divide the MYs 2011-2015 rulemaking into two parts: (1) MY 2011 standards, and (2) standards for MYs 2012 and beyond.

The request that the final rule establishing CAFE standards for MY 2011 passenger cars and light trucks be prescribed by March 30, 2009 was based on several factors. One was the requirement that the final rule regarding fuel economy standards for a given model year must be adopted at least 18 months before the beginning of that model year (49 U.S.C. § 32902(g)(2)). The other was that the beginning of MY 2011 is considered to be, for the purposes of CAFE standard setting, October 1, 2010.

For MYs 2012 and beyond, the President requested that, before promulgating a final rule concerning the model years after MY 2011, NHTSA

> [C]onsider the appropriate legal factors under the EISA, the comments filed in response to the Notice of Proposed Rulemaking, the relevant technological and scientific considerations, and to the extent feasible, the forthcoming report by the National Academy of Sciences mandated under section 107 of EISA.

In addition, the President requested that NHTSA consider whether any provisions regarding preemption are applicable.

1.2 JOINT RULEMAKING AND NEPA PROCESS

On September 28, 2009, NHTSA and EPA announced in the *Federal Register* the Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards.[11] These joint proposed rules address the urgent and closely intertwined challenges of energy independence and security and global warming. These proposed rules call for a strong and coordinated federal greenhouse gas (GHG) and fuel economy program for passenger cars, light-duty trucks, and medium-duty passenger vehicles (also referred to as light-duty vehicles), referred to as the National Program. The proposed rules can achieve substantial improvements in fuel economy and reductions of GHG emissions from the light-duty vehicle part of the transportation sector, based on technology that is already being commercially applied in most cases and that can be incorporated at a reasonable cost.

These joint proposed standards are consistent with the President's announcement on May 19, 2009 of a National Fuel Efficiency Policy for establishing consistent, harmonized, and streamlined requirements that would improve fuel economy and reduce GHG emissions for all new passenger cars and light trucks sold in the United States.[12] The National Program holds out the promise of delivering additional environmental and energy benefits, cost savings, and administrative efficiencies on a nationwide basis that might not be available under a less coordinated approach. The proposed National Program also offers the prospect of regulatory convergence by making it possible for the standards of two

[10] Memorandum for the Secretary of Transportation and the Administrator of the National Highway Traffic Safety Administration, 74 *FR* 4907 (Jan. 26, 2009).
[11] Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 74 *FR* 49454 (Sep. 28, 2009).
[12] President Obama Announces National Fuel Efficiency Policy, The White House, May 19, 2009. Available at: http://www.whitehouse.gov/the_press_office/President-Obama-Announces-National-Fuel-Efficiency-Policy/ (last accessed August 18, 2009). Remarks by the President on National Fuel Efficiency Standards, The White House, May 19, 2009. Available at: http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-on-national-fuel-efficiency-standards/ (last accessed August 18, 2009).

federal agencies and the standards of California and other states to act in a unified fashion in providing these benefits. This would allow automakers to produce and sell a single fleet nationally. Thus, it may also help to mitigate the additional costs that manufacturers would otherwise face in having to comply with multiple sets of federal and state standards. This joint notice is also consistent with the Notice of Upcoming Joint Rulemaking signed by DOT and EPA on May 19, 2009[13] and responds to the President's January 26, 2009 memorandum on CAFE standards for MYs 2011 and beyond.[14]

1.2.1 Building Blocks of the National Program

The National Program is both needed and possible because the relationship between improving fuel economy and reducing carbon dioxide (CO_2) tailpipe emissions is a very direct and close one. The amount of those CO_2 emissions is essentially constant per gallon combusted of a given type of fuel. Thus, the more fuel efficient a vehicle is, the less fuel it burns to travel a given distance. The less fuel it burns, the less CO_2 it emits in traveling that distance (Committee on Science, Engineering and Public Policy 1992). While there are emission control technologies that reduce the pollutants (*e.g.*, carbon monoxide) produced by imperfect combustion of fuel by capturing or destroying them, there is no such technology for CO_2. Further, while some of those pollutants can also be reduced by achieving a more complete combustion of fuel, doing so only increases the tailpipe emissions of CO_2. Thus, there is a single pool of technologies for addressing these twin problems, *i.e.*, those that reduce fuel consumption and thereby reduce CO_2 emissions as well.

1.2.1.1 DOT's CAFE Program

In 1975, Congress enacted EPCA, mandating that NHTSA establish and implement a regulatory program for motor vehicle fuel economy to meet the various facets of the need to conserve energy, including those with energy independence and security, environmental, and foreign policy implications. Fuel economy gains since 1975, due both to standards and market factors, resulted in saving billions of barrels of oil and avoiding billions of metric tons of CO_2 emissions. In December 2007, Congress enacted EISA, amending EPCA to require substantial, continuing increases in fuel economy standards.

The CAFE standards address most, but not all, real-world CO_2 emissions because EPCA requires the use of 1975 passenger car test procedures under which vehicle air conditioners are not turned on during fuel economy testing.[15] Fuel economy is determined by measuring the amount of CO_2 and other carbon compounds emitted from the tailpipe, not by attempting to measure directly the amount of fuel consumed during a vehicle test, a difficult task to accomplish with precision. The carbon content of the test fuel is then used to calculate the amount of fuel that had to be consumed per mile in order to produce that amount of CO_2.[16] Finally, that fuel consumption figure is converted into a miles-per-gallon figure. CAFE standards also do not address the 5–8 percent of GHG emissions that are not CO_2, *i.e.*, nitrous oxide (N_2O), and methane (CH_4), as well as emissions from the operation of the air conditioning system such as CO_2 and hydrofluorocarbons (HFCs).

[13] Notice of Upcoming Joint Rulemaking To Establish Vehicle GHG Emissions and CAFE Standards, 74 *FR* 24007 (May 22, 2009).
[14] Available at: http://www.whitehouse.gov/the_press_office/Presidential_Memorandum_Fuel_Economy/ (last accessed August 18, 2009)
[15] EPCA does not require the use of 1975 test procedures for light trucks.
[16] This is the method that EPA uses to determine compliance with NHTSA's CAFE standards.

1.2.1.2 EPA's Greenhouse Gas Standards for Light-Duty Vehicles

Under the Clean Air Act (CAA), EPA is responsible for addressing air pollutants from motor vehicles. On April 2, 2007, the U.S. Supreme Court issued its opinion in *Massachusetts v. EPA*,[17] a case involving a 2003 EPA order denying a petition for rulemaking to regulate GHG emissions from motor vehicles under section 202(a) of the CAA.[18] The Court held that GHGs were air pollutants for purposes of the CAA and further held that the Administrator must determine whether emissions from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. The Court further ruled that, in making these decisions, the EPA Administrator is required to follow the language of section 202(a) of the CAA. The Court rejected the argument that EPA cannot regulate CO_2 from motor vehicles because to do so would *de facto* tighten fuel economy standards, authority over which has been assigned by Congress to DOT. The Court stated that "[b]ut that DOT sets mileage standards in no way licenses EPA to shirk its environmental responsibilities. EPA has been charged with protecting the public's 'health' and 'welfare', a statutory obligation wholly independent of DOT's mandate to promote energy efficiency." The Court concluded that "[t]he two obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[19] The Court remanded the case back to the Agency for reconsideration in light of its findings.[20]

EPA has since found that emissions of GHGs from new motor vehicles and motor vehicle engines cause or contribute to air pollution that may reasonably be anticipated to endanger public health and welfare.[21] The forthcoming joint NHTSA-EPA Final Rule represents the second phase of EPA's response to the U.S. Supreme Court's decision.

1.2.1.3 California Air Resources Board Greenhouse Gas Program

In 2004, the California Air Resources Board approved standards for new light duty vehicles, which regulate the emission of CO_2 and other GHGs. Since then, 13 states and the District of Columbia, comprising approximately 40 percent of the light duty vehicle market, have adopted California's standards. These standards apply to MYs 2009 through 2016 and require reductions in CO_2 emissions for passenger cars and some light trucks of 323 grams per mile (g/mi) in 2009 up to 205 g/mi in 2016 and 439 g/mi for light trucks in 2009 up to 332 g/mi in 2016. On June 30, 2009, EPA granted California's request for a waiver of preemption under the CAA.[22] The granting of the waiver permits California and the other states to proceed with implementing the California emission standards.

[17] 549 U.S. 497 (2007).
[18] *See* Notice of Denial of Petition for Rulemaking, Control of Emissions From New Highway Vehicles and Engines, 68 *FR* 52922 (Sep. 8, 2003).
[19] 549 U.S. at 531-32.
[20] For further information on *Massachusetts v. EPA see* the July 30, 2008 Advance Notice of Proposed Rulemaking, "Regulating Greenhouse Gas Emissions under the Clean Air Act," 73 *FR* 44354 at 44397. This includes a comprehensive discussion of the litigation's history, the U.S. Supreme Court's findings, and subsequent actions undertaken by the Bush Administration and EPA from 2007–2008 in response to the Supreme Court remand.
[21] Final Rule, Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 *FR* 66496 (Dec. 15, 2009).
[22] California State Motor Vehicle Pollution Control Standards, Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles, 74 *FR* 32744 (Jul. 8, 2009).

1.2.2 Joint Proposal for a National Program

On May 19, 2009, DOT and EPA issued a Notice of Upcoming Joint Rulemaking to propose a strong and coordinated fuel economy and greenhouse gas National Program for MYs 2012-2016 light-duty vehicles. On September 28, 2009, NHTSA and EPA published the proposed rules in the *Federal Register*.[23] NHTSA and EPA proposed a harmonized and coordinated National Program with the following key elements.

1.2.2.1 Level of the Standards

NHTSA and EPA proposed two separate sets of standards, each under its respective statutory authority. NHTSA proposed CAFE standards for passenger cars and light trucks under 49 U.S.C. § 32902. These standards would require these vehicles to meet an estimated combined average fuel economy level of 34.1 miles per gallon (mpg) in MY 2016. EPA proposed national CO_2 emissions standards for light-duty vehicles under section 202(a) of the CAA. These standards would require these vehicles to meet an estimated combined average emissions level of 250 g/mi of CO_2 in MY 2016. The proposed standards for both agencies begin with the 2012 model year, with standards increasing in stringency through MY 2016. They represent a harmonized approach that will allow industry to build a single national fleet that will satisfy both the GHG requirements under the CAA and CAFE requirements under EPCA/EISA.

Given differences in their respective statutory authorities, however, the agencies' proposed standards include some important differences. Under the CO_2 fleet average standard proposed under CAA section 202(a), EPA expects manufacturers to take advantage of the option to generate CO_2-equivalent credits by reducing emissions of HFCs and CO_2 through improvements in their air conditioner systems. EPA accounted for these reductions in developing its proposed CO_2 standard. EPCA does not allow vehicle manufacturers to use air conditioning credits in complying with CAFE standards for passenger cars.[24] CO_2 emissions due to air conditioning operation are not measured by the test procedure mandated by statute for use in establishing and enforcing CAFE standards for passenger cars. As a result, improvements in the efficiency of passenger car air conditioners would not be considered as a possible control technology for purposes of CAFE.

The differences regarding the treatment of air conditioning improvements (related to CO_2 and HFC reductions) affect the relative stringency of the EPA standard and the NHTSA standard. The 250 g/mi of CO_2 equivalent emissions limit is equivalent to 35.5 mpg[25] if the automotive industry were to meet this CO_2 level entirely through fuel economy improvements. As a consequence of the prohibition against NHTSA's allowing credits for air conditioning improvements for purposes of passenger car CAFE compliance, NHTSA proposed fuel economy standards that are estimated to require a combined (passenger car and light truck) average fuel economy level of 34.1 mpg by MY 2016.

[23] Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 74 *FR* 49454 (Sep. 28, 2009).
[24] There is no such statutory limitation with respect to light trucks.
[25] The agencies are using a common conversion factor between fuel economy in units of miles per gallon and CO_2 emissions in units of grams per mile. This conversion factor is 8,887 grams CO_2 per gallon gasoline fuel. Diesel fuel has a conversion factor of 10,179 grams CO_2 per gallon diesel fuel though, for the purposes of this calculation, we are assuming 100% gasoline fuel.

1.2.2.2 Form of the Standards

In this rulemaking, NHTSA and EPA proposed to establish attribute-based standards for passenger cars and light trucks. NHTSA adopted an attribute standard based on vehicle footprint in its Reformed CAFE program for light trucks for MYs 2008-2011,[26] and recently extended this approach to passenger cars in the CAFE rule for MY 2011 as required by EISA.[27] Under an attribute-based standard, every vehicle model has a performance target (fuel economy for the CAFE standards, and CO_2 g/mi for the GHG emissions standards), the level of which depends on the vehicle's attribute (for this rulemaking, footprint). The manufacturers' fleet average performance is determined by the production-weighted[28] average (for CAFE, harmonic average) of those targets.

NHTSA and EPA proposed vehicle footprint as the attribute for the CAFE and GHG standards. Footprint is defined as a vehicle's wheelbase multiplied by its track width – in other words, the area enclosed by the points at which the wheels meet the ground. The agencies believe that the footprint attribute is the most appropriate attribute on which to base the standards under consideration, as discussed in the NPRM and in Chapter 2 of the Draft Joint Technical Support Document (TSD) (EPA and NHTSA 2009).

Under the proposed footprint-based standards, each manufacturer would have a CAFE and GHG target unique to its fleet, depending on the footprints of the vehicle models produced by that manufacturer. A manufacturer would have separate footprint-based standards for cars and for trucks. Generally, larger vehicles (*i.e.*, vehicles with larger footprints) would be subject to less stringent standards (*i.e.*, higher CO_2 g/mi standards and lower CAFE standards) than smaller vehicles. This is because, generally speaking, smaller vehicles are more capable of achieving higher standards than larger vehicles. Although a manufacturer's fleet average standard could be estimated throughout the model year based on projected production volume of its vehicle fleet, the standard to which the manufacturer must comply would be based on its final model year production figures. A manufacturer's calculation of fleet average emissions at the end of the model year would thus be based on the production-weighted average emissions of each model in its fleet.

In designing the footprint-based standards, the agencies built upon the footprint standard curves for passenger cars and light trucks used in the CAFE rule for MY 2011.[29] NHTSA and EPA worked together to design car and truck footprint curves that followed from logistic curves used in that rule. The agencies started by addressing two main concerns regarding the car curve. The first concern was that the 2011 car curve was relatively steep near the inflection point and that, therefore, small variations in footprint could produce relatively large changes in fuel economy targets. A curve that was directionally less steep would reduce the potential for gaming. The second issue was that the inflection point of the logistic curve was not centered on the distribution of vehicle footprints across the industries' fleet, thus resulting in a flat (universal or unreformed) standard for over half the fleet. The proposed car curve has been shifted and made less steep compared to the car curve adopted by NHTSA for 2011, such that it better aligns the sloped region with higher production volume vehicle models. Finally, both the car and truck curves are defined in terms of a constrained linear function for fuel consumption and, equivalently, a piece-wise linear function for CO_2. NHTSA and EPA included a full discussion of the development of these curves in the joint TSD. In addition, a full discussion of the equations and coefficients that define

[26] Final Rule, Average Fuel Economy Standards for Light Trucks Model Years 2008-2011, 71 *FR* 17566 (Apr. 6, 2006).
[27] Final Rule, Record of Decision, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196 (Mar. 30, 2009).
[28] Production for sale in the United States.
[29] 74 *FR* at 14407-14409 (Mar. 30, 2009).

the curves proposed by each agency was included in section III of the NPRM for the CO_2 curves and section IV of the NPRM for the mpg curves.

1.2.2.3 Program Flexibilities for Achieving Compliance

NHTSA and EPA proposed standards that are intended to provide compliance flexibility to manufacturers, especially in the early years of the program. This flexibility would be expected to provide sufficient lead time to make necessary technological improvements and additions, and to reduce the overall cost of the program without compromising overall environmental and fuel economy objectives. The broad goal of harmonizing the NHTSA and EPA standards would include providing manufacturer flexibilities in meeting the standards. The flexibility provisions that the agencies jointly and separately contemplated in developing the program include CAFE/CO_2 Credits Earned Based on Fleet Average Performance, Air Conditioning Credits, Flex-Fuel and Alternative Fuel Vehicle Credits, Temporary Lead-Time Allowance Alternative Standards (TLAAS), and Additional Potential Credit Opportunities. Some of these flexibilities will be available to manufacturers in aiding compliance under both sets of standards, but some flexibilities, such as the air conditioning credits and TLAAS, will only be available under the EPA standard due to differences between the CAFE and CAA legal authorities.[30]

1.2.2.4 Compliance

NHTSA and EPA proposed a program that recognizes and replicates as closely as possible the compliance protocols associated with the existing CAFE standards and CAA Tier 2 vehicle emission standards. The certification, testing, reporting, and associated compliance activities could closely track current practice and thus be familiar to manufacturers. EPA already oversees testing, collects and processes test data, and performs calculations to determine compliance with both CAFE and CAA standards. NHTSA determines compliance with the CAFE program, manages credits, issues letters of noncompliance, and collects civil penalties from manufacturers. In a coordinated approach, compliance mechanisms for both programs would be consistent and non-duplicative.

Under the National Environmental Policy Act (NEPA)[31] a federal agency must analyze environmental impacts if the agency implements a proposed action, provides funding for an action, or issues a permit for that action. Specifically, NEPA directs that "to the fullest extent possible," federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action).[32] To inform its development of the new MYs 2012-2016 CAFE standards required under EPCA, as amended by EISA, NHTSA prepared this EIS to analyze and disclose the potential environmental impacts of a proposed preferred alternative and other proposed alternative standards pursuant to CEQ NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.[33] This EIS compares the potential environmental impacts among alternatives, including a no action alternative. It also analyzes direct, indirect, and cumulative impacts, and discusses impacts in proportion to their significance.

Section 1501.6 of the CEQ regulations emphasizes agency cooperation early in the NEPA process and authorizes a lead agency (in this case, NHTSA) to request the assistance of other agencies that either

[30] *See* discussion of compliance flexibilities in Section 3.1.4.1 of the joint NHTSA-EPA NPRM.
[31] 42 U.S.C. §§ 4321-4347.
[32] 42 U.S.C. § 4332.
[33] NEPA is codified at 42 U.S.C. §§ 4321-4347. CEQ NEPA implementing regulations are codified at 40 CFR Parts 1500-1508, and NHTSA's NEPA implementing regulations are codified at 49 CFR Part 520.

have jurisdiction by law or have special expertise regarding issues considered in an EIS.[34] NHTSA invited EPA to be a cooperating agency, pursuant to CEQ regulations, because of its special expertise in the areas of climate change and air quality. On May 12, 2009, EPA accepted NHTSA's invitation and agreed to become a cooperating agency.

EPA leads the Nation's environmental science, research, education, and assessment efforts. The mission of EPA is to protect human health and the environment. EPA is legally required to comply with the procedural requirements of NEPA for its research and development activities, facilities construction, wastewater treatment construction grants under Title II of the Clean Water Act (CWA), EPA-issued National Pollutant Discharge Elimination System permits for new sources, and for certain projects funded through EPA annual Appropriations Acts. However, EPA actions under the CAA, including the EPA proposed vehicle GHG emission standards under the Joint Rulemaking, are not subject to the requirements of NEPA. Pursuant to the National Fuel Efficiency Policy announced by the President on May 19, 2009, NHTSA and EPA published their Notice of Upcoming Joint Rulemaking to ensure a coordinated national program on fuel economy and GHG emissions for passenger cars, light-duty trucks, and medium-duty passenger vehicles. In order to improve the usefulness of this EIS for NHTSA decisionmakers and the public, EPA's environmental analysis of its proposed rulemaking is summarized and referenced within the appropriate sections of this EIS.[35]

1.3 PROPOSED ACTION

For this EIS, NHTSA's Proposed Action is setting passenger car and light truck CAFE standards for MY 2012-2016, in accordance with EPCA, as amended by EISA. NHTSA and EPA proposed coordinated and harmonized CAFE standards and vehicle GHG emissions for passenger cars, light-duty trucks, and medium-duty passenger vehicles built in MY 2012 through 2016.

1.4 PURPOSE AND NEED

NEPA requires that a proposed action's alternatives be developed based on the action's purpose and need. The purpose and need statement explains why the action is needed, describes the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the NEPA analysis.[36] In accordance with EPCA, as amended by EISA, one purpose of the Joint Rulemaking is to establish MYs 2012-2016 CAFE standards at "the maximum feasible average fuel economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year."[37] When determining the level achievable by the manufacturers, EPCA requires that the agency consider the four statutory factors of technological feasibility, economic practicability, the effect of other motor vehicle

[34] 40 CFR § 1501.6.
[35] Pursuant to the National Fuel Efficiency Policy announced by the President on May 19, 2009, EPA and NHTSA published their Notice of Upcoming Joint Rulemaking to ensure a coordinated National program on GHG emissions and fuel economy for passenger cars, light-duty trucks, and medium-duty passenger vehicles. NHTSA takes no position on whether EPA's proposed rule on GHG emissions could be considered a "connected action" under the CEQ's regulation at 40 CFR § 1508.25. For the purposes of this EIS, however, NHTSA has decided to treat EPA's proposed rule as if it were a "connected action" under that regulation to improve the usefulness of the EIS for NHTSA decisionmakers and the public. NHTSA is aware that Section 7(c) of the Energy Supply and Environmental Coordination Act of 1974 (15 U.S.C. § 793(c)(1)) expressly exempts EPA action taken under the CAA from NEPA's requirements. NHTSA's discussion in this EIS of EPA's proposed GHG regulation should not be construed to affect in any way the express NEPA exemption for action taken under the CAA and places no obligation on EPA to comply with NEPA in promulgating its rule or taking any other action covered by the exemption.
[36] 40 CFR § 1502.13.
[37] 49 U.S.C. § 32902(a).

standards of the Government on fuel economy, and the need of the United States to conserve energy.[38] In addition, the agency has the authority to—and traditionally does—consider other relevant factors, such as the effect of the CAFE standards on motor vehicle safety.[39]

NHTSA has defined these considerations as follows:[40]

- "Technological feasibility" refers to whether a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established.
- "Economic practicability" refers to whether a standard is one within the financial capability of the industry, but not so stringent as to lead to adverse economic consequences, such as significant job losses or unreasonable elimination of consumer choice.
- "The effect of other motor vehicle standards of the Government on fuel economy," involves an analysis of the effects of compliance with emission,[41] safety, noise, or damageability standards on fuel economy capability and thus on average fuel economy.
- "The need of the United States to conserve energy" means the consumer cost, national balance of payments, environmental, and foreign policy implications of the Nation's need for large quantities of petroleum, especially imported petroleum.

NHTSA must establish separate standards for MYs 2011-2020 passenger cars and light trucks, subject to two principal requirements.[42] First, the standards are subject to a minimum requirement regarding stringency: they must be set at levels high enough to ensure that the combined U.S. passenger car and light truck fleet achieves an average fuel economy level of not less than 35 mpg not later than MY 2020.[43] Second, as discussed above and at length in the March 2009 final rule establishing the MY 2011 CAFE standards, EPCA requires that the agency establish standards for all new passenger cars and light trucks at the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year.[44]

Additionally, EPCA, as amended by EISA, requires that the CAFE standards for passenger cars and light trucks increase ratably in each model year between MY 2011 and MY 2020. Standards must be "based on one or more vehicle attributes related to fuel economy," and "expressed in the form of a

[38] 49 U.S.C. §§ 32902(a), 32902(f).
[39] *See, e.g.*, *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)); 73 *FR* 24352, 24364 (May 2, 2008).
[40] Final Rule, Record of Decision, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196 (Mar. 30, 2009).
[41] In the case of emission standards, this includes standards adopted by the federal government and can include standards adopted by the states as well since in certain circumstances the CAA allows states to adopt and enforce state standards different from the federal standards.
[42] EISA added the following additional requirements:

- Standards must be attribute-based and expressed in the form of a mathematical function. 49 U.S.C. § 32902(b)(3)(A).
- Standards for MYs 2011-2020 must "increase ratably" in each model year. 49 U.S.C. § 32902(b)(2)(C). NHTSA interprets this requirement, in combination with the requirement to set the standards for each model year at the level determined to be the maximum feasible level for that model year, to mean that the annual increases should not be disproportionately large or small in relation to each other.

[43] 49 U.S.C. § 32902(b)(2)(A).
[44] 49 U.S.C. § 32902(a).

mathematical function."[45] In any single rulemaking, standards may be established for not more than five model years.[46]

NHTSA is also guided by President Obama's memorandum to DOT on January 26, 2009, as described in Section 1.1.

1.5 PUBLIC REVIEW AND COMMENT

On April 1, 2009, NHTSA published an NOI to prepare an EIS for the MYs 2012-2016 CAFE standards. The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[47] by requesting public input on the scope of the environmental analysis to be conducted.[48] Two important purposes of scoping are identifying the substantial environmental issues that merit in-depth analysis in the EIS and identifying and eliminating from detailed analysis the environmental issues that are not substantial and therefore require only brief discussion in the EIS.[49] Scoping should "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[50] Consistent with NEPA and its implementing regulations, on April 2, 2009, NHTSA mailed the NOI to:

- 109 contacts at federal agencies having jurisdiction by law or special expertise with respect to the environmental impacts involved, or authorized to develop and enforce environmental standards, including other modes within DOT;
- The Governors of every state and U.S. territory;
- 65 organizations representing state and local governments;
- 599 Native American tribal organizations and academic centers that issued reports on climate change and tribal communities; and
- 265 contacts at other stakeholder organizations that NHTSA reasonably expected to be interested in the NEPA analysis for the MYs 2012-2016 CAFE standards, including automobile industry organizations, environmental organizations, and other organizations that expressed interest in prior CAFE rules.

NHTSA used its letters transmitting the NOI to develop a contact list for future notices about the NEPA process for the MYs 2012-2016 CAFE standards. For instance, NHTSA asked each Governor to "share [the] letter and the enclosed [NOI] with the appropriate environmental agencies and other offices within your administration and with interested local jurisdictions and government organizations within your State." NHTSA further requested that each Governor ask his or her representative to provide contact information for the state's lead office for the CAFE EIS by returning a contact list form to NHTSA or by sending NHTSA an e-mail containing the information requested on the form. NHTSA asked federal agency contacts to share the NOI with other interested parties within their organizations and to complete

[45] 49 U.S.C. § 32902(b)(3)(A).
[46] 49 U.S.C. § 32902(b)(3)(B).
[47] Scoping, as defined under NEPA, is an early and open process for determining the scope of issues to be addressed in an EIS and for identifying the significant issues related to a proposed action. *See* 40 CFR § 1501.7.
[48] *See* Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 74 *FR* 14857 (Apr. 1, 2009).
[49] *See* 40 CFR §§ 1500.4(g), 1501.7(a).
[50] 40 CFR § 1500.4(g).

the contact list form. NHTSA asked contacts at other stakeholder organizations whether they wished to remain on the agency's NEPA contact list for the CAFE EIS by returning a contact list form or sending NHTSA an e-mail containing the information requested on the form. NHTSA indicated that organizations that did not return the form would be removed from the NEPA contact list.

NHTSA submitted to EPA the DEIS that disclosed and analyzed the potential environmental impacts of new CAFE standards and reasonable alternative standards in the context of NHTSA's CAFE program pursuant to the CEQ NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.[51] On September 25, 2009, NHTSA published a *Federal Register* Notice of Availability announcing the availability of the DEIS.[52] NHTSA's Notice of Availability also announced the date and location of a public hearing. Specifically, NHTSA's Notice of Availability invited the public to participate at the NHTSA hearing on October 30, 2009 in Washington, DC. Also on September 25, 2009, EPA issued its Notice of Availability for the DEIS, triggering the 45-day public comment period.[53] In accordance with CEQ implementing regulations, the public was invited to submit written comments on the DEIS until November 9, 2009.

NHTSA mailed approximately 300 copies of the DEIS to interested parties, including federal, state, and local agencies; elected officials; environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 8 of the DEIS.

1.5.1 Agency Consultation

On May 5, 2009, NHTSA invited EPA to become a cooperating agency with NHTSA in the development of the EIS for the CAFE rulemaking for MYs 2012-2016 passenger cars and light trucks in accordance with 40 CFR § 1501.6 of the NEPA implementing regulations issued by CEQ. Under 40 CFR § 1501.6, a federal agency that has special expertise with respect to any environmental issue that should be addressed in the statement may be a cooperating agency upon request of the lead agency. In its invitation letter, NHTSA suggested that EPA's role in the development of the EIS could include the following, as they relate to EPA's areas of special expertise:

- Providing input on determining the significant issues to be analyzed in the EIS from a climate change and air quality perspective.
- Assisting NHTSA to "identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review (§ 1506.3), narrowing the discussion of these issues in the statement to a brief presentation of why they will not have a significant effect on the human environment or providing a reference to their coverage elsewhere." 40 CFR § 1501.7(a)(3).
- Participating in coordination meetings, as appropriate.
- Reviewing and commenting on the DEIS and FEIS prior to publication.

[51] Under Section 309 of the CAA, EPA is required to review and publicly comment on the environmental impacts of major federal actions including actions that are the subject of EISs. If EPA determines that the action is environmentally unsatisfactory, it is required by Section 309 to refer the matter to CEQ. This is done by the Office of Federal Activities.
[52] Notice of Availability of a Draft Environmental Impact Statement (DEIS) for New Corporate Average Fuel Economy Standards; Notice of Public Hearing, 74 *FR* 48894 (Sep. 25, 2009).
[53] Environmental Impact Statements; Notice of Availability, 74 *FR* 48951 (Sep. 25, 2009).

On May 12, 2009, EPA accepted NHTSA's invitation and agreed to become a cooperating agency. EPA staff participated in technical discussions and reviewed and commented on draft sections and the draft final version of the DEIS.

To comply with NEPA's requirements for agency consultation, on July 10, 2009, NHTSA mailed consultation letters to the following federal agencies: Bureau of Land Management, Centers for Disease Control and Prevention, Minerals Management Service, National Park Service, Advisory Council on Historic Preservation, U.S. Forest Service, and U.S. Army Corps of Engineers. On July 30, 2009, NHTSA received a response from the Centers for Disease Control and Prevention indicating that they are interested in consulting on this EIS.

NHTSA received a comment on the DEIS asserting that NHTSA must consult under Section 7(a)(2) of the ESA with the Services regarding consideration of potential effects of the CAFE standards on federally-listed endangered and threatened species. NHTSA has carefully considered the requirements of the ESA and determined that Section 7(a)(2) consultation with the Services is not required for this action. *See* Appendix G for an explanation of this determination.

1.5.2 Summary of Scoping Comments

NHTSA received seven responses to its scoping notice. Federal and state agencies, one automobile trade association, one environmental advocacy group, and three individuals provided comments. This section summarizes these scoping comments.

1.5.2.1 Federal Agencies

EPA was the only federal agency that provided scoping comments (Docket No. NHTSA-2009-0059-0005). EPA suggested that NHTSA incorporate material from the October 10, 2008 FEIS in a judicious manner, recommending that NHTSA examine areas where the earlier analysis is no longer applicable, including key baseline assumptions, the social cost of carbon, and the predicted cost of fuel. Refer to Section 2 of this EIS for a discussion of NHTSA's current approach and assumptions. NHTSA notes that while some material from the October 10, 2008 Final EIS may still be relevant and applicable to the current EIS, the present document is a new analysis with a new consideration of all issues and impacts. EPA further suggested that NHTSA be cautious when trying to incorporate future promulgated actions into the cumulative impacts assessment, as this could prove to be highly speculative and not appropriate in the current rapid flux of potential related legislative and regulatory action. Refer to Section 4.4.3 (Cumulative Climate Methodology) of this EIS for a discussion of the methodology used to analyze cumulative impacts to climate. NHTSA notes that EPA's scoping comment was submitted before EPA received NHTSA's letter inviting EPA to become a cooperating agency on this EIS.

1.5.2.2 States

NHTSA received a letter from the Attorneys General of the States of California, Connecticut, Massachusetts, New Mexico, and Oregon, the Secretary of the New Mexico Environment Department, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and the Corporation Counsel of the City of New York (Docket No. NHTSA-2009-0059-0006).

The Attorneys General emphasized that rather than focusing on the effects of the rulemaking on global climate change, NHTSA should explain how this rule is consistent with, and essential to, the Nation's efforts to address global warming. In this regard, they suggested that the 2008 EIS minimizes the effects of the CAFE program on global climate change and does not analyze cumulative impacts appropriately. Quoting the Ninth Circuit Court of Appeals, which stated in a 2007 ruling that "[a]ny given rule setting a CAFE standard might have an 'individually minor' effect on the environment but these rules are 'collectively significant actions taking place over a period of time,'" they suggested that the 2008 EIS failed to meet this standard, and instead, minimized the effect of the rulemaking by stating that one set of CAFE rules by itself would have a negligible effect on global warming and public health and welfare. Refer to Sections 4.1.2 (Temporal and Geographic Boundaries) and 4.4.4 (Climate Cumulative Impacts) of this EIS, which discuss the temporal and geographic boundaries used for the analysis and the cumulative impacts to climate analysis, respectively. NHTSA notes that the agency is taking a fresh approach to placing its analysis in the context of global climate change in this EIS.

The letter cites the EPA "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act,"[54] which states that while no single GHG source category dominates on the global scale, many could be very significant contributors. In particular the letter cites EPA's statement that motor vehicle source categories contribute 24 percent of total U.S. GHG emissions, and that total U.S. GHG emissions make up about 18 percent of the world's GHG emissions. The Attorneys General concluded that NHTSA should put the CAFE rules in context by demonstrating their importance for reducing GHG emissions and reducing global warming. The Attorneys General listed some ways to provide the proper context, including: comparing CO_2 emission reductions with the overall emission reduction goals that the President has endorsed (80 percent reduction by 2050); evaluating whether the automobile manufacturing industry is addressing global warming; and evaluating whether the rules will help prevent reaching a "tipping point" beyond which cataclysmic damages occur due to nonlinear changes in the climate. Refer to Sections 3.4 and 4.4 of this EIS, which discuss climate change due to direct or indirect and cumulative impacts. The Attorneys General also suggested evaluating whether new CAFE rules could constitute a "stabilization wedge." Refer to Section 2.5 of this EIS for a discussion of alternatives not included in the analysis and the reasons for their exclusion.

The Attorneys General letter also incorporated by reference previous comments submitted to the 2008 EIS docket, including their 2008 scoping comments (Docket No. NHTSA-2008-0060-0007); 2008 DEIS comments (Docket No. NHTSA-2008-0060-0585); and 2008 Notice of Proposed Rulemaking comments (Docket Nos. NHTSA-2008-0060-0585, as an attachment to the 2008 DEIS comments, and NHTSA-2008-0089-0524). Comments received on the MY 2011 rulemaking and MYs 2011-2015 CAFE EIS were addressed in previous documents. NHTSA re-examined all of these comments and considered them in the development of this EIS. NHTSA is taking a fresh approach to this EIS. Thus, refer to the relevant sections of this EIS and the NPRM for MYs 2012-2016 CAFE standards for new discussions of these issues.

1.5.2.3 Automobile Trade Associations

NHTSA received a letter from the Alliance of Automobile Manufacturers (AAM) that provided scoping comments (Docket No. NHTSA-2009-0059-0007). AAM commented that the rate of fuel efficiency increase proposed by NHTSA – a 3- to 7-percent annual increase depending on the alternative – is substantially greater than historical fuel efficiency increases of approximately 1 percent annually and is too stringent for manufacturers undergoing difficult economic times. AAM noted that achieving the EISA-mandated minimum fuel efficiency increases, which equate to an increase in fuel efficiency of 3 percent per year, represents a substantial challenge for manufacturers. Furthermore, AAM stated that the most aggressive standards suggested by NHTSA would require an average annual passenger car and light truck fuel economy of over 50 mpg in approximately 10 years, which no individual vehicle produced on a large scale can now achieve. These aggressive alternatives, AAM asserted, ignore the "economic

[54] 74 *FR* 18886, 18907 (Apr. 24, 2009).

practicability" provisions of EPCA and its case law. AAM suggested that NHTSA should keep in mind historical rates of fuel efficiency change when developing the alternatives in order to achieve a realistic increase in fuel efficiency. Refer to Section 2 (Alternatives) of this EIS for a discussion of the different alternatives selected for the analysis.

AAM further suggested that more reasonable alternatives can be constructed by focusing on realistic variations of the 2020 MY endpoint under EISA, rather than incremental increases in average annual fuel economy improvement. Specifically, AAM suggests that Alternative 2 (as described in NHTSA's April 1, 2009 NOI), could be redefined as improving fuel economy at a rate necessary to achieve 35-mpg fleet average fuel economy in MY 2020; Alternative 3 could be defined as improving fuel economy at a rate necessary to achieve a 36.75-mpg fleet average fuel economy in MY 2020; and Alternative 4 could be defined as improving fuel economy at the rate necessary to achieve a 38.5-mpg fuel economy in MY 2020. AAM noted that establishing a NEPA alternative based on a level of stringency tied to a "least capable manufacturer" analysis would provide important information to policymakers, especially regarding the effects of proposed standards on those companies which, they contended, are least likely to succeed under the new standards. AAM also suggested using increases based on only the reductions necessary to reach the MY 2020 endpoint under EISA. Refer to Section 2.5 (Alternatives Considered but Not Analyzed in Detail) of this EIS for a discussion of alternatives not included in the analysis and the reasons for their exclusion.

AAM highlighted that NHTSA's NEPA regulations require the agency to apply a "systematic, interdisciplinary approach,"[55] and that, pursuant to this approach, NHTSA should consider a number of factors resulting from CAFE increases, including the effects of the CAFE increases on local air quality – specifically due to fleet turnover and rebound effects; the socioeconomic consequences of CAFE increases, such as impacts on the quality of life for workers at companies, which would be adversely affected by the regulations; and the effect of CAFE standards on ground-level ozone concentrations. AAM also suggested that regulation of motor vehicle GHG emissions will increase the price of vehicles, thereby reducing fleet turnover and leading to increases in criteria pollutant emissions. It recommended that the EIS fully explore the relationships between fleet turnover, vehicle prices, and the continued air quality improvements that are expected to result from an increase in CAFE standards. Refer to Section 3.3.3 (Air Quality Impacts) for a discussion of the air quality impacts of climate change. Refer to the NPRM for MYs 2012-2016 CAFE standards for new discussions of the updated Volpe model.

AAM also suggested that the EIS should only use studies that have undergone "rigorous scientific peer review" and suggested that NHTSA should coordinate with EPA in choosing criteria to determine which scientific studies to rely upon. NHTSA recognizes the importance of peer review in the validation of scientific studies and analytic methods.[56] Refer to Section 4.1 for an explanation of the unique expert and panel review process of climate change research in the scientific community. We also note above that NHTSA is coordinating with EPA via EPA's role as a cooperating agency.

AAM incorporated by reference its comments submitted during the 2008 scoping period. In the 2008 comment letter, AAM raised questions regarding the requirement for and appropriate scope of an EIS for the CAFE rulemaking, the appropriate definition of the alternatives, and the scope of the cumulative effects analysis. Refer to Chapter 1, Section 1.3.3 in the 2008 FEIS, which summarizes the scoping comments and NHTSA's responses, for an explanation of how NHTSA addressed these concerns

[55] 49 CFR § 520.23(a).
[56] *See* 74 *FR* 14857, 14861 (explaining that scoping comments will be most useful when supported by reference to peer-reviewed scientific studies and reports).

in the 2008 FEIS. NHTSA is taking a fresh approach to this EIS. In this EIS, these issues are addressed in Chapters 1, 2, and 4.

AAM also incorporated by reference its comments on the 2008 DEIS. These comments addressed the requirement for and appropriate scope of an EIS for the CAFE rulemaking. AAM raised questions about the Volpe model and pointed out that the fleet turnover effect may result in an increase in air pollutant emissions. Please refer to Chapter 10, Responses to Public Comments, of the 2008 FEIS for complete responses as to how NHTSA addressed AAM's concerns in the 2008 FEIS. Refer to Chapters 1 and 2 in this EIS for a new discussion of these issues.

1.5.2.4 Environmental Advocacy Groups

The Center for Biological Diversity (CBD) was the only environmental advocacy group to provide scoping comments on the NOI to prepare an EIS (Docket No. NHTSA-2009-0059-0009).

CBD stated that there is a need for fundamental changes to the process by which the CAFE standards are developed in issuing a final rule that complies with EISA and EPCA. One such change CBD recommended was to eliminate the use of the Volpe model. CBD suggested that NHTSA: revise the definition of light trucks to appropriately address their use as passenger cars; revise the Volpe model to accurately incorporate the benefits of lower vehicle weight for vehicle safety and fuel efficiency; revise the economic assumptions of the Volpe model to accurately reflect the feasibility of setting more aggressive standards; and develop an independent process to derive technology and capacity estimates. Refer to Sections 2.2.1 (Volpe Model), Section 2.2.3 (Technology Assumptions), and Section 2.2.4 (Economic Assumptions) of this EIS for a discussion of the Volpe Model and the technology and economic assumptions used in the model. Refer to the NPRM for MYs 2012-2016 CAFE standards for detailed discussions of the updated Volpe model and the new assumptions.

CBD maintained that limiting technology implementation to manufacturer "redesign" and "refresh" cycles as done in previous EISs goes against the technology-forcing principle mandated by EPCA. By not including a technology-forcing alternative, CBD contended that NHTSA artificially constrains the range of alternatives analyzed in this EIS. In CBD's opinion, these development cycles should have no bearing on the considerations of technology implementation within the cost-benefit analysis. On a similar note, CBD suggested that NHTSA's "technology exhaustion" alternative, defined by the criteria "whether a particular method of improving fuel economy can be available for commercial application in the MY for which the standard is being established," cannot substitute for consideration of a technology-forcing alternative, because it does not include standards that may appear impossible today, but which would force innovation as industry strives to meet a more challenging standard. NHTSA notes that this EIS does not consider a technology exhaustion alternative. Refer to Section 2.5 (Alternatives Considered but Not Analyzed in Detail) of this EIS for a discussion of other alternatives not included in the analysis and the reasons for their exclusion. Again, refer to Sections 2.2.1 (Volpe Model) and Section 2.2.3 (Technology Assumptions) of this EIS and to the NPRM for MYs 2012-2016 CAFE standards for discussions of the updated Volpe model.

CBD suggested that the EIS must include a reasonable analysis of the combined impact of NHTSA's rulemaking on U.S. transportation-sector emissions overall, as well as U.S. emissions overall. CBD recommended that NHTSA use the EIS to determine whether the impact of the proposed rulemaking is sufficient to ensure that the necessary emissions reductions from the U.S. transportation sector overall will be achievable. Citing recent published reports that contend that it will be necessary to limit CO_2 concentrations to 350 parts per million (ppm) to avoid climate catastrophe, CBD requested that a maximum 350-ppm scenario be included as an upper limit for defining the range of alternatives. CBD suggested using the function in the Model for Assessment of Greenhouse Gas-induced Climate Change

(MAGGIC) that controls future emissions so that atmospheric CO_2 concentrations do not exceed values ranging from 350 to 750 ppm. Refer to Section 3.4.2 (Affected Environment – Climate) of this EIS for a discussion of U.S. and global GHG emissions trends. Refer to Section 3.4.4.1 (Environmental Consequences – Greenhouse Gas Emissions) for a discussion of the effect of the proposed CAFE standards and the alternatives on GHG emissions. Refer to Section 4.4.3.3 (Global Emissions Scenarios) for a discussion of reasonably foreseeable global emissions scenarios in the cumulative effects analysis.

Finally, CBD contended that NHTSA must initiate consultation with U.S. Fish and Wildlife Service and National Marine Fisheries Service on the impact of GHGs and other air pollutants on listed species. Specifically, CBD stated that NHTSA must further examine the impact of its action on species listed as threatened or endangered under Section 7 of the Endangered Species Act (ESA) and the National Environmental Policy Act. NHTSA is taking a fresh look at Section 7 consultations under the ESA for the MYs 2012-2016 CAFE rulemaking. As explained in Section 1.5.1, NHTSA has determined, in coordination with EPA, that consultation under the ESA is not required.

1.5.2.5 Individuals

Three individuals provided scoping comments on the proposed rulemaking: Jean Public (NHTSA-2009-0059-0002), Michael Gordon (NHTSA-2009-0059-0003), and James Adcock (NHTSA-2009-0059-0004).

Jean Public suggested that NHTSA raise fuel economy standards to 100 mpg. Refer to Section 2.5 of this EIS for a discussion of other alternatives not included in the analysis and the reasons for their exclusion.

Michael Gordon stated his strong opposition to increasing CAFE standards, suggesting that CAFE standards should be controlled by consumer demand alone. Refer to Section 1.3 (Purpose and Need) of this EIS for a discussion of why CAFE standards must be increased.

James Adcock suggested that, due to the rapidly changing world and unknown future events, NHTSA should consider issuing standards covering shorter time periods to allow the agency flexibility to re-address fuel economy standards. Refer to Section 1.3 of this EIS for a discussion of why the specific time scale was chosen. Mr. Adcock also suggested that NHTSA increase its fuel economy projections based on the leverage that the current administration has to impress change upon automobile manufacturers. Refer to the NPRM for a discussion of the current vehicle market.

Mr. Adcock stated that the Volpe Model source code and output results should be published so that the public can determine if any errors exist. NHTSA has published the Volpe Model source code and output results. Refer to NHTSA's website (www.nhtsa.gov) or the docket (NHTSA-2009-0059) for a publication of the Volpe Model source code and output results.

Mr. Adcock contended that, contrary to the "footprint" model used by NHTSA, safety can be assured largely independent of fuel economy. He further highlighted techniques like sobriety checkpoints and enhanced traffic enforcement that can achieve safety improvements and help eliminate the perceived "size-based safety need" for large vehicles. Refer to Section 3.5.4 (Safety and Other Impacts to Human Health) of this EIS and Section IV.G.6 of the NPRM for MYs 2012-2016 CAFE standards for a discussion of the safety impacts of the proposed action and alternatives.

Mr. Adcock commented on several assumptions used in the 2008 EIS. He recommended that NHTSA indicate which discount rate is used and why. Regarding gas price estimates, Mr. Adcock suggested that NHTSA use futures markets for oil and gas and up-to-date prices rather than relying on

EIA estimates of future gas prices. Mr. Adcock also stated that a backstop may be necessary to combat large fluctuations in fuel economy year to year due to changes in fuel costs and individuals involved in the automobile market. Furthermore, he recommended that NHTSA consider the global costs of CO_2 externalities instead of just the domestic costs. Similarly, he claimed that NHTSA should assume that CO_2 reductions in the United States will be matched by carbon dioxide reductions in other nations. Refer to Sections 2.2.1 (Volpe Model), Section 2.2.3 (Technology Assumptions), and Section 2.2.4 (Economic Assumptions) of this EIS for a discussion of the Volpe Model, and the technology and economic assumptions used in the model.

Mr. Adcock recommended that NHTSA allow an alternative certification path for vehicles in the United States, accept European Community vehicle certification standards, and permit the importation of higher fuel-efficiency European cars. The Vehicle Safety Act mandates that NHTSA set motor vehicle safety standards that are practicable, meet the need for motor vehicle safety, and are stated in objective terms.[57] NHTSA has done so. While NHTSA appreciates the commenter's suggestion, it is unable, pursuant to its statutory authority, to accept imported vehicles that do not comply with applicable federal motor vehicle safety standards.[58] NHTSA believes that the federal motor vehicle safety standards incorporate the appropriate balance of the codified statutory considerations and that adoption of the European Community standards would be in contravention of congressional mandate.

Mr. Adcock also suggested that NHTSA change its current approach and consider use of a de-powered "environmental" mode to increase fuel efficiency. He stated that NHTSA should also acknowledge that U.S. demand has shifted to smaller, more efficient vehicles. Refer to the NPRM for a discussion of the market demand for fuel efficient vehicles.

1.5.3 Summary of Comments on the DEIS

NHTSA received 11 written comment submissions on the DEIS from interested stakeholders consisting of federal agencies, state agencies, environmental advocacy groups, and private citizens. In addition, three interested parties spoke at the public hearing. The transcript from the public hearing and written comments submitted during the public comment period are part of the administrative record and are available on the Federal Docket website at http://www.regulations.gov, Reference Docket No. NHTSA-2009-0059.[59] In Chapter 10 of this FEIS, NHTSA provides excerpts of substantive comments on the DEIS, followed by NHTSA's responses to those comments. The comments received on the DEIS are summarized by commenter type in the paragraphs below.

1.5.3.1 Federal Agencies

Three federal agencies provided comments on the DEIS: the Centers for Disease Control and Prevention (CDC) (Docket No. NHTSA-2009-0059-0042); the U.S. Department of Agriculture (USDA) Agricultural Research Service (Docket No. NHTSA-2009-0059-0043); and EPA (Docket No. NHTSA-2009-0059-0052.1).

CDC commented that the health-related consequences of concurrent factors resulting from the proposed action, such as increasing demand for and decreased availability of fossil fuels, should be included in the scope of analysis pursuant to NEPA. It stated that the associated health impacts include benefits to mental health and stress reduction. CDC suggested collaboration with public health professionals. It also noted that the potential fleet design and composition by which vehicle

[57] 49 U.S.C. § 30111. The Secretary has delegated authority for these standards to NHTSA. *See* 49 CFR 1.50.
[58] *See* 49 U.S.C. § 30112 (prohibiting the importation of vehicles that do not comply with applicable standards).
[59] *See* Docket No. NHTSA-2009-0059-0054.

manufacturers will comply with new CAFE standards deserves further analysis, and that modeling these projections is critical to adequately analyzing the impact of new CAFE standards on the human environment.

USDA Agricultural Research Service noted that it purchases the type of vehicles covered by the proposed action and stated, therefore, that the increase in fuel economy of vehicles on the market will help the agency achieve its fuel consumption and GHG emission reduction requirements under the Energy Policy Act of 2005, EISA, and several executive orders.

EPA stated that it was supportive of the effort to raise fuel economy standards as part of the joint EPA/NHTSA National Program and noted that NHTSA's proposed action would result in environmental benefits.[60]

1.5.3.2 State Agencies

Three state agencies provided comments on the DEIS: the Tennessee Department of Transportation (Docket No. NHTSA-2009-0059-0046), the Missouri Department of Natural Resources (Docket No. NHTSA-2009-0059-0051), and the New York Department of Transportation (Docket No. NHTSA-2009-0059-0098).

The Tennessee Department of Transportation commented on the appropriateness of the joint rulemaking and the National Program. It commended the joint effort as an effective way to develop regulations in a coordinated fashion. The agency applauded NHTSA for developing rules that meet Congress' 2007 mandate for tighter CAFE standards and applying those standards by 2016, well in advance of the 2020 deadline mandated by Congress. It also stated that this initiative is the single largest step the United States can take to reduce energy consumption and GHG emissions and that the DEIS does not properly portray the significance of these reductions. The agency also cautioned that the final standards must guard against potential loopholes or other efforts to weaken the effectiveness of the program.

The Missouri Department of Natural Resources expressed support for implementing a CAFE standard more stringent than the No Action Alternative, but questioned some of the findings in the air quality analysis. Most of the issues raised by the agency were related to the use of a 10 percent rebound effect, which it questioned as not being appropriate. It noted that, by assuming an increase in vehicle miles traveled due to improved fuel economy (*i.e.*, the rebound effect), the DEIS is very conservative in estimating reductions of toxic pollutant air emissions. The agency also expressed concern regarding potential localized increases in emissions in nonattainment or maintenance areas due to the rebound effect and the uncertainty of estimating ozone levels.

The New York Department of Transportation suggested that CAFE standards be set at as stringent a level as possible using technology-forcing standards and that implementing more aggressive standards more quickly would be appropriate. The Department also suggested that the economic benefits of improved fuel economy at the consumer level were not considered and that the way in which the discount rate is applied should be more clearly defined. In the Department's opinion, the discount rate should be applied to both costs and benefits. The Department also stated that consideration should be given to the way in which the transportation sector might contribute to achieving an 80 percent reduction

[60] Under Section 309 of the CAA, EPA is required to review and publicly comment on the environmental impacts of major federal actions including actions that are the subject of EISs. If EPA determines that the action is environmentally unsatisfactory, it is required by Section 309 to refer the matter to CEQ. The Office of Federal Activities makes the referral.

in GHG emissions by 2050. Finally, the Department also suggested that mitigation strategies for offsetting future emissions increases be discussed.

1.5.3.3 Advocacy Groups

Four advocacy groups provided comments on the DEIS. Environmental Consultants of Michigan submitted a comment (Docket No. NHTSA-2009-0059-0050.1), and, additionally, CBD, Sierra Club, and Public Citizen submitted joint written comments (Docket No. NHTSA-2009-0059-0053.1). Mark Cooper of the Consumer Federation of America, Ann Mensikoff of Sierra Club, and Lena Pons of Public Citizen provided testimony at the public hearing.

In their combined comments, CBD, Sierra Club, and Public Citizen stated that the proposed rulemaking could substantially impact endangered species and that an analysis of these impacts was absent from the comparison of the impacts of each alternative in the DEIS. They stated that NHTSA must complete an Endangered Species Act Section 7 Consultation to ensure that its action will not jeopardize or adversely modify the critical habitat of threatened or endangered species.

With regard to the structure and readability of the DEIS, CBD, Sierra Club, and Public Citizen specifically questioned the appropriateness of the DEIS comparison of alternatives in regard to GHG reductions and climate change. They stated that comparing the alternatives based on their contribution to the reduction in global temperature and sea-level rise in 2100 minimizes differences among alternatives to the point that climate change impacts of the agency's proposed action are not shown in an appropriate or understandable context. They suggested that rather than being compared only to overall global concentrations, alternatives should be analyzed in a narrower context, for example, by analyzing their effects on emissions from motor vehicles in particular and on the U.S. transportation sector in general.

Also with regard to readability, Environmental Consultants of Michigan expressed concern that the DEIS is not written in plain language, which prohibits decisionmakers and the public from fully comprehending the analysis. They suggested presenting the impacts analysis in a context that is relevant to the reader. Furthermore, they stated that requiring each agency to set its own standard under this joint rulemaking was duplicative and unnecessary.

Additionally, CBD, Sierra Club, and Public Citizen expressed concern about how NHTSA's alternatives relate to the EPCA requirement to establish the "maximum feasible average fuel economy." They suggested that the DEIS fails to accurately describe maximum standards that are both technologically feasible and economically practicable, and that, consequently, the DEIS fails to propose standards at the maximum feasible level. They further criticized the DEIS for not considering a "technology forcing" alternative that is technologically exhaustive.

CBD, Sierra Club, and Public Citizen also criticized the use of the Volpe model in setting CAFE standards. They stated that the Volpe model fails to adequately incorporate and respond to the real-world impacts and costs at stake as a result of the impacts of climate change. Additionally, they suggested that the Volpe model is insensitive to the social cost of carbon and therefore is an inappropriate tool to use in setting CAFE standards.

CBD, Sierra Club, and Public Citizen also commented on the methodology for analyzing climate change impacts. They stated that the DEIS fails to adequately address climate change tipping points. They noted that under all scenarios considered in the DEIS, atmospheric CO_2 concentrations would reach 550 ppm or greater, which they stated is above the threshold for abrupt and catastrophic climate change caused by exceeding tipping points. They argued that none of the alternatives adequately addresses the need for deep reductions in CO_2 emissions. They also suggested alternative scenarios for modeling emission reduction impacts. Citing recent scientific evidence indicating that the avoidance of tipping points and climate catastrophe requires reductions in atmospheric CO_2 concentrations to 350 ppm, they suggested modeling alternative scenarios in which future emissions are controlled so that atmospheric CO_2 concentrations do not exceed values ranging from 350 to 750 ppm.

Both the public testimony and written comments of CBD, Sierra Club, and Public Citizen suggested that the DEIS fails to consider all reasonably foreseeable actions that could affect fuel efficiency standards and GHG emissions from the transportation sector. They suggested that the DEIS ignores foreseeable actions including the continued regulation of GHGs by California and the states and the policies to reduce vehicle miles traveled.

1.5.3.4 Individuals

Four individuals provided comments on the DEIS: Gail Gilbert (Docket No. NHTSA-2009-0059-0019), an anonymous commenter (Docket No. NHTSA-2009-0059-0044), Douglas Long (Docket No. NHTSA-2009-0059-0045), and James Adcock (Docket No. NHTSA-2009-0059-0049).

All four commenters addressed the merits of the agency's proposed action. Gail Gilbert stated that, despite her concern for loopholes, she considered the standards to be a big step forward. The anonymous commenter noted that the proposed action should not be under the control of the President or the U.S. Government in general. Douglas Long stated that NHTSA's proposed action would establish regulations that would protect the American people by requiring that car manufacturers produce cleaner and more fuel-efficient vehicles than previously required. James Adcock stated that NHTSA's proposed action does not represent a weighed consideration of climate change and that therefore NHTSA should change its proposal.

James Adcock also raised several additional issues concerning the DEIS. One issue pertains to the availability of materials for public review. For example, Mr. Adcock expressed frustration that the 2009 National Academy of Sciences update regarding the effectiveness and impact of CAFE standards was not available in time for the DEIS comment period. Additionally, Mr. Adcock expressed concern that the Volpe model could not be used on a personal computer for public validation of the model outputs.

Mr. Adcock further suggested that NHTSA should not base fuel economy regulations on vehicle designs that manufacturers produce but never sell in great quantities. Rather, he claimed, NHTSA should focus on the vehicle models that make up most of the vehicle sales. Similarly, Mr. Adcock expressed concern regarding the technological assumptions used in the Volpe model. For example, he disagreed with NHTSA's decision to exclude certain technologies, such as electric vehicles and plug-in hybrid electric vehicles, from consideration when setting CAFE standards for MYs 2012-2016.

Mr. Adcock also critiqued the DEIS discussion of the safety impacts of new CAFE standards. He indicated that, although there might be a correlation between weight or footprint and safety, there is unlikely to be a significant correlation to miles per gallon, contrary to what is reported in the DEIS.

Mr. Adcock also suggested that NHTSA fails to adequately account for species extinction when estimating the social cost of carbon. He believes NHTSA's social cost of carbon is too low. Mr. Adcock also noted that the "environmentally preferred alternative" is not identified in the DEIS.

1.5.4 Summary of Rulemaking Comments Relevant to the DEIS

On September 28, 2009, EPA and NHTSA published the joint NPRM in the *Federal Register*.[61] The publication of the proposed rule opened a 60-day comment period, and the public was invited to submit comments on or before November 27, 2009 by posting to either the NHTSA or EPA docket (NHTSA-2009-0059 or EPA-HQ-OAR-2009-0472). A total of 247 rulemaking comments was submitted to the NHTSA docket and a total of 11,109 rulemaking comments was submitted to the EPA docket. NHTSA reviewed these submissions and has fully considered them in the development of the final rule. In addition, comments on the joint rulemaking were considered during the preparation of the EIS to ensure that any comments that could affect the content of the EIS were taken into account. For purposes of the EIS, NHTSA specifically looked for comments that were related to the EIS, such as comments about the Preferred Alternative, the range of alternatives considered, and the analysis of environmental impacts. Following is a brief description of the most common comments submitted on the rulemaking that are relevant to the EIS.

Approximately 10,000 similar comments were received in support of the National Program. In these comments, commenters stated that they believed the benefits of the rulemaking would include: reducing GHG emissions from the transportation sector, thereby reducing climate change impacts; curbing dependence on foreign oil; improving national security; revitalizing the auto industry; reducing money spent on gasoline by consumers; encouraging the advancement and deployment of advanced technologies; and providing consumers with cleaner vehicle choices. Some comments were petitions that included signatures (more than 124,000 signatures were received).

Although expressing support for the rulemaking, some commenters questioned why joint rules by two agencies were necessary. Many expressed the belief that NHTSA's CAFE program is sufficient, while a few stated that the EPA GHG rule could replace the CAFE program. Several commenters had concerns about EPA's regulation of GHG gases under CAA. Several states noted that the state waiver from EPA already grants California and other states the authority to regulate GHG emissions from vehicles. Several manufacturers and trade associations expressed appreciation that NHTSA and EPA were proposing one national joint rule.

Although general support for the joint rulemaking was extensive, the second most frequent comment or recommendation was to adopt a more aggressive alternative for achieving higher levels of fuel economy and greater reductions in GHG emissions. These commenters were concerned that the proposed rulemakings were insufficient to avoid the adverse impacts of global warming and did not reflect fuel-saving technology advances that are currently or soon to be available. Commenters suggested CO_2 reductions from vehicles should be in the 30–50 percent range. A frequent suggestion was to set standards that required vehicles to reach 50 mpg by 2016 as opposed to the proposed 33.8 mpg combined average in 2016Commenters also felt that the deadline for compliance with the EPA rule should be 2015, not 2030. In addition to more aggressive alternatives, many commenters offered new alternatives for the agencies to consider. These suggested alternatives covered a broad range of approaches, including ideas beyond the jurisdictions of NHTSA and EPA. Suggestions included eliminating the use of gasoline and relying on electric or hydrogen-powered vehicles; taxing gasoline at dramatically higher levels to reduce average vehicle use; returning to the 55 mile-per-hour speed limit on U.S. interstates and highways; rationing gasoline; promoting mass transit; retrofitting existing vehicles to improve their fuel economy; and placing higher fuel economy standards on government-owned vehicles.

[61] Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 74 *FR* 49454 (Sep. 28, 2009).

Specific comments also were received on the components of the alternatives analyzed in the rulemaking. Some commenters expressed the belief that vehicle manufacturers have too much flexibility in compliance and cite the credits and the attribute-based standards as examples of this flexibility. These commenters are concerned that fully achieving the rule's GHG reduction estimates will be undermined by including these components, especially the proposed credits. Several commenters specifically expressed concern regarding EPA's credit for electric vehicles. Many stated that the benefit offered by this credit did not, through a life-cycle analysis, account for the GHGs emitted by the power plants that would provide these vehicles with their source of electricity. Other commenters, however, viewed the flexibility and credits as a benefit because they could reduce compliance costs for the automobile industry and allow for more consumer choice. Despite this compliance flexibility, other commenters noted that the rule's compliance costs, as estimated by NHSTA and EPA, are understated for small-volume manufacturers because such manufacturers have fewer vehicles over which the costs can be spread.

Commenters also raised questions about the adequacy of several cost and benefit measurements that are inputs into the Volpe model. In the EIS, the Volpe model establishes the mpg standard for the alternative that maximizes net benefits (MNB) (Alternative 6) and the alternative under which total cost equals total benefit (TCTB) (Alternative 9). Most notable were comments on the model's estimate for the social cost of carbon. The $20 per metric ton cost that was used initially was generally reproved as being too low. These commenters expressed their belief that this cost does not adequately reflect the adverse impacts of CO_2 emissions on society. Many of these commenters cited studies that used a much higher cost estimate. Similarly, comments were made regarding the undervaluation of national security benefits. These commenters believe that higher benefits should be claimed for reducing the nation's dependence on foreign oil and the possible resulting future reduction in defense costs. NHTSA responds to the DEIS comments on the Volpe model in Section 10.2.3.4.2 of this EIS.

Comments also were also received on the environmental impacts of the rule. A few commenters suggested that the environmental benefits of the rule in terms of climate change are inconsequential. Some suggested that there is evidence that climate change science is based on incorrect assumptions and data. One commenter suggested that the proposed rule relied too heavily on literature produced by the Intergovernmental Panel on Climate Change (IPCC) and that other peer-reviewed research also should be considered. Another commenter suggested that action is required now so that the climate tipping point is not passed. Some commenters suggested that only a world with a global concentration of 350-ppm CO_2 equivalent is sustainable. In this EIS, NHTSA discusses the effects of the rule on climate change in Sections 3.4, 4.4, and 4.5. NHTSA responds to similar comments received on the DEIS in Section 10.2.4.6 on the comparison of alternatives and the context of the analysis, Section 10.3.3 on climate tipping points, and Section 10.4.2 on climate methodology.

Several commenters suggested that a complete life cycle assessment of the rulemaking be completed. One commenter suggested that automobile manufacturers and their parts suppliers will need to retrofit their existing facilities or build new ones, which will require the extraction and processing of raw and recycled materials into useable building materials, transportation of those materials, and construction, which will produce GHG emissions. This commenter further suggested that vehicles will likely be manufactured from lighter weight materials to meet higher fuel economy requirements; some of these materials could require more energy to produce or recycle, leading to increased GHG emissions.

NHTSA agrees with these commenters that a complete life cycle assessment of the impacts of the CAFE rulemaking, which would include estimates of energy use and emissions from both vehicle manufacturing and the construction or modification of facilities for producing and assembling vehicle components, would be an informative and interesting addition to its analysis of alternative increases in CAFE standards. However, such an analysis would require a number of largely arbitrary assumptions about uncertain variables – such as the number of facilities that would need to be constructed or modified

– and the behavior of vehicle manufacturers. The necessary assumptions would introduce sufficient uncertainty into the calculations of total energy use and emissions that NHTSA does not believe the resulting analysis would be reliable or useful to decisionmakers. For example, a complete life cycle analysis would require the agency to make assumptions about what fraction of manufacturers would build new facilities or modify existing ones as a result of increased CAFE standards, what specific materials and construction methods would be employed in building or modifying these facilities, and on what magnitude or scale these facilities would operate. The agency does not believe it has any reasonable basis for speculating about these parameters, or about other equally important assumptions that would be necessary to conduct a comprehensive life cycle analysis of energy use and emissions resulting from vehicle manufacturers' responses to increases in CAFE standards for future model years. Therefore, NHTSA has not attempted a complete life cycle assessment as part of the analysis for the EIS or final rule establishing CAFE standards for MY 2012-2016 passenger cars and light trucks.

Many commenters expressed support for the rule because they believe the reduction in emissions would improve public health by reducing asthma and other health issues related to poor air quality. However, two states expressed concern about the possible increases in emissions of criteria pollutants and air toxics, such as acetaldehyde, 1,3- butadiene ethylbenzene, toluene, and the xylene isomers, due to increased vehicle use, stating that increases in these emissions could have direct health impacts. Two states suggested that, in areas with little or no fuel-refining industry, the rebound effect would result in an increase in criteria pollutant emissions that are of critical importance for compliance with the National Ambient Air Quality Standard for ground-level ozone, primarily the emissions of volatile organic compounds (VOC) and nitrogen oxides (NO_x). One state suggested that the emissions of all air toxics associated with the extraction, production, distribution, and combustion of fuel be examined and evidence be presented demonstrating that the proposed National Program will not increase air toxics emissions from mobile sources.

NHTSA addresses air quality, including emissions of criteria pollutants and air toxics both nationwide and in nonattainment areas, in Sections 3.3 and 4.3 of the EIS and responds to comments about the air analysis in Section 10.3.2. The analysis shows that VOC emissions would decrease in every nonattainment area. NO_x emissions would decrease in some nonattainment areas under Alternatives 2 through 4 and would decrease in all nonattainment areas under Alternatives 5 through 9. Some nonattainment areas would have NO_x emissions increases for some years and alternatives, but the increases would be very small compared to total NO_x emissions in the affected nonattainment areas. The EIS air quality analysis covers the air toxics that EPA and the Federal Highway Administration have identified those that typically are of greatest concern for emissions from highway vehicles (acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter, and formaldehyde). The analysis includes downstream (combustion) and upstream (extraction, production, storage, and distribution) emissions and predicts both increases and decreases in emissions of air toxics depending on pollutant, calendar year, and alternative. NHTSA conducted a photochemical air quality modeling analysis of the alternatives which demonstrates beneficial impacts to health effects and health-related economic costs. The photochemical air quality analysis is included as Appendix F of this EIS.

Some commenters pointed out that the rulemaking could affect vehicle safety due to changes in vehicle size and weight. Commenters expressed satisfaction that the number of larger vehicles on the road was likely to diminish and the number of smaller cars was likely to grow; however, they connected this outcome to concerns about safety, citing tradeoffs between vehicle safety and weight reduction. Commenters also expressed concerns that NHTSA and EPA reached different conclusions regarding the safety-related impacts that could result from implementation of the proposed standards and that NHTSA might be using outdated data. NHTSA incorporated the safety discussion from the preamble and Chapter 9 of the Preliminary Regulatory Impact Analysis on how future improvements in fuel economy might affect human health and welfare into the EIS in Section 3.5.4 (NHTSA 2009). NHTSA received similar comments on the DEIS and provides a response in Section 10.3.4.1.

Some commenters expressed concern that the cost of cars would increase, creating an affordability issue. Another commenter was concerned that the cost and availability of trucks would be negatively affected and thereby would negatively affect people such as farmers and ranchers whose jobs require trucks to haul heavy loads. Some commenters expressed concern that the cost for automobile manufacturers to implement the rule would force them to reduce the number of people they employ. Finally, commenters expressed general concerns about the affordability of cars manufactured to comply with the new standards.

1.5.5 Next Steps in the NEPA Process and CAFE Rulemaking

No sooner than 30 days after the availability of this EIS is announced in the Federal Register by EPA, NHTSA will execute a Record of Decision (ROD) and publish in the Federal Register the ROD and a final joint rule with EPA. The ROD will state and explain NHTSA’s decision.

Chapter 2 Proposed Action and Alternatives

2.1 INTRODUCTION

The National Environmental Policy Act[1] (NEPA) requires an agency to compare the environmental impacts of its proposed action and alternatives. An agency must rigorously explore and objectively evaluate all reasonable alternatives, including a No Action Alternative. For alternatives an agency eliminates from detailed study, the agency must "briefly discuss the reasons for their having been eliminated."[2] The purpose of and need for the agency's action provides the foundation for determining the range of reasonable alternatives to be considered in its NEPA analysis.[3]

For this EIS, the National Highway Traffic Safety Administration (NHTSA) Proposed Action is to set passenger car and light truck Corporate Average Fuel Economy (CAFE) standards for model years (MYs) 2012-2016 in accordance with the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA). In developing the new proposed MYs 2012-2016 CAFE standards and possible alternatives, NHTSA considered the four EPCA factors that guide the agency's determination of "maximum feasible" standards:

- Technological feasibility;
- Economic practicability;
- The effect of other standards of the Government on fuel economy; and
- The need of the Nation to conserve energy.[4]

In addition, NHTSA considered relevant environmental and safety factors.[5] The NEPA analysis presented in the Environmental Impact Statement (EIS) informs the agency's action in setting CAFE standards. During the standard-setting process, NHTSA consults with the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA) regarding a variety of matters as required by EPCA. NHTSA also is guided by President Obama's memorandum to the U.S. Department of Transportation (DOT) on January 26, 2009, and the NHTSA/EPA Joint Rulemaking announced on May 19, 2009, as described in Chapter 1.

2.2 STANDARDS-SETTING

In developing the proposed MYs 2012-2016 standards, the agency developed and considered a wide variety of alternatives. NHTSA took a new approach to defining alternatives as compared to the most recent prior CAFE rulemaking. In the NOI, in response to comments received in the last round of rulemaking, NHTSA selected a range of candidate stringencies that increased annually, on average, 3 percent to 7 percent. That same approach was carried over to this EIS and to the rulemaking. The majority of the alternatives considered by the agency are defined as average percentage increases in

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[1] 42 U.S.C. § 4332(2)(C). NEPA is codified at 42 U.S.C. § 4321, *et seq*.
[2] 40 CFR §§ 1502.14(a), (d).
[3] 40 CFR § 1502.13. *See Vermont Yankee Nuclear Power Corp. v. Natural Res. Def. Council*, 435 U.S. 519, 551 (1978); *City of Alexandria v. Slater*, 198 F.3d 862, 867-69 (D.C. Cir. 1999), *cert. denied sub nom.*, 531 U.S. 820 (2000).
[4] 49 U.S.C. § 32902(f).
[5] As mentioned in Chapter 1, NHTSA interprets the statutory factors as including environmental issues and permitting the consideration of other relevant societal issues, such as safety. *See, e.g.*, *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)); and 73 *Federal Register* (*FR*) 24352, 24364 (May 2, 2008).

stringency – 3 percent per year, 4 percent per year, 5 percent per year, and so on. NHTSA believes that this approach more clearly communicates the level of stringency of each alternative and is more intuitive than alternatives defined in terms of different cost-benefit ratios, and still allows us to identify alternatives that represent different ways to balance NHTSA's statutory requirements under EPCA/EISA.

In the NOI, we noted that each of the listed alternatives represents, in part, a different way in which NHTSA could conceivably balance conflicting policies and considerations in setting the standards. We were mindful that the agency would need to weigh and balance many factors, such as the technological feasibility, economic practicability (including lead-time considerations for the introduction of technologies and impacts on the auto industry), the impacts of the standards on fuel savings and CO_2 emissions, as well as other relevant factors such as safety. For example, the 7-Percent Alternative, the most stringent alternative, weighs energy conservation and climate change considerations more heavily and technological feasibility and economic practicability less heavily. In contrast, the 3-Percent Alternative, the least stringent alternative, places more weight on technological feasibility and economic practicability. We recognized that the "feasibility" of the alternatives also may reflect differences and uncertainties in the way in which key economic (*e.g.*, the price of fuel and the social cost of carbon) and technological inputs could be assessed and estimated or valued.

After working with EPA in thoroughly reviewing and in some cases reassessing the effectiveness and costs of technologies, most of which are already being incorporated in at least some vehicles, market forecasts and economic assumptions, we used the Volpe model extensively to assess the technologies that the manufacturers could apply in order to comply with each of the alternatives. This permitted us to assess the variety, amount, and cost of the technologies that could be needed to enable the manufacturers to comply with each of the alternatives. NHTSA estimated how the application of these and other technologies could increase vehicle costs. The following sections describe the Volpe model and the inputs to the Volpe model, to help the reader gain an overview of the analytical pieces and tools used in the agency's analysis of alternatives.

2.2.1 Volpe Model

Since 2002, NHTSA has employed, as part of its analysis, a modeling system developed specifically to assist NHTSA with applying technologies to thousands of vehicles and developing estimates of the costs and benefits of potential CAFE standards. The CAFE Compliance and Effects Modeling System, developed by the DOT Volpe National Transportation Systems Center and commonly referred to as "the Volpe model," enables the agency to efficiently, systematically, and reproducibly evaluate many more regulatory options, including attribute-based CAFE standards required by EISA, than were previously possible, and to do so much more quickly. Generally speaking, the model assumes that manufacturers apply the most cost-effective technologies first, and as more stringent fuel economy standards are evaluated, the model recognizes that manufacturers must apply less cost-effective technologies. The model then compares the discounted present value of costs and benefits for any specific CAFE standard. However, while the Volpe model does calculate average changes in vehicle prices (corresponding to total technology outlays and, where applicable, civil penalties), it does not currently predict manufacturers' decisions regarding the pricing or production of specific vehicle models. Nor does it currently estimate for consumer behavioral responses such as buying fewer vehicles or buying different types of vehicles.

Model documentation, publicly available in the rulemaking docket and on NHTSA's website, explains how the model is installed, how the model inputs and outputs are structured, and how the model is used. The model can be used on any Windows-based personal computer with Microsoft Office 2003 or 2007 and the Microsoft .NET framework installed (the latter available without charge from Microsoft). The executable version of the model, with all of its underlying source code and accompanying demonstration files, is also available on NHTSA's website for public download. The current version of the model was developed using Microsoft Development Environment 2003, and every line of computer code (primarily in $C^{\#}$.NET) has been made available to individuals who have requested the code.

The Volpe model requires the following types of input information: (1) a forecast of the future vehicle market; (2) estimates of the availability, applicability, and incremental effectiveness and cost of fuel-saving technologies; (3) estimates of vehicle survival and mileage accumulation patterns, the rebound effect, future fuel prices, the "social cost of carbon," and many other economic factors; (4) fuel characteristics and vehicular emissions rates; and (5) coefficients defining the shape and level of CAFE curves to be examined. The model is a tool that the agency uses for analysis: it makes no *a priori* assumptions regarding inputs such as fuel prices and available technology, and does not dictate the form or stringency of the CAFE standards to be examined. The agency makes those selections based on the best available information and data.

Using inputs selected by the agency, NHTSA projects a set of technologies each manufacturer could apply in attempting to comply with the various levels of potential CAFE standards to be examined. The model then estimates the costs associated with this additional technology utilization, as well as accompanying changes in travel demand, fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors.

Normally, the Volpe model uses technologies available on vehicles in the current year. For example, when modeling MY 2014, only vehicle models with technologies "enabled" in MY 2014 would be candidates for technology application. One of the updates to the model for the current rulemaking is the addition of a "multi-year planning" capability, developed in response to comments to prior CAFE rulemakings. When run in multi-year mode, the model is allowed to "look back" to earlier years when a technology was enabled on any vehicles but not used, and consider "back-dating" the application of that technology when calculating the effective cost. Thus, if the model did not apply an enabled technology in either MY 2012 or MY 2013, then that technology remains available for multi-year application in MY 2014. Multi-year mode is anticipated to be most useful in situations where the model finds that a manufacturer is able to reach compliance in earlier years of the modeling period (*e.g.*, MY 2012) but is challenged to reach compliance in later years (*e.g.*, MY 2014). In these cases, the model can go back to the earlier year and over-comply in order to make compliance in the later year easier to achieve.

Recognizing the uncertainty inherent in many of the underlying estimates in the model, such as the social cost of carbon, the discount rate, and so on, NHTSA has used the Volpe model to conduct both sensitivity analyses, by changing one factor at a time, and a probabilistic uncertainty analysis (a Monte Carlo analysis that allows simultaneous variation in these factors) to examine how key measures (*e.g.*, mpg levels of the standard, total costs, and total benefits) vary in response to change in these factors. This type of analysis is used to estimate the uncertainty of the costs and benefits of a given set of CAFE standards.

The model can also be used to estimate the stringency that (a) generates a specified average required CAFE level, (b) maximizes net benefits to society, (c) achieves a specified stringency at which total costs equal total benefits, or (d) results in a specified total incremental cost, *etc*. The agency uses this information from the Volpe model as a tool to assist in setting standards. For additional discussions of the Volpe model and its inputs, see the NPRM and the Draft Technical Support Document (TSD). Any changes made to the model inputs will be discussed in detail in the forthcoming joint NHTSA-U.S. Environmental Protection Agency (EPA) Final Rule promulgating MYs 2012-2016 CAFE standards and NHTSA's forthcoming Regulatory Impact Analysis (RIA), as well as the forthcoming NHTSA-EPA joint TSD.

Although NHTSA has used the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model does not determine the CAFE standards NHTSA will propose or promulgate as final regulations. NHTSA considers the results of analyses conducted using the Volpe model and external analyses, including assessments of greenhouse gases and air pollution emissions, and technologies that may be available in the long term. NHTSA also considers whether the standards could expedite the introduction of new technologies into the market, and the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information, the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues, such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

2.2.2 Vehicle Market Forecast

To determine what levels of stringency are feasible in future model years, the agencies must project what vehicles and technologies will exist in those model years, and then evaluate what technologies can feasibly be applied to those vehicles to raise their fuel economy and lower their CO_2 emissions. The agencies therefore establish a baseline vehicle fleet representing those vehicles, based on the best available information and a reasonable balancing of various policy concerns, against which they can analyze potential future levels of stringency and their costs and benefits.

NHTSA has historically based its analysis of potential new CAFE standards on detailed product plans the agency has requested from manufacturers planning to produce passenger cars and light trucks for sale in the United States. For this rulemaking, and as explained in the Draft TSD prepared jointly by NHTSA and EPA, both agencies used a baseline vehicle fleet constructed beginning with CAFE certification data for the 2008 model year, the most recent model year for which final data is currently available from manufacturers. This data was used as the source for MY 2008 production volumes and some vehicle engineering characteristics, such fuel economy ratings, engine sizes, numbers of cylinders, and transmission types.

Some information important for analyzing new CAFE standards is not contained in the CAFE certification data. EPA staff, in consultation with NHTSA staff, identified vehicle wheelbase and track widths using data from Motortrend.com and Edmunds.com. This information is necessary for calculating vehicle footprint, which is required for the analysis of footprint-based standards. Considerable additional information regarding vehicle engineering characteristics is also important for estimating the potential to add new technologies in response to new CAFE standards. In general, such information helps to avoid "adding" technologies to vehicles that already have the same or a more advanced technology. Examples include valvetrain configuration (*e.g.*, overhead valve configuration [OHV], single overhead cam [SOHC], double overhead cam [DOHC]), presence of cylinder deactivation, and fuel delivery (*e.g.*, stoichiometric gasoline direct injection [SGDI]). To the extent that such engineering characteristics were not available in certification data, EPA staff relied on data published by Ward's Automotive, supplementing this with information from internet sites such as Motortrend.com and Edmunds.com. NHTSA staff also added some more detailed engineering characteristics (*e.g.*, type of variable valve timing) using data available from ALLDATA® Online. Combined with the certification data, all of this information yielded a MY 2008 baseline vehicle fleet.

After the baseline was created the next step was to project the sales volumes for 2011-2016 model years. The agencies used total projected light-duty vehicle volumes for this period from the Energy

Information Administration (EIA) Annual Energy Outlook (AEO) 2010 Early Release (EIA 2009b).[6] However, AEO projects sales only at the car and truck level, not at the manufacturer and model-specific level, which are needed in order to estimate the effects new standards will have on individual manufacturers. Therefore, EPA purchased and shared with NHTSA data from CSM-Worldwide and used their projections of the number of vehicles of each type predicted to be sold by manufacturers in 2011-2015.[7] This provided the year-by-year percentages of cars and trucks sold by each manufacturer as well as the percentages of each vehicle segment, although it was, therefore, necessary to assume the same manufacturer and segment shares in 2016 as in 2015. Using these percentages normalized to the AEO projected volumes then provided the manufacturer-specific market share and model-specific sales for MYs 2011-2016.

The processes for constructing the MY 2008 baseline vehicle fleet and subsequently adjusting sales volumes to construct the MYs 2011-2016 baseline vehicle fleet are presented in detail in the Draft TSD. Any changes made to the agency's baseline vehicle fleet will be fully explained in the forthcoming NHTSA-EPA joint TSD. For a detailed discussion of NHTSA's prior product plan-based approach and the current baseline vehicle fleet approach used by NHTSA and EPA for this rulemaking, including the differences, advantages and disadvantages between the two approaches, *see* II.B.3 of the NPRM.

2.2.3 Technology Assumptions

The analysis of costs and benefits employed in the Volpe model reflects NHTSA's assessment of a broad range of technologies that can be applied to passenger cars and light trucks. In the agency's rulemakings covering light truck CAFE standards for MYs 2005-2007 and MYs 2008-2011, the agency relied on the 2002 National Academy of Sciences' report Effectiveness and Impact of Corporate Average Fuel Economy Standards for estimating potential fuel economy benefits and associated retail costs of applying combinations of technologies (NRC 2002). In developing its final rule adopting CAFE standards for MY 2011, NHTSA reviewed manufacturers' technology data and comments it received on its fuel saving technologies, and conducted its own independent analysis which involved hiring an international engineering consulting firm that specializes in automotive engineering. This same engineering consulting firm was also used by EPA in developing its advance NPRM to regulate greenhouse gas (GHG) emissions under the Clean Air Act (CAA).[8]

In the MY 2011 CAFE Final Rule, as requested by the President in his January 2009 memorandum, NHTSA also stated that it would continue to review these technology assumptions and the methodologies used to derive the costs and effectiveness values, in order to improve its assumptions. For the MYs 2012-2016 rulemaking, NHTSA worked with EPA to revise and update a common list of fuel-saving technology cost and effectiveness numbers. EPA is also using this list of fuel-saving technologies in its model for development of CO_2 standards in the forthcoming joint NHTSA-EPA Final Rule. The revised technology assumptions – that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies are applied – will be described in greater detail in the forthcoming NHTSA-EPA joint TSD and in NHTSA's forthcoming RIA.

[6] The agencies have also used the reference scenario fuel price forecast from the preliminary release of AEO 2010 (EIA 2009b), and high and low fuel price forecasts from AEO 2009 (EIA 2009a). Both agencies regard AEO as a credible source not only of such forecasts, but also of many underlying forecasts, including forecasts of the size the future light vehicle market.
[7] EPA also considered other sources of similar information, such as J.D. Powers, and concluded that CSM was better able to provide forecasts at the requisite level of detail for most of the model years of interest.
[8] *See* NHTSA, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196, 14233-14300 (Mar. 30, 2009); Environmental Protection Agency, Regulating Greenhouse Gas Emissions Under the Clean Air Act, Proposed Rule, 73 *FR* 44354 (Jul. 30, 2008).

The technologies considered by the model are briefly described below, under the five broad categories of engine, transmission, vehicle, electrification/accessory, and hybrid technologies.

Types of engine technologies that were considered under the benefit-cost analysis include the following:

- *Low-friction lubricants* – low-viscosity and advanced low-friction lubricants oils are now available with improved performance and better lubrication.

- *Reduction of engine friction losses* – can be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, piston surface treatments, and other improvements in the design of engine components and subsystems that improve engine operation.

- *Conversion to dual overhead cam with dual cam phasing* – as applied to overhead valves designed to increase the air flow with more than two valves per cylinder and reduce pumping losses.

- *Cylinder deactivation* – deactivates the intake and exhaust valves and prevents fuel injection into some cylinders during light-load operation. The engine runs temporarily as though it were a smaller engine which substantially reduces pumping losses

- *Variable valve timing* – alters the timing or phase of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control residual gases.

- *Discrete variable valve lift* – increases efficiency by optimizing air flow over a broader range of engine operation which reduces pumping losses. Accomplished by controlled switching between two or more cam profile lobe heights.

- *Continuous variable valve lift* – is an electromechanically controlled system in which cam period and phasing is changed as lift height is controlled. This yields a wide range of performance optimization and volumetric efficiency, including enabling the engine to be valve throttled.

- *Stoichiometric gasoline direct-injection technology* – injects fuel at high pressure directly into the combustion chamber to improve cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency.

- *Combustion restart* – can be used in conjunction with gasoline direct-injection systems to enable idle-off or start-stop functionality. Similar to other start-stop technologies, additional enablers, such as electric power steering, accessory drive components, and auxiliary oil pump, might be required.

- *Turbocharging and downsizing* – increases the available airflow and specific power level, allowing a reduced engine size while maintaining performance. This reduces pumping losses at lighter loads in comparison to a larger engine.

- *Exhaust-gas recirculation boost* – increases the exhaust-gas recirculation used in the combustion process to increase thermal efficiency and reduce pumping losses.

- *Diesel engines* – have several characteristics that give superior fuel efficiency, including reduced pumping losses due to lack of (or greatly reduced) throttling and a combustion cycle that operates at a higher compression ratio, with a very lean air/fuel mixture, than an equivalent-performance gasoline engine. This technology requires additional enablers, such as NO_x trap catalyst after-treatment or selective catalytic reduction NO_x after-treatment.

Types of transmission technologies considered include:

- *Improved automatic transmission controls* – optimizes shift schedule to maximize fuel efficiency under wide-ranging conditions, and minimizes losses associated with torque converter slip through lock-up or modulation.

- *Six-speed automatic transmissions* – the gear ratio spacing and transmission ratio are optimized to enable the engine to operate in a more efficient operating range over a broader range of vehicle operating conditions.

- *Dual clutch or automated shift manual transmissions* – are similar to manual transmissions, but the vehicle controls shifting and launch functions. A dual-clutch automated shift manual transmission uses separate clutches for even-numbered and odd-numbered gears, so the next expected gear is pre-selected, which allows for faster and smoother shifting.

- *Continuously variable transmission* – commonly uses V-shaped pulleys connected by a metal belt rather than gears to provide ratios for operation. Unlike manual and automatic transmissions with fixed transmission ratios, continuously variable transmissions can provide fully variable and an infinite number of transmission ratios that enable the engine to operate in a more efficient operating range over a broader range of vehicle operating conditions.

- *Manual 6-speed transmission* – offers an additional gear ratio, often with a higher overdrive gear ratio, than a 5-speed manual transmission.

Types of vehicle technologies considered include:

- *Low-rolling-resistance tires* – have characteristics that reduce frictional losses associated with the energy dissipated in the deformation of the tires under load, therefore reducing the energy needed to move the vehicle.

- *Low-drag brakes* – reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake pads are pulled away from the rotors.

- *Front or secondary axle disconnect for four-wheel drive systems* – provides a torque distribution disconnect between front and rear axles when torque is not required for the non-driving axle. This results in the reduction of associated parasitic energy losses.

- *Aerodynamic drag reduction* – is achieved by changing vehicle shape or reducing frontal area, including skirts, air dams, underbody covers, and more aerodynamic side view mirrors.

- *Mass reduction and material substitution* – Mass reduction encompasses a variety of techniques ranging from improved design and better component integration to application of lighter and higher-strength materials. Mass reduction is further compounded by reductions in engine power and ancillary systems (transmission, steering, brakes, suspension, etc.).

Types of electrification/accessory and hybrid technologies considered include:

- *Electric power steering (EPS)* – is an electrically-assisted steering system that has advantages over traditional hydraulic power steering because it replaces a continuously operated hydraulic pump, thereby reducing parasitic losses from the accessory drive.

- *Improved accessories (IACC)* – may include high efficiency alternators, electrically driven (i.e., on-demand) water pumps and cooling fans. This excludes other electrical accessories such as electric oil pumps and electrically driven air conditioner compressors.

- *Air Conditioner Systems* – These technologies include improved hoses, connectors, and seals for leakage control. They also include improved compressors, expansion valves, heat exchangers and the control of these components for the purposes of improving tailpipe CO_2 emissions as a result of A/C use. These technologies are covered separately in the EPA RIA.

- *12-volt micro-hybrid (MHEV)* – also known as idle-stop or start stop and commonly implemented as a 12-volt belt-driven integrated starter-generator, this is the most basic hybrid system that facilitates idle-stop capability. Along with other enablers, this system replaces a common alternator with an enhanced power starter-alternator, both belt driven, and a revised accessory drive system.

- *Higher Voltage Stop-Start/Belt Integrated Starter Generator (BISG)* – provides idle-stop capability and uses a high voltage battery with increased energy capacity over typical automotive batteries. The higher system voltage allows the use of a smaller, more powerful electric motor and reduces the weight of the motor, inverter, and battery wiring harnesses. This system replaces a standard alternator with an enhanced power, higher voltage, higher efficiency starter-alternator, that is belt driven and that can recover braking energy while the vehicle slows down (regenerative braking).

- *Integrated Motor Assist (IMA)/Crank integrated starter generator (CISG)* – provides idle-stop capability and uses a high voltage battery with increased energy capacity over typical automotive batteries. The higher system voltage allows the use of a smaller, more powerful electric motor and reduces the weight of the motor, inverter, and battery wiring harnesses. This system replaces a standard alternator with an enhanced power, higher voltage, higher efficiency starter-alternator that is crankshaft mounted and can recover braking energy while the vehicle slows down (regenerative braking).

- *2-mode hybrid (2MHEV)* – is a hybrid electric drive system that uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors that control the ratio of engine speed to vehicle speed, while clutches allow the motors to be bypassed. This improves both the transmission torque capacity for heavy-duty applications and reduces fuel consumption and CO_2 emissions at highway speeds relative to other types of hybrid electric drive systems.

- *Power-split hybrid (PSHEV)* – a hybrid electric drive system that replaces the traditional transmission with a single planetary gearset and a motor/generator. This motor/generator uses the engine to either charge the battery or supply additional power to the drive motor. A second, more powerful motor/generator is permanently connected to the vehicle’s final drive and always turns with the wheels. The planetary gear splits engine power between the first motor/generator and the drive motor to either charge the battery or supply power to the wheels.

- *Plug-in hybrid electric vehicles (PHEV)* – are hybrid electric vehicles with the means to charge their battery packs from an outside source of electricity (usually the electric grid). These vehicles have larger battery packs with more energy storage and a greater capability to be discharged. They also use a control system that allows the battery pack to be substantially depleted under electric-only or blended mechanical/electric operation.

- *Electric vehicles (EV)* – are vehicles with all-electric drive and with vehicle systems powered by energy-optimized batteries charged primarily from grid electricity.

2.2.4 Economic Assumptions

The NHTSA analysis of the energy savings, emission reductions, and environmental impacts likely to result from alternative CAFE standards relies on a range of forecasts, economic assumptions, and estimates of parameters used by the Volpe CAFE model. These economic values play a significant role in determining the reductions in fuel consumption, changes in emissions of criteria air pollutants and GHGs, reductions in U.S. petroleum imports, and resulting economic benefits of alternative increases in CAFE standards. Under alternatives where standards would be established, in part, by reference to their costs and benefits (*i.e.*, the Maximum Net Benefits Alternative, and the Total Cost Equals Total Benefit Alternative), these economic values also affect the levels of the CAFE standards themselves.

The economic forecasts, assumptions, and parameters used in the Volpe CAFE model include the following:

- Forecasts of sales of passenger cars and light trucks for MYs 2012-2016.

- Assumptions about the fraction of these vehicles that remain in service at different ages, how rapidly average annual use of passenger cars and light trucks grows over time, and how passenger car and light truck use declines with their increasing age.

- Forecasts of fuel prices over the expected lifetimes of MYs 2012-2016 passenger cars and light trucks.

- Forecasts of expected future growth in total passenger car and light truck use, including vehicles of all model years comprising the U.S. vehicle fleet.

- The size of the gap between test and actual on-road fuel economy.

- The magnitude of the fuel economy rebound effect, or the increase in vehicle use that results from improved fuel economy.

- Economic costs associated with U.S. consumption and imports of petroleum and refined petroleum products, over and above their market prices.

- Changes in emissions of criteria air pollutants and GHGs that result from saving each gallon of fuel and from each added mile of driving.

- The economic values of reductions in emissions of each criteria air pollutant and GHGs.

- The value of increased driving range and less frequent refueling that results from increases in fuel economy.

- The costs of increased congestion, traffic accidents, and noise caused by added passenger car and light truck use.

- The discount rate applied to future benefits.

Table 2.2-1 presents many of the specific forecasts, assumptions, and parameter values used to calculate the energy savings, environmental impacts, and economic benefits of each alternative. The direct, indirect, and cumulative impacts of the proposed CAFE alternatives examined in this EIS reflect this specific combination of economic inputs in the Volpe model. Detailed descriptions of the sources of forecast information, the rationale underlying each economic assumption, and the agency's choices of specific parameter values will be discussed in detail in the forthcoming joint NHTSA-EPA Final Rule and NHTSA's forthcoming RIA, as well as the forthcoming joint EPA-NHTSA final TSD for fuel economy and motor vehicle CO_2 emission standards.

NHTSA's main analysis of energy use and emissions resulting from alternative CAFE standards uses the forecasts, assumptions, and parameters reported in Table 2.2-1. The agency also analyzed the sensitivity of its estimates to plausible variations in the values of many of these variables. The specific alternative values of these variables that were used in the agency's sensitivity analysis and their effects on its estimates of fuel consumption and GHG emissions are reported and discussed in Section 2.4 of this EIS.

Table 2.2-1

Forecasts, Assumptions, and Parameters Used to Analyze Impacts of Regulatory Alternatives

Fuel Economy Rebound Effect	10%
"Gap" between Test and On-road MPG	20%
Value of Refueling Time ($ per vehicle-hour)	$ 24.64
Annual growth in average vehicle use	1.15%
Fuel Prices (2012-50 average, $/gallon)	
Retail gasoline price	$ 3.66
Pre-tax gasoline price	$ 3.29
Economic Benefits from Reducing Oil Imports ($/gallon)	$ 0.17
Emission Damage Costs (2020, $/ton or $/metric ton)	
Carbon monoxide (CO)	$ 0
Volatile organic compounds (VOCs)	$ 1,300
Nitrogen oxides (NO_x) – vehicle use	$ 5,300
Nitrogen oxides (NO_x) – fuel production and distribution	$ 5,100
Particulate matter ($PM_{2.5}$) – vehicle use	$ 290,000
Particulate matter ($PM_{2.5}$) – fuel production and distribution	$ 240,000
Sulfur dioxide (SO_2)	$ 31,000
Carbon dioxide (CO_2)	$ 56a/
Annual Increase in CO_2 Damage Cost	3%
External Costs from Additional Automobile Use ($/vehicle-mile)	
Congestion	$ 0.054
Accidents	$ 0.023
Noise	$ 0.001
Total External Costs	$ 0.078

Table 2.2-1

Forecasts, Assumptions, and Parameters Used to Analyze Impacts of Regulatory Alternatives

External Costs from Additional Light Truck Use ($/vehicle-mile)	
Congestion	$ 0.048
Accidents	$ 0.026
Noise	$ 0.001
Total External Costs	$ 0.075
Discount Rate Applied to Future Benefits	3%
Reduction in Consumer Benefits from Potential Welfare Losses b/	0%

a/ Federal government agencies are working toward, but do not yet have, an agreed-upon estimate for the social cost of carbon (SCC) to support federal regulatory activities where reducing CO_2 emissions is an important potential outcome. Nevertheless, NHTSA is obligated under EPCA to issue a CAFE rule regardless of whether there is a uniform federal government view on the SCC. For the analysis in the FEIS, the agency modeled a primary SCC value of $56, and then conducted a sensitivity analysis using $10 (see Section 2.4). However, neither of these values is necessarily the estimate of SCC that the agency will ultimately select for valuing reductions in CO_2 emissions in the final rule. The SCC used in the Volpe model in the Final EIS allows the stringency of the CAFE standards for the MNB Alternative and the TCTB Alternative to be higher than they would be for a lower valuation of SCC. This results in higher fuel savings and greater changes in environmental impacts for these alternatives than would result from using a lower SCC value in the model. The intent of this is to demonstrate the maximum differences in environmental impacts among the alternatives. The environmental impacts of the action alternatives other than the MNB Alternative and the TCTB Alternative are not significantly affected by the valuation of social cost of carbon in the model, as shown in Table 2.4-1.

In contrast, the SCC value that was used in the main NPRM and DEIS analysis was the $20/ton central value, based on interagency efforts to develop estimates of this value for government-wide use. NHTSA notes that it was this $20/ton SCC value that was intended to represent the federal government's interim "central" estimate of the SCC. The $56/ton SCC value was considered the "high" interim interagency SCC value for purposes of the NPRM and DEIS analysis. See section VI.C.3.l.iii of the NPRM, Chapter 4 of the draft joint TSD, and Chapter VIII of the PRIA for detail concerning the interim low, central, and high interagency guidance regarding SCC. NHTSA utilizes the $56 figure *only* in order to demonstrate the maximum potential environmental impacts, and not because the agency regards it as a more likely estimate of the "true" SCC. Detailed descriptions of the rationale underlying each economic assumption, and the agency's choices of specific parameter values will be provided in the forthcoming joint NHTSA-EPA Final Rule and NHTSA's forthcoming RIA, as well as the forthcoming joint EPA-NHTSA final TSD for fuel economy and motor vehicle CO_2 emission standards.

b/ The assumption used in the main analysis is that there is a zero percent reduction in consumer benefits from potential welfare losses to vehicle buyers or overestimation of the value of fuel savings, *i.e.*, there are no losses in consumer welfare or errors in estimating the value of fuel savings that would reduce the agency's estimates of the benefits to vehicle buyers from requiring higher fuel economy. This assumption is varied in the sensitivity analysis. See section 2.4 (Sensitivity Analysis) for an explanation of why consumer benefits could theoretically be reduced due to potential welfare losses.

2.3 ALTERNATIVES

EPCA, as amended by EISA, requires NHTSA to adopt attribute-based fuel economy standards for passenger cars and light trucks. NHTSA first employed this approach (then called "Reformed

CAFE") in establishing standards for MYs 2008-2011 light trucks.[9] In May 2008, NHTSA proposed separate standards for MYs 2011-2015 passenger cars and light trucks, again using this approach.[10] On March 30, 2009, NHTSA issued a final rule for MY 2011 passenger cars and light trucks, again using this approach.[11]

Under the standards, fuel economy targets are established for vehicles of different sizes. Each manufacturer's required level of CAFE is based on its distribution of vehicles among those sizes and the fuel economy target required for each size. Size is defined by vehicle footprint.[12] The fuel economy target for each footprint reflects the technological and economic capabilities of the industry. These targets are the same for all manufacturers, regardless of the differences in their overall fleet mix. Compliance is determined by comparing a manufacturer's harmonically averaged fleet fuel economy levels in a model year with an average required fuel economy level calculated using the manufacturer's actual production levels and the targets for each footprint of the vehicles that it produces.

NHTSA must establish separate standards for MYs 2011-2020 passenger cars and light trucks. The standards are subject to a minimum requirement regarding stringency: they must be set at levels high enough to ensure that the combined U.S. passenger-car and light-truck fleet achieves an average fuel economy level of not less than 35 mpg not later than MY 2020.[13] Additionally, EPCA, as amended by EISA, requires that the CAFE standards for passenger cars and light trucks increase ratably in each model year between MY 2011 and MY 2020. Standards must be "based on one or more vehicle attributes related to fuel economy," and "expressed in the form of a mathematical function."[14]

A large number of alternatives can be defined along a continuum from the least to the most stringent levels of potential CAFE standards. The specific alternatives NHTSA examined, described below, encompass a reasonable range to evaluate the potential environmental impacts of the CAFE standards and alternatives under NEPA, in view of EPCA requirements.

At one end of this range is the No Action Alternative (Alternative 1), which assumes no action would occur under the National Program. Under that alternative, neither NHTSA nor EPA would issue a rule regarding the CAFE standard or GHG emissions for MYs 2012-2016. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011. The MY 2011 fuel economy level represents the standard NHTSA believes manufacturers would continue to achieve, assuming NHTSA does not issue a rule. Costs and benefits of other alternatives are calculated relative to the baseline of the No Action Alternative. The No Action Alternative, by definition, would yield no incremental costs or benefits (and thus it would not satisfy the EPCA requirement to set standards such that the combined fleet achieves a combined average

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[9] *See* Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 *FR* 17566, 17587-17625, (Apr. 6, 2006) (describing this approach).
[10] Notice of Proposed Rulemaking; Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 *FR* 24352 (May 2, 2008). The proposed standards include light truck standards for one model year (MY 2011) that were previously covered by a 2006 final rule, Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 *FR* 17566 (Apr. 6, 2006).
[11] *See* Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196 (Mar. 30, 2009).
[12] A vehicle's footprint is generally defined as "the product of track width [the lateral distance between the centerlines of the base tires at ground, including the camber angle] … times wheelbase [the longitudinal distance between front and rear wheel centerlines] … divided by 144 …." 49 CFR § 523.2.
[13] 49 U.S.C. § 32902(b)(2)(A).
[14] 49 U.S.C. § 32902(b)(3)(A).

fuel economy of at least 35 mpg for MY 2020; nor would it satisfy the EPCA requirement to adopt annual fuel economy standard increases).[15]

NHTSA is also considering eight action alternatives. Alternative 2 (3-Percent Alternative), Alternative 3 (4-Percent Alternative), Alternative 5 (5-Percent Alternative), Alternative 7 (6-Percent Alternative), and Alternative 8 (7-Percent Alternative), require the average fuel economy for the industry-wide combined passenger car and light truck fleet to increase, on average, by a specified percentage for each model year from 2012-2016. Because the percentage increases in stringency are "average" increases, they may either be constant throughout the period or may vary from year to year. For a variety of reasons, the annual rates of increase in achieved mpg levels for passenger cars and light trucks separately will not exactly equal the rates of increase in combined passenger car and light truck required average mpg levels under each alternative. These include the fact that under some alternatives, separate required mpg levels for passenger cars and light trucks might not necessarily increase at annual rates that are identical to those for the combined standard.

NHTSA also added three alternatives to the list of alternatives first proposed in the NOI – the agency's Preferred Alternative (Alternative 4), an alternative that maximizes net benefits (MNB) (Alternative 6), and an alternative under which total cost equals total benefit (TCTB) (Alternative 9). The agency's Preferred Alternative represents the required fuel economy level that we have tentatively determined to be the maximum feasible under EPCA, based on our balancing of statutory considerations. *See* Section 2.1. The other two alternatives, MNB and TCTB, represent fuel economy levels that are dependent on the agency's best estimate of relevant economic variables (*e.g.*, gasoline prices, social cost of carbon, the discount rate, and rebound effect). *See* Section 2.2.4. The MNB Alternative and TCTB Alternative provide the decisionmaker and the public with useful information about where the standards would be set if costs and benefits were balanced in two different ways. All three alternatives (Preferred Alternative, MNB Alternative, and TCTB Alternative) are placed in context by identifying the approximate, on average, annual percentage fuel economy increase, so that the public is able to see where they fall on the continuum of alternatives.

Each of the alternatives considered by NHTSA represent, in part, a different way in which NHTSA conceivably could weigh EPCA's statutory requirements and account for NEPA's policies. For example, the 7-Percent Alternative weighs energy conservation and climate change considerations more heavily and technological feasibility and economic practicability less heavily. In contrast, the 3-Percent Alternative, the least stringent action alternative evaluated here, places more weight on technological feasibility and economic practicability. The "feasibility" of the alternatives also may reflect differences and uncertainties in the way in which key economic (*e.g.*, the price of fuel and the social cost of carbon) and technological inputs could be assessed and estimated or valued. For additional detail and discussion of how NHTSA considers the EPCA statutory and other factors that guide the agency's determination of "maximum feasible" standards, and inform an evaluation of the alternatives, we refer the reader to section IV.F of the NPRM. For detailed calculations and discussions of manufacturer cost impacts and estimated benefits for each of the DEIS alternatives, *see* Sections VII and VIII of NHTSA's PRIA.

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[15] Although EISA's recent amendments to EPCA direct NHTSA to increase CAFE standards and do not permit the agency to take no action on fuel economy, CEQ regulations mandate analysis of a no action alternative. *See* 40 CFR § 1502.14(d). CEQ has explained that "the regulations require the analysis of the no action alternative *even if the agency is under a court order or legislative command to act*." *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 *FR* 18026 (1981) (emphasis added).

2.3.1 Alternative 1: No Action

The No Action Alternative assumes that no action would occur under CAFE (or under the National Program).[16] Under this alternative, NHTSA would not issue a rule regarding CAFE standards for MYs 2012-2016. As explained above, the No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011. The No Action MY 2016 achieved mpg forecast represents the market forecast for mpg, assuming that NHTSA does not issue a rule.[17]

NEPA requires agencies to consider a No Action Alternative in their NEPA analyses,[18] although the recent amendments to EPCA direct NHTSA to set new CAFE standards and do not permit the agency to take no action on fuel economy.[19] In the NPRM, NHTSA refers to the No Action Alternative as the no increase or baseline alternative.

2.3.2 Alternative 2: 3-Percent Alternative

The 3-Percent Alternative requires a 3-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 35.5 mpg for passenger cars and 26.9 mpg for light trucks. The 3-Percent Alternative also results in a combined required fleetwide 32.0 mpg in MY 2016.

2.3.3 Alternative 3: 4-Percent Alternative

The 4-Percent Alternative requires a 4-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 37.2 mpg for passenger cars and 28.2 mpg for light trucks. The 4-Percent Alternative also results in a combined required fleetwide 33.6 mpg in MY 2016.

2.3.4 Alternative 4: Preferred Alternative

The Preferred Alternative requires approximately a 4.3-percent average annual increase in mpg, resulting in an estimated required MY 2016 fleetwide 37.8 mpg for passenger cars and 28.7 mpg for light trucks. The Preferred Alternative also results in a combined estimated required fleetwide 34.1 mpg in MY 2016. The agency's Preferred Alternative represents the required fuel economy level that we have tentatively determined to be the maximum feasible under EPCA, based on our balancing of statutory considerations. A full discussion regarding the agency's conclusion that Alternative 4 represents the "maximum feasible" average fuel economy level that the Secretary decides the manufacturers can achieve, considering the statutory and other relevant factors and is therefore the agency's Preferred Alternative will be found in the forthcoming joint NHTSA-EPA Final Rule.

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[16] Several commenters to the DEIS noted that the No Action Alternative should take into account state implementation of GHG standards in the absence of federal action. NHTSA has retained the No Action Alternative as defined in the DEIS without change. Although we agree that a number of states would likely enforce California GHG standards absent federal action, we believe that no change is necessary to the No Action Alternative under NEPA to properly inform the decisionmaker. For a full discussion of this issue, see the agency's response to comments in section 10.2.4.2 of this EIS.

[17] *See* 40 CFR §§ 1502.2(e) and 1502.14(d).

[18] S*ee* 40 CFR § 1502.14(d).

[19] CEQ regulations mandate analysis of a no action alternative. *See* 40 CFR § 1502.14(d). CEQ has explained that "the regulations require the analysis of the no action alternative *even if the agency is under a court order or legislative command to act*." *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 *FR* 18026 (1981) (emphasis added).

This alternative, along with EPA's light-duty vehicle GHG emission standards, form the National Program and are consistent with the National Fuel Efficiency Policy announced by President Obama on May 19, 2009. Under the National Program, the overall light-duty vehicle fleet would reach 35.5 mpg in MY 2016, if all reductions were made through fuel economy improvements.

2.3.5 Alternative 5: 5-Percent Alternative

The 5-Percent Alternative requires a 5-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 39.1 mpg for passenger cars and 29.6 mpg for light trucks. The 5-Percent Alternative also results in a required achieved fleetwide 35.2 mpg in MY 2016.

2.3.6 Alternative 6: MNB Alternative

In the MNB Alternative, the Volpe model applies technologies to the vehicle market forecast until marginal benefits are estimated to equal marginal costs and net benefits are maximized. In this case, the model continues to include technologies until the marginal cost of adding the next technology exceeds the marginal benefit. This alternative requires approximately a 6.0-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 40.9 mpg for passenger cars and 31.0 mpg for light trucks. The MNB Alternative also results in a combined required fleetwide 36.9 mpg in MY 2016.

2.3.7 Alternative 7: 6-Percent Alternative

The 6-Percent Alternative requires a 6-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 40.9 mpg for passenger cars and 31.0 mpg for light trucks. The 6-Percent Alternative also results in a combined required fleetwide 36.9 mpg in MY 2016.

The 6-Percent Alternative results in required mpg in 2016 that is equal to the required mpg under the MNB Alternative, but required mpg in 2012 through 2015 under the 6-percent Alternative is actually slightly lower than under the MNB Alternative. In general, the net result is that there is very little substantive difference in required mpg under the 6-percent and MNB Alternatives.

2.3.8 Alternative 8: 7-Percent Alternative

The 7-Percent Alternative requires a 7-percent average annual increase, resulting in a required MY 2016 fleetwide 42.9 mpg for passenger cars and 32.6 mpg for light trucks. The 7-Percent Alternative also results in a combined required fleetwide 38.7 mpg in MY 2016.

2.3.9 Alternative 9: TCTB Alternative

In the TCTB Alternative, the Volpe model applies technologies to the vehicle market forecast until total costs equal total benefits. In this case, the model increases the standard to a point where essentially total costs of the technologies added together over the baseline equals total benefits added over the baseline. This alternative requires approximately a 6.6-percent on average annual increase in mpg, resulting in a required MY 2016 fleetwide 42.3 mpg for passenger cars and 31.8 mpg for light trucks. The TCTB Alternative also results in a combined required fleetwide 38.0 mpg in MY 2016.

The TCTB Alternative results in required mpg in 2016 that is just slightly lower than required mpg under the 7-Percent Alternative, but required mpg in 2012 through 2015 under the TCTB Alternative is slightly higher than under the 7-Percent Alternative. In general, the net result is that there is very little substantive difference in required mpg under the 7-Percent and TCTB Alternatives.

2.3.10 Fuel Economy Levels for Each Alternative

As explained in Sections 1.2.2.2 and 2.2, the CAFE levels required under an attribute-based standard depend on the mix of vehicles produced for sale in the United States. The average fuel economy levels actually achieved by passenger cars and light trucks in a given model year may differ from the required CAFE levels for that model year. This occurs because some manufacturers' average fuel economy levels for their vehicles are projected to exceed the applicable CAFE standards during certain model years, while other manufacturers' fuel economy levels are projected to fall short of either the passenger car or light truck CAFE standards during some model years. Table 2.3-1 shows the fuel economy levels that would be required for each alternative not taking into account credits.

Table 2.3-1

Required MPG by Alternative

	Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**	**Alt. 5**	**Alt. 6**	**Alt. 7**	**Alt. 8**	**Alt. 9**
	No Action	**3%/year Increase**	**4%/year Increase**	**~4.3%/year Increase Preferred**	**5%/year Increase**	**~6.0%/year Increase MNB**	**6%/year Increase**	**7%/year Increase**	**~6.6%/year Increase TCTB**
2012									
Passenger Cars	30.5	31.8	32.1	33.4	32.4	33.1	32.7	33.0	33.4
Light Trucks	24.4	24.3	24.3	25.3	24.6	26.3	24.8	25.1	26.3
Combined	27.8	28.4	28.6	29.7	28.8	30.1	29.1	29.4	30.3
2013									
Passenger Cars	30.5	32.6	33.3	34.2	33.9	36.1	34.6	35.2	36.7
Light Trucks	24.4	24.8	25.3	25.9	25.7	27.8	26.2	26.7	28.0
Combined	27.8	29.1	29.7	30.5	30.3	32.4	30.8	31.4	32.8
2014									
Passenger Cars	30.5	33.6	34.6	35.0	35.5	38.1	36.6	37.6	39.2
Light Trucks	24.5	25.5	26.2	26.6	27.0	29.2	27.8	28.6	29.7
Combined	28.0	30.1	30.9	31.3	31.8	34.3	32.7	33.7	35.0
2015									
Passenger Cars	30.5	34.4	35.8	36.2	37.2	39.6	38.6	40.1	40.7
Light Trucks	24.4	26.1	27.1	27.5	28.2	30.3	29.3	30.4	30.7
Combined	28.0	31.0	32.2	32.6	33.4	35.7	34.7	36.1	36.5
2016									
Passenger Cars	30.5	35.5	37.2	37.8	39.1	40.9	40.9	42.9	42.3
Light Trucks	24.4	26.9	28.2	28.7	29.6	31.0	31.0	32.6	31.8
Combined	28.1	32.0	33.6	34.1	35.2	36.9	36.9	38.7	38.0

Analyzing the environmental impacts of these alternatives provides information on the full spectrum of CAFE choices reasonably available to the decisionmaker. Although NEPA requires – and this EIS analyzes – a full spectrum of alternatives, NHTSA is obligated by EPCA to consider additional requirements and factors in setting "maximum feasible" CAFE standards: (1) technological feasibility,

(2) economic practicability, (3) the effect of other motor vehicle standards of the Government on fuel economy, and (4) the need of the Nation to conserve energy. [20]

Table 2.3-2 shows the estimated [21] achieved fuel economy levels for each alternative. Comparing Table 2.3-1 with Table 2.3-2 shows that estimated achieved combined mpg in 2016 would actually exceed required mpg under the No Action Alternative, indicating that some manufacturers would exceed the no action required mpg. Under other action alternatives, the estimated achieved mpg in 2016 would be somewhat lower than the required mpg levels because some manufacturers are not expected to meet passenger car or light truck standards under some alternatives.[22] Estimated achieved and required fuel economy levels differ because manufacturers will, on average, undercomply[23] in some model years and overcomply[24] in others.[25]

[20] 49 U.S.C. § 32902(f).

[21] As discussed above, the CAFE level required under an attribute-based standard depends on the mix of vehicles produced for sale in the United States. NHTSA has developed the average mpg levels under each alternative based on the vehicle market forecast that NHTSA and EPA have used to develop and analyze new CAFE and CO_2 emissions standards.

[22] Based on the agency's analysis of technology application by manufacturers, given the different levels of stringency represented by the different alternatives, some of the more stringent alternatives might require so much more additional technology to be applied to vehicles that, although that level/amount of technology might be feasible for individual vehicle models, it would be beyond the realm of technological feasibility or economic practicability for the industry as a whole. Although NHTSA cannot predict how manufacturers *will* respond to the alternative CAFE standards, and although the agency's Volpe model analysis evaluates only one possible way that manufacturers could comply with whatever given level of CAFE standards, NHTSA believes that some of the more stringent alternatives may involve levels of technology and cost that, considering the current state of the automotive industry, would not be technologically feasible or economically practicable. *See* joint NHTSA-EPA NPRM, 74 FR 49454, 49695-49707.

[23] In NHTSA's analysis, "undercompliance" is mitigated either through use of flex-fuel vehicle (FFV) credits, use of existing or "banked" credits, or through fine payment. Because NHTSA cannot consider availability of credits in setting standards, the estimated achieved CAFE levels presented here do not account for their use. In contrast, because NHTSA is not prohibited from considering fine payment, the estimated achieved CAFE levels presented here include the assumption that BMW, Daimler (*i.e.*, Mercedes), Porsche, and Tata (*i.e.*, Jaguar and Rover) will only apply technology up to the point that it would be less expensive to pay civil penalties.

[24] In NHTSA's analysis, "overcompliance" occurs through multi-year planning: manufacturers apply some "extra" technology in early model years (*e.g.*, MY 2014) in order to carry that technology forward and thereby facilitate compliance in later model years (*e.g.*, MY 2016).

[25] Consistent with EPCA, NHTSA has not accounted for manufacturers' ability to earn CAFE credits for selling FFVs, carry credits forward and back between model years, and transfer credits between the passenger car and light truck fleets when setting standards. However, to begin understanding the extent to which use of credits might reduce manufacturers' compliance costs and the benefits of new CAFE standards, NHTSA does analyze the potential effects of provisions regarding FFVs. *See* Section 3.1.4.1.

Table 2.3-2

Achieved MPG by Alternative

	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
2012									
Passenger Cars	32.1	32.6	32.9	33.1	33.0	33.3	33.2	33.4	33.5
Light Trucks	24.3	24.5	24.6	25.0	24.9	25.5	25.0	25.1	25.5
Combined	28.5	28.9	29.1	29.4	29.3	29.8	29.5	29.6	29.8
2013									
Passenger Cars	32.4	33.8	34.4	34.9	35.1	36.1	35.6	36.1	36.4
Light Trucks	24.5	25.1	25.5	26.0	26.0	27.2	26.5	26.9	27.4
Combined	28.9	29.8	30.3	30.9	30.9	32.1	31.5	32.0	32.3
2014									
Passenger Cars	32.5	34.2	35.3	35.8	36.2	37.7	37.0	37.9	38.2
Light Trucks	24.7	25.8	26.4	26.9	27.3	28.8	28.1	28.8	29.1
Combined	29.1	30.6	31.4	31.9	32.4	33.9	33.1	33.9	34.2
2015									
Passenger Cars	32.4	34.8	36.3	36.7	37.4	38.9	38.4	39.3	39.4
Light Trucks	24.7	26.4	27.2	27.5	28.2	29.8	29.3	30.2	30.2
Combined	29.2	31.3	32.4	32.8	33.5	35.1	34.6	35.5	35.6
2016									
Passenger Cars	32.4	35.7	37.3	37.7	38.8	40.2	40.3	41.3	41.0
Light Trucks	24.7	26.8	28.0	28.4	29.3	30.5	30.5	31.4	31.1
Combined	29.3	32.1	33.5	33.9	34.9	36.3	36.3	37.2	37.0

2.3.11 Greenhouse Gas Emission Standards for Light-duty Vehicles

As explained above, NHTSA's proposed action is one part of a National Program consisting of new standards for light-duty vehicles that will improve fuel economy and reduce GHG emissions. EPA has proposed greenhouse gas emissions standards under Section 202(a) of the CAA, and NHTSA has proposed CAFE standards under EPCA, as amended. EPA's proposed standards would require light-duty vehicles to meet an estimated combined average emissions level of 250 grams per mile (g/mi) of CO_2 in MY 2016. The proposed standards for both agencies begin with MY 2012, with standards increasing in stringency through MY 2016. They represent a harmonized approach that will allow industry to build a single national fleet that will satisfy both the GHG requirements under the CAA and CAFE requirements under EPCA/EISA. Given differences in their respective statutory authorities, however, the agencies' proposed standards include some important differences. Refer to Section 3.7 for a discussion of these differences.

EPA is proposing GHG emissions standards, and Table 2.3-3 provides EPA's estimates of its projected overall fleet-wide CO_2 equivalent emission levels.[26] The g/mi values are CO_2 equivalent values because they include the projected use of air conditioning credits by manufacturers.

Table 2.3-3

Projected Fleet-Wide Emissions Compliance Levels under the Proposed Footprint-Based CO_2 Standards (g/mi)

	2012	2013	2014	2015	2016
Passenger Cars	261	253	246	235	224
Light Trucks	352	341	332	317	302
Combined Cars & Trucks	295	286	276	263	250

As shown in Table 2.3-3, fleet-wide CO_2 emission level requirements for cars under the proposed approach are projected to increase in stringency from 261 to 224 grams per mile between MY 2012 and MY 2016. Similarly, fleet-wide CO_2 equivalent emission level requirements for trucks are projected to increase in stringency from 352 to 302 g/mi. As shown, the overall fleet average CO_2 level requirements are projected to be 250 g/mi in 2016.

EPA anticipates that manufacturers will take advantage of program flexibilities such as flex fueled vehicle credits, and car/truck credit trading. Due to the credit trading between cars and trucks, the estimated improvements in CO_2 emissions are distributed differently than shown in Table 2.3-3, where full manufacturer compliance is assumed. Table 2.3-4 shows EPA projection of the achieved emission levels of the fleet for MYs 2012-2016, which does consider the increase in emissions due to program flexibilities such as the flex fueled vehicle credits, as well as the impact of car/truck trading and optional air conditioning credits. As shown in Table 2.3-4, the projected achieved levels are slightly higher for MYs 2012-2015 due to the projected use of the proposed flexibilities, but in MY 2016 the achieved value is projected to be 250 g/mi for the fleet.

Table 2.3-4

Projected Fleet-Wide Achieved Emission Levels under the Proposed Footprint-Based CO_2 Standards (g/mi)

	2012	2013	2014	2015	2016
Passenger Cars	264	254	245	232	220
Light Trucks	365	355	346	332	311
Combined Cars & Trucks	302	291	281	267	250

2.4 SENSITIVITY ANALYSIS

There are many variations in economic assumptions that can be used to examine the sensitivity of costs and benefits for each of the alternatives, including future fuel prices, the value of reducing CO_2 emissions (referred to as the social cost of carbon or SCC), the discount rate, the magnitude of the rebound effect, and the value of oil import externalities. Different combinations of economic assumptions can also affect the calculation of environmental impacts of the various action alternatives. This occurs partly because some economic inputs to the Volpe model – notably fuel prices and the size of the rebound effect – influence its estimates of vehicle use and fuel consumption, the main factors that determine

[26] These levels do not include the effect of flexible fuel credits, transfer of credits between cars and trucks, temporary lead time allowance, or any other credits with the exception of air conditioning.

emissions of GHGs, criteria air pollutants, and airborne toxics. In addition, changes in economic assumptions may affect the fuel economy levels required under the action alternatives established on the basis of economic benefits and costs (*i.e.*, Alternative 6 (MNB) and Alternative 9 (TCTB)).

The direct, indirect, and cumulative environmental impacts of the proposed CAFE Alternatives examined in this EIS reflect the following combination of economic inputs to the Volpe model, referred to as the "Expected Value[27]" model inputs:

- Annual Energy Outlook (AEO) 2010 Early Release Reference Case fuel price forecast;
- 3-percent discount rate used to determine present value of future costs and benefits;
- 10-percent rebound effect (the estimated increase in driving due to higher fuel economy standards and its effect on the cost per mile traveled);
- $56 SCC (dollar value of per metric ton of CO_2 emission reductions);[28]
- $0.17 reduction in oil import externalities per gallon of fuel saved (reduction in macroeconomic costs of oil price shocks only; includes no reduction in monopsony payments to oil producers or in military security outlays associated with oil imports).

NHTSA selected these values based on the best available information and data, but the agency recognizes that the forecasts and assumptions they reflect are subject to considerable uncertainty. For example, as noted in Table 2.2-1, the assumption used in the main analysis is that NHTSA's estimates of consumer benefits accurately reflect those perceived by potential vehicle buyers, that is, the agency has correctly estimated the value of fuel savings that buyers will experience, and no potential welfare losses to vehicle buyers will result from manufacturers' efforts to increase fuel economy. It is possible,

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[27] The tern "Expected Value" is used as defined in this section and does not refer to the term's normal mathematical definition.

[28] Federal government agencies are working toward, but do not yet have, an agreed-upon estimate for the social cost of carbon (SCC) to support federal regulatory activities where reducing CO_2 emissions is an important potential outcome. Nevertheless, NHTSA is obligated under EPCA to issue a CAFE rule regardless of whether there is a uniform federal government view on the SCC. For the analysis in the FEIS, the agency modeled a primary SCC value of $56, and then conducted a sensitivity analysis using $10 (*see* Section 2.4). However, neither of these values is necessarily the estimate of SCC that the agency will ultimately select for valuing reductions in CO_2 emissions in the final rule. The SCC used in the Volpe model in the FEIS allows the stringency of the CAFE standards for the MNB Alternative and the TCTB Alternative to be higher than they would be for a lower valuation of SCC. This results in higher fuel savings and greater changes in environmental impacts for these alternatives than would result from using a lower SCC value in the model. The intent of this is to demonstrate the maximum differences in environmental impacts among the alternatives. The environmental impacts of the action alternatives other than the MNB Alternative and the TCTB Alternative are not significantly affected by the valuation of SCC in the model, as shown in Table 2.4-1.

In contrast, the SCC value that was used in the main NPRM and DEIS analysis was the $20/ton central value, based on interagency efforts to develop estimates of this value for government-wide use. NHTSA notes that it was this $20/ton SCC value that was intended to represent the federal government's interim "central" estimate of the SCC. The $56/ton SCC value was considered the "high" interim interagency SCC value for purposes of the NPRM and DEIS analysis. See section VI.C.3.l.iii of the NPRM, Chapter 4 of the draft joint TSD, and Chapter VIII of the PRIA for detail concerning the interim low, central, and high interagency guidance regarding SCC. NHTSA utilizes the $56 figure *only* in order to demonstrate the maximum potential environmental impacts, and not because the agency regards it as a more likely estimate of the "true" SCC. Detailed descriptions of the rationale underlying each economic assumption, and the agency's choices of specific parameter values will be provided in the forthcoming joint NHTSA-EPA Final Rule and NHTSA's forthcoming RIA, as well as the forthcoming joint EPA-NHTSA final TSD for fuel economy and motor vehicle CO_2 emission standards.

however, that the agency's estimates of benefits from improving fuel efficiency overstate the benefits that potential vehicle buyers believe they will actually experience, or that the agency has failed to account for changes in other vehicle attributes that will be necessary for manufacturers to comply with higher fuel economy standards.

Specifically, buyers might not value increased fuel economy as highly as the agency's calculations suggest, either because they have shorter time horizons than the expected vehicle lifetimes assumed by NHTSA, or because they discount future fuel savings at rates higher than the 3-percent discount rate used by the agency. Potential buyers might also anticipate lower fuel prices in the future than those forecast by EIA, or they might expect larger differences between vehicles' rated and actual on-road mpg levels than the agency projects. Achieving the fuel economy improvements required by stricter CAFE standards could also require manufacturers to compromise the performance, passenger- and cargo-carrying capacity, safety, or other features of some vehicle models. This could reduce the overall utility that those models offer to their owners, despite the fact that the agency's analysis of feasibility was designed to allow manufacturers to hold these attributes constant while still achieving the desired levels of fuel economy. If this occurs, it could be viewed by potential buyers as a loss in welfare associated with requiring higher fuel economy, which NHTSA would have failed to acknowledge or deduct from its estimates of benefits from requiring higher fuel economy.

As a way of evaluating the potential effect of this issue, NHTSA has included several alternative estimates of reductions in consumer benefits in the sensitivity analysis. These runs are labeled in the last three lines of Table 2.4-1 as 25% Consumer Benefits, 50% Consumer Benefits, and 75% Consumer Benefits. The 25% Consumer Benefits sensitivity run assumes that the actual benefits to consumers from higher fuel economy are only 25 percent as large as NHTSA's estimate, either because the agency has overestimated the value of fuel savings to vehicle owners or because of accompanying changes in vehicle attributes that result in losses in consumer welfare. Similarly, the 50% Consumer Benefits sensitivity run assumes that the true benefits of fuel savings to buyers are only half as large as the agency's estimate, while the 75% Consumer Benefits sensitivity run assumes that 25 percent of consumer benefits from higher fuel economy represents an overestimate of the value of fuel savings, or are offset by losses in consumer welfare. All other model inputs used in these sensitivity runs are the Expected Value inputs.

We emphasize that, as illustrated in Table 2.4-1, for most of the alternatives fuel consumption is not sensitive to this assumption. Alternative 6 and Alternative 9 (the MNB and TCTB alternatives) are sensitive to this assumption because the stringency of these alternatives is determined by relating benefits to costs. Therefore, any reduction in benefits will reduce the stringency of CAFE standards that would be established by each of these alternatives, thus increasing total fuel consumption under each alternative. Because environmental impacts associated with each action alternative are derived primarily from changes in total fuel consumption from its baseline level under the No Action Alternative, the environmental impacts associated with most action alternatives are not sensitive to changes in the assumption regarding reduced consumer benefits due to overestimation of the value of fuel savings, or potential welfare losses.

The agency recognizes that, with respect to Alternatives 6 and 9, both the achieved fuel economy standards and resulting environmental impacts under Alternatives 6 and 9 depend, in part, on the choice of inputs utilized by the Volpe model. Table 2.4-1 presents a sensitivity analysis of how changes in key economic variables, including fuel price projections, the value of reducing CO_2 emissions, oil import externalities, consumer benefits losses, and the rebound effect influence the estimates of total fuel consumption over the period from 2012 to 2060 for selected Alternatives. The change in projected 2012-2060 fuel consumption associated with different economic inputs to the Volpe model also indicates the magnitude of related changes in emissions of criteria air pollutants, greenhouse gases, and airborne toxics, as well as in their associated environmental impacts. Table 2.4-1 shows that fuel consumption is relatively sensitive to fuel price projections, and somewhat sensitive to the estimated rebound effect, but relatively insensitive to changes in model input values for the discount rate, SCC, consumer benefit losses, and oil import externalities.

Table 2.4-1

Sensitivity Analysis of Fuel Consumption (2012-2060; billion gallons) under Expected Value Model Input Assumptions versus other Model Input Assumptions for Selected Alternatives

	Alt. 1	Alt. 2	Alt. 4	Alt. 6	Alt. 9
	No Action	3%/year Increase	~4.3%/year Increase Preferred	~6.0%/year Increase MNB	~6.6%/year Increase TCTB
Expected Value Model Inputs	10,180	9,479	9,081	8,613	8,488
High AEO Fuel Price Forecast	10,175	9,444	9,050	8,514	8,462
Low AEO Fuel Price Forecast	10,190	9,533	9,116	8,773	8,564
7% Discount Rate a/	10,180	9,479	9,081	8,635	8,488
5% Rebound Effect	10,179	9,373	8,926	8,413	8,277
15% Rebound Effect	10,181	9,585	9,236	8,813	8,699
$10/ton CO_2 b/	10,180	9,479	9,081	8,607	8,488
5¢/gal Oil Import Externality	10,180	9,479	9,081	8,613	8,488
25% Consumer Benefits	10,180	9,479	9,081	8,789	8,489
50% Consumer Benefits	10,180	9,479	9,081	8,719	8,489
75% Consumer Benefits	10,180	9,479	9,081	8,633	8,488

a/ Non-climate benefits in this sensitivity case are discounted at 7%. Non-climate benefits in the main analysis and all other sensitivity cases are discounted at 3% per guidance from the Office of Management and Budget. *See* Office of Management and Budget, Circular No. A-4 (2003), Docket No. NHTSA-2009-0059-0041.

b/ The sensitivity run using the $10/ton SCC estimate discounts climate-related benefits at the same 5% rate used to develop the $10/ton SCC estimate. In contrast, the $56/ton SCC estimate used in the environmental analysis of this EIS discounts climate-related benefits at 3%, because that is the discount rate that was used to develop the $56/ton SCC estimate. The discounting of climate-related benefits is explained in the joint NPRM. 74 FR 49454, 49677. The 7% discount rate is only used in the sensitivity analysis case labeled accordingly, and is only applied to non-climate benefits in that case.

The Expected Value model inputs result in 10,180 billion gallons of fuel consumption from 2012 to 2060 under the No Action Alternative, and 8,488 billion gallons under the TCTB Alternative, with fuel consumption under other action alternatives falling within this range. Changing the projected fuel price input to the AEO High Fuel Price Forecast (while leaving other model inputs the same) reduces projected 2012-2060 fuel consumption under each alternative by 0.05 percent to 1.15 percent from its estimated level under that alternative with the Expected Value model inputs (including the AEO Reference Case fuel price forecast). In contrast, changing the projected fuel price input to the AEO Low Fuel Price Forecast (while leaving other model inputs the same) increases projected 2012-2060 fuel consumption for each alternative by 0.10 percent to 1.86 percent from its level under that alternative using the Expected Value model inputs (including the AEO Reference Case fuel price forecast).

Reducing the rebound effect to 5 percent (while leaving other model inputs values the same, including the Reference Case fuel price forecast) reduces projected 2012-2060 fuel consumption for each alternative by 0.01 percent to 2.49 percent from its level under the same alternative with a 10 percent rebound effect (the Expected Value model input). In contrast, increasing the rebound effect to 15 percent increases projected 2012-2060 fuel consumption for each alternative by 0.01 percent to 2,49 percent. The sensitivity analysis in Table 2.4-1 shows that changes in the input values for the discount rate, the SCC, and oil import externalities result in less than a 1-percent change in projected 2012-2060 fuel consumption under each alternative (and less than a 0.01-percent change under most alternatives).

These results occur because variation in fuel prices and the magnitude of the rebound effect influence total vehicle use (as measured by the number of vehicle-miles traveled, or VMT), one of the two determinants of fuel consumption, under each alternative. This reflects the response of average vehicle use to changes in fuel cost per mile; variation in fuel prices directly affects fuel cost per mile, while the rebound effect expresses the sensitivity of average vehicle use to the resulting change in fuel cost per mile.[29] In addition, changes in fuel prices and the rebound effect significantly change the stringency of CAFE standards under alternatives that would establish standards on the basis of benefits and costs (Alternatives 6 and 9), which reinforces the effect of changes in vehicle use on total fuel consumption under those alternatives.

In contrast, variation in other economic assumptions, including the discount rate, the value of reducing CO_2 emissions, the reduced consumer benefits assumptions, and the value of petroleum import externalities have almost no effect on vehicle use under any alternative. Further, changes in these variables have only modest effects on the stringency of CAFE standards under alternatives that would establish standards on the basis of the economic costs and benefits from requiring higher fuel economy. As a consequence, changes in assumptions about these variables have little effect on total fuel consumption, as Table 2.4-1 illustrates, although changes in these variables *do* have significant effects on the total economic benefits resulting from the different Action Alternatives.

2.5 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

As a result of the scoping process, several suggestions were made to NHTSA regarding alternatives that should be examined in this EIS. NHTSA considered these alternatives and discusses them below along with the reasons why we believe these alternatives do not warrant further analysis in this EIS.

- **100 mpg**

  One commenter suggested NHTSA examine an alternative of setting standards to achieve 100 mpg within 5 years. NHTSA did not pursue this suggested alternative for two reasons. First, a fleet-wide 100-mpg average would require the production of vehicles different from those now made in volume at a rate that is not possible in 5 years, as well as the elimination of vehicles for which there is consumer demand and for which manufacturers currently have supply contracts established to build in the near future. Second, the suggested approach would not be an appropriate balancing of the statutory factors listed in EPCA since the measures are not economically practicable based on manufacturers' limitations concerning retooling and

[29] Mathematically, the rebound effect is equal in magnitude to the elasticity of average vehicle use with respect to fuel cost per mile driven, although the rebound effect is customarily expressed as a positive percentage.

established supply contracts.[30] Indeed, the suggested approach would result in a level that is substantially higher than the "maximum feasible" CAFE standard, as required by EPCA.

- **Wedge Approach**

The Attorneys General commented that NHTSA's EIS should show how the MYs 2012-2016 CAFE rules contribute to reducing GHG emissions and addressing global warming by evaluating whether the new CAFE rules could constitute a stabilization wedge. While this is an approach, the agency declines to pursue a wedge analysis to fulfill its obligations under NEPA. CEQ regulations require NHTSA to rigorously explore all reasonable alternatives and examine their direct and indirect effects on climate change.[31] NHTSA's current approach demonstrates changes in CO_2 concentration, global mean surface temperature, regional temperature and precipitation, and sea level for each alternative. Analysis of stabilization wedges, and framing the alternatives in terms of fractions of a stabilization edge, would only allow for a conceptual analysis of CO_2 reductions. NHTSA believes that framing the alternatives as average annual percentage increase over current fuel economy levels is more intuitive to the public and to decisionmakers than framing the alternatives as suggested by the commenter. Therefore, NHTSA believes its chosen approach for addressing global warming is best able to describe the direct and indirect effects of climate change on all reasonable alternatives in accordance with NEPA. NHTSA has added a discussion of the wedge theory and how NHTSA's proposed action generally looks in terms of a stabilization wedge in Section 3.4.4.1.

- **Least Capable Manufacturer**

In their scoping comments the Alliance of Automobile Manufacturers ("AAM") suggested an alternative of NHTSA setting standards tailored to the "least capable manufacturer." As NHTSA explained in the FEIS for MY 2011 CAFE standards, the agency chose not to pursue the suggested approach for two reasons. First, the approach would not result in the EISA mandated fuel economy increases – namely, 35 mpg by MY 2020. Second, tailoring to the least capable manufacturer is unnecessary in Reformed CAFE, which was codified when EISA required that all CAFE standards be based on one or more vehicle attributes.[32] Reformed CAFE standards specify variable levels of CAFE depending on the production mix of each manufacturer, making it unnecessary to tailor to the least capable manufacturer.

- **Variations based on increases from EISA MY 2020 endpoint**

The AAM also suggested that NHTSA "consider crafting a couple of alternatives that would model increased CAFE stringency levels over the baseline level for MY 2020 as required by EISA. For instance: Alternative (2) could be redefined as improving fuel economy at the rate necessary to achieve 35 mpg fleet average fuel economy in MY 2020…Alternative (3) could be defined as improving fuel economy at the rate necessary to achieve a 36.75 mpg fleet average fuel economy in MY 2020, an increase of 5 [percent] above EISA's baseline level in MY 2020." Docket No. NHTSA-2009-0059-0007. NHTSA recognizes that this is one possible approach to creating regulatory alternatives, but instead prefers to establish regulatory alternatives by specifying average annual percentage increases over MY 2011 CAFE standards because the agency believes alternatives expressed this way are more intuitive and understandable to the

[30] 49 U.S.C. § 32902(f) (the determination of maximum feasibility is based on: technological feasibility, economic practicability, the effect of other motor vehicle standards on fuel economy, and the need of the United States to conserve energy).
[31] *See* 40 CFR § 1502.14-16.
[32] 49 U.S.C. § 32902(b)(3)(A); *see* 73 *FR* 24352, 24354-24355 (May 2, 2008).

public. We believe this approach best fulfills the goals of NEPA to inform both decisionmakers and the general public. CEQ regulations instruct agencies to write an EIS using plain language to enable understandability of complex environmental analyses for both decisionmakers and the public.[33] CEQ regulations also indicate that a major purpose of an EIS is to facilitate public involvement in and knowledge of the NEPA process.[34] NHTSA believes the approach chosen for generating alternatives best presents understandable regulatory approaches to CAFE increases.

- **Technology Exhaustion**

In the 2008 EIS, NHTSA analyzed a "technology exhaustion" alternative, which was developed by using the Volpe model to progressively increase the stringency of the standard in each model year until every manufacturer (among those without a history of paying civil penalties) exhausted technologies estimated to be available during the relevant model years. In its scoping comments, the Center for Biological Diversity stated that NHTSA should include one or more "technology forcing" alternatives, which would include standards that may appear impossible today, but which would force innovation as industry strives to meet a challenging standard. We consider the upper range of alternatives presented in this EIS to be technology forcing in the sense that at these higher average annual percentage increases some manufacturers run out of technologies, which would provide encouragement to seek other technologies to improve fuel economy. Since these higher average annual percentage increase regulatory alternatives would tend to induce manufacturers to do something they could not do with available technologies, they are in that sense "technology forcing" as well. We consider our range of alternatives to represent a reasonable range of possible agency actions.

2.6 COMPARISON OF ALTERNATIVES

The CEQ NEPA regulations direct federal agencies to use the NEPA process to identify and assess the reasonable alternatives to proposed actions that would avoid or minimize adverse effects of these actions upon the quality of the human environment.[35] CEQ regulations state:

> Based on the information and analysis presented in the sections on the Affected Environment (Sec. 1502.15) and the Environmental Consequences (Sec. 1502.16), [an EIS] should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public. [36]

This section summarizes the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality, and climate. For more detailed discussions on assumptions and methodologies associated with the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality and climate, see Sections 3.1 and 4.1. Please note that assumptions and methodologies may differ for each regulatory alternative. No quantifiable, alternative-specific effects were identified for the other resources discussed in Chapters 3 and 4 of this EIS. Refer to the text in Chapter 3 and 4 for qualitative discussions of the potential direct and indirect effects of the alternatives on these other resources.

[33] *See* 40 CFR § 1502.8.
[34] *See* 40 CFR § 1500.1(b).
[35] *See* 40 CFR § 1500.2(e).
[36] *See* 40 CFR § 1502.14.

The consideration of the effects goes beyond MYs 2012-2016 vehicles. In the alternatives analyzed in the EIS, the growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use (annual vehicle miles traveled per vehicle), is projected to result in growth in total passenger car and light truck travel. This growth in travel outpaces improvements in fuel economy for each of the action alternatives, resulting in projected increases in total fuel consumption by U.S. passenger cars and light trucks. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks. NHTSA estimates that the proposed CAFE standards will reduce fuel consumption and CO_2 emissions from what they otherwise are estimated to be in the absence of the CAFE program (*i.e.*, fuel consumption and CO_2 emissions under the "no action" alternative). For more detailed discussions on assumptions and methodologies associated with the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality and climate, see Sections 3.1 and 4.1.

2.6.1 Direct and Indirect Effects

Under NEPA, direct effects "are caused by the action and occur at the same time and place." 40 CFR § 1508.8. CEQ regulations define indirect effects as those that "are caused by the action and are later in time or father removed in distance but are still reasonably foreseeable. Indirect effects may include … effects on air and water and other natural systems, including ecosystems." 40 CFR § 1508.8. Below is a description of the direct and indirect effects of the CAFE alternatives on energy, air quality, and climate.

2.6.1.1 Energy

Tables 2.6-1 through 2.6-3 show the impact on annual fuel consumption for passenger cars and light trucks from 2020 through 2060, when the entire passenger car and light truck fleet is likely to be composed of MY 2016 or later passenger cars. Table 2.6-1 shows annual total fuel consumption (both gasoline and diesel gasoline equivalent) under the No Action Alternative and the eight action alternatives. For passenger cars, fuel consumption under the No Action Alternative is 205.5 billion gallons in 2060. Fuel consumption ranges from 188.4 billion gallons under Alternative 2 (3-Percent Alternative) to 166.5 billion gallons under Alternative 8 (7-Percent Alternative). Fuel consumption is 179.4 billion gallons under the Preferred Alternative.

For light trucks, fuel consumption under the No Action Alternative is 113.0 billion gallons in 2060. Fuel consumption ranges from 104.6 billion gallons under Alternative 2 (3-Percent Alternative) to 92.4 billion gallons under Alternative 8 (7-percent annual increase in mpg). Fuel consumption is 99.4 billion gallons under the Preferred Alternative (Alternative 4).

For passenger cars and light trucks combined, fuel consumption under the No Action Alternative is 318.5 billion gallons in 2060. Fuel consumption ranges from 293.0 billion gallons under Alternative 2 (3-Percent Alternative) to 258.9 billion gallons under Alternative 8 (7-percent annual increase in mpg). Fuel consumption is 278.8 billion gallons under the Preferred Alternative (Alternative 4).

Table 2.6-1

Passenger Car Annual Fuel Consumption and Fuel Savings by Alternative (billion gallons gasoline equivalent)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
Calendar Year	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Fuel Consumption									
2020	74.1	70.5	68.9	68.4	67.5	66.2	66.4	65.6	65.6
2030	103.9	95.5	92.0	91.1	89.0	86.5	86.5	84.8	85.2
2040	134.5	123.3	118.6	117.4	114.7	111.3	111.3	109.0	109.6
2050	167.6	153.6	147.7	146.2	142.8	138.6	138.6	135.8	136.5
2060	205.5	188.4	181.2	179.4	175.2	170.0	170.0	166.5	167.4
Fuel Savings Compared to No Action									
2020	--	3.6	5.2	5.7	6.6	7.9	7.7	8.5	8.4
2030	--	8.4	11.9	12.8	14.8	17.4	17.3	19.1	18.7
2040	--	11.2	15.9	17.1	19.9	23.2	23.3	25.5	24.9
2050	--	14.0	19.8	21.3	24.8	28.9	29.0	31.8	31.1
2060	--	17.2	24.3	26.2	30.4	35.5	35.5	39.0	38.1

Table 2.6-2

Light Truck Annual Fuel Consumption and Fuel Savings by Alternative (billion gallons gasoline equivalent)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
Calendar Year	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Fuel Consumption									
2020	75.8	73.5	72.4	71.9	71.4	70.2	70.5	69.8	69.8
2030	72.2	67.7	65.7	64.9	63.9	62.2	62.2	61.1	61.3
2040	78.6	73.1	70.5	69.6	68.3	66.2	66.1	64.8	65.1
2050	93.0	86.2	83.0	81.9	80.4	77.8	77.7	76.1	76.5
2060	113.0	104.6	100.7	99.4	97.5	94.4	94.3	92.4	92.8
Fuel Savings Compared to No Action									
2020	--	2.3	3.4	3.9	4.4	5.6	5.4	6.0	6.1
2030	--	4.4	6.5	7.2	8.2	10.0	10.0	11.0	10.9
2040	--	5.6	8.2	9.1	10.3	12.4	12.5	13.8	13.5
2050	--	6.8	10.0	11.1	12.6	15.2	15.3	16.9	16.5
2060	--	8.3	12.3	13.5	15.5	18.6	18.7	20.6	20.2

Table 2.6-3

Car & Light Truck Annual Fuel Consumption and Fuel Savings by Alternative a/ (billion gallons gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	149.9	144.0	141.3	140.3	139.0	136.5	136.9	135.4	135.4
2030	176.0	163.2	157.7	156.0	153.0	148.7	148.7	146.0	146.5
2040	213.2	196.4	189.1	187.0	183.0	177.5	177.4	173.9	174.7
2050	260.5	239.7	230.7	228.2	223.2	216.5	216.3	211.9	213.0
2060	318.5	293.0	281.9	278.8	272.7	264.5	264.3	258.9	260.3
Fuel Savings Compared to No Action									
2020	--	6.0	8.7	9.7	10.9	13.5	13.0	14.5	14.5
2030	--	12.8	18.4	20.0	23.1	27.4	27.3	30.1	29.5
2040	--	16.8	24.1	26.2	30.2	35.7	35.8	39.3	38.4
2050	--	20.8	29.9	32.4	37.4	44.1	44.3	48.6	47.5
2060	--	25.5	36.6	39.7	45.8	54.0	54.2	59.6	58.3

a/ Some of the values shown for car and light truck fuel consumption in this table vary slightly from the sum of values shown separately for passenger cars and light trucks in previous tables due to rounding error.

2.6.1.2 Air Quality

Table 2.6-4 summarizes the total national criteria and air toxic pollutant emissions in 2030 for the nine alternatives, left to right in order of generally increasing fuel economy requirements. Changes in overall emissions between the No Action Alternative and Alternatives 2 through 4 are generally smaller than those between the No Action Alternative and Alternatives 5 through 9. In the case of particulate matter ($PM_{2.5}$), sulfur oxides (SO_x), nitrogen oxides (NO_x), and volatile organic compounds (VOCs), the No Action Alternative results in the highest emissions, and emissions generally decline as fuel economy standards increase across alternatives. Across Alternatives 4 through 9 some emissions increase from one alternative to another, but emissions remain below the levels under the No Action Alternative. In the case of carbon monoxide (CO), emissions under Alternatives 2 through 4 are slightly higher than under the No Action Alternative. Emissions of CO generally decline as fuel economy standards increase across Alternatives 5 through 9.

The trends for toxic air pollutant emissions across the alternatives are mixed. Annual emissions of acetaldehyde in 2030 increase under each successive alternative from the No Action Alternative to Alternative 4, and then decrease from Alternative 5 to Alternative 9. Annual emissions of acrolein in 2030 are higher than under the No Action Alternative. Acrolein emissions increase, though not consistently, from the No Action Alternative to Alternative 8, and then decrease under Alternative 9. Annual emissions of 1,3-butadiene in 2030 increase under each successive alternative from the No Action Alternative to Alternative 3 and then decrease, though not consistently, from Alternative 3 to Alternative 9. The minimum emissions of 1,3-butadiene occurs under Alternative 8. Annual emissions in 2030 of benzene and DPM decrease from the No Action Alternative to Alternative 9, though the decrease is not consistent between Alternatives 6 and 9. The minimum emissions of benzene and DPM occur under Alternative 8. Annual emissions of formaldehyde in 2030 decrease from the No Action Alternative to Alternative 2. Formaldehyde emissions increase, though not consistently, from Alternative 2 to Alternative 8, and then decrease slightly under Alternative 9.

Table 2.6-4

Nationwide Criteria Pollutant Emissions and Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks (tons/year, Calendar Year 2030) by Alternative

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Criteria Pollutant Emissions									
Carbon monoxide (CO)	20,516,692	20,625,314	20,653,244	20,611,910	19,847,892	19,203,414	19,361,096	18,867,420	19,034,022
Nitrogen oxides (NO_x)	1,425,733	1,410,414	1,402,605	1,398,774	1,371,749	1,345,911	1,351,818	1,332,981	1,338,453
Particulate matter ($PM_{2.5}$)	84,021	81,726	80,498	80,206	81,194	81,484	81,637	82,126	81,839
Sulfur oxides (SO_x)	216,228	200,884	194,149	192,374	192,985	191,324	190,961	190,214	189,760
Volatile organic compounds (VOCs)	1,881,987	1,810,076	1,778,691	1,767,262	1,708,646	1,649,731	1,655,217	1,614,158	1,627,859
Toxic Air Pollutant Emissions									
Acetaldehyde	7,927	7,951	7,973	7,976	7,929	7,905	7,902	7,872	7,879
Acrolein	391	394	395	397	425	449	445	463	457
Benzene	28,961	28,900	28,863	28,815	28,203	27,673	27,788	27,388	27,519
1,3-butadiene	3,751	3,771	3,777	3,776	3,747	3,724	3,734	3,717	3,722
Diesel particulate matter (DPM)	113,884	105,735	102,053	100,991	99,301	96,641	96,743	95,220	95,595
Formaldehyde	9,190	9,173	9,194	9,224	9,580	9,911	9,818	10,051	9,964

The reductions in emissions are expected to lead to reductions in adverse health effects as compared to the No Action Alternative. Table 2.6-5 summarizes the national changes in health outcomes in 2030 for the nine alternatives, left to right in order of increasing fuel economy requirements. There would be reductions in adverse health effects nationwide under Alternatives 2 (3-Percent Alternative) through 9 (TCTB) compared to the No Action Alternative. The No Action Alternative results in no reductions in adverse health effects and the reductions become larger as fuel economy standards increase and emissions decrease across alternatives. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_2.

The economic value of health impacts would vary proportionally with changes in health outcomes. Table 2.6-6 lists the corresponding annual monetized health benefits in 2030 under Alternatives 2 (3-Percent Alternative) through 9 (TCTB) compared to the No Action Alternative. Monetized health benefits are given based on data from two alternative studies, which EPA considers co-equal, and for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health benefits.

Table 2.6-5

Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions (cases/year) from Passenger Cars and Light Trucks by Alternative a/

Out. and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Mortality (ages 30 and older), Pope *et al*.									
2030	0	-149	-223	-243	-235	-257	-247	-251	-257
Mortality (ages 30 and older), Laden *et al*.									
2030	0	-380	-571	-623	-600	-658	-632	-643	-657
Chronic bronchitis									
2030	0	-97	-146	-160	-155	-170	-163	-166	-169
Emergency Room Visits for Asthma									
2030	0	-137	-204	-222	-211	-228	-221	-224	-230
Work Loss Days									
2030	0	-17,499	-26,298	-28,705	-27,756	-30,507	-29,237	-29,792	-30,423

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

Table 2.6-6

Nationwide Monetized Health Benefits (U.S. million dollars/year) from Criteria Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

Rate and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
3% Discount Rate									
Pope *et al*.									
2030	0	-1,322	-1,983	-2,164	-2,087	-2,287	-2,197	-2,235	-2,284
Laden *et al*.									
2030	0	-3,239	-4,860	-5,302	-5,112	-5,603	-5,382	-5,477	-5,596
7% Discount Rate									
Pope *et al*.									
2030	0	-1,199	-1,799	-1,963	-1,893	-2,075	-1,993	-2,028	-2,072
Laden *et al*.									
2030	0	-2,926	-4,390	-4,789	-4,618	-5,061	-4,861	-4,947	-5,055

a/ Negative changes indicate monetized health benefits; positive emissions changes indicate monetized health disbenefits.
b/ Changes in outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which impacts under the action alternatives are compared.

2.6.1.3 Climate Change

This EIS uses a climate model to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each alternative. NHTSA also estimated changes in global precipitation.

2.6.1.3.1 GHG Emissions

Table 2.6-7 shows total GHG emissions and emissions reductions from new passenger cars and light trucks, summed for the period 2012 through 2100 under each of the nine alternatives. Although GHG emissions from this sector will continue to rise over the period (absent other reduction efforts) across all the alternatives, the effect of the alternatives is to slow this increase by varying amounts. Emissions for the period range from 227,700 million metric tons of CO_2 ($MMTCO_2$) for the 7%/year Increase (Alternative 8) to 276,000 $MMTCO_2$ for the No Action Alternative (Alternative 1). Compared to the No Action Alternative, projections of emissions reductions over the period 2012 to 2100 due to the MYs 2012-2016 CAFE standards range from 20,700 to 48,300 $MMTCO_2$. Compared to cumulative global emissions of 5,293,896 $MMTCO_2$ over this period (projected by the RCP 4.5 MiniCAM reference scenario), this rulemaking is expected to reduce global CO_2 emissions by about 0.4 to 0.9 percent.

Table 2.6-7

Emissions and Emissions Reductions ($MMTCO_2$) from 2012-2100 by Alternative a/

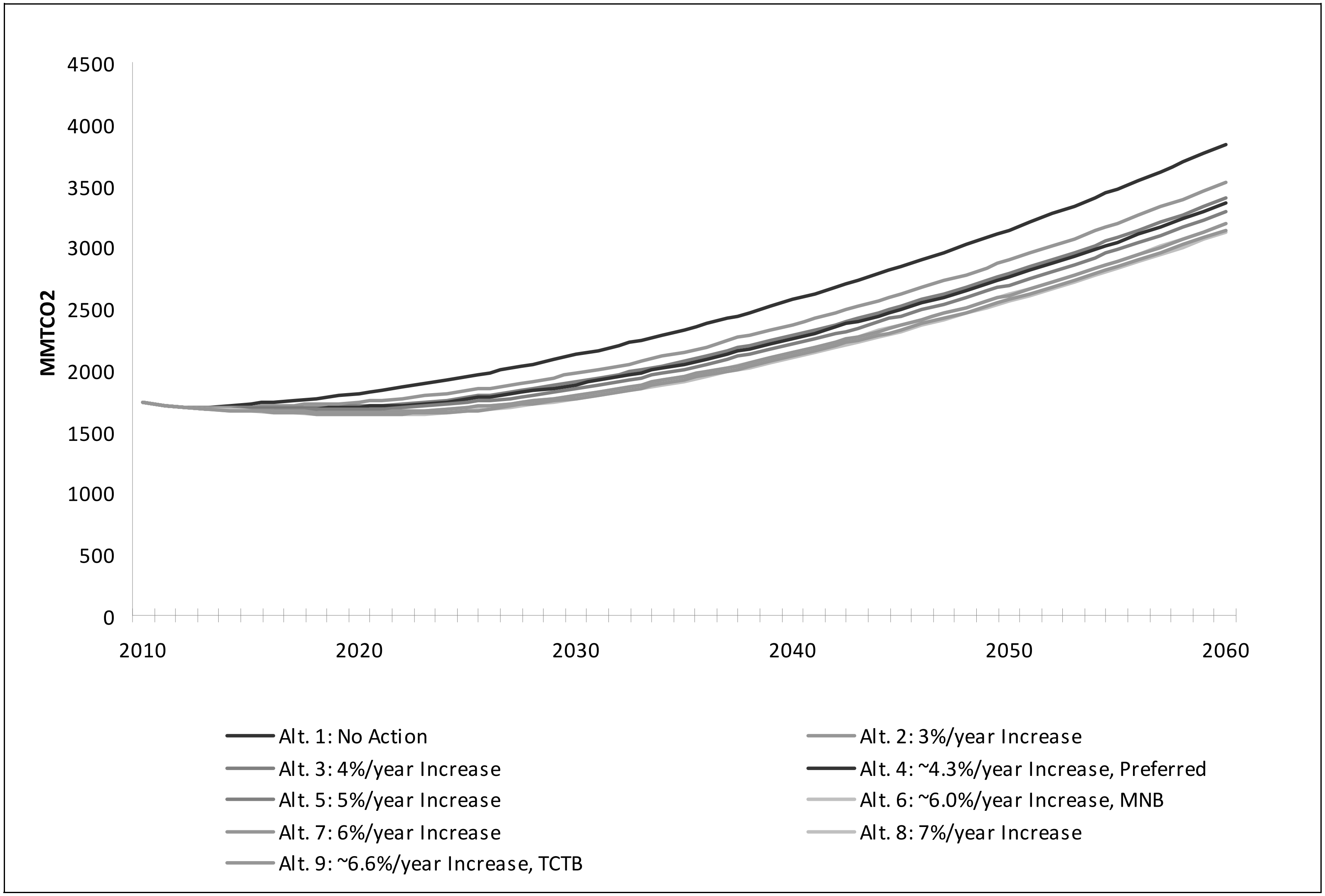
Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	276,000	0
2 3%/year Increase	255,300	20,700
3 4%/year Increase	246,300	29,700
4 ~4.3%/year Increase, Preferred	243,800	32,300
5 5%/year Increase	238,900	37,100
6 ~6.0%/year Increase, MNB	232,200	43,900
7 6%/year Increase	232,100	43,900
8 7%/year Increase	227,700	48,300
9 ~6.6%/year Increase, TCTB	228,700	47,300

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

To get a sense of the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from passenger cars and light trucks as a whole and to compare them against emissions projections for the United States. U.S. passenger cars and light trucks currently account for approximately 19.1 percent of CO_2 emissions in the United States (EPA 2009a). With the action alternatives reducing U.S. passenger car and light truck CO_2 emissions by 7.5 to 17.5 percent of cumulative emissions from 2012 to 2100, the CAFE alternatives would have a noticeable impact on total U.S. CO_2 emissions. Compared to total U.S. CO_2 emissions in 2100 projected by the MiniCAM reference scenario of 7,886 $MMTCO_2$, the action alternatives would reduce annual U.S. CO_2 emissions by 3.9 to 9.1 percent in 2100. As another comparison of the magnitude of these reductions, average annual CO_2 emission reductions from the CAFE alternatives range from 232 to 543 $MMTCO_2$ over 2012 to 2100, equivalent to the annual CO_2 emissions of 60 to 141 coal-fired power plants.[37] Figure 2.6-1 shows projected annual emissions from passenger cars and light trucks under the MYs 2012-2016 alternative CAFE standards.

[37] Estimated using EPA's Greenhouse Gas Equivalencies Calculator (EPA 2009b).

Figure 2.6-1. Projected Annual Emissions ($MMTCO_2$) by Alternative



Under all of the alternatives analyzed, growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth in total passenger car and light truck travel. This growth in travel overwhelms improvements in fuel economy for each of the alternatives, resulting in projected increases in total fuel consumption by U.S. passenger cars and light trucks over most of the period shown in the table. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger car and light truck fleet represented about 3.3 percent of total global emissions of CO_2 in 2005.[38] Although substantial, this source is still a small percentage of global emissions. The relative contribution of CO_2 emissions from the U.S. passenger cars and light trucks is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions).

2.6.1.3.2 CO_2 Concentration, Global Mean Surface Temperature, Sea-level Rise, and Precipitation

Table 2.6-8 shows estimated CO_2 concentrations, increase in global mean surface temperature, and sea-level rise in 2030, 2050, and 2100 under the No Action Alternative and the eight action alternatives. Figures 2.6-2 through 2.6-5 graphically illustrate estimated CO_2 concentrations and reductions for the eight action alternatives.

Table 2.6-8

CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise by Alternative a/

	CO_2 Concentration (parts per million)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (centimeters)		
	2030	2050	2100	2030	2050	2100	2030	2050	2100
Totals by Alternative									
1 No Action	441.8	514.8	783.0	0.923	1.557	3.136	8.38	15.17	38.00
2 3%/year Increase	441.6	514.3	781.0	0.922	1.554	3.128	8.38	15.16	37.94
3 4%/year Increase	441.5	514.0	780.2	0.922	1.553	3.125	8.38	15.15	37.91
4 ~4.3%/year Increase, Preferred	441.5	514.0	779.9	0.922	1.553	3.124	8.38	15.15	37.90
5 5%/year Increase	441.5	513.8	779.5	0.921	1.552	3.122	8.38	15.15	37.88
6 ~6.0%/year Increase, MNB	441.4	513.7	778.8	0.921	1.551	3.120	8.38	15.14	37.86
7 6%/year Increase	441.4	513.7	778.8	0.921	1.551	3.120	8.38	15.14	37.86
8 7%/year Increase	441.4	513.6	778.4	0.921	1.551	3.118	8.38	15.14	37.84
9 ~6.6%/year Increase, TCTB	441.4	513.6	778.5	0.921	1.551	3.118	8.38	15.14	37.84
Reductions under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.5	2.0	0.001	0.002	0.007	0.00	0.01	0.06
3 4%/year Increase	0.3	0.8	2.8	0.001	0.003	0.011	0.00	0.02	0.09
4 ~4.3%/year Increase, Preferred	0.3	0.8	3.1	0.001	0.004	0.012	0.00	0.02	0.10
5 5%/year Increase	0.3	1.0	3.5	0.002	0.004	0.014	0.00	0.02	0.12
6 ~6.0%/year Increase, MNB	0.4	1.1	4.2	0.002	0.006	0.016	0.00	0.03	0.14
7 6%/year Increase	0.4	1.1	4.2	0.002	0.006	0.016	0.00	0.03	0.14
8 7%/year Increase	0.4	1.2	4.6	0.002	0.006	0.018	0.00	0.03	0.16
9 ~6.6%/year Increase, TCTB	0.4	1.2	4.5	0.002	0.006	0.017	0.00	0.03	0.16

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

[38] Includes land-use change and forestry, and excludes international bunker fuels.

Figure 2.6-2. CO_2 Concentrations (ppm)

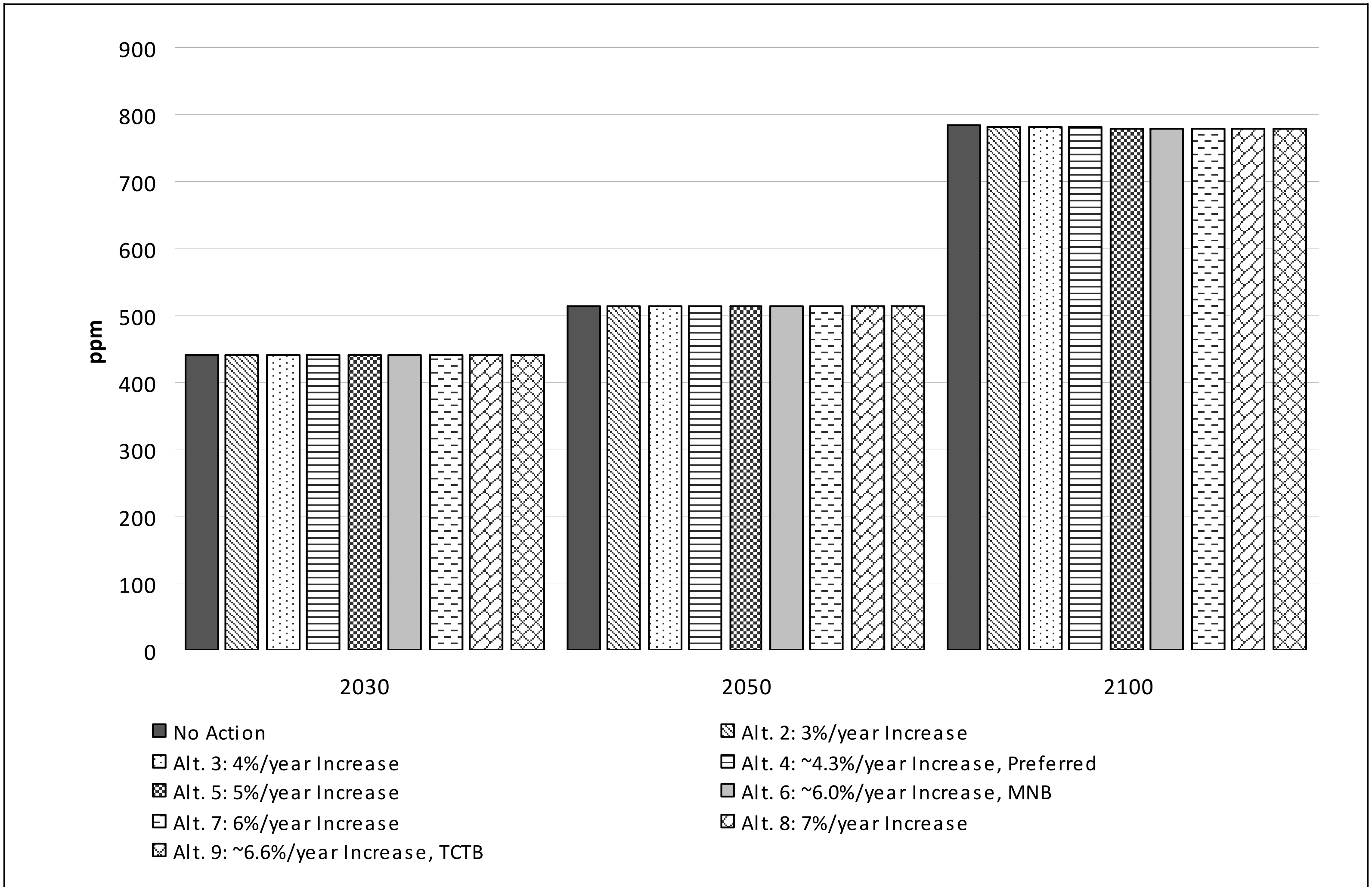


Figure 2.6-3. Global Mean Surface Temperature Increase (°C)

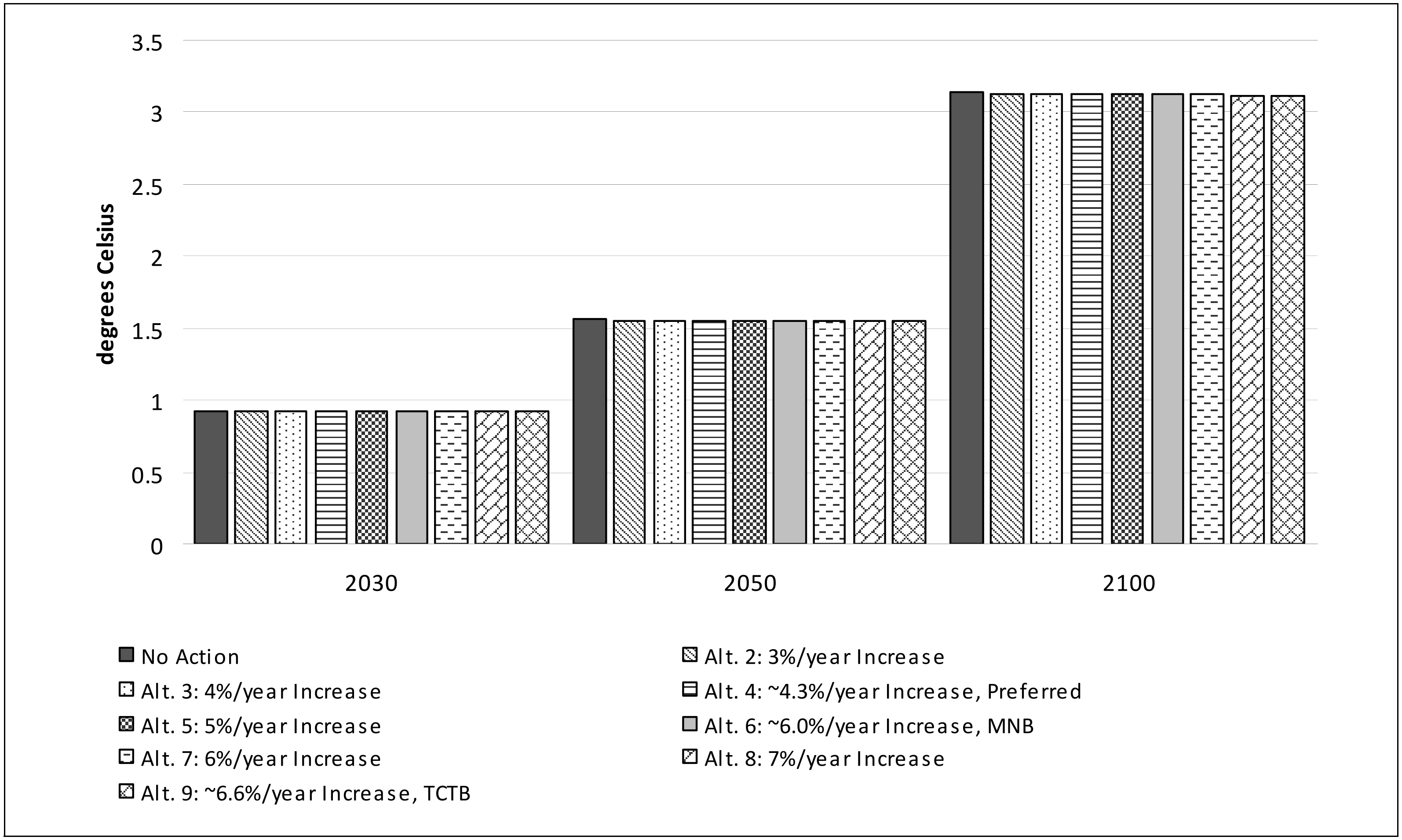


Figure 2.6-4. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

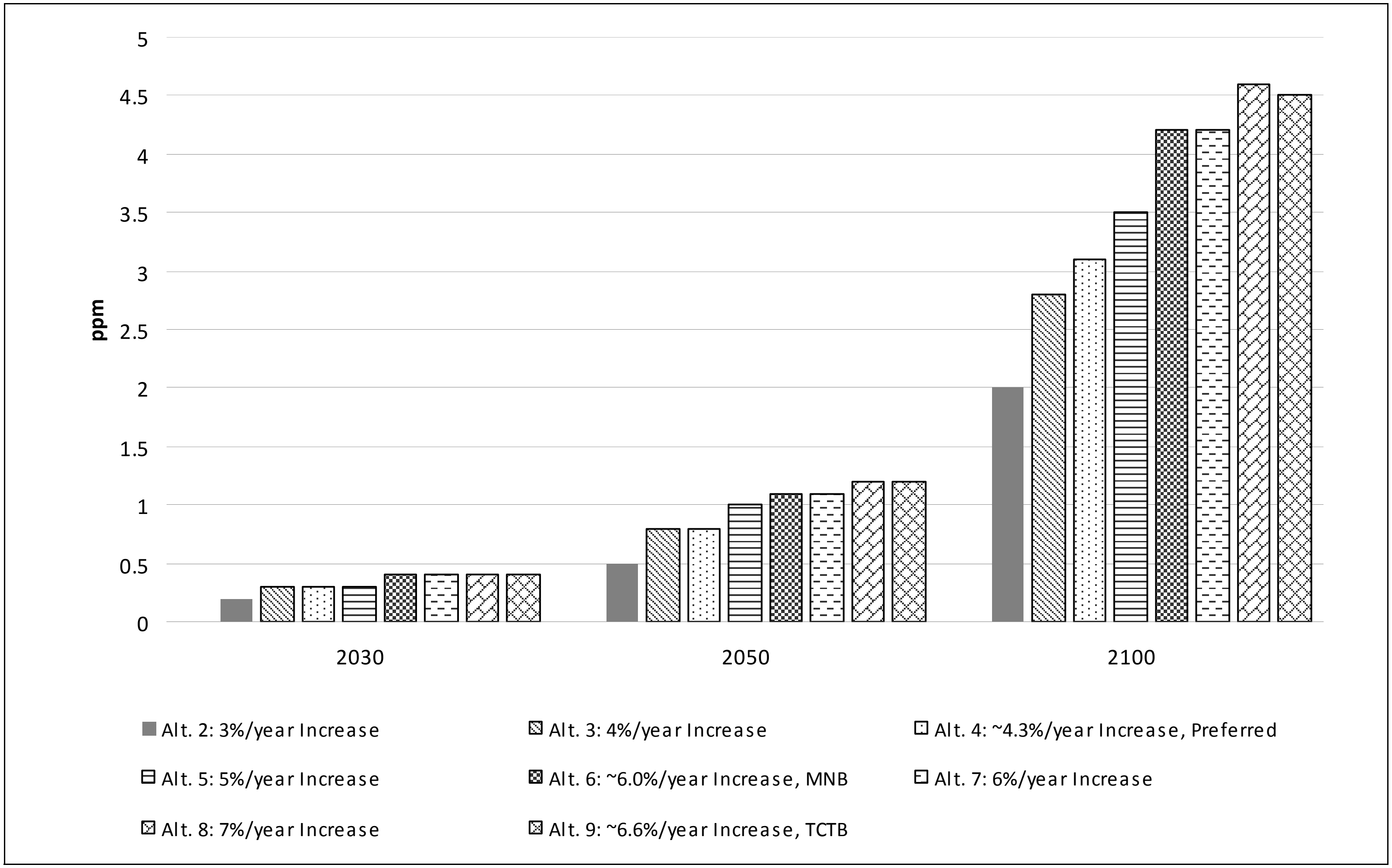


Figure 2.6-5. Reduction in Global Mean Temperature Compared to the No Action Alternative

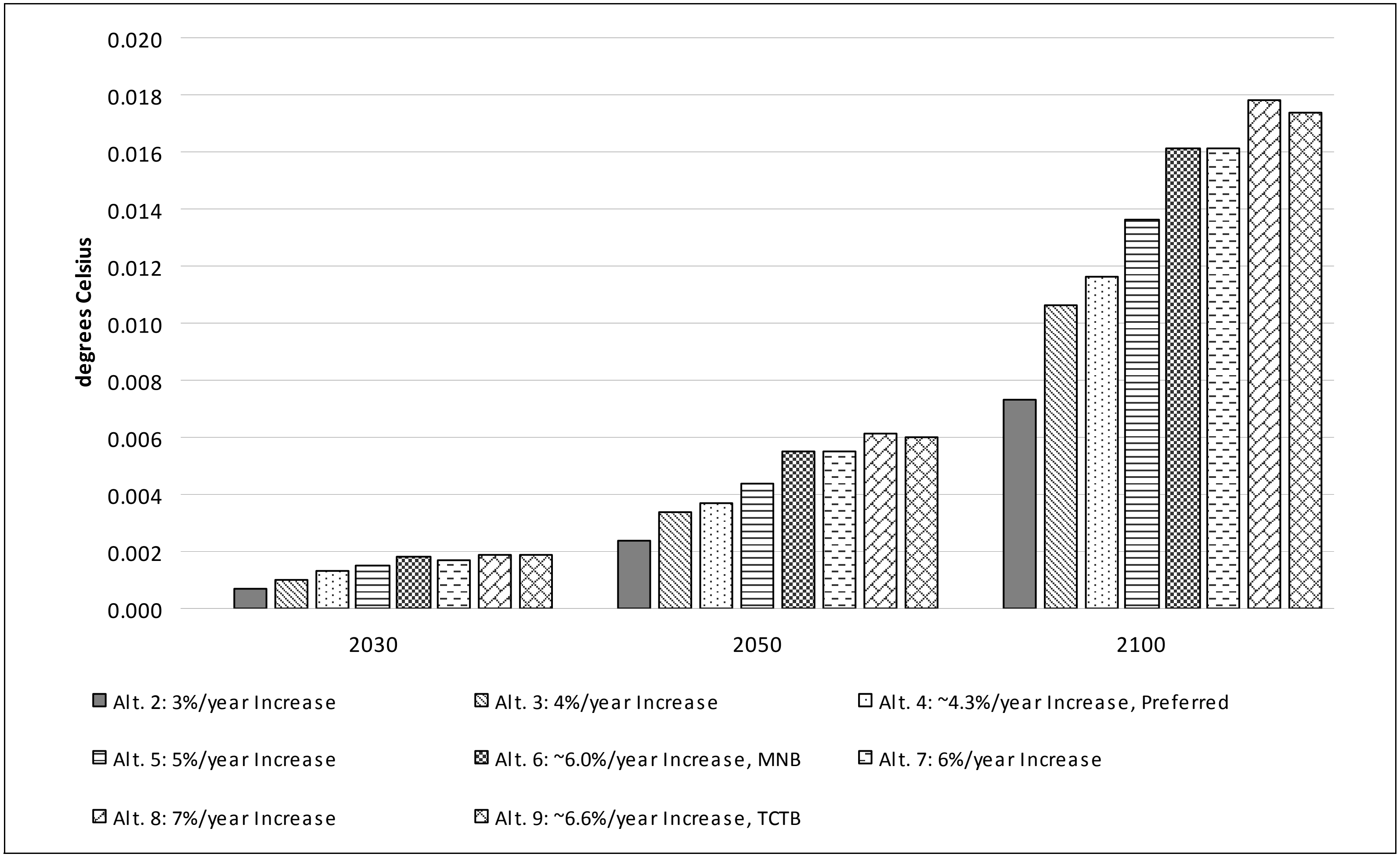


Table 2.6-8 lists the impacts on sea-level rise under the scenarios and shows sea-level rise in 2100 ranging from 38.00 centimeters under the No Action Alternative to 37.84 centimeters under Alternatives 8 and 9, for a maximum reduction of 0.16 centimeters by 2100 from the No Action Alternative.

Estimated CO_2 concentrations for 2100 range from 778.4 ppm under Alternative 8 to 783.0 ppm under the No Action Alternative. For 2030 and 2050, the range is even smaller. Because CO_2 concentration is the key driver of other climate effects (which in turn act as drivers on the resource impacts discussed in Section 4.5), this leads to small differences in these effects. For the No Action alternative, the temperature increase from 1990 is 0.92 °C (1.65 °F) for 2030, 1.56 °C (2.80 °F) for 2050, and 3.14 °C (5.65 °F) for 2100. The differences among alternatives are small, as shown in Figures 2.6-2 through 2.6-5. For 2100, the reduction in temperature increase, in relation to the No Action Alternative, ranges from 0.007 °C (0.013 °F) to 0.018 °C (0.032 °F).

Given that all the action alternatives reduce temperature increases slightly in relation to the No Action Alternative, they also slightly reduce predicted increases in precipitation, as shown in Table 2.6-9.

In summary, the impacts of the proposed action and alternatives on global mean surface temperature, precipitation, or sea-level rise are small in absolute terms. This is because the action alternatives have a small proportional change in the emissions trajectories in the RCP 4.5 MiniCAM reference scenario.[39] This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lived.

NHTSA examined the sensitivity of climate effects to key assumptions used in the analysis. The sensitivity analysis is based on the results provided for two CAFE alternatives – the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4) – using climate sensitivities of 2.0, 3.0, and 4.5 °C for a doubling of CO_2 concentrations in the atmosphere. The sensitivity analysis was conducted for only two CAFE alternatives, as this was deemed sufficient to assess the effect of various climate sensitivities on the results.

The use of different climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) not only directly affects warming, it also indirectly affects CO_2 concentration (through feedbacks on the solubility of CO_2 in the oceans) and sea-level rise (through effects on thermal expansion and melting of land-based ice).

As shown in Table 2.6-10, the sensitivity of the simulated CO_2 emissions in 2030, 2050, and 2100 to changes in climate sensitivity is low; the reduction of CO_2 concentrations from the No Action Alternative to the Preferred Alternative in 2100 is from 3.0 to 3.2 ppm.

[39] These conclusions are not meant to be interpreted as expressing NHTSA's views that impacts on global mean surface temperature, precipitation, or sea-level rise are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] of *the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). This analysis fulfills NHTSA's obligations in this regard.

Table 2.6-9

Global Mean Precipitation (percent change) a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % per °C)	1.45	1.51	1.63
Global Temperature above Average 1980-1999, Mid-level Results (ºC)			
1 No Action	0.648	1.716	2.816
2 3%/year Increase	0.648	1.713	2.809
3 4%/year Increase	0.648	1.712	2.806
4 ~4.3%/year Increase, Preferred	0.648	1.712	2.806
5 5%/year Increase	0.648	1.711	2.804
6 ~6.0%/year Increase, MNB	0.648	1.709	2.801
7 6%/year Increase	0.648	1.709	2.801
8 7%/year Increase	0.648	1.709	2.800
9 ~6.6%/year Increase, TCTB	0.648	1.709	2.800
Reduction in Global Temperature (ºC) for Alternative CAFE Standards, Mid-level Results (Compared to No Action Alternative)			
2 3%/year Increase	0.000	0.003	0.006
3 4%/year Increase	0.000	0.004	0.009
4 ~4.3%/year Increase, Preferred	0.000	0.004	0.010
5 5%/year Increase	0.000	0.005	0.012
6 ~6.0%/year Increase, MNB	0.000	0.007	0.014
7 6%/year Increase	0.000	0.007	0.014
8 7%/year Increase	0.000	0.007	0.016
9 ~6.6%/year Increase, TCTB	0.000	0.007	0.016
Global Mean Precipitation Change (%)			
1 No Action	0.94%	2.59%	4.59%
2 3%/year Increase	0.94%	2.59%	4.58%
3 4%/year Increase	0.94%	2.58%	4.57%
4 ~4.3%/year Increase, Preferred	0.94%	2.58%	4.57%
5 5%/year Increase	0.94%	2.58%	4.57%
6 ~6.0%/year Increase, MNB	0.94%	2.58%	4.57%
7 6%/year Increase	0.94%	2.58%	4.57%
8 7%/year Increase	0.94%	2.58%	4.56%
9 ~6.6%/year Increase, TCTB	0.94%	2.58%	4.56%
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 3%/year Increase	0.00%	0.00%	0.01%
3 4%/year Increase	0.00%	0.01%	0.02%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~6.0%/year Increase, MNB	0.00%	0.01%	0.02%
7 6%/year Increase	0.00%	0.01%	0.02%
8 7%/year Increase	0.00%	0.01%	0.03%
9 ~6.6%/year Increase, TCTB	0.00%	0.01%	0.03%

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

Table 2.6-10

CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives a/

CAFE Alternative	Climate Sensitivity (°C for 2xCO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea- level Rise (cm)
		2030	2050	2100	2030	2050	2100	2100
1 No Action								
	2.0	440.2	510.7	765.1	0.699	1.168	2.292	28.68
	3.0	441.8	514.8	783.0	0.923	1.557	3.136	38.00
	4.5	443.6	519.5	805.3	1.168	1.991	4.132	48.67
4 Preferred								
	2.0	439.9	509.9	762.1	0.698	1.166	2.283	28.60
	3.0	441.5	514.0	779.9	0.922	1.553	3.124	37.90
	4.5	443.3	518.7	802.1	1.166	1.987	4.118	48.54
Reduction compared to No Action								
	2.0	0.3	0.8	3.0	0.001	0.003	0.009	0.08
	3.0	0.3	0.8	3.1	0.001	0.004	0.012	0.10
	4.5	0.3	0.8	3.2	0.001	0.005	0.015	0.13

a/ Values in this table are rounded.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, is also shown in Table 2.6-10. In 2030, the impact is low, due primarily to the slow rate at which the global mean surface temperature increases in response to increases in radiative forcing. The relatively slow response in the climate system explains the observation that even by 2100, when CO_2 concentrations more than double in comparison to pre-industrial levels, the temperature increase is below the equilibrium sensitivity levels, *i.e.*, the climate system has not had enough time to equilibrate to the new CO_2 concentrations. Nonetheless, as of 2100 there is a larger range in temperatures across the different values of climate sensitivity: the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative ranges from 0.009 °C (0.016 °F) for the 2.0 °C climate sensitivity to 0.015 °C (0.027 °F) for the 4.5 °C climate sensitivity.

The sensitivity of the simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 2.6-10. Scenarios with lower climate sensitivities have lower increases in sea-level rise. The greater the climate sensitivity, the greater the decrement in sea-level rise for the Preferred Alternative as compared to the No Action Alternative.

2.6.2 Cumulative Effects

CEQ identifies the impacts that must be addressed and considered by federal agencies in satisfying the requirements of NEPA. These include permanent, temporary, direct, indirect, and cumulative impacts. CEQ regulations implementing the procedural provisions of NEPA define cumulative impacts as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency . . . or person undertakes such other actions.” 40 CFR § 1508.7. Following is a description of the cumulative effects of the proposed action and alternatives on energy, air quality, and climate.

The cumulative effects evaluation assumes ongoing gains in average new passenger car and light truck mpg consistent with further increases in CAFE standards to an EISA-mandated minimum level of 35 mpg combined for passenger car and light trucks by the year 2020. After 2020, all alternatives continue to increase in fuel economy consistent with AEO 2010 Early Release Reference Case projections of annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg through 2030.[40] AEO Reference Case projections are regarded as the official U.S. government energy projections by both the public and private sector.

2.6.2.1 Energy

The nine alternatives examined in this EIS will result in different future levels of fuel use, total energy, and petroleum consumption, which will in turn have an impact on emissions of GHG and criteria air pollutants. Table 2.6-11 presents the cumulative fuel consumption and fuel savings of passenger cars from the onset of the proposed new CAFE standards. By 2060, fuel consumption reaches 193.2 billion gallons under the No Action Alternative (Alternative 1). Consumption falls across the alternatives, from 167.3 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 156.3 billion gallons under Alternative 8 (7-percent annual increase in mpg) representing a fuel savings of 26.0 to 36.9 billion gallons in 2060, as compared to fuel consumption projected under the No Action Alternative.

Table 2.6-11

Cumulative Effects of Passenger Car Annual Fuel Consumption and Fuel Savings by Alternative (billion gallons gasoline equivalent)

Calendar Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Fuel Consumption									
2020	73.8	69.4	68.4	68.0	67.3	66.0	66.2	65.4	65.4
2030	100.4	88.0	87.6	87.5	86.0	83.6	83.6	81.9	82.3
2040	127.0	110.0	109.9	109.9	108.1	104.9	104.9	102.7	103.3
2050	157.5	136.4	136.3	136.3	134.1	130.2	130.1	127.5	128.2
2060	193.2	167.3	167.2	167.2	164.5	159.6	159.6	156.3	157.2
Fuel Savings Compared to No Action									
2020	--	4.4	5.5	5.8	6.5	7.8	7.6	8.4	8.4
2030	--	12.4	12.8	12.9	14.4	16.8	16.8	18.5	18.1
2040	--	17.0	17.1	17.1	18.9	22.0	22.1	24.2	23.7
2050	--	21.2	21.2	21.2	23.4	27.4	27.4	30.1	29.4
2060	--	26.0	26.0	26.0	28.7	33.6	33.6	36.9	36.0

Table 2.6-12 presents the cumulative fuel consumption and fuel savings for light trucks from the onset of the proposed new CAFE standards. Fuel consumption by 2060 reaches 103.8 billion gallons under the No Action Alternative (Alternative 1). Consumption declines across the alternatives, from 92.2 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 84.6 billion gallons under Alternative 8 (7-percent annual increase in mpg). This represents a fuel savings of 11.5 to 19.1 billion gallons in 2060, as compared to fuel consumption projected under the No Action Alternative.

[40] NHTSA considers these AEO projected mpg increases to be reasonably foreseeable future action under NEPA because the AEO projections reflect future consumer and industry actions that result in ongoing mpg gains through 2030. The AEO projections of fuel economy gains beyond the EISA requirement of combined achieved 35 mpg by 2020 result from a future forecasted increase in consumer demand for fuel economy resulting from projected fuel price increases.

Table 2.6-12

Cumulative Effects of Light Truck Annual Fuel Consumption and Fuel Savings by Alternative (billion gallons gasoline equivalent)

Calendar Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Fuel Consumption									
2020	75.6	72.8	72.2	71.7	71.2	70.0	70.2	69.6	69.6
2030	69.4	63.4	63.2	62.5	61.5	59.8	59.9	58.9	59.0
2040	73.1	65.4	65.4	64.7	63.5	61.5	61.4	60.2	60.5
2050	85.6	76.2	76.2	75.3	73.9	71.5	71.4	70.0	70.3
2060	103.8	92.2	92.3	91.2	89.4	86.6	86.4	84.6	85.1
Fuel Savings Compared to No Action									
2020	--	2.7	3.4	3.9	4.4	5.6	5.3	6.0	6.0
2030	--	6.0	6.3	6.9	7.9	9.6	9.6	10.6	10.4
2040	--	7.7	7.7	8.5	9.7	11.6	11.7	12.9	12.6
2050	--	9.4	9.4	10.3	11.7	14.1	14.2	15.6	15.3
2060	--	11.5	11.5	12.6	14.3	17.2	17.3	19.1	18.7

Table 2.6-13 presents the cumulative fuel consumption and fuel savings for passenger cars and light trucks combined from the onset of the proposed new CAFE standards. Fuel consumption by 2060 reaches 297.0 billion gallons under the No Action Alternative (Alternative 1). Consumption declines across the alternatives, from 259.5 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 241.0 billion gallons under Alternative 8 (7-percent annual increase in mpg). This represents a fuel savings of 37.5 to 56.0 billion gallons in 2060, as compared to fuel consumption projected under the No Action Alternative.

Table 2.6-13

Cumulative Effects of Car & Light Truck Annual Fuel Consumption and Fuel Savings by Alternative (billion gallons gasoline equivalent)

Calendar Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Fuel Consumption									
2020	149.4	142.2	140.5	139.7	138.5	136.0	136.4	135.0	135.0
2030	169.9	151.5	150.7	150.0	147.6	143.4	143.5	140.8	141.4
2040	200.1	175.4	175.3	174.6	171.6	166.4	166.3	163.0	163.8
2050	243.1	212.5	212.5	211.7	208.0	201.7	201.5	197.4	198.4
2060	297.0	259.5	259.5	258.4	253.9	246.2	246.0	241.0	242.2
Fuel Savings Compared to No Action									
2020	--	7.1	8.9	9.7	10.9	13.4	13.0	14.4	14.4
2030	--	18.4	19.1	19.9	22.3	26.4	26.4	29.1	28.5
2040	--	24.7	24.8	25.5	28.5	33.7	33.8	37.1	36.3
2050	--	30.6	30.6	31.5	35.2	41.4	41.6	45.7	44.7
2060	--	37.5	37.5	38.5	43.1	50.8	51.0	56.0	54.7

2.6.2.2 Air Quality

Table 2.6-14 summarizes the cumulative impacts for national toxic and criteria pollutants in 2050.[41] The table lists the action alternatives (Alternatives 2 through 9) left to right in order of generally increasing fuel economy requirements. In the case of $PM_{2.5}$, SO_x, NO_x, and VOCs, the No Action Alternative results in the highest annual emissions, and emissions generally decline as fuel economy standards increase across alternatives. Exceptions to this declining trend are NO_x under Alternatives 7 and 9; $PM_{2.5}$ under Alternatives 5 through 8; SO_x under Alternatives 3 and 5; and VOCs under Alternatives 7 and 9. Despite these individual increases, emissions of $PM_{2.5}$, SO_x, NO_x, and VOCs remain below the levels under the No Action Alternative. In the case of CO, emissions under Alternatives 2 through 4 are slightly higher than under the No Action Alternative and are lower than under the No Action Alternative under Alternatives 5 through 9. Emissions of CO decline as fuel economy standards increase across Alternatives 2 through 9.

Table 2.6-14

Cumulative Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Criteria Pollutant Emissions (Calendar Year 2050)									
Carbon monoxide (CO)	28,943,491	29,227,165	29,179,262	29,098,748	27,809,337	26,721,219	26,941,788	26,099,919	26,408,318
Nitrogen oxides (NO_x)	1,736,474	1,699,529	1,697,706	1,693,875	1,649,549	1,606,445	1,614,485	1,582,550	1,593,216
Particulate matter ($PM_{2.5}$)	123,444	117,742	117,605	117,478	118,957	119,187	119,450	120,068	119,763
Sulfur oxides (SO_x)	298,565	261,582	261,779	261,029	262,851	260,415	259,761	258,601	258,142
Volatile organic com-pounds (VOC)	2,157,634	1,988,851	1,986,963	1,978,405	1,892,334	1,803,021	1,808,713	1,745,102	1,767,929
Toxic Air Pollutant Emissions (Calendar Year 2050)									
Acetaldehyde	10,061	10,138	10,144	10,143	10,024	9,951	9,947	9,871	9,894
Acrolein	494	500	501	504	547	585	579	609	585
Benzene	29,272	29,163	29,128	29,057	28,000	27,082	27,243	26,539	26,794
1,3-butadiene	4,376	4,426	4,422	4,418	4,359	4,310	4,325	4,289	4,304
Diesel particulate matter (DPM)	157,271	137,711	137,612	137,050	135,284	131,578	131,581	129,470	130,085
Formaldehyde	11,476	11,456	11,491	11,534	12,063	12,550	12,425	12,772	12,638

[41] Because the Chapter 4 analysis assumes that new vehicles in model years beyond MY 2016 have a higher fleet average fuel economy based on AEO fuel economy projections, these assumptions result in emissions reductions and fuel savings that continue to grow as these new, more fuel-efficient vehicles are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet have these higher mpg levels. Because of this, NHTSA analyzed the air emissions through 2050, when most of the fleet would achieve the average fuel economy levels the agency projects in 2030 (based on AEO fuel economy forecasts). By 2050, 98 percent of passenger cars and 88 percent of light trucks will have been produced in 2030 or later. Because newer vehicles are utilized more than older ones, the fraction of total passenger car and light truck VMT that these vehicles account for would be even higher – 99 percent for passenger cars and 94 percent for light trucks.

The trends for cumulative emissions of toxic air pollutants across the alternatives are mixed. Annual emissions of acetaldehyde in 2050 increase under each successive alternative from the No Action Alternative to Alternative 3, and then decrease from Alternative 3 to Alternative 9. Annual emissions of acrolein are higher than the No Action Alternative, and increase under each successive alternative from the No Action Alternative to Alternative 9, though the increase is not consistent between Alternatives 6 and 9. Annual emissions of 1,3-butadiene in 2050 increase from the No Action Alternative to Alternative 2 and then decrease, though not consistently, from Alternative 3 to Alternative 9. The minimum emissions of 1,3-butadiene occurs under Alternative 8. Annual emissions in 2050 of benzene and DPM decrease from the No Action Alternative to Alternative 9, though the decrease is not consistent between Alternatives 6 and 9. The minimum emissions of benzene and DPM occur under Alternative 8. Annual emissions of formaldehyde in 2050 decrease from the No Action Alternative to Alternative 2, and then increase, though not consistently, from Alternative 2 to Alternative 9.

Cumulative emissions in 2030 generally would be less than noncumulative emissions for the same combination of pollutant and alternative because of differing changes in VMT and fuel consumption under the cumulative case compared to the noncumulative case. The exceptions in 2030 are acetaldehyde for all alternatives, acrolein for all alternatives (except Alternatives 1 through 4 and Alternative 8), 1,3-butadiene all alternatives, and CO for all alternatives.(*See* Section 4.3 for cumulative emissions data for 2030. Cumulative emissions were compared to noncumulative emissions for 2030 rather 2050 because noncumulative emissions were not estimated for 2050.)

The reductions in emissions are expected to lead to reductions in cumulative adverse health effects. Table 2.6-15 summarizes the national annual changes in health outcomes in 2050 for the nine alternatives, left to right in order of increasing fuel economy requirements. Reductions in mortality are given based on data from two alternative studies, which EPA considers co-equal, consistent with EPA policy for presentation of future health outcomes. There would be reductions in adverse health effects nationwide under all the action alternatives compared to the No Action Alternative. Reductions in adverse health effects increase from Alternative 2 through Alternative 4, with mixed results under Alternatives 5 through 7, and increase again under Alternatives 8 and 9. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_2.

Table 2.6-15

Cumulative Nationwide Changes in Health Outcomes (cases/year) from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

Out-come and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Mortality (ages 30 and older), Pope *et al*. 2002									
2050	0	-410	-417	-430	-415	-466	-449	-465	-465
Mortality (ages 30 and older), Laden *et al*. 2006									
2050	0	-1,048	-1,067	-1,098	-1,062	-1,192	-1,147	-1,188	-1,190
Chronic bronchitis									
2050	0	-260	-265	-273	-265	-298	-286	-297	-297
Emergency Room Visits for Asthma									
2050	0	-362	-366	-376	-358	-394	-383	-394	-396
Work Loss Days									
2050	0	-44,853	-45,691	-47,074	-45,648	-51,374	-49,365	-51,187	-51,231

a/ Negative changes indicate reductions; positive changes indicate increases.
b/ Changes in health outcome under the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

The economic value of health impacts would vary proportionally with changes in health outcomes. Table 2.6-16 lists the corresponding annual monetized health benefits in 2050 under the action alternatives compared to the No Action Alternative. Monetized health benefits are given based on data from two alternative studies, which EPA considers co-equal, and for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health benefits.

Table 2.6-16

Cumulative Nationwide Monetized Health Benefits (U.S. million dollars/year) from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

Disc. and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
3-% Discount Rate									
Pope *et al*. 2002									
2050	0	-3,709	-3,775	-3,888	-3,760	-4,219	-4,061	-4,205	-4,212
Laden *et al*. 2006									
2050	0	-9,091	-9,253	-9,529	-9,214	-10,339	-9,952	-10,305	-10,322
7-% Discount Rate									
Pope *et al*. 2002									
2050	0	-3,364	-3,424	-3,526	-3,410	-3,827	-3,683	-3,814	-3,820
Laden *et al*. 2006									
2050	0	-8,211	-8,358	-8,607	-8,322	-9,338	-8,989	-9,307	-9,323

a/ Negative changes indicate monetized health benefits; positive emissions changes indicate monetized health disbenefits.
b/ Changes in outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which impacts under the action alternatives are compared.

2.6.2.3 Climate Change

The Reference Case global emissions scenario used in the cumulative impacts analysis (and described in Chapter 4 of this EIS) differs from the global emissions scenario used for the climate change modeling presented in Chapter 3. In Chapter 4, the Reference Case global emissions scenario reflects reasonably foreseeable actions in global climate change policy; in Chapter 3, the global emissions scenario used for the analysis assumes that there are no significant global controls. Given that the climate system is non-linear, the choice of a global emissions scenario could produce different estimates of the benefits of the proposed action and alternatives, if the emission reductions of the alternatives were held constant. *See* Section 4.4 for more information on the emissions scenarios chosen for this analysis.

The SAP 2.1 MiniCAM Level 3 scenario assumes a moderate level of global GHG reductions, resulting in a global atmospheric CO_2 concentration of roughly 650 parts per million by volume (ppmv) as of 2100. The following regional, national, and international initiatives and programs are reasonably foreseeable actions to reduce GHG emissions: Regional Greenhouse Gas Initiative (RGGI); Western Climate Initiative (WCI); Midwestern Greenhouse Gas Reduction Accord; EPA's Proposed GHG Emissions Standards; Cap-and-Trade Bills in the 111th Congress; Renewable Fuel Standard (RFS2); White House Goal to Reduce U.S. GHG Emissions by 17 percent by 2020; United Nation's Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol and the December 2009 Conference of the Parties (COP)-15; The European Union Greenhouse Gas Emission Trading System (EU ETS); G8 Declaration – Summit 2009; and the Asia Pacific Partnership on Clean Development and Climate.[42]

NHTSA used the MiniCAM Level 3 scenario as the primary global emissions scenario for evaluating climate effects, and used the MiniCAM Level 2 scenario and the RCP 4.5 MiniCAM reference emissions scenario to evaluate the sensitivity of the results to alternative emission scenarios. The sensitivity analysis provides a basis for determining climate responses to varying levels of climate sensitivities and global emissions under the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). Some responses of the climate system are believed to be non-linear; by using a range of emissions cases and climate sensitivities, it is possible to estimate the effects of the alternatives in relation to different reference cases.

2.6.2.3.1 Cumulative GHG Emissions

Table 2.6-17 shows total GHG emissions and emissions reductions from new passenger cars and light trucks from 2012-2100 under each of the nine alternatives. Projections of emissions reductions over the 2012 to 2100 period due to the MYs 2012-2016 CAFE standards and other reasonably foreseeable future actions ranged from 30,200 to 45,600 $MMTCO_2$. Compared to global emissions of 3,919,462 $MMTCO_2$ over this period (projected by the SAP 2.1 MiniCAM Level 3 scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.8 to 1.2 percent from their projected levels under the No Action Alternative.

Table 2.6-17

Cumulative Effects of Emissions and Emissions Reductions ($MMTCO_2$) from 2012-2100 by Alternative

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	259,800	0
2 3%/year Increase	229,600	30,200
3 4%/year Increase	229,300	30,400
4 ~4.3%/year Increase, Preferred	228,400	31,400
5 5%/year Increase	224,700	35,100
6 ~6.0%/year Increase, MNB	218,400	41,400
7 6%/year Increase	218,300	41,500
8 7%/year Increase	214,200	45,600
9 ~6.6%/year Increase, TCTB	215,200	44,600

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger car and light truck fleet represented about 3.3 percent of total global emissions of CO_2 in 2005. Although substantial, this source is a still small percentage of global emissions. The relative contribution of CO_2 emissions from U.S. passenger cars and light trucks is expected to decline in the future, due primarily to

[42] The regional, national, and international initiatives and programs discussed above are those which NHTSA has tentatively concluded are reasonably foreseeable past, current, or future actions to reduce GHG emissions. Although some of the actions, policies, or programs listed are not associated with precise GHG reduction commitments, collectively they illustrate a current and continuing trend of U.S. and global awareness, emphasis, and efforts towards significant GHG reductions. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA.

rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions).

2.6.2.3.2 CO_2 Concentration, Global Mean Surface Temperature, Sea-level Rise, and Precipitation

The mid-range results of MAGICC model simulations for the No Action Alternative and the eight action alternatives in terms of CO_2 concentrations and increase in global mean surface temperature in 2030, 2050, and 2100 are presented in Table 2.6-18 and Figures 2.6-6 through 2.6-9. As Figures 2.6-8 and 2.6-9 show, the impact on the growth in CO_2 concentrations and temperature is just a fraction of the total growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the action alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature in the TCTB Alternative (Alternative 9).

As shown in the table and figures, there is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 653.4 ppm for Alternative 8 (7%/year increase in fuel economy) to 657.4 ppm for the No Action Alternative (Alternative 1). For 2030 and 2050, the range is even smaller. Because CO_2 concentrations are the key driver of all other climate effects, this leads to small differences in these effects. Although these effects are small, they occur on a global scale and are long-lived.

The MAGICC simulations of mean global surface air temperature increases are also shown in Table 2.6-18. For all alternatives, the cumulative global mean surface temperature increase is about 0.80 °C to 0.81 °C (1.44 to 1.46 °F) as of 2030; 1.32 to 1.33 °C (2.38 to 2.39 °F) as of 2050; and 2.59 to 2.61 °C (4.66 to 4.70 °F) as of 2100.[43] The differences among alternatives are small. For 2100, the reduction in temperature increase for the action alternatives in relation to the No Action Alternative is about 0.01 to 0.02 °C (0.02 to 0.04 °F).

The impact on sea-level rise from the scenarios is presented in Table 2.6-18, showing sea-level rise in 2100 ranging from 32.84 centimeters under the No Action Alternative (Alternative 1) to 32.68 centimeters under Alternatives 8 and 9, for a maximum reduction of 0.16 centimeters (0.06 inches) by 2100 from the action alternatives.

Given that the action alternatives would reduce temperature increases slightly in relation to the No Action Alternative (Alternative 1), they also would reduce predicted increases in precipitation slightly, as shown in Table 2.6-19.

In summary, the impacts of the proposed action and alternatives and other reasonably foreseeable future actions on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the SRES scenarios.[44] This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lived.

[43] Because the actual increase in global mean surface temperature lags the commitment to warming, the impact on global mean surface temperature increase is less than the long-term commitment to warming.

[44] These conclusions are not meant to be interpreted as expressing NHTSA's views that impacts on global mean surface temperature, precipitation, or sea-level rise are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] of *the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). This analysis fulfills NHTSA's obligations in this regard.

Table 2.6-18

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (MiniCAM Level 3) by Alternative a/

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Totals by Alternative	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
1 No Action	438.7	498.0	657.4	0.805	1.327	2.611	7.83	13.67	32.84
2 3%/year Increase	438.5	497.2	654.8	0.805	1.323	2.599	7.83	13.65	32.74
3 4%/year Increase	438.5	497.2	654.8	0.804	1.323	2.599	7.83	13.65	32.74
4 ~4.3%/year Increase, Preferred	438.5	497.2	654.7	0.804	1.323	2.599	7.83	13.65	32.73
5 5%/year Increase	438.4	497.1	654.3	0.804	1.322	2.597	7.83	13.65	32.72
6 ~6.0%/year Increase, MNB	438.4	496.9	653.8	0.804	1.321	2.594	7.83	13.64	32.69
7 6%/year Increase	438.4	496.9	653.8	0.804	1.321	2.594	7.83	13.64	32.69
8 7%/year Increase	438.3	496.8	653.4	0.804	1.321	2.592	7.83	13.64	32.68
9 ~6.6%/year Increase, TCTB	438.3	496.8	653.5	0.804	1.321	2.593	7.83	13.64	32.68
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.8	2.7	0.001	0.004	0.012	0.00	0.02	0.10
3 4%/year Increase	0.2	0.8	2.7	0.001	0.004	0.012	0.00	0.02	0.10
4 ~4.3%/year Increase, Preferred	0.2	0.8	2.8	0.001	0.004	0.012	0.00	0.02	0.11
5 5%/year Increase	0.3	0.9	3.2	0.001	0.004	0.014	0.00	0.02	0.12
6 ~6.0%/year Increase, MNB	0.3	1.1	3.7	0.002	0.006	0.017	0.00	0.03	0.15
7 6%/year Increase	0.3	1.1	3.7	0.002	0.005	0.017	0.00	0.03	0.15
8 7%/year Increase	0.4	1.2	4.1	0.002	0.006	0.019	0.00	0.03	0.16
9 ~6.6%/year Increase, TCTB	0.4	1.2	4.0	0.002	0.006	0.018	0.00	0.03	0.16

a/ Values in this table are rounded.

Figure 2.6-6. Cumulative Effects on CO_2 Concentrations Using MAGICC

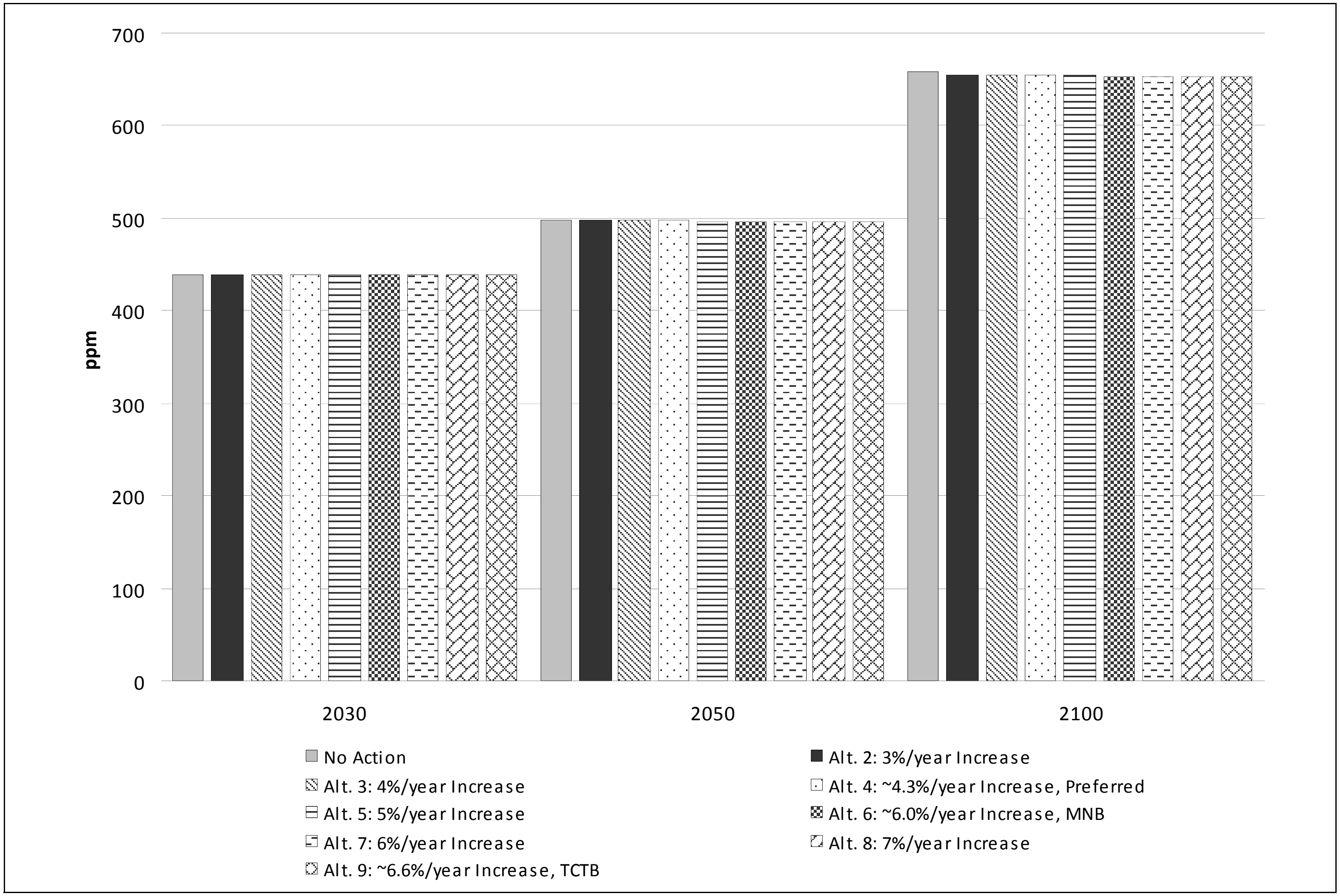


Figure 2.6-7. Cumulative Effects on the Global Mean Surface Temperature Increase Using MAGICC by Alternative

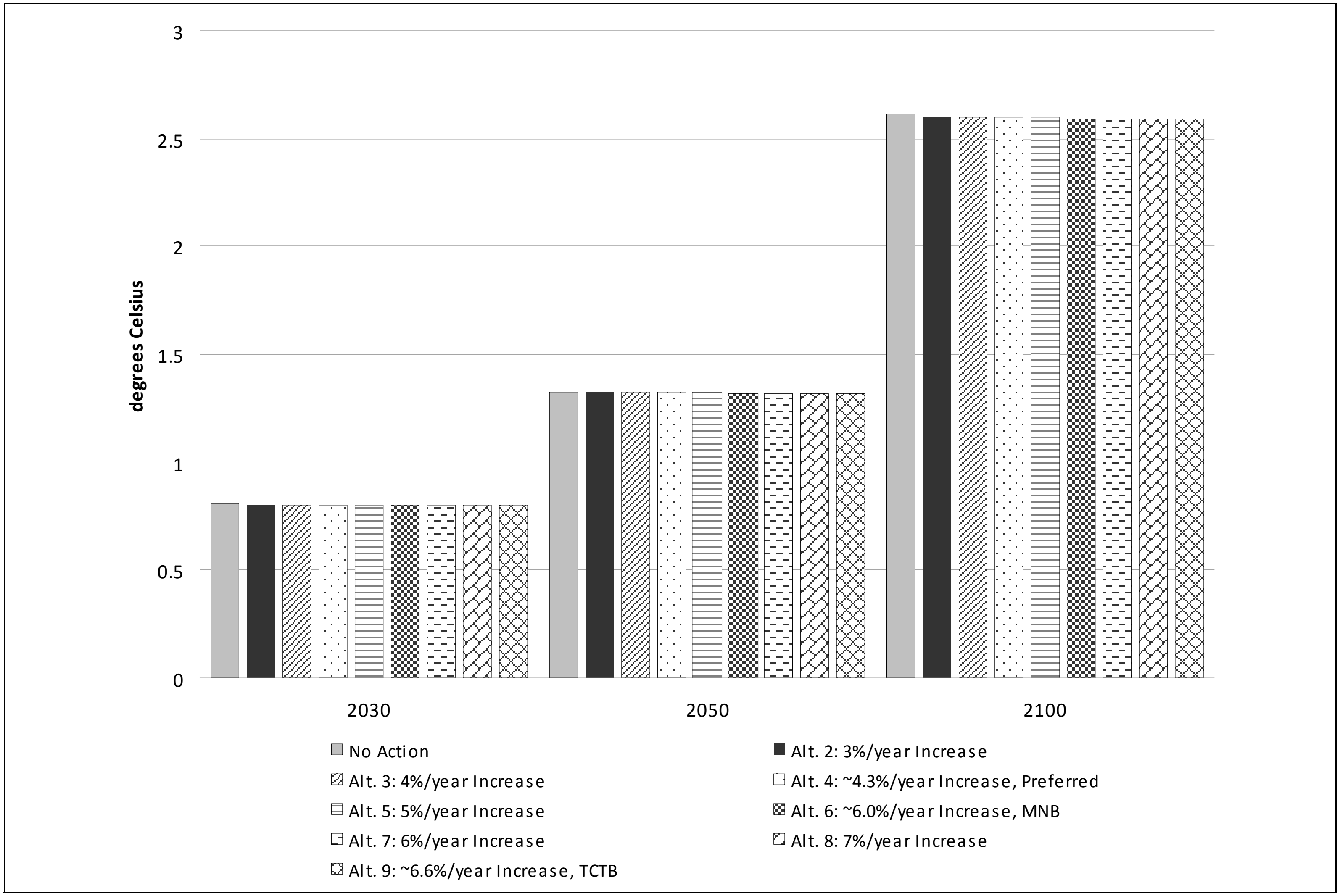


Figure 2.6-8. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

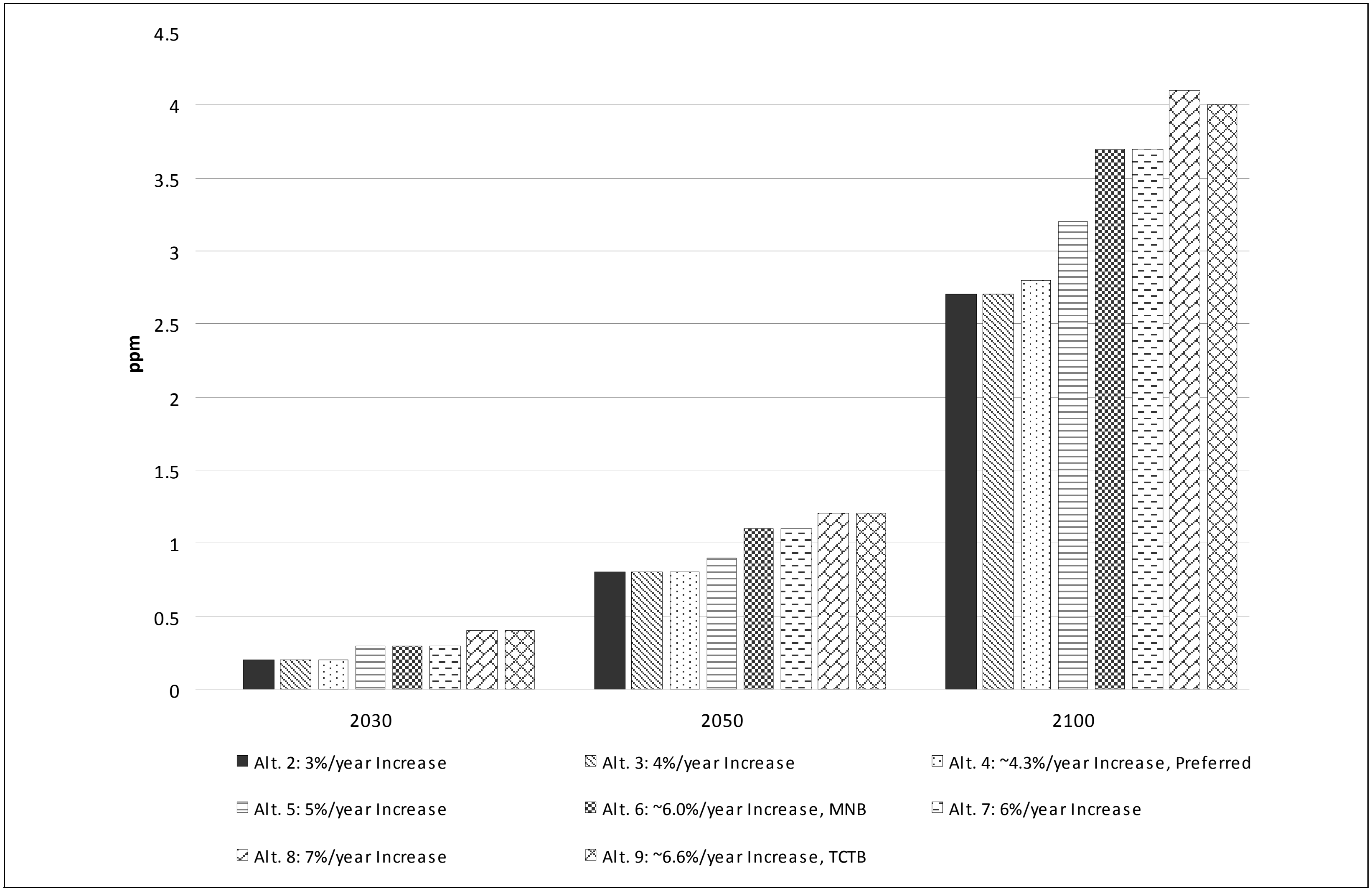


Figure 2.6-9. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)

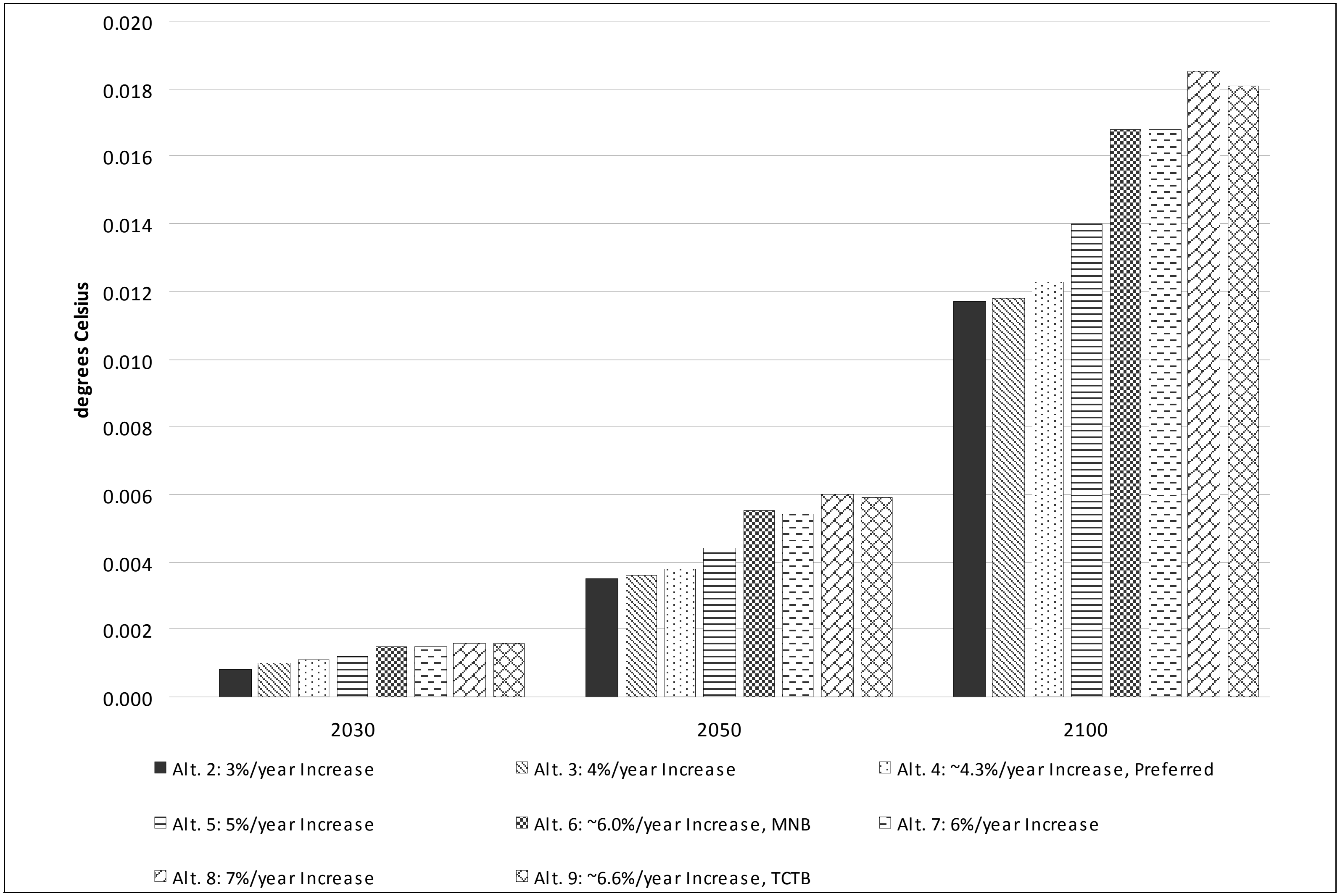


Table 2.6-19

Cumulative Effects on Global Mean Precipitation (percent change) a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % per °C)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°C)			
1 No Action	0.586	1.466	2.415
2 3%/year Increase	0.586	1.462	2.405
3 4%/year Increase	0.585	1.461	2.405
4 ~4.3%/year Increase, Preferred	0.585	1.461	2.405
5 5%/year Increase	0.585	1.459	2.403
6 ~6.0%/year Increase, MNB	0.585	1.459	2.401
7 6%/year Increase	0.585	1.459	2.401
8 7%/year Increase	0.585	1.459	2.399
9 ~6.6%/year Increase, TCTB	0.585	1.459	2.400
Reduction in Global Temperature (°C) for Alternative CAFE Standards, Mid-level Results (Compared to No Action Alternative)			
2 3%/year Increase	0.000	0.004	0.010
3 4%/year Increase	0.000	0.004	0.010
4 ~4.3%/year Increase, Preferred	0.000	0.005	0.011
5 5%/year Increase	0.000	0.005	0.012
6 ~6.0%/year Increase, MNB	0.000	0.007	0.015
7 6%/year Increase	0.000	0.007	0.015
8 7%/year Increase	0.000	0.007	0.016
9 ~6.6%/year Increase, TCTB	0.000	0.007	0.016
Global Mean Precipitation Change (%)			
1 No Action	0.85%	2.21%	3.94%
2 3%/year Increase	0.85%	2.21%	3.92%
3 4%/year Increase	0.85%	2.21%	3.92%
4 ~4.3%/year Increase, Preferred	0.85%	2.21%	3.92%
5 5%/year Increase	0.85%	2.21%	3.92%
6 ~6.0%/year Increase, MNB	0.85%	2.20%	3.91%
7 6%/year Increase	0.85%	2.20%	3.91%
8 7%/year Increase	0.85%	2.20%	3.91%
9 ~6.6%/year Increase, TCTB	0.85%	2.20%	3.91%
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 3%/year Increase	0.00%	0.01%	0.02%
3 4%/year Increase	0.00%	0.01%	0.02%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~6.0%/year Increase, MNB	0.00%	0.01%	0.02%
7 6%/year Increase	0.00%	0.01%	0.02%
8 7%/year Increase	0.00%	0.01%	0.03%
9 ~6.6%/year Increase, TCTB	0.00%	0.01%	0.03%

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

NHTSA examined the sensitivity of climate effects on key assumptions used in the analysis. The two variables for which assumptions were varied were climate sensitivity and global emissions.

Climate sensitivities used included 2.0, 3.0, and 4.5 °C for a doubling of CO_2 concentrations in the atmosphere. Global emissions scenarios used included the SAP 2.1 MiniCAM Level 3 (650 ppm as of 2100), the SAP 2.1 MiniCAM Level 2 (550 ppm as of 2100), and RCP 4.5 MiniCAM reference scenario (783 ppm as of 2100). The sensitivity analysis is based on the results provided for two alternatives – the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). The sensitivity analysis was conducted only for two alternatives, as this was deemed sufficient to assess the effect of various climate sensitivities on the results.

The results of these simulations illustrate the uncertainty due to factors influencing future global emissions of GHGs (factors other than the CAFE rulemaking).

The use of different climate sensitivities[45] (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) can affect not only warming but also indirectly affect sea-level rise and CO_2 concentration. The use of alternative global emissions scenarios can influence the results in several ways. Emissions reductions can lead to larger reductions in the CO_2 concentrations in later years because more anthropogenic emissions can be expected to stay in the atmosphere.

As shown in Table 2.6-20, the sensitivity of the simulated CO_2 emissions in 2030, 2050, and 2100 to assumptions of global emissions and climate sensitivity is low; stated simply, CO_2 emissions do not change much with changes in global emissions and climate sensitivity. For 2030 and 2050, the choice of global emissions scenario has little impact on the results. By 2100, the Preferred Alternative (Alternative 4) has the greatest impact in the global emissions scenario with the highest CO_2 emissions (MiniCAM Reference) and the least impact in the scenario with the lowest CO_2 emissions (MiniCAM Level 2). The total range of the impact of the Preferred Alternative on CO_2 concentrations in 2100 is from 2.6 to 3.1 ppm. The Reference Case using the MiniCAM Level 3 scenario and a 3.0 °C climate sensitivity has an impact of 2.8 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 is also shown in Table 2.6-20. In 2030, the impact is low due primarily to the slow rate at which the global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is large due not only to the climate sensitivity but also to the change in emissions. In 2030, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative is 0.001 to 0.002 °C (0.002 to 0.004 °F) across the climate sensitivities and global emissions scenarios, as shown in Table 2.6-20. The impact on global mean surface temperature due to assumptions concerning global emissions of GHG is also important. The scenarios with the higher global emissions of GHGs, such as the MiniCAM Reference, have a lower reduction in global mean surface temperature and the scenarios with lower global emissions have a higher reduction. This is in large part due to the non-linear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are high; therefore, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

The sensitivity of simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 2.6-20. Scenarios with lower climate sensitivities have lower increases in sea-level rise; the increase in sea-level rise is lower under the

[45] Equilibrium climate sensitivity (or climate sensitivity) is the projected responsiveness of Earth's global climate system to forcing from GHG drivers, and is often expressed in terms of changes to global surface temperature resulting from a doubling of CO_2 in relation to pre-industrial atmospheric concentrations. According to IPCC, using a likely emissions scenario that results in a doubling of the concentration of atmospheric CO_2, there is a 66- to 90-percent probability of an increase in surface warming of 2.5 to 4.0 °C by the end of the century (relative to 1990 average global temperatures), with 3 °C as the single most likely surface temperature increase.

Preferred Alternative (Alternative 4) than it would be under scenarios with higher climate sensitivities. Conversely, scenarios with higher climate sensitivities have higher sea-level rise; the increase of sea-level rise is higher under the Preferred Alternative than it would be under scenarios with lower climate sensitivities. Higher global GHG emissions have higher sea-level rise, but the impact of the Preferred Alternative is less than in scenarios with lower global emissions. Conversely, scenarios with lower global GHG emissions have lower sea-level rise, though the impact of the Preferred Alternative is greater than in scenarios with higher global emissions.

Table 2.6-20

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives a/

Emissions Scenario	CAFE Alternative	Climate Sensitivity (°C for $2xCO_2$)	CO_2 concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)
			2030	2050	2100	2030	2050	2100	2100
MiniCAM Level 2									
	1 No Action	2.0	434.5	483.8	553.5	0.613	0.989	1.555	22.40
		3.0	436.0	487.3	565.9	0.813	1.327	2.189	30.03
		4.5	437.6	491.3	581.3	1.035	1.709	2.963	38.88
	4 Preferred	2.0	434.3	482.9	550.9	0.612	0.986	1.545	22.31
		3.0	435.7	486.4	563.1	0.812	1.323	2.175	29.91
		4.5	437.3	490.4	578.5	1.033	1.704	2.946	38.74
	Reduction compared to No Action								
		2.0	0.2	0.9	2.6	0.001	0.003	0.010	0.09
		3.0	0.3	0.9	2.8	0.001	0.004	0.014	0.12
		4.5	0.3	0.9	2.8	0.001	0.005	0.017	0.14
MiniCAM Level 3									
	1 No Action	2.0	437.3	494.5	643.4	0.607	0.990	1.888	24.68
		3.0	438.7	498.0	657.5	0.805	1.327	2.611	32.84
		4.5	440.3	502.0	675.2	1.024	1.706	3.475	42.24
	4 Preferred	2.0	437.0	493.7	640.6	0.606	0.987	1.879	24.59
		3.0	438.5	497.2	654.7	0.804	1.323	2.599	32.73
		4.5	440.0	501.2	672.2	1.023	1.701	3.459	42.10
	Reduction compared to No Action								
		2.0	0.3	0.8	2.8	0.001	0.003	0.009	0.09
		3.0	0.2	0.8	2.8	0.001	0.004	0.012	0.11
		4.5	0.3	0.8	3.0	0.001	0.005	0.015	0.14
MiniCAM Reference									
	1 No Action	2.0	440.2	510.7	765.1	0.699	1.168	2.292	28.68
		3.0	441.8	514.8	783.0	0.923	1.557	3.136	38.00
		4.5	443.6	519.5	805.3	1.168	1.991	4.132	48.67
	4 Preferred	2.0	439.9	509.9	762.2	0.698	1.165	2.284	28.60
		3.0	441.5	514.0	780	0.922	1.553	3.124	37.90
		4.5	443.3	518.7	802.2	1.166	1.987	4.118	48.54
	Reduction compared to No Action								
		2.0	0.3	0.8	2.9	0.001	0.003	0.008	0.08
		3.0	0.3	0.8	3.0	0.001	0.004	0.011	0.10
		4.5	0.3	0.8	3.1	0.002	0.005	0.014	0.13

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

Chapter 3 Affected Environment and Environmental Consequences

3.1 INTRODUCTION

Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) suggest a standard format for an environmental impact statement (EIS) that includes a section to describe the affected environment (existing conditions) and a section to describe the potential environmental consequences (impacts) of a proposed action and alternatives. In this EIS, the National Highway Traffic Safety Administration (NHTSA) describes the affected environment and potential environmental consequences of the proposed action and alternatives in sections under the heading for each resource area – energy (Section 3.2), air quality (Section 3.3), climate (Section 3.4), and various other potentially affected resource areas (Section 3.5). This structure enables the reader to readily learn about existing environmental conditions and potential environmental consequences related to each resource area. Section 3.6 identifies unavoidable impacts and irreversible and irretrievable commitments of resources associated with the implementation of the Corporate Average Fuel Economy (CAFE) standards evaluated in this EIS.

The following table lists topics addressed in a typical EIS and the section(s) in this chapter that address each topic.

Typical NEPA Topics	EIS Sections
Water	3.4 Climate; 3.5.1 Water Resources
Ecosystems	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources
Threatened and endangered species	3.5.2.1.4 Endangered Species
Publicly owned parklands, recreational areas, wildlife and waterfowl refuges, historic sites, Section 4(f)-related issues	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources
Properties and sites of historic and cultural significance	3.4 Climate; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources
Considerations relating to pedestrians and bicyclists	3.4 Climate; 3.5.3 Land Use and Development
Social impacts	3.2 Energy; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.9 Environmental Justice
Noise	3.4 Climate; 3.5.3 Land Use and Development; 3.5.8 Noise
Air	3.2 Energy; 3.3 Air Quality; 3.4 Climate
Energy supply and natural resource development	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Floodplain management evaluation	3.4 Climate; 3.5.1 Water Resources
Wetlands and coastal zones	3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources
Construction impacts	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Land use and urban growth	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development
Human environment involving community disruption and relocation	3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.4 Safety and Other Human Health Impacts; 3.5.5 Hazardous Materials and Regulated Wastes; 3.5.9 Environmental Justice

3.1.1 Direct and Indirect Impacts

CEQ regulations state that an EIS "shall succinctly describe" the environment to be affected by the alternatives under consideration and to provide data and analyses "commensurate with the importance of the impact[s]." 40 CFR §§ 1502.15, 1502.16. This chapter provides the analysis to determine and compare the significance of the direct and indirect effects of the proposed action and alternatives. Under NEPA, direct effects "are caused by the action and occur at the same time and place." 40 CFR § 1508.8. CEQ regulations define indirect effects as those that "are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include…effects on air and water and other natural systems, including ecosystems." 40 CFR § 1508.8. Sections 3.2, 3.3, and 3.4 provide a quantitative analysis of the direct and indirect effects of the proposed action and alternatives on energy, air, and climate, respectively. Section 3.5 qualitatively describes impacts to other resource areas typically addressed in an EIS and the areas required by U.S. Department of Transportation (DOT) Order 5610, such as biological resources, water resources, noise, land use, and environmental justice, because there were not enough data available in the literature for a quantitative analysis and because many of these effects are not localized. In this EIS, such qualitative analysis is sufficient for NEPA purposes (DOT 1979). [1]

3.1.2 Areas Not Affected

DOT NEPA procedures describe various areas that should be considered in an EIS. Many of these areas are addressed Sections 3.2 through 3.6. NHTSA has considered the impact of the proposed action and alternatives on all areas outlined in the procedures and has determined that the action alternatives would not directly or indirectly affect the human environment in relation to disruption and relocation, and considerations related to pedestrians and bicyclists, floodplain management, and construction impacts. However, the cumulative impacts of the proposed action and alternatives in combination with other foreseeable actions could affect some of these areas of the human environment (*see* Chapter 4).

3.1.3 Approach to Scientific Uncertainty and Incomplete Information

CEQ regulations recognize that many federal agencies encounter limited information and substantial uncertainties when they analyze the potential environmental impacts of their actions. Accordingly, the regulations provide agencies with a means of formally acknowledging incomplete or unavailable information in NEPA documents. Where "information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known," the regulations require an agency to include in its NEPA document:

1. A statement that such information is incomplete or unavailable;
2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;
3. A summary of existing credible scientific evidence relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

[1] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ (1984) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

4. The agency's evaluation of such impacts based on theoretical approaches or research methods generally accepted in the scientific community.

40 CFR § 1502.22(b).

Relying on these provisions is appropriate when an agency is performing a NEPA analysis that involves potential environmental impacts due to carbon dioxide (CO_2) emissions. *See, e.g.*, *Mayo Found. v. Surface Transp. Bd.*, 472 F.3d 545, 555 (8th Cir. 2006). CEQ regulations also authorize agencies to incorporate material into a NEPA document by reference to "cut down on bulk without impeding agency and public review of the action." 40 CFR § 1502.21.

Throughout this EIS, NHTSA uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas for which NHTSA cannot develop a credible estimate of the potential environmental impacts of the proposed action and alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of CO_2 and other greenhouse gases (GHGs) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. NHTSA often relies on the Intergovernmental Panel on Climate Change (IPCC) 2007 Fourth Assessment Report (IPCC 2007a, 2007b, 2007c) as a recent "summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment." 40 CFR § 1502.22(b)(3).

3.1.4 Common Methodologies

The CAFE Compliance and Effects Modeling System (referred to herein as the Volpe model) is a peer-reviewed modeling system developed by the DOT Volpe National Transportation Systems Center (Volpe Center). The Volpe model enables NHTSA to efficiently, systematically, and reproducibly evaluate many regulatory options by projecting technologies each manufacturer could apply in a given year to comply with a specific set of standards and by calculating the costs and effects of manufacturers' application of technologies, including changes in fuel use and therefore CO_2 emissions. The Volpe model provides outputs that NHTSA used to analyze potential impacts to energy, air, and climate.

The Volpe model begins with an initial state of the domestic vehicle market, which in this case is the market for passenger cars and light trucks. The model is designed to calculate incremental costs, effects, and benefits of alternative scenarios (*i.e.*, regulatory alternatives) relative to a specified baseline scenario (*i.e.*, a no-action alternative) and based on a specified market forecast. The market forecast, the baseline scenario, and all alternative scenarios are specified in model inputs – the model does not determine these inputs. For this analysis, the market forecast through model year (MY) 2016 specified as an input to the Volpe model is based on the MY 2008 fleet, with adjustments to sales volumes of specific vehicle models. NHTSA used the Volpe model to estimate the extent to which manufacturers could add technology under the baseline scenario, under which manufacturers are assumed to continue to comply with the MY 2011 CAFE standards. This baseline scenario forms NHTSA's no-action alternative. All environmental effects attributable to technologies added under this scenario are subtracted from those attributable to all the other scenarios (*i.e.*, regulatory alternatives).

For the model years covered under the current proposal, the combined passenger car and light truck market forecast developed by NHTSA and the U.S. Environmental Protection Agency (EPA) staff using MY 2008 CAFE compliance data includes about 1,100 vehicle models, about 400 specific engines, and about 200 specific transmissions. This level of detail in the representation of the vehicle market is similar to that NHTSA used in recent CAFE analyses, and to that NHTSA uses when determining actual compliance with CAFE standards. Within the limitations of information that can be made available to the public, it provides the foundation for a realistic analysis of manufacturer-specific costs and the analysis of footprint-based CAFE standards, and this level of detail is much greater than the level of detail used by other models and analyses relevant to combined passenger car and light truck fuel economy.[2]

The Volpe model also uses several additional categories of data and estimates provided in various external input files for all 12 vehicle subclasses (sub-compact, sub-compact performance, compact, compact performance, midsize, midsize performance, large, and large performance cars; small sport utility vehicles [SUVs]/pickup trucks/vans, midsize SUVs/pickup trucks/vans, large SUVs/pickup trucks/vans, and minivans) including:

- Fuel-saving technology characteristics, such as:
  - Commercialization year;
  - Effectiveness and cost;
  - "Learning effect" cost coefficients;
  - "Technology path" inclusion/exclusion;
  - "Phase-in caps" on penetration rates; and
  - "Synergy" effects.
- Vehicular emissions rates for criteria air pollutants and their chemical precursors, including carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_x), particulate matter (PM), and sulfur dioxide (SO_2); these emission rates are functions of either vehicle use, as measured by the number of vehicle miles traveled (VMT), or fuel consumption, economic, and other data and estimates, such as:
  - Vehicle survival (percent of vehicles of a given vintage that remain in service);
  - Mileage accumulation (annual travel by vehicles of a given vintage);
  - Price/fuel taxation rates for seven fuels (such as gasoline and diesel);
  - Pump prices (including taxes) for vehicle fuel savings/retail price;
  - Rebound effect coefficient (the elasticity of VMT in relation to per-mile cost of fuel);
  - Discount rate; "payback period" (the number of years purchasers consider when taking into account fuel savings);
  - Fuel economy "gap" (for example, laboratory versus actual);
  - Per-vehicle value of travel time (in dollars per hour);
  - The economic costs (in dollars per gallon) of petroleum consumption;
  - Various external costs (all in dollars per mile) associated with changes in vehicle use;
  - Damage costs (all on a dollar-per-ton basis) for each of the above-mentioned criteria pollutants; and
  - The civil-penalties rate for noncompliance.
- Properties of different fuels, such as:
  - Upstream CO_2 and criteria pollutant emissions rates (that is, U.S. emissions resulting from the production and distribution of each fuel);
  - Density (pounds per gallon); energy density (British thermal unit per gallon);
  - Carbon content;
  - Shares of fuel savings leading to reduced domestic refining; and
  - Relative shares of different gasoline blends.

[2] Because CAFE standards apply to the average performance of each manufacturer's fleet of passenger cars and light trucks, the impact of potential standards on individual manufacturers cannot be credibly estimated without analysis of the fleets that manufacturers can be expected to produce in the future. Furthermore, because required CAFE levels under an attribute-based CAFE standard depend on manufacturers' fleet composition, the stringency of an attribute-based standard cannot be predicted without performing analysis at this level of detail.

- Sensitivity analysis coefficients; high and low fuel price forecasts.
- CAFE scenarios
  - Baseline (no action or business-as-usual); and
  - Alternative scenarios defining coverage, structure, and stringency of CAFE standards.

NHTSA estimates and specifies all of the input data, then uses the modeling system to project a set of technologies that each manufacturer could apply to its individual vehicle models in attempting to comply with the various levels of potential CAFE standards to be examined. The Volpe model then estimates the costs associated with this additional technology utilization, and accompanying changes in travel demand; fuel consumption; fuel outlays; emissions of criteria air pollutants; toxic air pollutants; and GHGs, and economic externalities related to petroleum consumption and other factors.

One of the updates to the model for the current rulemaking is the addition of a "multi-year planning" capability, developed in response to comments on prior CAFE rulemakings. The version of the Volpe model used in the previous EIS did not have that capability. For example, when modeling MY 2014, only vehicles with technologies "enabled" in MY 2014 would be candidates for technology application. When run in multi-year mode, the model "looks back" to earlier years when a technology was enabled on any vehicles but not used, and considers "back-dating" the application of that technology when calculating the effective cost. Thus, if the model did not apply an enabled technology in MYs 2012 or 2013, then that technology remains available for multi-year application in MY 2014.

The Volpe model's multi-year analysis mode is anticipated to be most useful in situations where the model finds that a manufacturer is able to reach compliance in earlier years of the modeling period (*e.g.*, MY 2012) but is challenged to reach compliance in later years (*e.g.*, MY 2014). In these cases, the model can go back to the earlier year and over-comply to make compliance in the later year easier to achieve. Although this capability is computationally implemented in this "backward-looking" fashion, the approach simulates a manufacturer's ability to apply foresight in earlier model years to facilitate compliance in later model years, adding "extra" technology to a given model year's fleet to boost CAFE levels ahead of time, so that less technology needs to be added in years that are not major redesign years.

The Volpe model completes this compliance simulation for all manufacturers and all model years and produces various outputs from the effects of changes in fuel economy. The outputs include:

- Total cost (TC) of all applied technologies;
- Year-by-year mileage accumulation, including increased vehicle use due to the rebound effect;
- Year-by-year fuel consumption;
- Benefits from additional travel due to the fuel economy rebound effect, as measured by consumer surplus;[3]
- Emissions of CO_2, other GHGs, criteria air pollutants, and airborne toxics, including emissions from vehicle use and domestic emissions from fuel production and distribution,[4] and the economic value of resulting damages to human health;
- Total discounted/undiscounted national societal costs of year-to-year fuel consumption;

[3] Consumer surplus measures the net benefits drivers receive from additional travel and refers to the amount by which the benefits from additional travel exceed its costs (for fuel and other operating expenses).
[4] Domestic full-fuel-cycle emissions include the emissions associated with production, transportation, and refining operations, and the CO_2 emissions from fuel combustion.

- Economic externalities caused by increased vehicle use (congestion, accidents, noise);
- Value of refueling time saved; and
- Total discounted/undiscounted societal benefits, including net social benefits and benefit-cost ratio.

The specific outputs associated with each action alternative examined in this EIS reflect the assumed values for key inputs to the Volpe model. The outputs of the Volpe model provide data used to analyze impacts to energy, air, and climate, so these environmental impacts also reflect the inputs into the Volpe model. Recognizing the uncertainty inherent in many of the underlying estimates in the model, NHTSA has used the Volpe model to conduct both sensitivity analyses (by changing the assumed value of one input at a time), and a probabilistic uncertainty analysis (a Monte Carlo analysis that allows simultaneous variation in these factors) to examine how key measures (*e.g.*, miles-per-gallon [mpg] levels of the standard, total costs, and total benefits) vary in response to changes in these factors. This type of analysis is used to estimate the uncertainty surrounding the model's estimates of the costs and benefits of a given set of CAFE standards. Chapter 2 describes the results of the sensitivity analysis.

The model can also be used to estimate the stringency at which various criteria are satisfied, such as (a) a specified average required CAFE level, (b) maximum net benefits to society, (c) total costs equal to total benefits to society, or (d) a specified total incremental cost. However, while the Volpe model does calculate average changes in vehicle prices (corresponding to total technology outlays and, where applicable, civil penalties), it does not currently predict manufacturers' decisions regarding the pricing or production of specific vehicle models. Nor does it currently estimate for consumer behavioral responses such as buying fewer vehicles or buying different types of vehicles. The agency uses information from the Volpe model, and analysis performed outside the model, to assist in setting standards.

Although NHTSA has used the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model does not determine the CAFE standards NHTSA will propose or promulgate as final regulations. NHTSA considers the results of analyses conducted using the Volpe model and external analyses, including assessments of GHGs and air pollutant emissions, and technologies that might be available in the longer term. NHTSA also considers whether the standards could expedite the introduction of new technologies into the market, and the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information, the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues, such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

For additional detail on how the Volpe model works and the outputs it produces (and which outputs NHTSA uses to estimate environmental impacts), see the joint NHTSA-EPA Notice of Proposed Rulemaking (NPRM) (Sections II.A, II.B, and II.C) and the accompanying joint Technical Support Document. *See* Docket Nos. NHTSA-2009-0059-0015, NHTSA-2009-0059-0029.

3.1.4.1 Effect of Credit Flexibility on Emissions

Consistent with the Energy Independence and Security Act (EISA), NHTSA's March 30, 2009 MY 2011 CAFE final rule not only set MY 2011 CAFE standards for passenger cars and light trucks, but also revised and added new regulatory provisions regarding the creation and application of CAFE credits. *See* 74 FR , 14196, 14428-14436 (Mar. 30, 2009). CAFE credits are earned when a manufacturer exceeds an applicable CAFE standard. Manufacturers can then use those credits to achieve compliance in years in which their measured average fuel economy falls below the standards. In this context, CAFE credits refer to flexibilities allowed under the Energy Policy and Conservation Act (EPCA) provisions governing use of Alternative Motor Fuels Act (AMFA) credits, allowable banked credits, and transfers of credits between the passenger car and light truck fleets allowed under EISA. Through MY 2019, AMFA credits allow manufacturers to increase their CAFE levels by producing alternative fuel vehicles, such as dual-fueled/flexible-fueled vehicles (FFVs) that can run on both gasoline and E85 ethanol-based fuel. The AMFA amended EPCA in 1988 to provide an incentive for producing these vehicles by specifying that their fuel economy is to be determined using a special calculation procedure that results in those vehicles being assigned a high fuel economy level. The additional flexibility to transfer credits between manufacturing companies is addressed separately below. Because EPCA prohibits NHTSA from considering these flexibilities when determining the stringency of CAFE standards, NHTSA did not attempt to do so when it developed standards it has considered for this action.

Under the EISA, AMFA credits are being phased out. The allowable credits are reduced so that, by law, by 2020 such credits will no longer be allowed. However, notwithstanding the EPCA constraints regarding the context for establishing CAFE standards, NHTSA could attempt to account for the creation and application of CAFE credits when evaluating the environmental impacts of new CAFE standards under NEPA.

NHTSA believes that manufacturers are likely to take advantage of these flexibility mechanisms, thereby reducing benefits and costs. Manufacturers producing dual-fueled vehicles are entitled to a CAFE benefit of up to 1.2 mpg in 2012-2014, 1.0 mpg in 2015, and 0.8 mpg in 2016 for each fleet. NHTSA estimates that the impact of the use of AMFA credits could result in an average reduction of approximately 0.9 mpg in achieved average fuel economy in 2012-2016, and a related increase in CO_2 emissions. Regarding credits other than AMFA credits (*e.g.*, CAFE credits earned through over-compliance, credits transferred between fleets, and credits acquired from other manufacturers), NHTSA does not have a sound basis to predict the extent to which manufacturers might use them, particularly because the credit-transfer and credit-trading programs have been only recently authorized, and credit transfers could involve complex interactions and multi-year planning.[5]

3.1.4.2 Difficulties in Quantifying Emissions Implications of Credits

Questions NHTSA might need to address in performing an analysis of potential credit use and the resulting emissions include the following:

- Would manufacturers that have never used CAFE flexibilities do so in the future?
- Would flexibility-induced increases in the sale of flexible-fuel vehicles (FFVs) lead to increases in the use of alternative fuels?
- Having earned CAFE credits in a given model year, in what model year would a given manufacturer most likely apply those credits, and how might that affect technologies added through multi-year planning?
- Having earned CAFE credits in one fleet (*i.e.*, passenger car or light truck), to which fleet would a given manufacturer most likely apply those credits?

Such questions are similar to, though possibly less tractable than, the behavioral and strategic questions that were entailed in representing manufacturers' ability to "pull ahead" the implementation of some technologies, and that would be involved in attempting to estimate CAFE-induced changes in market shares. Although the Volpe model has been modified to account for multi-year planning effects,

[5] For example, if a manufacturer is planning to redesign many vehicles in MY 2013, but few vehicles in MY 2015 when standards will also be significantly more stringent, the benefits (in terms of reducing regulatory burden) of using some flexibilities in MY 2013 (*e.g.*, credit transfers) could be outweighed by the benefits of applying extra technologies in MY 2013 to carry them forward to facilitate compliance in MY 2015.

substantial concerns remain about how to develop a credible market-share model for integration into the modeling system NHTSA has used to analyze the costs and effects of CAFE standards.

3.1.4.3 Market Behavior

Some manufacturers make substantial use of current flexibilities. Other manufacturers regularly exceed CAFE standards applicable to one or both fleets, and allow the corresponding excess CAFE credits to expire. Some manufacturers transfer earned CAFE credits to future (or past) model years, but do not produce FFVs and create corresponding CAFE credits. Finally, still other manufacturers regularly pay civil penalties for noncompliance, even when producing FFVs would substantially reduce the magnitude of those penalties.

Notwithstanding these uncertainties, NHTSA anticipates that manufacturers would make varied use of the flexibilities provided by EPCA, as amended by EISA. These flexibilities could result in somewhat lower benefits (that is, CO_2 emissions reductions) than estimated here, because manufacturers' actions would cause VMT levels, fuel consumption, and emissions to be higher than reported here. NHTSA expects that the nine alternatives evaluated in this EIS, including the No Action Alternative in relation to which NHTSA measures the effects of the eight action alternatives, would be affected. Insofar as the No Action Alternative would be affected, it is even less certain how the net effects of each of the eight action alternatives would change.

NHTSA expects that use of flexibilities would tend to be greater under more stringent standards. As stringency increases, the potential for manufacturers to face greater cost increases, and for some, depending on their level of technological implementation, costs could rise substantially. The economic advantage of employing allowed CAFE increases through the use of flexibilities could affect manufacturer behavior in this regard. A critical factor in addressing the fuel and emissions impacts of such flexibilities is that the likely extent of utilization cannot be assumed constant across the alternatives.

3.1.4.4 Trading Between Companies

The allowable trading between manufacturers is categorically different from the case discussed above. The provisions in Section 104 of Title I of the EISA require that fuel savings, and thus, GHG emissions, be conserved in any trades between manufacturers.[6] Therefore, there would not be an environmental impact of any such trades because any increases in fuel use or emissions would have to be offset by the manufacturer buying the credits.

[6] "The Secretary of Transportation [by delegation, the Administrator of NHTSA] may establish by regulation a fuel economy credit trading program to allow manufacturers whose automobiles exceed the average fuel economy standards prescribed under section 32902 to earn credits to be sold to manufacturers whose automobiles fail to achieve the prescribed standards such that total oil savings associated with manufacturers that exceed the prescribed standards are preserved when trading credits to manufacturers that fail to achieve the prescribed standards." 49 U.S.C. § 32903(f)(1).

3.2 ENERGY

Energy intensity in the United States (energy use per dollar of gross domestic product [GDP]) has declined steadily at about 2 percent per year since 1973, when the U.S. Department of Energy (DOE) began tracking the statistic (EIA 2009a). Since 2000, energy intensity in the U.S. economy has fallen from 10.08 million British thermal units per dollar of "real" or inflation-adjusted GDP, measured in year 2000 dollars to 8.52 million British thermal units per dollar of GDP (in year 2000 dollars), and DOE projections show a further steady decline through 2035, with energy intensity reaching 5.12 million British thermal units per dollar of GDP (in year 2000 dollars) in the latter year (EIA 2009c). Although U.S. population and economic activity have grown steadily, energy intensity has fallen due to a combination of increased efficiency and a structural shift in the economy toward less energy-intensive industries. The most recent projection from the DOE Energy Information Administration (EIA) has population increasing 28 percent between 2008 and 2030, but energy consumption per capita declining 0.4 percent annually during the same period. Despite this continuing improvement in economy-wide energy efficiency, however, transportation fuel consumption has grown steadily, and now represents the major use of petroleum in the U.S. economy.

3.2.1 Affected Environment

NHTSA uses energy projections from the EIA, which collects and provides the official energy statistics for the United States. EIA is the primary source of data used by government agencies and private firms to analyze and model energy systems. Every year EIA issues projections of energy consumption and supply for both the United States (*Annual Energy Outlook* [AEO]) and for the world (*International Energy Outlook* [IEO]). EIA reports and projects energy consumption by energy mode, by sector, and by geographic region. The modeling used to formulate the EIA's projections incorporates all federal and state laws and regulations that are in force at the time of the modeling.

In the case of the AEO 2010, EIA issued an early release (December 14, 2009) update of the Reference Case released in April 2009 to incorporate the impacts of the American Recovery and Reinvestment Act of 2009,[7] the MY 2011 CAFE standards, and an update of the macroeconomic assumptions (EIA 2009c). Table 3.2.1-1 shows U.S. and global energy consumption by sector. Actual energy-consumption data show a steady increase in energy use in all U.S. sectors. By 2004, the transportation sector was the second largest consumer of energy after the industrial sector, and comprised 27.8 and 17.3 percent of U.S. and global (less U.S.) energy use, respectively. Both very high oil prices and the beginning of the global recession resulted in data for 2006 and 2008 being somewhat atypical. Over half of U.S. energy consumption in the transportation sector can be attributed to passenger cars and light trucks, ranging from 60 percent in 2008 to 57 percent by 2035. Going forward in time, transportation energy consumption is expected to continue to be the largest component after the industrial sector, but in the forecasted outer years in the United States the gap between energy consumption in the two sectors first widens and then narrows. As a percentage of total economy-wide energy consumption, projected energy use in the U.S. transportation sector remains fairly constant throughout the projection years.

The EIA projections include all forms of energy, including renewable fuels and biofuels. Despite efforts to increase the use of non-fossil fuels in transportation, fuel use remains largely petroleum based. In 2007, finished motor gasoline and on-road diesel constituted 66 percent of all finished petroleum products consumed in the United States. If other transportation fuels (aviation fuels, marine and locomotive diesel, and bunkers) are included, transportation fuels constitute approximately 79 percent of the finished petroleum products used. In the same year, the biofuel component of the total U.S. transportation sector energy consumption was slightly more than 2 percent. According to AEO

[7] Pub. L. No. 111-5, 123 Stat. 115 (Feb. 17, 2009).

projections, the biofuels share of energy consumption in the transportation sector will rise to 12 percent by 2035.

Table 3.2.1-1

Energy Consumption By Sector

Sector (Quadrillion BTU c/)	Actual a/ 1990	1995	2000	2004	Forecast b/ 2010	2015	2020	2025	2030
United States									
Residential	17.0	18.6	20.5	21.2	22.1	21.8	22.5	23.3	24.0
Commercial	13.3	14.7	17.2	17.7	19.3	20.4	21.5	22.6	23.8
Industrial	31.9	34.0	34.8	33.6	29.7	31.3	31.7	32.3	31.9
Transportation	22.4	23.8	26.6	27.9	28.0	28.7	28.9	30.0	31.2
Total	84.7	91.2	99.0	100.4	99.1	102.1	104.7	108.2	111.0
Transportation (%)	26.5	26.2	26.8	27.8	28.3	28.1	27.6	27.7	28.1
World									
Residential	- -	- -	- -	47.7	52.8	55.6	58.9	62.1	65.7
Commercial	- -	- -	- -	24.5	27.8	29.8	32.2	34.9	37.7
Industrial	- -	- -	- -	163.6	185.9	205.8	219.4	233.7	245.5
Transportation	- -	- -	- -	87.7	96.0	102.8	111.0	118.9	127.7
Total	347.4	365.0	398.1	446.7	508.3	551.5	595.7	637.3	678.3
Transportation (%)	- -	- -	- -	19.6	18.9	18.6	18.6	18.7	18.8
International (World less United States)									
Residential	- -	- -	- -	26.5	30.7	33.8	36.4	38.8	41.7
Commercial	- -	- -	- -	6.8	8.5	9.4	10.7	12.3	13.9
Industrial	- -	- -	- -	130.0	156.2	174.5	187.7	201.4	213.6
Transportation	- -	- -	- -	59.8	68.0	74.1	82.1	88.9	96.5
Total	262.8	273.9	299.2	346.3	409.2	449.4	491.0	529.1	567.3
Transportation (%)	- -	- -	- -	17.3	16.6	16.5	16.7	16.8	17.0

a/ Actual United States data: EIA (2009c).
Actual World data: EIA (2009d).
b/ Forecasted United States data: EIA (2009c).
Forecasted World data: EIA (2009d).
c/ Btu = British thermal unit.

The analysis of fuel consumption and energy use conducted for this EIS assumes that fuel consumed by U.S. passenger cars and light trucks will consist predominantly of gasoline or diesel fuel derived from petroleum for the foreseeable future. Implicitly, ethanol FFVs are assumed to operate exclusively on gasoline, while diesel vehicles are assumed to operate exclusively on petroleum-based diesel rather than on biodiesel. The estimates of gasoline consumption reported in this analysis include ethanol used as a gasoline additive to increase its oxygen content, while the estimates of diesel fuel consumption include biodiesel used as a blending agent.[8] The analysis makes no other assumption about the use of renewable fuels or biofuels.

Most U.S. gasoline and diesel is produced domestically (EIA 2009a). In 2007, 4 percent of finished motor gasoline and 6 percent of on-road diesel were imported. However, increasing volumes of crude oil are imported for processing in U.S. refineries because domestic production is steadily declining. By 2006, petroleum imports equaled 60 percent of total liquids supplied and by 2007, crude oil imports

[8] EIA data indicate that during 2007, ethanol accounted for approximately 3.6 percent of the energy content of fuel labeled at retail as gasoline, while biodiesel accounted for about 1.2 percent of the energy content of fuel sold at retail as diesel. Computed from information reported in AEO 2009 (EIA 2009b), Reference Case, Table 17 and Supplemental Table 46.

had surpassed 10 million barrels per day (EIA 2009a), a high proportion of it coming from volatile and unstable regions.

A fall in the demand for transportation fuels likely would affect imports of crude oil more than motor gasoline. Over the last decade there has been a shift in product imports, with volumes of finished gasoline stabilizing and declining slightly. However, volumes of motor gasoline blending components have been rapidly increasing, so that by 2007, the imports of blending components were twice that of finished gasoline.

According to EIA, net imports of crude oil – in part due to improvements in fuel efficiency required by the changes in CAFE standards, in part due to substitution of biofuels, in part due to high prices, and in part due to a steady increase in U.S. production from the offshore – will fall to 41 percent of liquid fuel supply in 2020 and then decline further to 39 percent in 2035. The further decrease in 2035 is due in part to a projected surge in domestic crude oil production. The impact of these anticipated developments on the petroleum industry is likely to be felt largely by overseas producers (EIA 2009c), although the net impact on petroleum production levels of overseas suppliers and the associated change in their emissions of air pollutants and GHGs will ultimately depend on whether demand for motor fuel in developing nations rises sufficiently to replace declining U.S. demand.

3.2.2 Methodology

The methodology for examining the impact of higher CAFE standards on gasoline and diesel consumption relies on outputs from the Volpe model. The Volpe model, as described in Section 3.1.4, requires the following types of input information: (1) a forecast of the future vehicle market; (2) estimates of the availability, applicability, and incremental effectiveness and cost of fuel-saving technologies; (3) estimates of vehicle survival and mileage accumulation patterns, the rebound effect, future fuel prices, the “social cost of carbon,” and many other economic factors; (4) fuel characteristics and vehicular emissions rates; and (5) coefficients defining the shape and level of CAFE curves to be examined.

Using NHTSA-selected inputs, the agency projects a set of technologies each manufacturer could apply in attempting to comply with the various levels of potential CAFE standards to be examined. The model then estimates the costs associated with this additional technology utilization, and accompanying changes in travel demand, fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors.

The analysis of costs and benefits employed in the Volpe model reflects the NHTSA assessment of a broad range of technologies that can be applied to passenger cars and light trucks. In the agency’s rulemakings covering light truck CAFE standards for MYs 2005-2007 and MYs 2008-2011, the agency relied on the 2002 National Academy of Sciences report, *Effectiveness and Impact of Corporate Average Fuel Economy Standards* (NRC 2002) for estimating potential fuel economy benefits and associated retail costs of applying combinations of technologies. In developing its final rule adopting CAFE standards for MY 2011, NHTSA reviewed manufacturers’ technology data and comments it received on its fuel-saving technologies, and conducted its own independent analysis, which involved hiring an international engineering consulting firm that specializes in automotive engineering, the same firm EPA used in developing its advance notice of proposed rulemaking to regulate GHG emissions under the Clean Air Act (CAA). Since then, NHTSA and EPA have collaborated on further updates to estimates of the cost, effectiveness, and availability of fuel-saving technologies the agencies expect to be available during MYs 2012-2016. The revised technology assumptions – that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies are applied – are described in greater detail in the NHTSA-EPA joint technical support document (TSD) and in NHTSA’s preliminary RIA, Docket Nos. NHTSA-2009-0059-0016.1 (RIA), NHTSA-2009-0059-0029 (TSD). See Section 3.1.4 for further information on the Volpe model. A full discussion of changes made to the technology assumptions since the joint NPRM will be detailed in the forthcoming joint NHTSA-EPA final rule.

The Volpe model produces various outputs, including its estimates of year-by-year fuel consumption by U.S. passenger car and light truck fleets. The Volpe model estimates annual fuel consumption and fuel savings for each calendar year from 2012, when the CAFE standards considered in this EIS would first take effect, through 2060, when almost all passenger cars and light trucks in use would have met CAFE standards at least as stringent as those established for MY 2016.[9] Therefore, the estimated fuel savings during 2060 represents the maximum annual fuel savings resulting from the CAFE standards established by this rulemaking.

To calculate fuel savings for each action alternative, NHTSA subtracted fuel consumption under that alternative from its level under the No Action Alternative. The Volpe model estimated fuel savings using the following mpg assumptions: for MYs 2012-2016, the fuel economy of new passenger cars and light trucks under each action alternative increases annually in accordance with the CAFE standards specified in that particular alternative.[10] For MYs 2017-2060, all new vehicles were assumed to meet the MY 2016 CAFE standards that would be established under each action alternative. In effect, this means that fuel economy achieved by passenger cars and light trucks produced in MYs 2017-2060 remains constant at their levels estimated for MY 2016 under each action alternative.[11]

3.2.3 Environmental Consequences

Table 3.2.3-1, which lists the impact on fuel consumption for passenger cars from 2020 through 2060, shows the increasing impact of alternative CAFE standards over time. The table reports total fuel consumption for passenger cars, both gasoline and diesel, under the No Action Alternative (Alternative 1) and each of the eight action alternatives, as described in Section 2.3. By 2060, when nearly the entire passenger car and light truck fleet is likely to be composed of MY 2016 or later passenger cars and light trucks, fuel consumption reaches 205.5 billion gallons under the No Action Alternative. Fuel consumption is less than that projected under the No Action alternative for all the action alternatives, ranging from 188.4 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 166.5 billion gallons under Alternative 8 (7-percent annual increase in mpg). In 2060, fuel consumption under the TCTB Alternative (Alternative 9) amounts to 10.9 million barrels of fuel per day, while under Alternative 4 (the Preferred Alternative), daily fuel consumption amounts to 11.7 million barrels per day.[12] As a point of reference, NHTSA projects that fuel consumption under the No Action Alternative would be 13.4 million barrels per day in 2060. In 2007, the United States consumed 9.3 million barrels of fuel per day (EIA 2009a).

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[9] This assumes that if NHTSA does not establish more stringent CAFE standards for model years after MY 2016, the standards established for MY 2016 as part of the current rulemaking would be extended to apply to subsequent model years.

[10] The average fuel economy levels actually achieved by passenger cars and light trucks produced during a model year do not necessarily equal the CAFE standards for that model year. This occurs because some manufacturers' average fuel economy levels for their passenger cars or light trucks are projected to exceed the applicable CAFE standards during certain model years, while other manufacturers' fuel economy levels are projected to fall short of either the passenger car or light truck CAFE standards during some model years. As explained in Section 3.1.4.1, manufacturers may earn or use credits in these situations, but EPCA prohibits NHTSA from considering these flexibilities when determining the stringency of CAFE standards.

[11] *See* footnote 8 in this chapter.

[12] Billions of gallons (annual) are converted to millions of barrels per day by dividing by 365 and then dividing by 42.

Table 3.2.3-1

Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	74.1	70.5	68.9	68.4	67.5	66.2	66.4	65.6	65.6
2030	103.9	95.5	92.0	91.1	89.0	86.5	86.5	84.8	85.2
2040	134.5	123.3	118.6	117.4	114.7	111.3	111.3	109.0	109.6
2050	167.6	153.6	147.7	146.2	142.8	138.6	138.6	135.8	136.5
2060	205.5	188.4	181.2	179.4	175.2	170.0	170.0	166.5	167.4
Fuel Savings Compared to No Action									
2020	--	3.6	5.2	5.7	6.6	7.9	7.7	8.5	8.4
2030	--	8.4	11.9	12.8	14.8	17.4	17.3	19.1	18.7
2040	--	11.2	15.9	17.1	19.9	23.2	23.3	25.5	24.9
2050	--	14.0	19.8	21.3	24.8	28.9	29.0	31.8	31.1
2060	--	17.2	24.3	26.2	30.4	35.5	35.5	39.0	38.1

Table 3.2.3-2 lists comparable results for light trucks for the same period and for the same alternative CAFE standards. As in the previous table, reported fuel consumption includes light truck diesel and gasoline consumption. Fuel consumption under the No Action Alternative is estimated to total 113.0 billion gallons in 2060, and to decline progressively under the action alternatives, from 104.6 billion gallons under Alternative 2 to 92.4 billion gallons under Alternative 8. These represent fuel savings compared to the No Action Alternative that range from 8.3 billion gallons annually under Alternative 2 to 20.6 billion gallons annually under Alternative 8, or from 0.5 million to 1.3 million barrels of petroleum per day.

Table 3.2.3-2

Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	75.8	73.5	72.4	71.9	71.4	70.2	70.5	69.8	69.8
2030	72.2	67.7	65.7	64.9	63.9	62.2	62.2	61.1	61.3
2040	78.6	73.1	70.5	69.6	68.3	66.2	66.1	64.8	65.1
2050	93.0	86.2	83.0	81.9	80.4	77.8	77.7	76.1	76.5
2060	113.0	104.6	100.7	99.4	97.5	94.4	94.3	92.4	92.8
Fuel Savings Compared to No Action									
2020	--	2.3	3.4	3.9	4.4	5.6	5.4	6.0	6.1
2030	--	4.4	6.5	7.2	8.2	10.0	10.0	11.0	10.9
2040	--	5.6	8.2	9.1	10.3	12.4	12.5	13.8	13.5
2050	--	6.8	10.0	11.1	12.6	15.2	15.3	16.9	16.5
2060	--	8.3	12.3	13.5	15.5	18.6	18.7	20.6	20.2

Table 3.2.3-3 shows the combined passenger car and light truck projected fuel consumption and fuel savings under the various alternatives. Combined passenger car and light truck fuel consumption under the No Action Alternative is estimated to total 318.5 billion gallons in 2060, and to decline progressively under the action alternatives, from 293.0 billion gallons under Alternative 2 to 258.9 billion

gallons under Alternative 8. These represent fuel savings compared to the No Action Alternative that range from 25.5 billion gallons annually under Alternative 2 to 59.6 billion gallons annually under Alternative 8.

Table 3.2.3-3

Combined Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings a/ (billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	149.9	144.0	141.3	140.3	139.0	136.5	136.9	135.4	135.4
2030	176.0	163.2	157.7	156.0	153.0	148.7	148.7	146.0	146.5
2040	213.2	196.4	189.1	187.0	183.0	177.5	177.4	173.9	174.7
2050	260.5	239.7	230.7	228.2	223.2	216.5	216.3	211.9	213.0
2060	318.5	293.0	281.9	278.8	272.7	264.5	264.3	258.9	260.3
Fuel Savings Compared to No Action									
2020	--	6.0	8.7	9.7	10.9	13.5	13.0	14.5	14.5
2030	--	12.8	18.4	20.0	23.1	27.4	27.3	30.1	29.5
2040	--	16.8	24.1	26.2	30.2	35.7	35.8	39.3	38.4
2050	--	20.8	29.9	32.4	37.4	44.1	44.3	48.6	47.5
2060	--	25.5	36.6	39.7	45.8	54.0	54.2	59.6	58.3

a/ Some of the values shown for car & light truck fuel consumption in this table vary slightly from the sum of values shown separately for passenger cars and light trucks in previous tables due to rounding error.

The reductions in U.S. gasoline consumption and demand for crude petroleum projected to result from alternative increases in CAFE standards could lead to reductions in global petroleum prices, and thus to lower gasoline prices throughout the world. One consequence of lower prices would be increases in gasoline consumption outside the U.S., which would lead to increased emissions of greenhouse gases, criteria air pollutants, and airborne toxics from global fuel production and use. These increases have the potential to offset a modest share of the reductions in emissions projected to occur as a consequence of lower fuel production and consumption within the United States. A numerical example using Leiby's (2008) mean estimate of the sensitivity of global petroleum prices to changes in U.S. import demand suggests that increases in fuel consumption outside the U.S. could offset about 8 percent of the emissions reductions projected to result from the alternative increases in CAFE standards analyzed in this FEIS.[13] Given the various assumptions and uncertainties in our analyses, an 8 percent change would not change the overall conclusions or analysis of the alternatives made in this EIS.

[13] Using Leiby's reported range of uncertainty surrounding his mean estimate of the sensitivity of global petroleum prices to U.S. import demand, increases in fuel consumption outside the U.S. could offset from 3 percent (under Alternative 2) to 15 percent (under Alternative 9) of the emissions reductions projected to result from alternative increases in CAFE standards (Leiby 2008).

3.3 AIR QUALITY

3.3.1 Affected Environment

3.3.1.1 Relevant Pollutants and Standards

The proposed CAFE standards would affect air pollution and air quality, which in turn, have the potential to affect public health and welfare and the environment. The CAA is the primary federal legislation that addresses air quality. Under the authority of the CAA and its amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants[14] (relatively commonplace pollutants that can accumulate in the atmosphere as a result of normal levels of human activity). This EIS air quality analysis assesses the impacts of the No Action Alternative and action alternatives in relation to criteria pollutants and some hazardous air pollutants from mobile sources.

The criteria pollutants are CO, nitrogen dioxide (NO_2) (one of several oxides of nitrogen), ozone, SO_2, PM with an aerodynamic diameter equal to or less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), and lead. Ozone is not emitted directly from vehicles, but is evaluated based on emissions of the ozone precursor pollutants nitrogen oxides (NO_x) and VOCs.[15]

The U.S. transportation sector is a major source of emissions of certain criteria pollutants or their chemical precursors. Total emissions from on-road mobile sources (passenger cars and light trucks) have declined dramatically since 1970 as a result of pollution controls on vehicles and regulation of the chemical content of fuels, despite continuing increases in the amount of vehicle travel. From 1970 to 2008, the most recent year for which data are available, emissions from on-road mobile sources declined 76 percent for CO, 59 percent for NO_x, 64 percent for PM_{10}, 77 percent for SO_2, and 80 percent for VOCs. Emissions of $PM_{2.5}$ from on-road mobile sources declined 66 percent from 1990, the earliest year for which data are available, to 2008 (EPA 2009i).

On-road mobile sources are responsible for 50 percent of total U.S. emissions of CO, 4 percent of $PM_{2.5}$ emissions, and 1 percent of PM_{10} emissions (EPA 2009i). Almost all of the PM in motor-vehicle exhaust is $PM_{2.5}$; therefore, this analysis focuses on $PM_{2.5}$ rather than PM_{10}. On-road mobile sources also contribute 21 percent of total nationwide emissions of VOCs and 32 percent of NO_x, which are chemical precursors of ozone. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors. On-road mobile sources contribute only 1 percent of SO_2, but SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere; however, on-road mobile sources contribute only 1 percent of SO_2. With the elimination of lead in automotive gasoline, lead is no longer emitted from motor vehicles in more than negligible quantities. Lead is not assessed further in this analysis.

Table 3.3.1-1 lists the primary and secondary NAAQS for each criteria pollutant. Primary standards are set at levels intended to protect against adverse effects on human health; secondary standards are intended to protect against adverse effects on public welfare, such as damage to agricultural

[14] "Criteria pollutants" is a term used to collectively describe the six common air pollutants for which the CAA requires EPA to set NAAQS. EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human-health-based and/or environmentally based criteria (science-based guidelines) for setting permissible levels. "Hazardous air pollutants," by contrast, refer to substances defined as hazardous by the 1990 CAA amendments. These substances include certain VOCs, compounds in PM, pesticides, herbicides, and radionuclides that present tangible hazards, based on scientific studies of human (and other mammal) exposure.

[15] Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly into the air, but is formed through complex chemical reactions between precursor emissions of VOCs and NO_x in the presence of the ultraviolet component of sunlight.

crops or vegetation, and damage to buildings or other property. Because each criteria pollutant has different potential effects on human health and public welfare, the NAAQS specify different permissible levels for each pollutant. NAAQS for some pollutants include standards for both short- and long-term average levels. Short-term standards, which typically specify higher levels of a pollutant, are intended to protect against acute health effects from short-term exposure to higher levels of a pollutant; long-term standards are established to protect against chronic health effects resulting from long-term exposure to lower levels of a pollutant.

Table 3.3.1-1

National Ambient Air Quality Standards

Pollutant	Primary Standards		Secondary Standards	
	Level a/	Averaging Time	Level a/	Averaging Time
Carbon monoxide	9 ppm ($10\ mg/m^3$)	8 hours b/	None	
	35 ppm ($40\ mg/m^3$)	1 hour b/		
Lead	$0.15\ \mu g/m^3$	Rolling 3-month average	Same as Primary	
Nitrogen dioxide	0.053 ppm ($100\ \mu g/m^3$)	Annual (Arithmetic Mean)	Same as Primary	
	0.100 ppm ($200\ \mu g/m^3$)	1 hour c/	None	
Particulate matter (PM_{10})	$150\ \mu g/m^3$	24 hours d/	Same as Primary	
Particulate matter ($PM_{2.5}$)	$15.0\ \mu g/m^3$	Annual e/ (Arithmetic Mean)	Same as Primary	
	$35\ \mu g/m^3$	24 hours f/	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8 hours g/	Same as Primary	
	0.08 ppm (1997 std.)	8 hours h/ i/	Same as Primary	
Sulfur dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm ($1300\ \mu g/m^3$)	3 hours b/
	0.14 ppm	24 hours b/		

a/ Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air ($\mu g/m^3$).
b/ Not to be exceeded more than once per year.
c/ To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average at each monitor within an area must not exceed 0.100 ppm (effective January 22, 2010).
d/ Not to be exceeded more than once per year on average over 3 years.
e/ To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed $15.0\ \mu g/m^3$.
f/ To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed $35\ \mu g/m^3$ (effective December 17, 2006).
g/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm (effective May 27, 2008).
h/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
i/ The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.

Source: 40 CFR 50, as presented in EPA 2010.

Under the CAA, EPA is required to review NAAQS every 5 years and to change the levels of the standards if warranted by new scientific information. NAAQS formerly included an annual PM_{10} standard, but EPA revoked the annual PM_{10} standard in 2006 based on an absence of evidence of health effects associated with annual PM_{10} levels. In September 2006, EPA tightened the 24-hour $PM_{2.5}$ standard from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$. In March 2008, EPA tightened the 8-hour ozone standard from 0.08 part per million (ppm) to 0.075 ppm. At present, EPA is considering further changes to the $PM_{2.5}$ standards and changes to the ozone standard.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the atmosphere to the levels established by NAAQS. Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts of air or in micrograms of a pollutant per cubic meter of air present in repeated air samples taken at designated monitoring locations. These ambient concentrations of each criteria pollutant are compared to the permissible levels specified by NAAQS to assess whether the region's air quality could be unhealthful.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by NAAQS, EPA designates the region as an attainment area for that pollutant; regions where concentrations of criteria pollutants exceed federal standards are called nonattainment areas. Former nonattainment areas that have attained NAAQS are designated as maintenance areas. Each nonattainment area is required to develop and implement a State Implementation Plan (SIP), which documents how the region will reach attainment levels within periods specified in the CAA. In maintenance areas, the SIP documents how the state intends to maintain compliance with NAAQS. When EPA changes a NAAQS, states must revise their SIPs to address how they will attain the new standard.

Compounds emitted from vehicles, which are known or suspected to cause cancer or other serious health and environmental effects, are known as mobile source air toxics (MSATs). The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde. EPA and the Federal Highway Administration (FHWA) have identified these air toxics as the MSATs that typically are of greatest concern for impacts of highway vehicles (EPA 2007, FHWA 2006). DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class.

Section 3.4 addresses the major GHGs – CO_2, methane (CH_4), and nitrous oxides (N_2O); these GHGs are not included in this air quality analysis, except the evaluation of NO_x includes N_2O because it is one of the oxides of nitrogen.

3.3.1.2 Health Effects of Criteria Pollutants

The following paragraphs briefly describe the health effects of the six federal criteria pollutants. This information is adapted from the EPA Green Book, Criteria Pollutants (EPA 2008b). EPA's most recent technical reports and *Federal Register* notices for NAAQS reviews contain more information on the health effects of criteria pollutants (*see* http://www.epa.gov/ttn/naaqs/).

Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly into the air, but is formed through complex chemical reactions between precursor emissions of VOCs and NO_x in the presence of the ultraviolet component of sunlight. Ground-level ozone causes health problems because it irritates the mucous membranes, damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Exposure to ozone for several hours at relatively low concentrations has been found to substantially reduce lung function and induce respiratory inflammation in normal, healthy people during exercise. There is also evidence that short-term exposure to ozone directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality.

PM is a generic term for a broad class of chemically and physically diverse substances that exist as discrete particles. PM includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air, and particles formed in the atmosphere by condensation or by the transformation of emitted gases such as NO_x, SO_x and VOCs. The definition of PM also includes particles composed of elemental carbon (carbon black or black carbon). Both gasoline-fueled and diesel-fueled vehicles emit PM. In general, the smaller the PM, the deeper it can penetrate into the respiratory system and the more damage it can cause. Depending on its size and composition, PM can damage lung tissue, aggravate existing respiratory and cardiovascular diseases, alter the body's defense systems against foreign materials, and cause cancer and premature death. As noted above, EPA regulates PM according to two particle size classifications, PM_{10} and $PM_{2.5}$. This analysis only considers $PM_{2.5}$ because almost all of the PM emitted in exhaust from passenger cars and light trucks is $PM_{2.5}$.

CO is a colorless, odorless, poisonous gas produced by incomplete combustion of carbon in fuels. Motor vehicles are the single largest source of CO emissions nationally[16]. When CO enters the bloodstream, it acts as an asphyxiant by reducing the delivery of oxygen to the body's organs and tissues. It can impair the brain's ability to function properly. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease.

Lead is a toxic heavy metal used in industry, such as in battery manufacturing, and formerly in widespread use as an additive in paints. Lead gasoline additives (in piston-engine powered aircraft), non-ferrous smelters, and battery plants are the most significant contributors to atmospheric lead emissions. Lead exposure can occur through multiple pathways, including inhalation of air and ingestion of lead in food, water, soil, or dust. Excessive lead exposure can cause seizures, mental retardation, behavioral disorders, severe and permanent brain damage, and death. Even low doses of lead can lead to central nervous system damage. Because of the prohibition of lead as an additive in motor vehicle liquid fuels, vehicles are no longer a major source of lead pollution.

SO_2, one of various oxides of sulfur (SO_x), is a gas formed from combustion of fuels containing sulfur. Most SO_2 emissions are produced by stationary sources such as power plants. SO_2 is also formed when gasoline is extracted from crude oil in petroleum refineries, and in other industrial processes. High concentrations of SO_2 cause severe respiratory distress (difficulty breathing), irritate the upper respiratory tract, and can aggravate existing respiratory and cardiovascular disease. SO_2 also is a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues.

NO_2 is a reddish-brown, highly reactive gas, one of the oxides of nitrogen formed by high-temperature combustion (as in vehicle engines) of nitrogen and oxygen. Most NO_x created in the combustion reaction consists of nitric oxide (NO), which oxidizes to NO_2 in the atmosphere. NO_2 can irritate the lungs and mucous membranes, cause bronchitis and pneumonia, and lower resistance to respiratory infections. Oxides of nitrogen are an important precursor both to ozone and acid rain, and can affect both terrestrial and aquatic ecosystems.

3.3.1.3 Health Effects of Mobile Source Air Toxics (adapted from EPA 2009d)

Motor vehicle emissions contribute to ambient levels of air toxics known or suspected as human or animal carcinogens, or that have noncancer health effects. The population experiences an elevated risk of cancer and other noncancer health effects from exposure to air toxics (EPA 1999a). These compounds include, but are not limited to, acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde. These

[16] Highway motor vehicles accounted for 50 percent of national CO emissions in 2008. Passenger cars and light trucks accounted for about 76 percent of the CO emissions from highway motor vehicles (EPA 2009f)

five air toxics, plus DPM, comprise the six priority MSATs analyzed in this EIS. These compounds, except acetaldehyde, plus polycyclic organic matter (POM) and naphthalene, were identified as national or regional risk drivers in the EPA 2002 National-scale Air Toxics Assessment (NATA) and have significant inventory contributions from mobile sources (EPA 2009a). This EIS does not analyze POM separately, but it can occur as a component of DPM and is addressed under DPM below. Naphthalene is not analyzed separately in this EIS; however, naphthalene is a member of the POM class of compounds discussed under DPM.

Acetaldehyde is classified in EPA's Integrated Risk Information System (IRIS) database as a probable human carcinogen, based on nasal tumors in rats, and is considered toxic by the inhalation, oral, and intravenous routes (EPA 1991). Acetaldehyde is reasonably anticipated to be a human carcinogen by the U.S. Department of Health and Human Services (DHHS) in the 11th Report on Carcinogens and is classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC) (NTP 2005, IARC 1999). EPA is reassessing cancer risk from inhalation exposure to acetaldehyde.

The primary noncancer effects of exposure to acetaldehyde vapors include eye, skin, and respiratory-tract irritation (EPA 1991). In short-term (4-week) rat studies, degeneration of olfactory epithelium was observed at various concentration levels of acetaldehyde exposure (Appleman *et al.* 1982, 1986). EPA used data from these studies to develop an inhalation reference concentration. Some asthmatics have been shown to be a sensitive subpopulation to decrements in functional expiratory volume (FEV1 test) and bronchoconstriction upon acetaldehyde inhalation (Myou *et al.* 1993). EPA is reassessing the health hazards from inhalation exposure to acetaldehyde.

Acrolein is extremely acrid and irritating to humans when inhaled, with acute exposure resulting in upper respiratory tract irritation, mucus hypersecretion, and congestion. Levels considerably lower than 1 ppm (2.3 mg/m^3) elicit subjective complaints of eye and nasal irritation and a decrease in the respiratory rate (Weber-Tschopp *et al*. 1977, Sim and Pattle 1957). Lesions to the lungs and upper respiratory tracts of rats, rabbits, and hamsters have been observed after subchronic exposure to acrolein. Based on animal data, individuals with compromised respiratory function (*e.g.*, emphysema, asthma) are expected to be at increased risk of developing adverse responses to strong respiratory irritants such as acrolein. This was demonstrated in mice with allergic-airway disease by comparison to non-diseased mice in a study of the acute respiratory irritant effects of acrolein (Morris *et al.* 2003). The intense irritancy of this carbonyl has been demonstrated during controlled tests in human subjects, who suffer intolerable eye and nasal mucosal sensory reactions within minutes of exposure (Sim and Pattle 1957).

EPA determined in 2003 that the human carcinogenic potential of acrolein could not be determined because the available data were inadequate. No information was available on the carcinogenic effects of acrolein in humans and the animal data provided inadequate evidence of carcinogenicity (EPA 2003). IARC determined in 1995 that acrolein was not classifiable as to its carcinogenicity in humans (IARC 1995).

The EPA IRIS database lists *benzene* as a known human carcinogen (causing leukemia) by all routes of exposure, and concludes that exposure is associated with additional health effects, including genetic changes in both humans and animals and increased proliferation of bone marrow cells in mice (EPA 2000a, IARC 1982, Irons *et al*. 1992). EPA states in its IRIS database that data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. IARC has determined that benzene is a human carcinogen and DHHS has characterized benzene as a known human carcinogen (IARC 1987, NTP 2005).

A number of adverse noncancer health effects, including blood disorders such as preleukemia and aplastic anemia, have also been associated with long-term exposure to benzene (Askoy 1989, Goldstein 1988). The most sensitive noncancer effect observed in humans, based on current data, is the depression of the absolute lymphocyte count in blood (Rothman *et al* 1996, EPA 2002a). In addition, recent work, including studies sponsored by the Health Effects Institute, provides evidence that biochemical responses are occurring at lower levels of benzene exposure than previously known (Qu *et al.* 2002, 2003; Lan *et al.* 2004; Turtletaub and Mani 2003) The EPA IRIS program has not yet evaluated these new data.

EPA has characterized *1,3-butadiene* as carcinogenic to humans by inhalation (EPA 2002b, 2002c). IARC has determined that 1,3-butadiene is a human carcinogen, and DHHS has characterized 1,3-butadiene as a known human carcinogen (IARC 1999, NTP 2005). There are numerous studies consistently demonstrating that animals and humans in experiments metabolize 1,3-butadiene into genotoxic metabolites. The specific mechanisms of 1,3-butadiene-induced carcinogenesis are not known; however, scientific evidence strongly suggests that the carcinogenic effects are mediated by genotoxic metabolites. Animal data suggest that females could be more sensitive than males for cancer effects associated with 1,3-butadiene exposure; there are insufficient data in humans from which to draw conclusions about sensitive subpopulations. 1,3-butadiene also causes a variety of reproductive and developmental effects in mice; no human data on these effects are available. The most sensitive effect was ovarian atrophy observed in a lifetime bioassay of female mice (Bevan *et al.* 1996).

DPM is a component, along with diesel exhaust organic gases, of diesel exhaust. DPM particles are very fine, with most particles smaller than 1 micron, and their small size allows inhaled DPM to reach the lungs. Particles typically have a carbon core coated by condensed organic compounds such as POM, which include mutagens and carcinogens. DPM also includes elemental carbon (carbon black or black carbon) particles emitted from diesel engines. Diesel exhaust is likely to be carcinogenic to humans by inhalation from environmental exposure.

DPM can contain *POM*, which is generally defined as a large class of organic compounds that have multiple benzene rings and a boiling point greater than 100 degrees Celsius (ºC). EPA classifies many of the compounds included in the POM class as probable human carcinogens based on animal data. Polycyclic aromatic hydrocarbons (PAHs) are a subset of POM that contains only hydrogen and carbon atoms. A number of PAHs are known or suspected carcinogens. Recent studies have found that maternal exposures to PAHs in a population of pregnant women were associated with several adverse birth outcomes, including low birth weight and reduced length at birth, and impaired cognitive development at age 3 (Perera *et al.* 2002, 2006). EPA has not yet evaluated these recent studies.

Since 1987, EPA has classified *formaldehyde* as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys (EPA 1987). EPA is reviewing recently published epidemiological data. For example, National Cancer Institute (NCI) research found an increased risk of nasopharyngeal cancer and lymphohematopoietic malignancies such as leukemia among workers exposed to formaldehyde (Hauptmann *et al.* 2003, 2004). In an analysis of the lymphohematopoietic cancer mortality from an extended followup of these workers, NCI confirmed an association between lymphohematopoietic cancer risk and peak exposures to formaldehyde (Beane Freeman *et al.* 2009). A recent National Institute of Occupational Safety and Health study of garment workers also found increased risk of death due to leukemia among workers exposed to formaldehyde (Pinkerton 2004). Extended followup of a cohort of British chemical workers did not find evidence of an increase in nasopharyngeal or lymphohematopoietic cancers, but did report a continuing statistically significant excess in lung cancers (Coggon *et al*. 2003). Recently, IARC reclassified formaldehyde as a human carcinogen (Group 1) (IARC 2006).

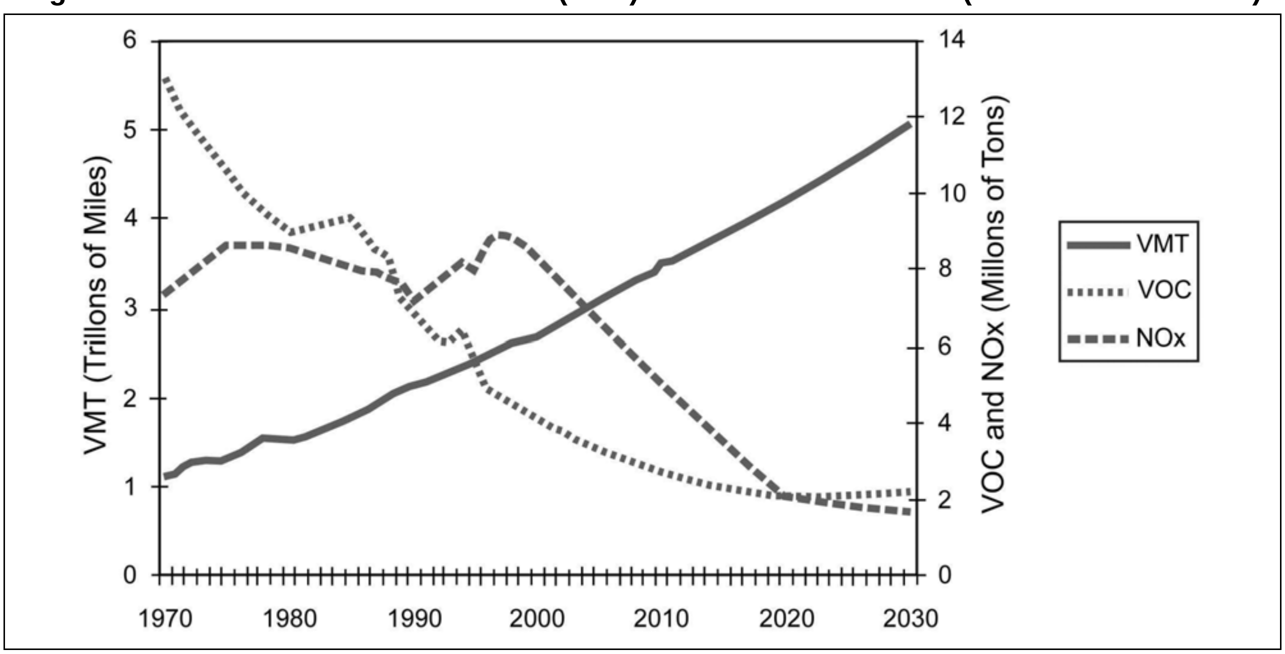
Formaldehyde exposure also causes a range of noncancer health effects, including irritation of the eyes (burning and watering), nose, and throat. Effects in humans from repeated exposure include respiratory-tract irritation, chronic bronchitis, and nasal epithelial lesions such as metaplasia and loss of cilia. Animal studies suggest that formaldehyde might also cause airway inflammation, including eosinophil infiltration into the airways. There are several studies suggesting that formaldehyde might increase the risk of asthma, particularly in the young (ATSDR 1999, WHO 2002).

3.3.1.4 Clean Air Act and Conformity Regulations

3.3.1.4.1 Vehicle Emission Standards

Under the CAA, EPA has established emission standards for vehicles. EPA has tightened the emission standards over time as more effective emission-control technologies have become available. These reductions in the levels of the standards are responsible for the declines in total emissions from motor vehicles, as discussed above. The EPA Tier 2 Vehicle & Gasoline Sulfur Program, which went into effect in 2004 established the CAA emissions standards that will apply to MYs 2012-2016 passenger cars and light trucks (EPA 1999b). Under the Tier 2 standards, emissions from passenger cars and light trucks will continue to decline. In 2004, the Nation's refiners and importers of gasoline began to manufacture gasoline with sulfur levels capped at 300 ppm, approximately a 15-percent reduction from the previous industry average of 347 ppm. By 2006, refiners met a 30-ppm average sulfur level with a cap of 80 ppm. These fuels enable post-2006 model year vehicles to use emissions controls that reduce tailpipe emissions of NO_x by 77 percent for passenger cars and by as much as 95 percent for pickup trucks, vans, and SUVs, compared to 2003 levels. Figure 3.3.1-1 shows that cleaner vehicles and fuels will result in continued reductions in emissions from passenger cars and light trucks, despite increases in travel. Figure 3.3.1-1 illustrates current trends in travel and emissions from passenger cars and light trucks under the existing CAFE standards. Figure 3.3.1-1 does not show the effects of the proposed action and alternatives; *see* Section 3.3.3.

Figure 3.3.1-1. Vehicle Miles Traveled (VMT) vs. Vehicle Emissions (Source: Smith 2002)



From 1970 to 1999, aggregate emissions traditionally associated with vehicles substantially decreased (with the exception of NO_x) even as VMT has increased by approximately 149 percent. NO_x

emissions increased 16 percent between 1970 and 1999, due mainly to emissions from light trucks and heavy-duty vehicles. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the proposed alternative CAFE standards.

EPA is addressing air toxics through its MSAT rules (EPA 2007). These rules limit the benzene content of gasoline beginning in 2011. They also limit exhaust emissions of hydrocarbons (many VOCs and MSATs are hydrocarbons) from passenger cars and light trucks when they are operated at cold temperatures. The cold-temperature standard will be phased in from 2010 to 2015. The MSAT rules also adopt nationally the California evaporative emissions standards. EPA projects that these controls will substantially reduce emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde.

3.3.1.4.2 Conformity Regulations

Section 176(c) of the CAA prohibits federal agencies from taking actions in nonattainment or maintenance areas that do not "conform" to the SIP. The purpose of this conformity requirement is to ensure that general activities do not interfere with meeting the emissions targets in SIPs, do not cause or contribute to new violations of NAAQS, and do not impede the ability to attain or maintain NAAQS. EPA has issued two sets of regulations to implement CAA Section 176(c), as follows:

- The Transportation Conformity Rules (40 CFR Part 93, Subpart A), which apply to transportation plans, programs, and projects funded under U.S.C. Title 23 or the Federal Transit Act. Highway and transit infrastructure projects funded by FHWA or the Federal Transit Administration (FTA) usually are subject to transportation conformity.
- The General Conformity Rule (40 CFR Part 51, Subpart W) apply to all other federal actions not covered under transportation conformity. The General Conformity Rule established emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of a project. If the net emissions increases due to the project are less than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the emissions increases exceed any of these thresholds, then a conformity determination is required. The conformity determination can entail air quality modeling studies, consultation with EPA and state air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The CAFE standards and associated program activities are not funded under U.S.C. Title 23 or the Federal Transit Act. Further, NHTSA establishes CAFE standards, not FHWA or FTA. Accordingly, the CAFE standards and associated rulemakings are not subject to transportation conformity.

The General Conformity Rule contains several exemptions applicable to federal actions, which the conformity regulations define as "any activity engaged in by a department, agency, or instrumentality of the Federal Government, or any activity that a department, agency or instrumentality of the Federal Government supports in any way, provides financial assistance for, licenses, permits, or approves, other than activities [subject to transportation conformity]." 40 CFR 51.852. "Rulemaking and policy development and issuance" are exempted at 40 CFR 51.853(c)(2)(iii). Because NHTSA's CAFE standards involve a rulemaking process, NHTSA's action is exempt from general conformity. Also, emissions for which a federal agency does not have a "continuing program responsibility" are not considered "indirect emissions" subject to general conformity under 40 CFR 51.852. "Emissions that a Federal agency has a continuing program responsibility for means emissions that are specifically caused by an agency carrying out its authorities, and does not include emissions that occur due to subsequent activities, unless such activities are required by the Federal agency." 40 CFR 51.852. Emissions that occur as a result of the CAFE standards are not caused by NHTSA carrying out its statutory authorities and clearly occur due to subsequent activities, including vehicle manufacturers' production of passenger car and light truck fleets and consumer purchases and driving behavior. Thus, changes in any emissions that result from NHTSA's new CAFE standards are not those for which the agency has a "continuing program responsibility;" therefore, a general conformity determination is not required. Nonetheless, NHTSA is evaluating the potential impacts of air emissions for the purposes of NEPA.

3.3.2 Methodology

3.3.2.1 Overview

To analyze impacts to air quality, NHTSA calculated the emissions of criteria pollutants and MSATs from passenger cars and light trucks that would occur under each alternative and assessed the changes in emissions in relation to the No Action Alternative (Alternative 1).

For purposes of analyzing potential direct and indirect impacts (environmental consequences), the No Action Alternative in this EIS consists of the existing CAFE standards with no changes in the future. That is, the No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011. *See* Section 2.3.2. The basic method used to estimate emissions entails multiplying activity levels of passenger cars and light trucks, expressed as the total VMT, by emission factors measured in grams of pollutant emitted per VMT. National emissions estimates for all passenger cars and light trucks projected to be in use during future years were developed using the Volpe model. The Volpe model utilizes emission factors developed using EPA's draft MOVES2009 emission model (EPA 2009j) for light-duty gasoline vehicles, and MOBILE6.2 (EPA 2004) for light-duty diesel vehicles. MOVES reflects EPA's updated estimates of real-world emissions from passenger cars and trucks, and accounts for emission control requirements on exhaust (tailpipe) emissions and evaporative emissions, including the Tier 2 Vehicle & Gasoline Sulfur Program and Mobile Source Air Toxics (MSAT) rule.

Impacts on upstream emissions (oil refining as well as fuel transport, storage, and distribution) were estimated using emission factors provided by EPA. These were based on the Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation model (GREET, version 1.8) developed by DOE Argonne National Laboratory (Argonne 2002). EPA modified GREET for use in analyzing its Renewable Fuel Standard rulemaking[17] analysis to account for recent EPA emission standards for gasoline transport and the addition of air toxics emission factors.

By reducing the cost of fuel consumed per mile driven, setting future CAFE standards that require higher mpg levels would create an incentive for additional driving. The resulting increase in driving offsets part of the fuel savings that would otherwise result from requiring higher fuel economy; this phenomenon is known as the fuel economy "rebound effect." The total amount of passenger car and light truck VMT would increase slightly due to the rebound effect, and emissions from these vehicles would increase in proportion to the increased VMT. Although higher CAFE standards would decrease the total amount of fuel consumed from its level under the No Action Alternative despite the rebound effect, the reduction in fuel usage cannot be linked directly to any decrease in emissions resulting directly from vehicle use.

[17] 74 *FR* 24904, May 26, 2009.

The NHTSA CAFE standards and the EPA emissions standards impose separate requirements on motor-vehicle manufacturers. Although manufacturers must meet both the CAFE standards and the EPA emissions standards simultaneously, neither NHTSA nor EPA dictates the design and technology choices manufacturers must make to comply. For example, a manufacturer could use a technique that increases fuel economy but also increases emissions, as long as the manufacturer's production still meets both the CAFE standards and the EPA emissions standards. For this reason, the air quality analysis methodology does not assume any reduction in direct emissions from motor vehicle use solely due to improvements in fuel economy.

However, the proposed CAFE standards would lead to reductions in "upstream" emissions, which are emissions associated with petroleum extraction, refining, storage, and distribution of transportation fuels. Upstream emissions would decrease as a consequence of the proposed CAFE standards because the total amount of fuel used by passenger cars and light trucks would decrease.

Although the rebound effect is assumed to result in identical percentage increases in VMT and emissions from vehicle use in all regions of the Nation, the associated changes in upstream emissions are expected to vary among regions because fuel refining and storage facilities are not uniformly distributed across the Country. Thus, an individual region could experience either a net increase or a net decrease in emissions of each pollutant due to the proposed CAFE standards, depending on the relative magnitudes of the increase in emissions from vehicle use and the regional reduction in emissions from fuel production and distribution.

To assess regional differences in the effects of the alternatives, NHTSA estimated net emissions changes for individual nonattainment areas. NHTSA used nonattainment areas because these are the regions in which air quality problems have been greatest. All nonattainment areas assessed were in nonattainment for ozone or $PM_{2.5}$ because these are the pollutants for which emissions from passenger cars and light trucks are of greatest concern. NHTSA did not quantify PM_{10} emissions separately from $PM_{2.5}$ because almost all the PM in the exhaust from passenger cars and light trucks is $PM_{2.5}$. The road-dust component of PM_{10} concentrations from passenger cars and light trucks would increase in proportion to the rebound effect. There are no longer any nonattainment areas for annual PM_{10} because EPA revoked the annual PM_{10} standard. Currently there are no NO_2 nonattainment areas, and only one area remains designated nonattainment for CO.

The air quality analysis is nationwide and regional and does not address the specific geographic locations of increases in emissions because emissions increases due to the rebound effect consist of higher emissions from passenger cars and light trucks operating on regional roadway networks. Thus, any emissions increases due to the VMT rebound effect would be distributed along a region's entire road network. At any one location the increase would be small compared to total emissions near the source (*i.e.*, existing emissions from traffic on the road), so the localized impacts on ambient concentrations and health should also be small. The aggregate of such small near-source impacts on ambient concentrations and health nationwide might be larger, but is not feasible to quantify.

3.3.2.2 Time Frames for Analysis

Ground-level concentrations of criteria and toxic air pollutants generally respond quickly to changes in emission rates. The longest averaging period for measuring whether ambient concentrations of a pollutant comply with the NAAQS is 1 year.[18] The air quality analysis considers the emissions that

[18] Compliance with the ozone NAAQS is based on the average of the fourth highest daily maximum 8-hour concentration over a 3-year period; compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the average of the daily

would occur over annual periods, consistent with NAAQS. NHTSA selected calendar years that are meaningful for the timing of likely effects of the alternatives.

Passenger cars and light trucks remain in use for many years, so the change in emissions due to any change in the CAFE standards for MYs 2012-2016 would also continue for many years. The influence of vehicles produced during a particular model year declines over time as those vehicles are gradually retired from service as they age, while those that remain in use are driven progressively less. The Volpe model defines vehicle lifetime as the point at which less than 2 percent of the vehicles originally produced in a model year remain in service. Under this definition, passenger cars survive in the fleet for as long as 26 years, while light trucks can survive for up to 37 years. Of course, any individual vehicle might not necessarily survive to these maximum ages; the typical or "expected" lifetimes for passenger cars and light trucks are approximately half of their respective maximum lifetimes, or 13 years for passenger cars and 18.5 years for light trucks.

The survival of vehicles and the amount they are driven can be forecast with reasonable accuracy for a decade or two, while the influences of fuel prices and general economic conditions are less certain. To evaluate impacts to air quality, specific years must be selected for which emissions will be estimated and their effects on air quality calculated. NHTSA performed the air quality analysis in two ways that affect the choice of analysis years. For the NEPA direct and indirect impacts analysis, NHTSA assumed that the CAFE standards for MYs 2012-2016 would remain in force indefinitely at the 2016 level; NHTSA did not include potential CAFE standards for MYs 2017-2020 because they are not within the scope of this rulemaking.

The paragraphs below describe the analysis years NHTSA used in this EIS and the rationales for each.

- 2016 – First year of complete implementation of the MYs 2012-2016 CAFE standards; year of highest overall emissions from passenger cars and light trucks following complete implementation.
- 2020 – Latest required attainment date for 8-hour ozone nonattainment areas (2020 is latest full year, because the last attainment date is June 2021 for South Coast Air Basin, California[19]); by this point a large proportion of passenger car and light truck VMT would be accounted for by vehicles that meet the MYs 2012-2016 standards; first year of complete implementation of potential MYs 2017-2020 CAFE standards (*see* Section 4.3).
- 2030 – By 2030, almost all passenger cars and light trucks in operation would meet at least the MYs 2012-2016 standards, and the impact of these standards would be determined primarily by VMT growth rather than further tightening of the standards. The year-by-year impacts of the CAFE standards for MYs 2012-2016 and the EPA standards by 2030 will change little from model year turnover, and most changes in emissions from year to year will come from added driving due to the fuel economy rebound effect.

98th percentile concentrations averaged over a 3-year period; and compliance with the annual $PM_{2.5}$ NAAQS is based on the 3-year average of the weighted annual mean concentrations.

[19] The South Coast area is currently classified as severe-17; however, the California Air Resources Board has submitted a request to EPA to bump up the area to extreme. Clean Air Act section 181(b)(3) requires the Administrator to grant such requests. Once granted the area's attainment date will be June 2024 and the last full year prior to that date will be 2023.

3.3.2.3 Treatment of Incomplete or Unavailable Information

As noted throughout this methodology section, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emissions rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years comprising the passenger car and light truck fleet, VMT projections, emissions from fuel refining and distribution, and economic factors. To approximate the health benefits associated with each alternative, NHTSA used screening-level estimates of health outcomes in the form of cases per ton of criteria pollutant emissions reduced, and of monetized health benefits in the form of dollars per ton of criteria pollutant emissions reduced. The use of such dollars-per-ton numbers, however, does not account for all potential health and environmental benefits, because the information necessary to monetize all potential health and environmental benefits is unavailable. As a result, NHTSA has probably underestimated the total criteria pollutant benefits. Reductions in emissions of toxic air pollutants should result in health benefits as well, but scientific data that would support quantification and monetization of these benefits are not available.

Where information in the analysis included in the EIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information. *See* 40 CFR § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the EIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the EIS assumptions regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis.

3.3.2.4 Allocation of Exhaust Emissions to Nonattainment Areas

For each alternative, the Volpe model provided national emissions estimates for each criteria air pollutant (or its chemical precursors) and MSAT. National emissions were allocated to the county level using VMT data for each county. EPA provided passenger car and light truck VMT data for all counties in the United States for 2014, 2020, and 2030 and consistent with the EPA National Emissions Inventory (NEI) (EPA 2006 as cited in EPA 2009g). Data for 2014, 2020, and 2030 were based on growth from economic modeling and EIA (2006). The VMT data used in the NEI were projected from traffic counts taken by counties and states on major roadways, and therefore are subject to some uncertainty. NHTSA used the VMT data from the NEI only to allocate nationwide total emissions to counties, and not to calculate the emissions. The estimates of nationwide total emissions are based on the national VMT data used in the Volpe model.

NHTSA used the county-level VMT allocations, expressed as fractions of national VMT for each county, to derive the county-level emissions from the estimates of nationwide total emissions. Emissions for each nonattainment area were derived by summing the emissions for the counties included in each nonattainment area. Most nonattainment areas comprise one or more counties, and because county-level emissions are aggregated for each nonattainment area, uncertainties in the country-level emissions estimates carry over to NHTSA's estimates of emissions within each nonattainment area. Over time, some counties will grow faster than others, and VMT growth rates will also vary. EPA provided the VMT data which includes forecasts of the county allocation only as far as 2030. The EPA forecasts of county-level VMT allocation introduce some uncertainty into the nonattainment-area-level VMT estimates. Additional uncertainties that affect county-level exhaust emissions estimates arise from differences between counties or nonattainment areas other than VMT, such as ambient temperatures, vehicle age distributions, vehicle speed distributions, vehicle inspection and maintenance programs, and fuel composition requirements. This uncertainty increases as the projection period lengthens, such as analysis year 2030 compared to 2016.

The geographic definitions of ozone and $PM_{2.5}$ nonattainment areas came from the current EPA Greenbook list (EPA 2009e). For nonattainment areas that include portions of counties, NHTSA calculated the proportion of county population that falls within the nonattainment area boundary as a proxy for the proportion of county VMT within the nonattainment area boundary. This method assumes that per-capita VMT is constant within each county, so that the proportion of county population in the partial county area reflects the VMT in that area. This assumption introduces some uncertainty into the allocation of VMT to partial counties, because actual VMT per capita can vary according to the characteristics of land use and urban development. For example, VMT per capita can be lower than average in urban centers with mass transit and higher than average in suburban and rural areas where people tend to drive more (Cook *et al*. 2006).

Partial county boundaries were taken from geographic information system files based on 2006 nonattainment area definitions. In some cases, partial counties within nonattainment areas as currently defined were not included in the 2006 nonattainment areas. In those cases, NHTSA did not add any part of the missing counties' VMT to the nonattainment area totals, on the basis that partial counties added to nonattainment areas between 2006 and 2009 are likely to represent relatively small additions to total nonattainment area VMT. Several urban areas are in nonattainment for both ozone and $PM_{2.5}$. Where boundary areas differ between the two pollutants, NHTSA used the larger boundary. This approach is conservative (tending to overestimate emissions within the nonattainment area for the pollutant having the smaller boundary) because it assigns the larger area's VMT (and thus, its emissions) to the smaller area. Table 3.3.2-1 lists the current nonattainment and maintenance areas.

Table 3.3.2-1

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Classification a/		General Conformity Threshold b/	
	O_3	$PM_{2.5}$	O_3	$PM_{2.5}$
Albany-Schenectady-Troy, NY	Subpart 1	-	100	-
Allegan Co., MI	Subpart 1	-	100	-
Amador and Calavaras Cos. (Central Mountain Counties), CA	Subpart 1	-	100	-
Atlanta, GA	Moderate	Nonattainment	100	100
Baltimore, MD	Moderate	Nonattainment	100	100
Baton Rouge, LA	Moderate	-	100	-
Beaumont/Port Arthur, TX	Moderate	-	100	-
Birmingham, AL	-	Nonattainment	-	100
Boston-Lawrence-Worcester (E. MA), MA	Moderate	-	100	-
Boston-Manchester-Portsmouth, MA-SE. NH	Moderate	-	100	-
Buffalo-Niagara Falls, NY	Subpart 1	-	100	-
Canton-Massillon, OH	-	Nonattainment	-	100
Charleston, WV	-	Nonattainment	-	100
Charlotte-Gastonia-Rock Hill, NC-SC	Moderate	-	100	-
Chattanooga, AL-TN-GA	-	Nonattainment	-	100
Chicago-Gary-Lake Co., IL-IN	Moderate	Nonattainment	100	100
Chico, CA	Subpart 1	-	100	-
Cincinnati-Hamilton, OH-KY-IN	Subpart 1	Nonattainment	100	100
Cleveland-Akron-Lorain, OH	Subpart 1	Nonattainment	100	100
Columbus, OH	Subpart 1	Nonattainment	100	100
Dallas-Fort Worth, TX	Moderate	-	100	-

Table 3.3.2-1 (cont'd)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Classification a/		General Conformity Threshold b/	
	O_3	$PM_{2.5}$	O_3	$PM_{2.5}$
Dayton-Springfield, OH	-	Nonattainment	-	100
Denver-Boulder-Greeley-Ft. Collins, CO	Subpart 1	-	100	-
Detroit-Ann Arbor, MI	Marginal	Nonattainment	100	100
Door Co., WI	Subpart 1	-	100	-
Essex Co., NY (Whiteface Mountain)	Subpart 1	-	100	-
Evansville, IN	-	Nonattainment	-	100
Greater Connecticut, CT	Moderate	-	100	-
Greensboro-Winston Salem-High Point, NC	-	Nonattainment	-	100
Harrisburg-Lebanon-Carlisle, PA	-	Nonattainment	-	100
Haywood and Swain Cos. (Great Smoky Mountains National Park), NC	Subpart 1	-	100	-
Hickory, NC	-	Nonattainment	-	100
Houston-Galveston-Brazoria, TX	Severe 15	-	100	-
Huntington-Ashland, WV-KY-OH	-	Nonattainment	-	100
Imperial Co., CA	Moderate	-	100	-
Indianapolis, IN	-	Nonattainment	-	100
Jamestown, NY	Subpart 1	-	100	-
Jefferson Co., NY	Moderate	-	100	-
Johnstown, PA	-	Nonattainment	-	100
Kern Co. (Eastern Kern), CA	Subpart 1	-	100	-
Knoxville, TN	Subpart 1	Nonattainment	100	100
Lancaster, PA	-	Nonattainment	-	100
Las Vegas, NV	Subpart 1	-	100	-
Libby, MT	-	Nonattainment	-	100
Liberty-Clairton, PA	-	Nonattainment	-	100
Los Angeles South Coast Air Basin, CA	Severe 17	Nonattainment	25	100
Los Angeles-San Bernardino Cos. (W. Mojave Desert), CA	Moderate	-	100	-
Louisville, KY-IN	-	Nonattainment	-	100
Macon, GA	-	Nonattainment	-	100
Manitowoc Co., WI	Subpart 1	-	100	-
Mariposa & Tuolumne Cos. (Southern Mountain Counties), CA	Subpart 1	-	100	-
Martinsburg, WV-Hagerstown, MD	-	Nonattainment	-	100
Memphis, TN-AR	Moderate	-	100	-
Milwaukee-Racine, WI	Moderate	-	100	-
Nevada (Western Part), CA	Subpart 1	-	100	-
New York-N. New Jersey-Long Island, NY-NJ-CT	Moderate	Nonattainment	100	100
Parkersburg-Marietta, WV-OH	-	Nonattainment	-	100
Philadelphia-Wilmington-Atlantic City, PA-DE-MD-NJ	Moderate	Nonattainment	100	100
Phoenix-Mesa, AZ	Subpart 1	-	100	-
Pittsburgh-Beaver Valley, PA	Subpart 1	Nonattainment	100	100
Poughkeepsie, NY	Moderate	-	100	-
Providence (All RI), RI	Moderate	-	100	-
Reading, PA	-	Nonattainment	-	100
Riverside Co., CA (Coachella Valley)	Serious	-	50	-

Table 3.3.2-1 (cont'd)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Classification a/		General Conformity Threshold b/	
	O_3	$PM_{2.5}$	O_3	$PM_{2.5}$
Rochester, NY	Subpart 1	-	100	-
Rome, GA	-	Nonattainment	-	100
Sacramento Metro, CA	Serious	-	50	-
San Diego, CA	Subpart 1	-	100	-
San Francisco Bay Area, CA	Marginal	-	100	-
San Joaquin Valley, CA	Serious	Nonattainment	50	100
Sheboygan, WI	Moderate	-	100	-
Springfield (Western MA), MA	Moderate	-	100	-
St. Louis, MO-IL	Moderate	Nonattainment	100	100
Steubenville-Weirton, OH-WV	-	Nonattainment	-	100
Sutter County (Sutter Buttes), CA	Subpart 1	-	100	-
Ventura Co., CA	Serious	-	50	-
Washington, DC-MD-VA	Moderate	Nonattainment	100	100
Wheeling, WV-OH	-	Nonattainment	-	100
York, PA	-	Nonattainment	-	100

a/ Pollutants for which the area is designated nonattainment or maintenance as of 2009, and severity classification.
b/ Tons per year of VOCs or NO_x in ozone nonattainment areas; primary $PM_{2.5}$ in $PM_{2.5}$ nonattainment areas.
Source: EPA 2009e.

3.3.2.4.1 Allocation of Upstream Emissions to Nonattainment Areas

Upstream emissions associated with the production and distribution of fuels used by motor vehicles are generated when fuel products are produced, processed, and transported. Upstream emissions are typically divided into four categories:

- Feedstock recovery (mainly petroleum extraction);
- Feedstock transportation;
- Fuel refining; and
- Fuel transportation, storage, and distribution (TS&D).

Feedstock recovery refers to the extraction or production of fuel feedstocks. In the case of petroleum, this is the stage of crude-oil extraction. During the next stage, feedstock transportation, crude oil, or other feedstocks are shipped to fuel refineries. Fuel refining refers to the processing of crude oil into gasoline and diesel fuel. TS&D refers to the movement of gasoline and diesel from refineries to bulk terminals, storage at bulk terminals, and transportation of fuel from bulk terminals to retail outlets. Emissions of pollutants at each stage are associated with expenditure of energy, as well as with leakage or spillage and evaporation of fuel products.

To analyze the impact of the alternatives on individual nonattainment areas, NHTSA allocated emissions reductions to geographic areas according to the following methodology:

- Feedstock recovery – NHTSA assumed that little to no extraction of crude oil occurs in nonattainment areas. Of the top 50 highest producing oil fields in the United States, only nine are in nonattainment areas. These nine fields account for just 10 percent of domestic production, or 3 percent of total crude-oil imports plus domestic production (EIA 2006, EIA 2008). Therefore, because relatively little extraction occurs in nonattainment areas, NHTSA ignored emissions reductions from feedstock recovery in nonattainment areas. As a result of not quantifying the upstream emissions reductions associated with feedstock recovery, this part of the analysis is conservative (tending to underestimate the emission reduction benefits of the proposed CAFE standards).

- Feedstock transportation – NHTSA assumed that little to no crude oil is transported through nonattainment areas. Most refineries are outside of, or on the outskirts of, urban areas. Crude oil is typically transported hundreds of miles from extraction points and ports to reach refineries. Most transportation is by ocean tanker and pipeline. Probably only a very small proportion of criteria pollutants emitted in the transport of crude oil occur in nonattainment areas. Therefore, NHTSA ignored emissions reductions from feedstock transportation within nonattainment areas.

Because NHTSA ignores emissions changes from the first two upstream stages, our assumptions produce conservative estimates of emission reductions in nonattainment areas (*i.e.*, the estimates slightly underestimate the emissions benefits reductions associated with lower fuel production and use).

- Fuel refining – Fuel refining is the largest source of upstream emissions of criteria pollutants. Depending on the specific fuel and pollutant, fuel refining accounts for between one third and three quarters of all upstream emissions (based on outputs of the Volpe model). NHTSA used projected emissions data for 2022 from EPA's 2005-based air quality modeling platform (EPA 2009h) to allocate fuel refining emission reductions to nonattainment areas. The NEI estimates emissions of criteria and toxic pollutants by county and by source category code (SCC). Because there are specific SCCs for fuel refining processes, it is possible to determine the share of national fuel refining emissions allocated to each nonattainment area. It is assumed that the share of fuel refining emissions allocated to each nonattainment area does not change over time, and that fuel refining emissions will change uniformly across all refineries nationwide as a result of the alternatives.

- TS&D – NHTSA used data from the EPA modeling platform (EPA 2009h) to allocate TS&D emissions to nonattainment areas in the same way as for fuel refining emissions. It is assumed that the share of TS&D emissions allocated to each nonattainment area does not change over time, and that TS&D emissions will change uniformly nationwide as a result of the alternatives.

The data provided by EPA was missing county-level data for acetaldehyde, benzene, and formaldehyde. Therefore, for these three pollutants, NHTSA allocated national emissions based on the allocation of the pollutant that is believed to behave most similarly to the pollutant in question, as follows:

- For acetaldehyde, the data provided by EPA did not report TS&D emissions at the national or county level, so NHTSA assumed there are no acetaldehyde emissions associated with TS&D (*i.e.*, that 100 percent of upstream acetaldehyde emissions come from refining). The EPA data included national fuel-refining emissions of acetaldehyde, but data by county are not available. To allocate acetaldehyde emissions to counties, NHTSA used the county allocation of acrolein, because acrolein is the toxic air pollutant which has, among those for which county-level data were available, the highest proportion of its emissions coming from refining. Thus, the use of acrolein data for allocation of acetaldehyde emissions to counties is most consistent with the assumption that 100 percent of acetaldehyde emissions come from refining

- For benzene, the EPA data included nationwide fuel refining and TS&D emissions, and TS&D emissions at the county level, but not refining emissions at the county level. To allocate fuel refining emissions of benzene to counties, NHTSA used the same county allocation as butadiene because, among toxic air pollutants for which county-level data were available, butadiene has the ratio of fuel refining and TS&D emissions that is closest to the ratio for benzene emissions.

- For formaldehyde, the EPA data included national fuel refining and TS&D emissions, but county-level data were not available. To allocate formaldehyde emissions to counties, NHTSA used the same county allocation as for butadiene because, among toxic air pollutants for which county-level data were available, butadiene has the ratio of fuel refining and TS&D emissions that is closest to the ratio for formaldehyde emissions.

3.3.2.4.2 Health Outcomes and Monetized Benefits

Overview

This section describes the NHTSA approach to addressing public comments on the need to provide more quantitative estimates of adverse health effects of conventional air pollutants associated with each alternative.

In this analysis, NHTSA quantified and monetized impacts to human health for each alternative. The agency evaluated the health impacts of CAFE alternatives for four health outcomes – premature mortality, chronic bronchitis, respiratory emergency-room visits, and work-loss days. For each analysis year, this methodology estimates the health impacts of each alternative, expressed as the number of additional or avoided outcomes per year. The general approach to calculating health outcomes associated with each alternative is to multiply the pollutant-specific incidence-per-ton value (number of annual outcomes avoided per ton of pollutant emissions reduced) by the emissions of the pollutant (tons per year), summed across all pollutants. Similarly, the general approach to calculating the monetary value of the health outcomes for each alternative is to multiply the pollutant-specific benefits-per-ton value (dollar value of human health benefits per ton of pollutant emissions reduced) by the emissions of the pollutant (tons per year), summed across all pollutants. The impact of a CAFE action alternative is calculated as the difference in the monetized value of benefits or the number of health outcomes between that alternative and the No Action Alternative.

NHTSA estimated only the $PM_{2.5}$-related human health impacts that are expected to result from reduced population exposure to atmospheric concentrations of $PM_{2.5}$. The estimates are derived from $PM_{2.5}$-related dollar-per-ton estimates that include only quantifiable reductions in health impacts likely to result from reduced population exposure to particular matter (PM). Three other pollutants – NO_x, SO_2, and VOCs – are included in the analysis as precursor emissions that contribute to $PM_{2.5}$ not emitted directly from a source, but instead formed by chemical reactions in the atmosphere (secondary $PM_{2.5}$). The dollar-per-ton estimates do not include all health impacts related to reduced exposure to PM, nor do they include any reductions in health impacts resulting from lower population exposure to other criteria air pollutants (particularly ozone) and air toxics.

Monetized Health Impacts

The $PM_{2.5}$ benefit-per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of directly emitted $PM_{2.5}$, or its precursors (such as NO_x, SO_2, and VOCs), from a specified source. NHTSA followed the benefit-per-ton technique used in the EPA recent Ozone NAAQS Regulatory Impact Analysis (RIA) (EPA 2008a), Portland Cement National Emission Standards for Hazardous Air Pollutants (NESHAP) RIA (EPA 2009b), and NO_2 NAAQS (EPA 2009c). Table 3.3.2-2 lists the quantified and unquantified $PM_{2.5}$-related benefits captured in those benefit-per-ton estimates.

Table 3.3.2-2

Human Health and Welfare Effects of $PM_{2.5}$

Effects Quantified and Monetized in Primary Estimates	Unquantified Effects Changes in:
Adult premature mortality	Subchronic bronchitis cases
Bronchitis: chronic and acute	Low birth weight
Hospital admissions: respiratory and cardiovascular	Pulmonary function
Emergency room visits for asthma	Chronic respiratory diseases other than chronic bronchitis
Nonfatal heart attacks (myocardial infarction)	Non-asthma respiratory emergency room visits
Lower and upper respiratory illness	Visibility
Minor restricted-activity days	Household soiling
Work loss days	
Asthma exacerbations (asthmatic population)	
Infant mortality	

The benefits estimates utilize the concentration-response functions as reported in the epidemiology literature. Readers interested in reviewing the complete methodology for creating the benefit-per-ton estimates used in this analysis can consult the EPA Technical Support Document accompanying the final ozone NAAQS RIA (EPA 2008a). Readers can also refer to Fann *et al*. (2009) for a detailed description of the benefit-per-ton methodology.[20]

As described in the documentation for the benefit-per-ton estimates cited above, national per-ton estimates are developed for selected pollutant/source category combinations. The per-ton values calculated therefore apply only to tons reduced from those specific pollutant/source combinations (*e.g.*, NO_2 emitted from mobile sources; direct PM emitted from stationary sources). The NHTSA estimate of $PM_{2.5}$ benefits is therefore based on the total direct $PM_{2.5}$ and $PM_{2.5}$-related precursor emissions controlled by sector and multiplied by this per-ton value.

The benefit-per-ton coefficients were derived using modified versions of the health impact functions used in the EPA PM NAAQS RIA. Specifically, this analysis incorporated functions directly from the epidemiology studies without an adjustment for an assumed threshold.

PM-related mortality provides most of the monetized value in each benefit-per-ton estimate. NHTSA calculated the premature-mortality-related effect coefficients that underlie the benefits-per-ton estimates from epidemiology studies that examined two large population cohorts – the American Cancer

[20] The values included in this analysis are different from those in Fann *et al.* (2009) cited above. Benefits methods change to reflect new information and evaluation of the science. Since publication of Fann *et al.* (2009), EPA has made two significant changes to its benefits methods: (1) EPA no longer assumes that there is a threshold in PM-related models of health impacts and (2) EPA has revised the Value of a Statistical Life to equal $6.3 million (in year 2000 dollars), up from an estimate of $5.5 million (in year 2000 dollars) used in Fann *et al.* (2009). Refer to the following website for updates to the dollar-per-ton estimates: http://www.epa.gov/air/benmap/bpt.html.

Society cohort (Pope *et al.* 2002) and the Harvard Six Cities cohort (Laden *et al.* 2006). These are logical choices for anchor points when presenting PM-related benefits because, while both studies are well designed and peer reviewed, there are strengths and weaknesses inherent in each, which argues for using both studies to generate benefits estimates. However, due to the analytical limitations associated with this analysis, NHTSA chose to use the benefit-per-ton value derived from the American Cancer Society study and note that benefits would be approximately 145 percent (or almost two-and-a-half times) larger if the agency used the Harvard Six Cities values.

The benefits-per-ton estimates used in this analysis are based on a value of statistical life (VSL) estimate that was vetted and endorsed by EPA's Science Advisory Board (SAB) in the Guidelines for Preparing Economic Analyses (EPA 2000b).[21] This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (in 2000 dollars). The dollar-per-ton estimates NHTSA used in this analysis are based on this VSL and listed in Table 3.3.2-3.

Table 3.3.2-3

Benefits-per-ton Values (2007$) Derived Using the ACS Cohort Study for PM-related Premature Mortality (Pope *et al.* 2002) a/ and a 3-Percent Discount Rate b/

Year c/	All Sources d/		Stationary (Non-EGU e/) Sources		Mobile Sources	
	SO_x	VOC	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
2016	$29,000	$1,200	$4,800	$220,000	$4,900	$270,000
2020	$31,000	$1,300	$5,100	$240,000	$5,300	$290,000
2030	$36,000	$1,500	$6,100	$280,000	$6,400	$350,000
2040	$43,000	$1,800	$7,200	$330,000	$7,600	$420,000

a/ The benefit-per-ton estimates in this table are based on an estimate of premature mortality derived from the American Cancer Society study (Pope *et al.* 2002). If the benefit-per-ton estimates were based on the Six Cities study (Laden *et al.* 2006), the values would be approximately 145 percent (nearly two-and-a-half times) larger.
b/ The benefit-per-ton estimates in this table assume a 3-percent discount rate in the valuation of premature mortality to account for a 20-year segmented cessation lag. If a 7-percent discount rate had been used, the values would be approximately 9 percent lower.
c/ Benefit-per-ton values were estimated for the years 2015, 2020, and 2030. For 2016, NHTSA interpolated exponentially between 2015 and 2020. For 2040, NHTSA extrapolated exponentially based on the growth between 2020 and 2030.
d/ Note that the benefit-per-ton value for SO_x is based on the value for Stationary (Non-EGU) sources; no SO_x value was estimated for mobile sources. The benefit-per-ton value for VOCs was estimated across all sources.
e/ Non-EGU = Sources other than electric generating units (power plants).

Quantified Health Impacts

Table 3.3.2-4 lists the incidence-per-ton estimates for select PM-related endpoints (derived by the same process as described above for the dollar-per-ton estimates).

For the analysis of direct and indirect impacts (*see* Section 3.4), NHTSA used the values for 2016, 2020, and 2030 (*see* Section 3.3.2.2). For the analysis of cumulative impacts (s*ee* Section 4.3), which also includes estimated impacts for 2050, NHTSA used the same values and used the values for 2040 for the 2050 analysis.

[21] In the (draft) update of the Economic Guidelines (EPA 2008c), EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming in the near future. Therefore, this report does not represent final agency policy.

Table 3.3.2-4

Incidence-per-ton Values for Health Outcomes – Pope *et al.* 2002b

Year a/	All Sources b/		Stationary (Non-EGU c/) Sources		Mobile Sources	
	SO_x	VOC	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
			Premature Mortality – Pope *et al.* 2002b/			
2016	0.003325787	0.000137288	0.000547035	0.025732657	0.000569579	0.031175340
2020	0.003458671	0.000143397	0.000570861	0.026715546	0.000596007	0.032639009
2030	0.003975998	0.000167016	0.000663928	0.030515150	0.000697373	0.038060658
2040	0.004570704	0.000194525	0.000772167	0.034855151	0.000815979	0.044382895
			Chronic Bronchitis			
2016	0.002277723	0.000096601	0.000397136	0.017420574	0.000414238	0.022207886
2020	0.0023816082	0.0001012424	0.0004171427	0.0181752796	0.0004359040	0.0232993398
2030	0.0026209886	0.0001118571	0.0004635162	0.0199109220	0.0004858213	0.0258578276
2040	0.002884430	0.000123585	0.000515045	0.021812309	0.000541455	0.028697262
			Emergency Room Visits – Respiratory			
2016	0.003099058	0.000103060	0.000451637	0.025462154	0.000441076	0.025601267
2020	0.0032303276	0.0001070418	0.0004698051	0.0265119244	0.0004597436	0.0266615404
2030	0.0035320012	0.0001164697	0.0005108599	0.0289098974	0.0005019649	0.0291780116
2040	0.003861848	0.000126728	0.000555502	0.031524764	0.000548064	0.031932002
			Work Loss Days			
2016	0.438375533	0.018707314	0.077980894	3.360146515	0.081423310	4.305601155
2020	0.4465435076	0.0190630849	0.0796512748	3.4161853728	0.0832854645	4.3980698724
2030	0.4691223356	0.0199715639	0.0839602703	3.5832489831	0.0879939906	4.6493469302
2040	0.492842829	0.020923338	0.088502375	3.758482598	0.092968712	4.914980322

a/ Benefit-per-ton values were estimated for the years 2015, 2020, and 2030. For 2016, NHTSA interpolated exponentially between 2015 and 2020. For 2040, NHTSA extrapolated exponentially based on growth between 2020 and 2030.
b/ The PM-related premature mortality incidence-per-ton estimates presented in this table are based on an estimate of premature mortality derived from the ACS study (Pope *et al.* 2002). If the incidence-per-ton estimates were based on the Six Cities study (Laden *et al.* 2006), the values would be approximately 145 percent (nearly two-and-a-half times) larger.
c/ Non-EGU = Sources other than electric generating units (power plants).

Assumptions and Uncertainties

The benefit-per-ton estimates are subject to a number of assumptions and uncertainties, as follows:

- They do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an overestimate or underestimate of the actual benefits of controlling fine particulates. Emissions changes and benefits-per-ton estimates alone are not a good indication of local or regional air quality and health impacts, because there could be localized impacts associated with the proposed action. Because the atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone, and air toxics is very complex, full-scale photochemical air quality modeling would be necessary to control for local variability. Full-scale photochemical modeling would provide the needed spatial and temporal detail to more completely and accurately estimate changes in ambient levels of these pollutants and their associated health and welfare impacts. To support and confirm the screening-level, benefit-per-ton estimates, NHTSA performed full-scale photochemical air quality modeling of a selection of alternatives as discussed below and in Appendix F. This modeling provides insight into the uncertainties associated with the use of benefits-per-ton estimates. EPA is conducting full-scale photochemical modeling for its rulemaking on vehicle GHG standards, which is an element of the joint NHTSA-EPA rulemaking for CAFE (NHTSA) and GHG (EPA) standards for MYs 2012-2016 passenger cars and light trucks. It should be noted that the air quality modeling presented in Appendix F differs in a number of key respects from the modeling EPA is conducting for the analysis of the final standard, as discussed in Appendix E. These differences include:

- Use of a more recent version of CMAQ by EPA (this version was not publicly available at the time NHTSA performed its modeling),
- Use of a 2005 base year modeling platform compared to the 2002 platform used in the NHTSA modeling,
- Use of a finer 12-km U.S. spatial modeling grid compared to the 36-km resolution used in the NHTSA modeling,
- Estimation of global boundary conditions from a global chemistry model compared to the static boundary conditions used in the NHTSA modeling, and
- EPA's modeling of vehicle emissions accounts for geographic variations in factors such as ambient temperature, age distribution of the fleet, and fuel composition (especially with regard to the ethanol fraction), while the NHTSA modeling of vehicle emissions is based on national average characteristics.

- NHTSA assumed that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from stationary sources might differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but there are no clear scientific grounds to support estimating differential effects by particle type.
- NHTSA assumed that the health impact function for fine particles is linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both regions that are in attainment with the fine-particle standard and those that do not meet the standard down to the lowest modeled concentrations.
- There are several health-benefits categories NHTSA was unable to quantify due to limitations associated with using benefits-per-ton estimates, several of which could be substantial. Because NO_x and VOCs are also precursors to ozone, reductions in NO_x and VOC emissions would also reduce ozone formation and the health effects associated with ozone exposure. Unfortunately, there are no benefits-per-ton estimates because of issues associated with the complexity of the atmospheric air chemistry and nonlinearities associated with ozone formation. The PM-related benefits-per-ton estimates also do not include any human welfare or ecological benefits.

Photochemical Air Quality Modeling and Risk Assessment

To support and confirm the health effects and health-related economic estimates in this EIS, a national-scale photochemical air quality modeling and heath risk assessment was conducted for a representative subset of the DEIS alternatives. The study used air quality modeling and health benefits analysis tools to quantify the air quality and health-related benefits associated with the alternative CAFE standards. Four alternatives from the DEIS were modeled: the No Action Alternative and Alternative 2 (the 3-Percent Alternative) to represent fuel economy requirements at the lower end of the range; Alternative 4 (the Preferred Alternative); and Alternative 8 (the 7 Percent Alternative) to represent fuel economy requirements at the higher end of the range. The photochemical air quality study is included as Appendix F to this EIS.

NHTSA used the DEIS Volpe model data and the photochemical air quality modeling tools to determine whether NHTSA's EIS scaling approach to estimating health effects and monetized health benefits – using the EPA incidence-per-ton and benefits-per-ton data – is sufficient to determine the differences among the alternatives as NEPA requires. Because the photochemical air quality analysis is a detailed analysis that takes several months to complete, the FEIS Volpe data were not available when the agency began its analysis. The photochemical air quality modeling is a more detailed examination of the air quality impacts already analyzed using the EIS benefits-per-ton estimates scaling approach. Because NHTSA's analysis shows agreement between the scaling method and the results of the photochemical modeling, the new information confirms the adequacy of the air quality analysis methodology NHTSA uses in its EIS as sufficient to distinguish air quality impacts among the alternatives. Therefore, the photochemical modeling did not reveal significant effects not previously considered. This analysis is an appropriate tool to confirm NHTSA's air quality and health effects methodology and results, and a supplemental EIS is not required.[22]

The photochemical air quality modeling analysis provides the most detailed, comprehensive, and accurate estimates available on the potential health effects and health-related economic effects of the CAFE alternatives. The analysis demonstrates that the health and economic effects calculated in the EIS using EPA's incidence-per-ton and benefits-per-ton data are comparable to the detailed estimates from the photochemical air quality analysis.

3.3.3 Environmental Consequences

3.3.3.1 Results of the Emissions Analysis

The CAA has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and EPA projects that they will continue to decline. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternative CAFE standards. The analysis by alternative in this section shows that the CAFE action alternatives will lead to both reductions and increases in emissions from passenger cars and light trucks, compared to current trends without the proposed CAFE standards. The amounts of the reductions and increases would vary by pollutant, calendar year, and action alternative. The more restrictive action alternatives generally would result in greater emissions reductions compared to the No Action Alternative.

Sections 3.3.3.2 through 3.3.3.10 describe the results of the emissions analysis for Alternatives 1 through 9.

[22] *See Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 374 (1989) (noting that application of the rule of reason in the supplemental EIS context turns on the value of the new information to the decisionmaking process). An agency must prepare a supplement to a draft EIS if there "are significant new circumstances or information relevant to environmental consequences and bearing on the proposed action or its impacts." 40 CFR § 1502.9(c). *See Sierra Club v. L. Van Antewerp*, 526 F.3d 1353, 1360 (11th Cir. 2008) (noting that an agency must prepare a supplemental EIS when the receipt of additional information reveals new, significant effects on the quality of the human environment not previously considered).

3.3.3.2 Alternative 1: No Action

3.3.3.2.1 Criteria Pollutants

Under the No Action Alternative, average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturers' required level of average fuel economy for MY 2011. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The EPA vehicle emissions standards regulate all criteria pollutants except SO_2, which is regulated through fuel sulfur content. The No Action Alternative would not result in any change in criteria pollutant emissions, other than current trends, in nonattainment and maintenance areas throughout the United States.

Table 3.3.3-1 summarizes the total national emissions from passenger cars and light trucks by alternative for each of the criteria pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 9) left to right in order of increasing fuel economy requirements. Figure 3.3.3-1 illustrates this information. Table 3.3.3-1 and Figure 3.3.3-1 show that changes in overall emissions between the No Action Alternative and Alternatives 2 through 4 are generally smaller than those between the No Action Alternative and Alternatives 5 through 9. In the case of NO_x, $PM_{2.5}$, SO_x, and VOCs, the No Action Alternative results in the highest emissions, and emissions generally decline as fuel economy standards increase across alternatives. Across Alternatives 4 through 9 there are some emissions increases from one alternative to another, but emissions remain below the levels under the No Action Alternative. In the case of CO, emissions under Alternatives 2 through 4 are slightly higher than under the No Action Alternative. Emissions of CO generally decline, though unevenly, as fuel economy standards increase across Alternatives 5 through 9.

Total emissions are composed of four components: tailpipe emissions and upstream emissions for passenger cars, and tailpipe emissions and upstream emissions for light trucks. To show the relationship among these four components for criteria pollutants, Table 3.3.3-2 breaks down the total emissions of criteria pollutants by component for calendar year 2030.

Table 3.3.3-3 lists the net change in nationwide emissions from passenger cars and light trucks compared to the No Action Alternative for each of the criteria pollutants and analysis years. The table lists the action alternatives (Alternatives 2 through 9) left to right in order of increasing fuel economy requirements. In Table 3.3.3-3, the nationwide emissions reductions of NO_x, SO_x, and VOCs generally become greater from left to right, reflecting the increasing fuel economy requirements assumed under successive alternatives, although the decreases are smaller for some pollutants and years under Alternatives 5 through 9 due to the interaction of VMT, fuel economy, and the share of VMT accrued by diesel vehicles. Emissions of $PM_{2.5}$ follow the same trend to a lesser extent, with the reductions becoming smaller from Alternative 5 to Alternative 8 before increasing again under Alternative 9. Emissions of CO under Alternatives 2 through 4 are exceptions, showing increases compared to the No Action Alternative, because increases in VMT more than offset increases in fuel efficiency and declines in CO emission rates per vehicle.

One of the ways that the Volpe model projects vehicle manufacturers can achieve higher fuel economy is to increase the share of new vehicles that use diesel engines. The resulting increase in the use of diesel fuel as mpg standards become more stringent across action alternatives can interact with other factors, such as changes in VMT, the car and light truck shares, and the shares of other technologies such as hybrids, to affect emissions of different pollutants in different ways across Alternatives. Another result of increasing forecasted use of diesel engines can be that differing upstream emission rates might change

Table 3.3.3-1

Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
2016	20,380,537	20,393,938	20,394,480	20,383,598	20,272,923	20,182,256	20,228,025	20,168,102	20,173,726
2020	19,129,794	19,168,534	19,173,637	19,152,242	18,857,762	18,607,550	18,702,398	18,525,038	18,566,710
2030	20,516,692	20,625,314	20,653,244	20,611,910	19,847,892	19,203,414	19,361,096	18,867,420	19,034,022
Nitrogen oxides (NO_x)									
2016	2,210,405	2,207,302	2,205,558	2,204,404	2,201,606	2,197,765	2,199,718	2,197,430	2,196,989
2020	1,756,741	1,749,121	1,745,092	1,742,950	1,733,886	1,724,211	1,727,891	1,721,445	1,721,997
2030	1,425,733	1,410,414	1,402,605	1,398,774	1,371,749	1,345,911	1,351,818	1,332,981	1,338,453
Particulate matter ($PM_{2.5}$)									
2016	68,793	68,374	68,122	68,024	68,424	68,603	68,606	68,737	68,605
2020	68,906	67,821	67,223	67,055	67,782	68,113	68,159	68,484	68,247
2030	84,021	81,726	80,498	80,206	81,194	81,484	81,637	82,126	81,839
Sulfur Oxides (SO_x)									
2016	176,518	173,665	172,306	171,666	172,232	171,378	171,729	171,422	170,947
2020	184,239	177,076	173,851	172,779	173,439	172,286	172,419	171,950	171,414
2030	216,228	200,884	194,149	192,374	192,985	191,324	190,961	190,214	189,760
Volatile organic compounds (VOCs)									
2016	2,505,277	2,491,567	2,484,860	2,480,794	2,470,902	2,455,914	2,461,292	2,453,075	2,452,838
2020	2,163,685	2,129,680	2,114,100	2,107,249	2,082,209	2,052,680	2,058,723	2,040,157	2,043,942
2030	1,881,987	1,810,076	1,778,691	1,767,262	1,708,646	1,649,731	1,655,217	1,614,158	1,627,859

Figure 3.3.3-1. Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative

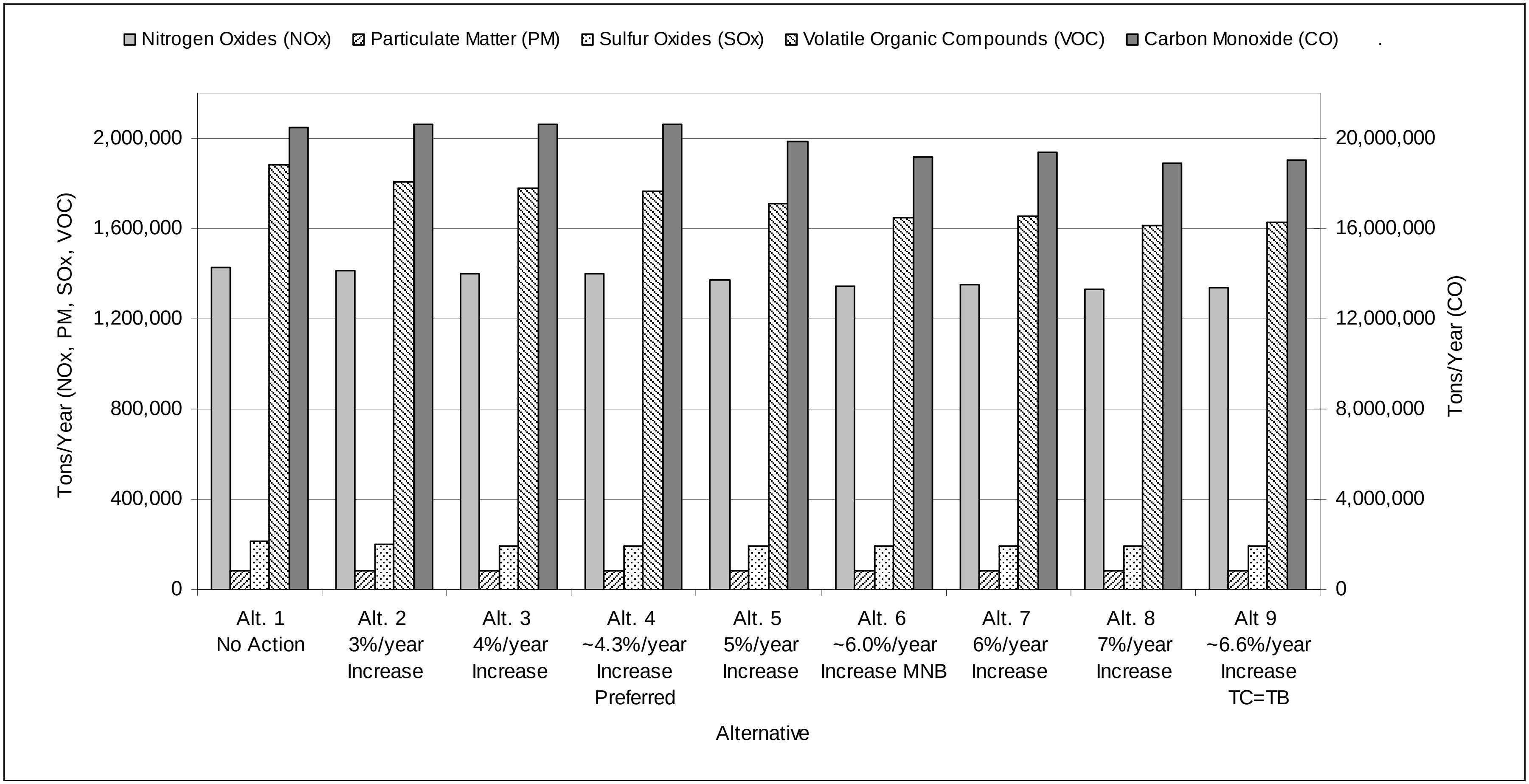


Table 3.3.3-2

Nationwide Criteria Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Poll. and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
Car Tail	10,045,431	10,056,403	10,114,957	10,117,191	9,852,164	9,676,743	9,646,119	9,467,007	9,520,432
Car Up	56,362	52,139	50,141	49,671	49,712	49,083	49,198	48,933	48,972
Truck Tail	10,375,524	10,479,934	10,452,279	10,409,473	9,909,803	9,441,137	9,629,644	9,315,162	9,428,649
Truck Up	39,375	36,839	35,868	35,576	36,214	36,451	36,135	36,318	35,969
Total	20,516,692	20,625,314	20,653,244	20,611,910	19,847,892	19,203,414	19,361,096	18,867,420	19,034,022
Nitrogen oxides (NO_x)									
Car Tail	360,141	360,706	362,717	362,816	354,215	348,510	347,521	341,730	343,464
Car Up	176,443	163,055	156,849	155,362	154,888	152,523	152,828	151,653	151,867
Truck Tail	766,002	771,372	770,883	769,408	750,084	732,206	739,610	727,565	731,947
Truck Up	123,148	115,280	112,157	111,188	112,563	112,673	111,859	112,034	111,175
Total	1,425,733	1,410,414	1,402,605	1,398,774	1,371,749	1,345,911	1,351,818	1,332,981	1,338,453
Particulate matter ($PM_{2.5}$)									
Car Tail	22,502	22,920	22,931	22,976	23,924	24,585	24,689	25,358	25,168
Car Up	24,026	22,234	21,380	21,180	21,231	20,984	21,036	20,942	20,954
Truck Tail	20,703	20,867	20,890	20,874	20,558	20,299	20,441	20,255	20,308
Truck Up	16,790	15,706	15,297	15,175	15,481	15,616	15,472	15,572	15,410
Total	84,021	81,726	80,498	80,206	81,194	81,484	81,637	82,126	81,839
Sulfur Oxides (SO_x)									
Car Tail	19,460	17,814	17,180	17,000	16,330	15,662	15,642	15,157	15,276
Car Up	107,889	99,867	96,023	95,130	95,437	94,385	94,624	94,250	94,289
Truck Tail	13,465	12,669	12,239	12,077	11,592	10,957	11,045	10,656	10,802
Truck Up	75,414	70,534	68,708	68,168	69,625	70,319	69,649	70,151	69,394
Total	216,228	200,884	194,149	192,374	192,985	191,324	190,961	190,214	189,760
Volatile organic compounds (VOCs)									
Car Tail	289,746	290,863	292,113	292,259	288,769	286,519	286,102	283,812	284,522
Car Up	588,841	537,102	518,485	512,862	485,595	460,751	459,531	440,785	445,478
Truck Tail	597,298	599,279	599,260	598,828	592,877	587,618	590,056	586,425	587,601
Truck Up	406,101	382,832	368,833	363,313	341,405	314,844	319,529	303,135	310,259
Total	1,881,987	1,810,076	1,778,691	1,767,262	1,708,646	1,649,731	1,655,217	1,614,158	1,627,859

Table 3.3.3-3

Nationwide Changes in Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative a/ b/

Poll. and Year	Alt. 1 No Action c/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
2016	0	13,402	13,943	3,062	-107,614	-198,280	-152,511	-212,434	-206,811
2020	0	38,740	43,844	22,448	-272,031	-522,244	-427,396	-604,755	-563,084
2030	0	108,622	136,552	95,218	-668,801	-1,313,279	-1,155,596	-1,649,272	-1,482,670
Nitrogen oxides (NO_x)									
2016	0	-3,103	-4,847	-6,001	-8,799	-12,640	-10,687	-12,976	-13,416
2020	0	-7,620	-11,649	-13,791	-22,855	-32,530	-28,850	-35,296	-34,744
2030	0	-15,319	-23,128	-26,959	-53,984	-79,822	-73,915	-92,752	-87,280
Particulate matter ($PM_{2.5}$)									
2016	0	-420	-672	-770	-369	-191	-187	-57	-189
2020	0	-1,085	-1,683	-1,851	-1,125	-793	-747	-423	-659
2030	0	-2,295	-3,523	-3,816	-2,827	-2,537	-2,384	-1,895	-2,182
Sulfur Oxides (SO_x)									
2016	0	-2,853	-4,212	-4,852	-4,286	-5,140	-4,788	-5,096	-5,571
2020	0	-7,163	-10,388	-11,460	-10,800	-11,953	-11,820	-12,289	-12,825
2030	0	-15,344	-22,079	-23,854	-23,243	-24,904	-25,267	-26,014	-26,468
Volatile organic compounds (VOCs)									
2016	0	-13,710	-20,417	-24,484	-34,375	-49,363	-43,985	-52,202	-52,439
2020	0	-34,005	-49,585	-56,436	-81,475	-111,004	-104,961	-123,527	-119,742
2030	0	-71,911	-103,296	-114,725	-173,341	-232,255	-226,770	-267,829	-254,128

a/ Emissions changes have been rounded to the nearest whole number.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

pollutant emissions estimates, as compared to those rates for gasoline fueled engines. Projected changes in the share of diesel vehicles appear to be a factor in the results for CO that show increases in emissions compared to the No Action Alternative under Alternatives 2 through 4 and decreases in emissions compared to the No Action Alternative under Alternatives 6 through 9.

3.3.3.2.2 Toxic Air Pollutants

Under Alternative 1 (No Action), the average fuel economy would remain at the MY 2011 level in future years. As with the criteria pollutants, current trends in the levels of toxic air pollutant emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. An exception to this general trend is DPM, for which emissions are projected to increase over time under the No Action Alternative due to increasing use of diesel vehicles and increasing VMT. EPA regulates toxic air pollutants from motor vehicles through vehicle emissions standards and fuel quality standards, as discussed in Section 3.3.1. The No Action Alternative would not change the current CAFE standards and therefore would not result in any change in toxic air pollutant emissions, other than current trends in emissions and VMT, in nonattainment and maintenance areas throughout the United States.

Table 3.3.3-4 summarizes the total national emissions of toxic air pollutants from passenger cars and light trucks by alternative for each of the pollutants and analysis years. Figure 3.3.3-2 lists the total national emissions of toxic air pollutants from passenger cars and light trucks by alternative. Emissions of benzene and DPM are highest under the No Action Alternative, and emissions of acrolein and formaldehyde are highest under Alternative 8. Emissions of acetaldehyde are highest under Alternatives 8 and 9 in 2016, Alternative 8 in 2020, but highest under Alternative 4 in 2030. Emissions of 1,3-butadiene is highest under Alternative 8 in 2016, Alternative 8 in 2020,, and highest under Alternative 3 in 2030.

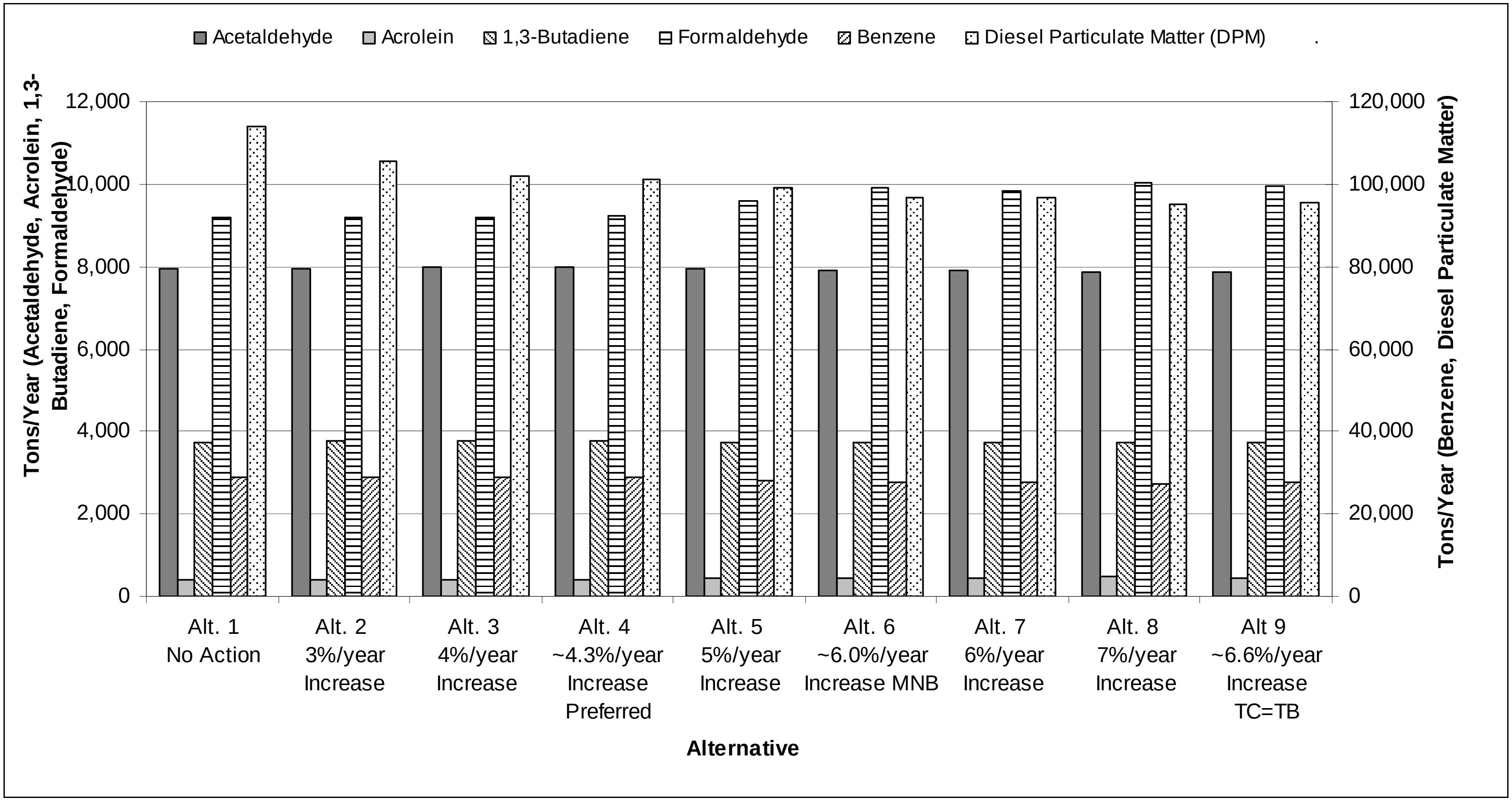
The trends for toxic air pollutant emissions across the alternatives are mixed. Table 3.3.3-4 shows the emissions of acetaldehyde increase under each successive alternative from Alternative 1 to Alternative 9, except for Alternatives 2, 7, and 9 in 2016, Alternatives 7 and 9 in 2020, and Alternatives 5 through 8 in 2030. In Alternatives 6 through 9 in 2030, acetaldehyde emissions are below those in the No Action alternative. Emissions of acrolein remain constant or increase under each successive alternative from Alternative 1 to Alternative 9, except for Alternatives 7 and 9. Emissions of benzene decrease under each successive alternative from Alternative 1 to Alternative 9, except for Alternatives 7 and 9. Emissions of 1,3-butadiene in 2016 increase under each successive alternative from Alternative 1 to Alternative 9, except under Alternatives 7 and 9; emissions of 1,3-butadiene in 2020 increase under each successive alternative from Alternative 1 to Alternative 9, except under Alternative 9; emissions of 1,3-butadiene in 2030 increase under each successive alternative from Alternative 1 to Alternative 9, except for Alternatives 4 through 6 and 8. Emissions of DPM decrease under each successive alternative from Alternative 1 to Alternative 9, except for Alternative 7 in 2016, Alternatives 7 and 9 in 2020 and 2030. Emissions of formaldehyde decrease under each successive alternative from Alternative 1 to Alternative 9, except for Alternatives 3 through 6 and 8. These trends are accounted for by the interaction between the share of VMT accrued by diesel vehicles, which increases across successive years as well as successive alternatives in the Volpe model, and fuel economy, which increases across successive alternatives except for Alternative 9.

Table 3.3.3-4

Nationwide Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Acetaldehyde									
2016	10,921	10,919	10,924	10,928	10,955	10,976	10,960	10,977	10,977
2020	9,024	9,027	9,036	9,041	9,069	9,098	9,084	9,104	9,097
2030	7,927	7,951	7,973	7,976	7,929	7,905	7,902	7,872	7,879
Acrolein									
2016	561	561	561	562	569	576	572	577	576
2020	455	456	456	458	472	486	482	491	488
2030	391	394	395	397	425	449	445	463	457
Benzene									
2016	56,184	56,162	56,150	56,139	56,080	56,019	56,045	56,008	56,010
2020	43,121	43,075	43,049	43,025	42,840	42,669	42,729	42,613	42,635
2030	28,961	28,900	28,863	28,815	28,203	27,673	27,788	27,388	27,519
1,3-butadiene									
2016	6,100	6,101	6,102	6,103	6,107	6,112	6,109	6,113	6,112
2020	4,874	4,879	4,881	4,882	4,883	4,887	4,888	4,891	4,889
2030	3,751	3,771	3,777	3,776	3,747	3,724	3,734	3,717	3,722
Diesel particulate patter (DPM)									
2016	93,117	91,618	90,856	90,463	90,213	89,313	89,679	89,227	89,075
2020	97,085	93,300	91,516	90,865	90,117	88,550	88,862	88,008	88,018
2030	113,884	105,735	102,053	100,991	99,301	96,641	96,743	95,220	95,595
Formaldehyde									
2016	13,700	13,685	13,692	13,707	13,833	13,937	13,874	13,948	13,943
2020	10,980	10,956	10,968	10,990	11,223	11,434	11,351	11,498	11,457
2030	9,190	9,173	9,194	9,224	9,580	9,911	9,818	10,051	9,964

Figure 3.3.3-2. Nationwide Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative



One of the ways that the Volpe model projects vehicle manufacturers can achieve higher fuel economy is to increase the share of new vehicles that use diesel engines. The resulting increase in the use of diesel fuel as mpg standards become more stringent across action alternatives can interact with other factors, such as changes in VMT, the car and light truck shares, and the shares of other technologies such as hybrids, to affect emissions of different pollutants in different ways across Alternatives. Another result of increasing forecasted use of diesel engines can be that differing upstream emission rates might change pollutant emissions estimates, as compared to those rates for gasoline fueled engines. Projected changes in the share of diesel vehicles appear to be a factor in the results for acetaldehyde and 1,3-butadiene that show increases in emissions compared to the No Action Alternative under Alternatives 2 through 4 and decreases in emissions compared to the No Action Alternative under Alternatives 6 through 9.

Total emissions are composed of four components: tailpipe emissions and upstream emissions for passenger cars, and tailpipe emissions and upstream emissions for light trucks. To show the relationship among these four components for air toxic pollutants, Table 3.3.3-5 breaks down the total emissions of air toxic pollutants by component for calendar year 2030.

Table 3.3.3-6 lists the net change in nationwide emissions from passenger cars and light trucks for each of the toxic air pollutants and analysis years. After the No Action Alternative (Alternative 1), the table presents the action alternatives (Alternatives 2 through 9) left to right; this corresponds to the order of increasing fuel economy except for Alternative 9. In Table 3.3.3-6, the nationwide emissions changes are uneven in relation to pollutant and alternative, although some demonstrate reductions, reflecting the changes in VMT and emissions by passenger cars versus light trucks and gasoline versus diesel engines projected to occur with the increasing fuel economy requirements assumed under successive alternatives.

3.3.3.2.3 Health Outcomes and Monetized Benefits

Under Alternative 1 (No Action), average fuel economy would remain at the MY 2011 level in future years. Current trends in the levels of criteria pollutants and toxic air pollutants emissions from vehicles would continue, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. The human health-related impacts that occur under current trends would continue. The No Action Alternative would not result in any other increase or decrease in human health impacts throughout the United States.

3.3.3.3 Alternative 2: 3-Percent Annual Increase

3.3.3.3.1 Criteria Pollutants

Under the 3-Percent Alternative (Alternative 2), generally the CAFE standards would require increased fuel economy compared to the No Action Alternative (Alternative 1). Alternative 2 would increase fuel economy less than would Alternatives 3 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 2 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.1 to 1.1 percent, $PM_{2.5}$ emissions would be reduced 0.6 to 2.7 percent, SO_x emissions would be reduced 1.6 to 7.1 percent, and VOC emissions would be reduced 0.5 to 3.8 percent. There would be increases of CO emissions. CO emissions would increase 0.1 to 0.5 percent under Alternative 2, depending on the year.

Table 3.3.3-5

Nationwide Toxic Air Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Poll. and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Acetaldehyde									
Car Tail	3,453	3,467	3,484	3,486	3,435	3,403	3,397	3,364	3,374
Car Up	63	58	56	55	54	52	52	51	51
Truck Tail	4,367	4,385	4,394	4,397	4,401	4,413	4,415	4,421	4,416
Truck Up	44	41	40	39	39	37	37	37	37
Total	7,927	7,951	7,973	7,976	7,929	7,905	7,902	7,872	7,879
Acrolein									
Car Tail	162	166	166	166	178	187	188	196	194
Car Up	9	8	8	8	7	7	7	7	7
Truck Tail	215	214	216	218	234	250	244	255	251
Truck Up	6	6	5	5	5	5	5	5	5
Total	391	394	395	397	425	449	445	463	457
Benzene									
Car Tail	9,427	9,447	9,495	9,498	9,310	9,185	9,163	9,038	9,076
Car Up	1,274	1,165	1,124	1,112	1,064	1,017	1,015	981	989
Truck Tail	17,378	17,458	17,443	17,415	17,076	16,764	16,896	16,685	16,758
Truck Up	881	829	801	790	753	707	714	685	696
Total	28,961	28,900	28,863	28,815	28,203	27,673	27,788	27,388	27,519
1,3-butadiene									
Car Tail	1,518	1,529	1,534	1,536	1,532	1,530	1,529	1,527	1,528
Car Up	14	13	12	12	12	12	12	12	12
Truck Tail	2,210	2,220	2,221	2,220	2,194	2,173	2,183	2,168	2,173
Truck Up	10	9	9	9	9	9	9	9	9
Total	3,751	3,771	3,777	3,776	3,747	3,724	3,734	3,717	3,722
Diesel particulate matter (DPM)									
Car Tail	15	269	193	218	1,204	1,883	1,992	2,674	2,476
Car Up	67,202	61,635	59,410	58,800	56,920	54,897	54,865	53,437	53,782
Truck Tail	88	49	95	138	572	996	841	1,121	1,015
Truck Up	46,580	43,781	42,355	41,835	40,605	38,865	39,045	37,988	38,322
Total	113,884	105,735	102,053	100,991	99,301	96,641	96,743	95,220	95,595

Table 3.3.3-5 (cont'd)

Nationwide Toxic Air Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Pollutant and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Formaldehyde									
Car Tail	3,564	3,612	3,619	3,624	3,698	3,754	3,761	3,814	3,799
Car Up	472	434	418	414	405	394	394	387	388
Truck Tail	4,827	4,820	4,859	4,891	5,186	5,480	5,379	5,571	5,497
Truck Up	328	308	298	295	291	284	284	279	280
Total	9,190	9,173	9,194	9,224	9,580	9,911	9,818	10,051	9,964

Table 3.3.3-6

Nationwide Changes in Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative a/ b/

Poll. and Year	Alt. 1 No Action c/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Acetaldehyde									
2016	0	-2	3	7	33	55	39	56	56
2020	0	2	12	16	44	74	60	80	73
2030	0	24	46	50	2	-21	-25	-54	-48
Acrolein									
2016	0	0	0	1	8	15	11	16	15
2020	0	0	1	3	17	30	26	36	33
2030	0	3	4	6	34	58	53	72	66
Benzene									
2016	0	-21	-33	-45	-104	-165	-139	-175	-174
2020	0	-46	-72	-96	-282	-452	-393	-508	-486
2030	0	-61	-98	-146	-757	-1,288	-1,172	-1,572	-1,441
1,3-Butadiene									
2016	0	1	2	3	7	12	10	13	13
2020	0	5	7	8	9	13	14	17	15
2030	0	20	25	25	-4	-27	-17	-34	-29
Diesel particulate matter (DPM)									
2010	0	-1,499	-2,261	-2,654	-2,904	-3,804	-3,438	-3,890	-4,042
2020	0	-3,786	-5,570	-6,220	-6,969	-8,536	-8,223	-9,078	-9,068
2030	0	-8,150	-11,832	-12,894	-14,584	-17,243	-17,141	-18,665	-18,290
Formaldehyde									
2010	0	-15	-7	8	134	237	175	249	243
2020	0	-24	-11	10	244	454	371	518	477
2030	0	-18	4	33	390	721	627	861	774

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.

At the national level, the reduction in upstream emissions of criteria air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. For example, a nonattainment area that contains petroleum-refining facilities, such as Houston-Galveston-Brazoria, Texas, would experience more reductions in upstream emissions than an area that has none. There can be net emissions reductions if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. Under Alternative 2, all nonattainment areas would experience reductions in emissions of SO_x and VOCs. Some nonattainment areas would experience increases of CO, NO_x, and $PM_{2.5}$ emissions. The increases in CO, NO_x, and $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect, particularly for CO emissions, which are dominated by tailpipe emissions rather than upstream emissions. Although NO_x and $PM_{2.5}$ emissions would increase in some nonattainment areas, the increase in each area is generally quite small. The decreases in nationwide NO_x and $PM_{2.5}$ emissions are the result of the decreases in upstream emissions and do not occur in all nonattainment areas. Although NO_x and $PM_{2.5}$ emissions would decrease in fewer nonattainment areas, the decreases in each area are much larger. The net result is decreased NO_x and $PM_{2.5}$ emissions nationwide.

Tables in Appendix C list the emissions reductions for each nonattainment area. Table 3.3.3-7 summarizes the criteria air pollutant results by nonattainment area.

Table 3.3.3-7

Criteria Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative a/

Criteria Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
CO	Maximum Increase	5,420	2030	2	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	56,925	2030	9	Los Angeles South Coast Air Basin, CA
NO_x	Maximum Increase	149	2030	2	Dallas-Fort Worth, TX
	Maximum Decrease	4,350	2030	8	Houston-Galveston-Brazoria, TX
$PM_{2.5}$	Maximum Increase	23	2020	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	402	2030	6	Houston-Galveston-Brazoria, TX
SO_x	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	1,713	2030	6	Chicago-Gary-Lake Co, IL-IN
VOCs	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	7668	2030	9	Houston-Galveston-Brazoria, TX

a/ Emissions changes have been rounded to the nearest whole number.

3.3.3.3.2 Toxic Air Pollutants

There would be reductions in nationwide emissions of benzene, DPM, and formaldehyde in all analysis years under Alternative 2 compared to the No Action Alternative. Emissions for the other toxic air pollutants and years are constant or higher under Alternative 2 than under Alternative 1.

Compared to Alternatives 3 through 9, Alternative 2 would have higher emissions of benzene and DPM, but the same or lower emissions of acrolein and formaldehyde. For acetaldehyde and 1,3-butadiene, Alternative 2 would have lower emissions than Alternatives 3 through 9 in 2016 and 2020, lower emissions than Alternatives 3 and 4 in 2030, and higher emissions than Alternatives 5 through 9 in 2030.

At the national level, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, as noted above, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. For example, a nonattainment area that contains petroleum-refining facilities, such as Houston-Galveston-Brazoria, Texas, would experience more reductions in upstream emissions than an area that has none. There can be net emissions reductions if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect.

Under Alternative 2, many nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.3.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 2 compared to the No Action Alternative (*see* Table 3.3.3-8). These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x (while the magnitude of $PM_{2.5}$ reductions under this alternative is smaller than that of SO_x, the pollutant is the largest contributor to adverse health effects on a per-ton basis). Compared to the No Action Alternative, Alternative 2 would reduce cases of premature mortality by 149 (under Pope *et al.*; reductions would be 155 percent greater under Laden *et al.*) in year 2030. In the same year, the number of work-loss days would be reduced by 17,499.

Table 3.3.3-8

Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions (cases/year) from Passenger Cars and Light Trucks by Alternative a/

Out. and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Mortality (ages 30 and older), Pope *et al.*									
2016	0 a/	-23 b/	-36	-42	-31	-32	-29	-29	-34
2020	0	-61	-93	-103	-88	-90	-85	-83	-91
2030	0	-149	-223	-243	-235	-257	-247	-251	-257
Mortality (ages 30 and older), Laden *et al.*									
2016	0	-60	-93	-107	-80	-83	-75	-73	-87
2020	0	-157	-239	-265	-225	-231	-219	-212	-232
2030	0	-380	-571	-623	-600	-658	-632	-643	-657
Chronic bronchitis									
2016	0	-16	-25	-29	-21	-22	-20	-19	-23
2020	0	-42	-64	-71	-60	-62	-58	-56	-62
2030	0	-97	-146	-160	-155	-170	-163	-166	-169
Emergency Room Visits for Asthma									
2016	0	-22	-34	-40	-30	-31	-29	-28	-33
2020	0	-59	-89	-99	-84	-86	-82	-80	-88
2030	0	-137	-204	-222	-211	-228	-221	-224	-230
Work Loss Days									
2016	0	-3,047	-4,750	-5,510	-4,110	-4,201	-3,821	-3,708	-4,430
2020	0	-7,900	-11,994	-13,323	-11,313	-11,627	-10,945	-10,602	-11,634
2030	0	-17,499	-26,298	-28,705	-27,756	-30,507	-29,237	-29,792	-30,423

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 2 compared to the No Action Alternative. Health-related benefits under Alternative 2 would be $1.32 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al.*, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

Table 3.3.3-9

Nationwide Monetized Health Benefits (U.S. million dollars/year) from Criteria Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

Rate and Year	Alt. 1 No Action b/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
3-Percent Discount Rate									
Pope et al.									
2016	0 a/	-196 b/	-304	-353	-264	-272	-248	-241	-287
2020	0	-534	-809	-898	-763	-785	-741	-719	-788
2030	0	-1,322	-1,983	-2,164	-2,087	-2,287	-2,197	-2,235	-2,284
Laden et al.									
2016	0	-480	-746	-865	-648	-666	-607	-591	-704
2020	0	-1,308	-1,982	-2,200	-1,870	-1,922	-1,816	-1,761	-1,930
2030	0	-3,239	-4,860	-5,302	-5,112	-5,603	-5,382	-5,477	-5,596
7-Percent Discount Rate									
Pope et al.									
2016	0	-178	-276	-320	-240	-247	-225	-219	-260
2020	0	-484	-734	-815	-693	-712	-672	-652	-715
2030	0	-1,199	-1,799	-1,963	-1,893	-2,075	-1,993	-2,028	-2,072
Laden et al.									
2016	0	-433	-674	-781	-585	-602	-549	-534	-636
2020	0	-1,182	-1,790	-1,987	-1,689	-1,737	-1,640	-1,591	-1,743
2030	0	-2,926	-4,390	-4,789	-4,618	-5,061	-4,861	-4,947	-5,055

a/ Negative changes indicate monetized health benefits; positive emissions changes indicate monetized health disbenefits.
b/ Changes in outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which impacts under the action alternatives are compared.

3.3.3.4 Alternative 3: 4-Percent Annual Increase

3.3.3.4.1 Criteria Pollutants

Under the 4-Percent Alternative (Alternative 3), generally the CAFE standards would increase fuel economy more than would Alternative 2 but less than would Alternatives 4 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 3 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.2 to 1.6 percent, $PM_{2.5}$ emissions would be reduced 1.0 to 4.2 percent, SO_x emissions would be reduced 2.4 to 10.2 percent, and VOC emissions would be reduced 0.8 to 5.5 percent. The NO_x, SO_x, and VOC emissions reductions are generally greater than would occur under Alternative 2 but less than would occur under Alternatives 4 through 9. The $PM_{2.5}$ emissions reductions are greater than would occur under Alternative 2 and Alternatives 5 through 9, but less than would occur under Alternative 4. There would be increases of CO emissions from 0.1 to 0.7 percent, depending on the year. Under Alternative 3, all nonattainment areas would experience reductions in emissions of SO_x and VOCs. Most nonattainment areas would experience increases of CO, NO_x, and $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in CO, NO_x, and $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Although NO_x and $PM_{2.5}$ emissions would increase in many nonattainment areas, the increase in each area is quite small. The decreases in nationwide NO_x and $PM_{2.5}$ emissions are the result of the decreases in upstream emissions and do not occur in all nonattainment areas. There would be fewer nonattainment areas with decreases in NO_x and $PM_{2.5}$ emissions than with increases, but the decreases would be much larger than the increases. The net result is decreased NO_x and $PM_{2.5}$ emissions nationwide. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.4.2 Toxic Air Pollutants

Alternative 3 would reduce emissions of toxic air pollutants compared to the No Action Alternative for benzene and DPM in all years. For formaldehyde, Alternative 3 would reduce emissions in 2016 and 2020, but increase emissions in 2030. Emissions of acetaldehyde, acrolein, and 1,3-butadiene would remain constant or increase in all years under Alternative 3 compared to the No Action Alternative. Alternative 3 would have higher emissions of benzene and DPM but lower emissions of acrolein and formaldehyde compared to Alternatives 4 through 9 in all years. Alternative 3 would have lower emissions of 1,3-butadiene compared to Alternatives 4 through 9 in 2016 and 2020, but higher than under Alternatives 4 through 9 in 2030. Results would be mixed for acetaldehyde, depending on the year and alternative.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with Alternative 2, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 3, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area. Table 3.3.3-10 summarizes the air toxic results by nonattainment area.

Table 3.3.3-10

Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative a/

Hazardous Air Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	4.25	2020	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-7.57	2030	8	Houston-Galveston-Brazoria, TX
Acrolein	Maximum Increase	3.47	2030	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-0.49	2030	8	Beaumont/Port Arthur, TX
Benzene	Maximum Increase	4.97	2030	3	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	-63.2	2030	8	New York-N. New Jersey-Long Island, NY-NJ-CT
1,3-Butadiene	Maximum Increase	1.30	2030	3	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-1.51	2030	8	Los Angeles South Coast Air Basin, CA
Diesel particulate matter	Maximum Increase	76	2030	8	Atlanta, GA
	Maximum Decrease	-2,104	2030	8	Houston-Galveston-Brazoria, TX
Formaldehyde	Maximum Increase	47	2030	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-38	2030	9	Houston-Galveston-Brazoria, TX

a/ Emissions changes have been rounded to the nearest whole number except to present values greater than zero but less than one.

3.3.3.4.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 3 compared to the No Action Alternative, as shown in Table 3.3.3-8. These reductions primarily reflect the projected

$PM_{2.5}$ reductions, and secondarily the reductions in SO_x (while the magnitude of $PM_{2.5}$ reductions under this alternative is smaller than that of SO_x, the pollutant is the largest contributor to adverse health effects on a per-ton basis). Compared to the No Action Alternative, Alternative 3 would reduce cases of mortality by 223 (under Pope *et al.*; reductions would be 156 percent greater under Laden *et al.*) and the number of work-loss days by 26,289 in 2030.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 3 compared to the No Action Alternative. Monetized health benefits under Alternative 3 would be $1.98 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al.*, economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.5 Alternative 4: Preferred Alternative

3.3.3.5.1 Criteria Pollutants

Under the Preferred Alternative (Alternative 4), the CAFE standards would increase fuel economy more than would Alternatives 1 through 3 but less than would Alternatives 5 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 4 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.3 to1.9 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.5 percent, SO_x emissions would be reduced 2.7 to 11.0 percent, and VOC emissions would be reduced 1.0 to 6.1 percent. These emissions reductions are greater than would occur under Alternative 3 but less than would occur under Alternatives 5 through 9 (except for $PM_{2.5}$, and SO_x under Alternative 5). There would be increases of CO emissions of 0.02 to 0.5 percent, depending on the year.

Under Alternative 4, all nonattainment areas would experience reductions in emissions of SO_x and VOCs. Most nonattainment areas would experience increases of CO, NO_x, and $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in CO, NO_x, and $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Although NO_x and $PM_{2.5}$ emissions would increase in some nonattainment areas, the increase in each area is quite small. The decreases in nationwide NO_x and $PM_{2.5}$ emissions are the result of the decreases in upstream emissions and do not occur in all nonattainment areas. Although NO_x and $PM_{2.5}$ emissions would decrease in fewer nonattainment areas, the decreases in each area are much larger. The net result is decreased NO_x and $PM_{2.5}$ emissions nationwide. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.5.2 Toxic Air Pollutants

Alternative 4 would result in reduced emissions of benzene and DPM, and increased emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde, compared to the No Action Alternative. Compared to Alternatives 5 through 9, Alternative 4 would have lower emissions of acrolein and formaldehyde, and higher emissions of benzene and DPM. Emissions of acetaldehyde would be lower in 2016 and 2020, but higher in 2030 than under Alternatives 5 through 9. Emissions of 1,3-butadiene under Alternative 4 would be lower than under Alternatives 5 through 9 in 2016 and 2020, but higher than under Alternatives 5 through 9 in 2030.

At the national level, emissions of toxic air pollutants might decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with prior alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 4, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C. Potential air quality impacts from these increases would be minor, because the VMT and emissions increases would be distributed throughout each nonattainment area.

3.3.3.5.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 4 compared to the No Action Alternative, as shown in Table 3.3.3-8. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x (while the magnitude of $PM_{2.5}$ reductions under this alternative is smaller than that of SO_x, the pollutant is the largest contributor to adverse health effects on a per-ton basis). Compared to the No Action Alternative, Alternative 4 would reduce cases of premature mortality by 243 (under Pope *et al.*; reductions would be 156 percent greater under Laden *et al.*) in year 2030. In the same year, the number of work-loss days would be reduced by 28,705.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 4 compared to the No Action Alternative. Monetized health benefits under Alternative 4 would be $2.16 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.6 Alternative 5: 5-Percent Annual Increase

3.3.3.6.1 Criteria Pollutants

Under the 5-Percent Alternative (Alternative 5), the CAFE standards would increase fuel economy more than would Alternatives 1 through 4 but less than would Alternatives 6 through 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 5 compared to the No Action Alternative. Reductions would be greater than under Alternative 4 (except for $PM_{2.5}$ and SO_x), but less than under Alternatives 6 through 9 (except for $PM_{2.5}$). Depending on the year, CO emissions would be reduced0.5 to 3.3 percent, NO_x emissions would be reduced 0.4 to 3.8 percent, $PM_{2.5}$ emissions would be reduced 0.5 to 3.4 percent, SO_x emissions would be reduced 2.4 to 10.7 percent, and VOC emissions would be reduced 1.4 to 9.2 percent. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in some nonattainment areas and would decrease in others compared to the No Action Alternative. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.6.2 Toxic Air Pollutants

Alternative 5 would result in reduced emissions of benzene and DPM, and increased emissions of acetaldehyde, acrolein, and formaldehyde, compared to the No Action Alternative. Emissions of 1,3-butadiene would be increased in 2016 and 2020, but be reduced in 2030 compared to the No Action Alternative. Compared to Alternatives 6 through 9, Alternative 5 would have lower emissions of acrolein and formaldehyde, and higher emissions of benzene and DPM. For acetaldehyde and 1,3-butadiene, Alternative 5 would have lower emissions in 2016 and 2020, and higher emissions in 2030. At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with prior alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 5, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see*

Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.6.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 5 compared to the No Action Alternative, as shown in Table 3.3.3-8. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x (while the magnitude of $PM_{2.5}$ reductions under this alternative is smaller than that of SO_x, the pollutant is the largest contributor to adverse health effects on a per-ton basis). Compared to the No Action Alternative, Alternative 5 would reduce cases of premature mortality by 235 (under Pope *et al.*; reductions would be 155 percent greater under Laden *et al*.) in year 2030. In the same year, the number of work-loss days would be reduced by 27,756.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 5 compared to the No Action Alternative. Monetized health benefits under Alternative 5 would be $2.09 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.7 Alternative 6: MNB

3.3.3.7.1 Criteria Pollutants

Under the MNB (Alternative 6), the CAFE standards would increase fuel economy more than would Alternatives 1 through 5 but less than would Alternatives 7 through 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 6 compared to the No Action Alternative. Reductions in CO, NO_x, and VOC emissions would be greater than under Alternatives 5 and 7, but less than under Alternatives 8 through 9. For $PM_{2.5}$ and SO_x, the emissions would be similar for Alternatives 5 through 9; the reductions under Alternative 6 are slightly greater or less than the reductions under Alternatives 5 and 7 through 9, depending on the year and alternative. Depending on the year, CO emissions would be reduced 1.0 to 6.4 percent, NO_x emissions would be reduced 0.6 to 5.6 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 3.0 percent, SO_x emissions would be reduced 2.9 to 11.5 percent, and VOC emissions would be reduced 2.0 to 12.3 percent. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in some nonattainment areas and would decrease in others compared to the No Action Alternative. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.7.2 Toxic Air Pollutants

Alternative 6 would result in reduced emissions of benzene and DPM, and increased emissions of acrolein and formaldehyde, compared to the No Action Alternative. For acetaldehyde and 1,3-butadiene, Alternative 6 would result in higher emissions in 2016 and 2020, and lower emissions in 2030, compared to the No Action Alternative. Compared to Alternative 7, Alternative 6 would have higher emissions of acetaldehyde, acrolein, and formaldehyde, and lower emissions of benzene and DPM. Compared to Alternatives 8 and 9, Alternative 6 would have the same or lower emissions of acrolein and formaldehyde, and higher emissions of benzene and DPM. Results are mixed for acetaldehyde and 1,3-butadiene depending on year and alternative. At the national level, emissions of toxic air pollutants could decrease for many combinations of pollutant, year, and alternative because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with prior alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 6, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.7.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 6 compared to the No Action Alternative, as shown in Table 3.3.3-8. The reductions in mortality, chronic bronchitis, and work loss days primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x. The reductions in emergency room visits for asthma primarily reflect the projected SO_x reductions, and secondarily the reductions in $PM_{2.5}$. Compared to the No Action Alternative, Alternative 6 would reduce cases of premature mortality by 257 (under Pope *et al*.; reductions would be 156 percent greater under Laden *et al*.) in year 2030. In the same year, the number of work-loss days would be reduced by 30,507.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 6 compared to the No Action Alternative. Monetized health benefits under Alternative 6 would be $2.29 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.8 Alternative 7: 6-Percent Annual Increase

3.3.3.8.1 Criteria Pollutants

Under the 6-Percent Alternative (Alternative 7), the CAFE standards would increase fuel economy more than would Alternatives 1 through 6 but less than would Alternatives 8 and 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 7 compared to the No Action Alternative. Reductions in emissions of all criteria pollutants under Alternative 7 would be less than under Alternative 6 (except for SO_x in 2030).emissions of all criteria pollutants under Alternative 7 would be less than under Alternatives 8 and 9 (except for $PM_{2,5}$). Depending on the year, CO emissions would be reduced 0.7 to 5.6 percent, NO_x emissions would be reduced 0.5 to 5.2 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 2.8 percent, SO_x emissions would be reduced 2.7 to 11.7 percent, and VOC emissions would be reduced 1.8 to 12.0 percent. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs under Alternative 7. $PM_{2.5}$ emissions would increase in some nonattainment areas and would decrease in others compared to the No Action Alternative. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.8.2 Toxic Air Pollutants

Alternative 7 would result in reduced emissions of benzene and DPM, and increased emissions of acrolein and formaldehyde, compared to the No Action Alternative. For acetaldehyde and 1,3-butadiene, Alternative 7 would result in higher emissions in 2016 and 2020, and lower emissions in 2030, compared to the No Action Alternative. Compared to Alternatives 8 and 9, Alternative 7 would have lower emissions of acrolein and formaldehyde, and higher emissions of benzene and DPM. For acetaldehyde and 1,3-butadiene, Alternative 7 would result in lower emissions in 2016 and 2020, and higher emissions in 2030, compared to Alternatives 8 and 9.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with previous alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 7, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.8.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 7 compared to the No Action Alternative, as shown in Table 3.3.3-8. The reductions in mortality, chronic bronchitis, and work loss days primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x. The reductions in emergency room visits for asthma primarily reflect the projected SO_x reductions, and secondarily the reductions in $PM_{2.5}$. Compared to the No Action Alternative, Alternative 7 would reduce cases of premature mortality by 247 (under Pope *et al.*; reductions would be 156 percent greater under Laden *et al*.) in 2030. In the same year, the number of work-loss days would be reduced by 29,237.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 7 compared to the No Action Alternative. Monetized health benefits under Alternative 7 would be $2.20 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.9 Alternative 8: 7-Percent Annual Increase

3.3.3.9.1 Criteria Pollutants

Under the 7-Percent Alternative (Alternative 8), the CAFE standards would increase fuel economy more than all the other alternatives. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 8 compared to the No Action Alternative. Compared to Alternative 7, reductions in emissions under Alternative 8 would be greater for CO, NO_x, SO_x, and VOC, but less for $PM_{2.5}$. Reductions in emissions under Alternative 8 would be greater than under Alternative 9 for CO, NO_x in 2020 and 2030, and VOC in 2020 and 2030, but would be less than under Alternative 9 for NO_x in 2016, $PM_{2.5}$ and SO_x in all years, and VOC in 2016. CO emissions would be reduced 1.0 to 8.0 percent, NO_x emissions would be reduced 0.6 to 6.5 percent, $PM_{2.5}$ emissions would be reduced 0.1 to 2.3 percent, SO_x emissions would be reduced 2.9 to 12.0 percent, and VOC emissions would be reduced 2.1 to 14.2 percent compared to the No Action Alternative, depending on the year. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in some nonattainment areas and would decrease in others compared to the No Action Alternative. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.9.2 Toxic Air Pollutants

Alternative 8 would result in reduced emissions of benzene and DPM, and increased emissions of acrolein and formaldehyde, compared to the No Action Alternative. For acetaldehyde and 1,3-butadiene, Alternative 8 would result in higher emissions in 2016 and 2020, and lower emissions in 2030, compared to the No Action Alternative. Compared to Alternative 9, Alternative 8 would have higher emissions of acetaldehyde (in 2020), acrolein, 1,3-butadiene (in 2016 and 2020), DPM (in 2016), and formaldehyde. Emissions reductions of acetaldehyde (in 2030), benzene, 1,3-butadiene (in 2030), and DPM under Alternative 8 would be greater than with any other alternative. Similarly, emissions increases of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde under Alternative 8 would be the same or greater than with any other alternative.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with prior alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 8, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.9.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 8 compared to the No Action Alternative, as shown in Table 3.3.3-8. The reductions in mortality, chronic bronchitis, and work loss days primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x. The reductions in emergency room visits for asthma primarily reflect the projected SO_x reductions, and secondarily the reductions in $PM_{2.5}$. In comparison to the No Action Alternative, Alternative 8 would reduce cases of premature mortality by 251 (under Pope *et al.*; reductions would be 156 percent greater under Laden *et al*.) in year 2030. In the same year, the number of work-loss days would be reduced by 29,792.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 8 compared to the No Action Alternative. Monetized health benefits under Alternative 8 would be $2.24 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.3.3.10 Alternative 9: TCTB

3.3.3.10.1 Criteria Pollutants

Under the TCTB Alternative (Alternative 9), the CAFE standards would increase fuel economy more than would Alternatives 1 through 7 but less than would Alternative 8. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 9 compared to the No Action Alternative. Emissions reductions under Alternative 9 would be greater than with any other alternative for NO_x in 2016, SO_x in all years, and VOC in 2016. Emission reductions under Alternative 9 would be greater than the reductions under Alternatives 2 through 7, but less than the reductions under Alternative 8, for CO in all years, NO_x in 2020 and 2030, and VOC in 2020 and 2030. Emission reductions under Alternative 9 would be less than the reductions under Alternatives 2 through 6, but greater than the reductions under Alternatives 7 and 8, for $PM_{2.5}$ in 2016; in 2020 and 2030 the $PM_{2.5}$ reductions under Alternative 9 would be less than the reductions under Alternatives 2 through 7, but greater than the reductions under Alternative 8. Depending on the year, CO emissions would be reduced 1.0 to 7.2 percent, NO_x emissions would be reduced 0.6 to 6.1 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 2.6 percent, SO_x emissions would be reduced 3.2 to 12.2 percent, and VOC emissions would be reduced 2.1 to 13.5 percent compared to the No Action Alternative. All individual nonattainment areas would experience reductions in emissions of CO, NO_x, SO_x, and VOCs. $PM_{2.5}$ emissions would increase in some nonattainment areas and would decrease in others compared to the No Action Alternative. Tables in Appendix C list the emissions reductions for each nonattainment area.

3.3.3.10.2 Toxic Air Pollutants

Alternative 9 would result in reduced emissions of acetaldehyde (in 2030), benzene, 1,3-butadiene (in 2030), and DPM, and increased emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde, compared to the No Action Alternative.

At the nationwide level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with prior alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 9, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (*see* Appendix C). However, the sizes of the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

3.3.3.10.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 9 compared to the No Action Alternative, as shown in Table 3.3.3-8. The reductions in mortality, chronic bronchitis, and work loss days primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_x. The reductions in emergency room visits for asthma primarily reflect the projected SO_x reductions, and secondarily the reductions in $PM_{2.5}$. Compared to the No Action Alternative, Alternative 9 would reduce cases of premature mortality by 257 (under Pope *et al*.; reductions would be 156 percent greater under Laden *et al*.) in 2030. In the same year, the number of work-loss days would be reduced by 30.423 days.

Table 3.3.3-9 lists the corresponding monetized health benefits under Alternative 9 compared to the No Action Alternative. Monetized health benefits under Alternative 9 would be $2.29 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Using Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, monetized health benefits would be 9.3 to 9.7 percent less.

3.4 CLIMATE

This section describes how the MYs 2012-2016 CAFE standards would affect the anticipated pace and extent of future changes in the global climate. Because there is little precedent for addressing climate change within the structure of an EIS, several reasonable judgments were required to distinguish the direct and indirect effects of alternative CAFE standards (Chapter 3) from the cumulative impacts associated with those same alternatives (Chapter 4).

NHTSA determined that the scope of climate change issues covered in Chapter 3 would be narrower than the scope of those addressed in Chapter 4 in two respects: (1) the discussion in Chapter 3 focuses on impacts associated with reductions in GHG emissions due exclusively to the MYs 2012-2016 CAFE standards (which are then assumed to remain in place at the MY 2016 levels from 2016 through 2060) and (2) the Chapter 3 discussion of consequences focuses on GHG emissions and their effects on the climate system, for example, atmospheric CO_2 concentrations, temperature, sea level, and precipitation. The analysis presented in Chapter 4 is more comprehensive in that (1) it addresses the effects of the MYs 2012-2016 standards together with those of reasonably foreseeable future actions, including the continuing increases in CAFE standards for MYs 2017-2020 that are necessary under some alternatives to reach the EISA-mandated target of a combined 35 mpg; and (2) continuing market-driven increases in fuel economy based on AEO projections through 2030 as a reasonably foreseeable future action (since the AEO forecasted fuel economy increases result from projections of rising future demand for fuel economy, as opposed to future increases in CAFE standards). These reasonably foreseeable future actions would affect fuel consumption and emissions attributable to passenger cars and light trucks through 2060. The climate modeling in Chapter 4 applies different assumptions about the effect of broader global GHG policies on emissions outside the U.S. transportation sector, and it extends the discussion of consequences to include not only the immediate effects of emissions on the climate system, but also the impacts of changes in the climate system on key resources (such as freshwater resources, terrestrial ecosystems, and coastal ecosystems). Thus, the reader is encouraged to explore the cumulative impacts discussion in Chapter 4 to fully understand NHTSA's approach to climate change in this EIS.

Section 3.4.1 introduces key topics on GHGs and climate change, while Section 3.4.2 outlines the methodology NHTSA used to evaluate climate effects. Section 3.4.3 describes the affected environment, and Section 3.4.4 describes the direct and indirect environmental consequences of the proposed action and alternative actions that were considered by NHTSA.

3.4.1 Introduction – Greenhouse Gases and Climate Change

This document primarily draws upon panel-reviewed synthesis and assessment reports from the IPCC and U.S. Global Change Research Program (USGCRP). It also cites EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for GHGs under the Clean Air Act* (EPA 2009b) – which heavily relied on these panel reports. NHTSA similarly relies on panel reports because they have assessed numerous individual studies to draw general conclusions about the state of science; have been reviewed and formally accepted by, commissioned by, or in some cases authored by, U.S. government agencies and individual government scientists and provide NHTSA with assurances that this material has been well vetted by both the climate change research community and by the U.S. government; and in many cases, they reflect and convey the consensus conclusions of expert authors. These reports therefore provide the overall scientific foundation for U.S. climate policy at this time.

This document also refers to new peer-reviewed literature that has not been assessed or synthesized by an expert panel. This new literature supplements but does not supersede the findings of the panel-reviewed reports.

NHTSA's consideration of newer studies and highlighting of particular issues responds to previous public comments received on the scoping document and the prior EIS for the MY 2011 CAFE standard, as well as the Ninth Circuit's decision in CBD v. NHTSA, 538 F.3d 1172 (9th Cir. 2008). The level of detail regarding the science of climate change in this draft EIS, and NHTSA's consideration of other studies that show illustrative research findings pertaining to the potential impacts of climate change on health, society, and the environment, are provided to help inform the public and the decisionmaker, consistent with the agency's approach in the prior EIS for the MY 2011 CAFE standards.

3.4.1.1 Uncertainty within the IPCC Framework

The IPCC reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent likelihood of occurrence. The *IPCC Fourth Assessment Synthesis Report* and the *IPCC Fourth Assessment Report Summary for Policymakers* (IPCC 2007c, IPCC 2007b) briefly explain this convention. The IPCC Guidance Notes for Lead Authors of the *IPCC Fourth Assessment Report on Addressing Uncertainties* (IPCC 2005) provides a more detailed discussion of the IPCC treatment of uncertainty.

This EIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and 4 when discussing qualitative environmental impacts on certain resources. The reader should refer to the referenced IPCC documents to gain a full understanding of the meaning of those uncertainty terms, because they might be used differently than similar language describing uncertainty in the EIS, as required by the CEQ regulations described in Section 3.1.3.1. Section 4.5.2.2 of this EIS summarizes the IPCC treatment of uncertainty.

3.4.1.2 What is Climate Change?

Global climate change refers to long-term (*i.e.*, multi-decadal) trends in global average surface temperature, precipitation, ice cover, sea level, cloud cover, sea-surface temperatures and currents, and other climatic conditions. Scientific research has shown that over the 20th century, Earth's global-average surface temperature rose by an average of about 0.74 °C (1.3 °F) (EPA 2009b, IPCC 2007b); global average sea level has been gradually rising, increasing about 0.17 meters (6.7 inches) during the 20th Century (IPCC 2007b) with a maximum rate of about 2 millimeters (0.08 inch) per year over the last 50 years on the northeastern coast of the United States (EPA 2009b); Arctic sea ice cover has been decreasing at a rate of about 4.1 percent per decade, with faster decreases of 7.4 percent per decade in summer; and the extent and volume of mountain glaciers and snow cover have also been decreasing (EPA 2009b, IPCC 2007b) (*see* Figure 3.4.1-1).

3.4.1.3 What Causes Climate Change?

Earth absorbs heat energy from the sun and returns most of this heat to space as terrestrial infrared radiation. Accumulated GHGs trap heat in the troposphere (the layer of the atmosphere that extends from Earth's surface up to about 8 miles above the surface), absorb heat energy emitted by Earth's surface and lower atmosphere, and reradiate much of it back to Earth's surface, thereby causing warming. This process, known as the "greenhouse effect," is responsible for maintaining surface temperatures warm enough to sustain life (*see* Figure 3.4.1-2). Human activities, particularly fossil-fuel combustion, lead to the presence of increased concentrations of GHGs in the atmosphere; this buildup of GHGs in the atmosphere is upsetting Earth's energy balance.

Figure 3.4.1-1. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover (Source: IPCC 2007b)

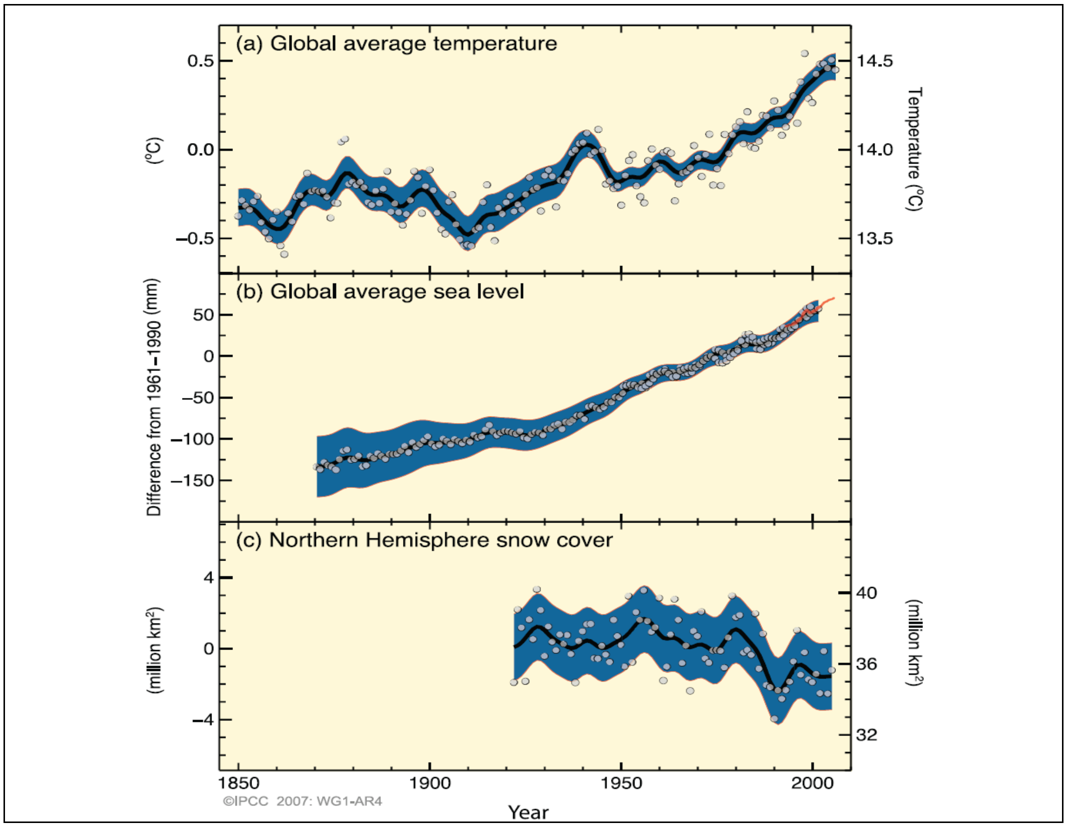
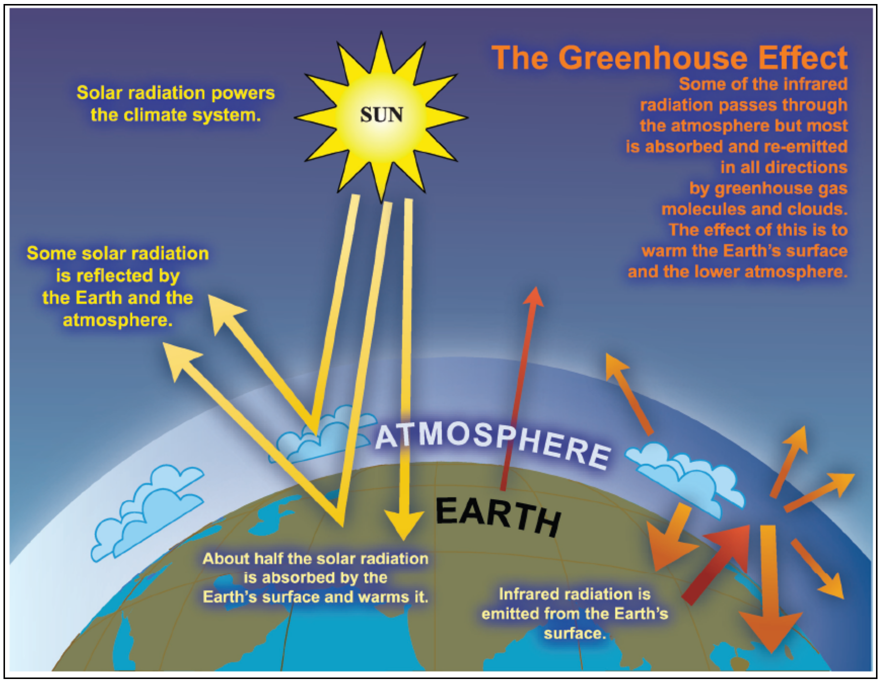


Figure 3.4.1-2. The Greenhouse Effect (Source: Le Treut *et al.* 2007)



The observed changes in the global climate described in Section 3.4.1.2 are largely a result of GHG emissions from human activities. Both EPA and the IPCC have recently concluded that "[m]ost of the observed increase in global average temperatures since the mid-20th Century is *very likely* due to the observed increase in anthropogenic [human-caused] GHG concentrations" (EPA 2009b, IPCC 2007b).[23]

Most GHGs, including CO_2, methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone, occur naturally. Human activities such as the combustion of fossil fuel for transportation and electric power, the production of agricultural and industrial commodities, and the loss of soil fertility and the harvesting of trees can contribute to very significant increases in the concentrations of these gases in the atmosphere. In addition, several very potent anthropogenic GHGs, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), are created and emitted through industrial processes and emitted as a result, for example, of leaks in refrigeration and air-conditioning systems.

3.4.1.4 What are the Anthropogenic Sources of Greenhouse Gases?

Human activities that emit GHGs to the atmosphere include the combustion of fossil fuels, industrial processes, solvent use, land-use change and forestry, agricultural production, and waste management. Atmospheric concentrations of CO_2, CH_4, and N_2O – the most important anthropogenic GHGs, comprising over 99 percent of anthropogenic emissions (WRI 2009)[24] – have increased approximately 38, 149, and 23 percent, respectively, since the beginning of the Industrial Revolution in the mid-1700s. During this time, the atmospheric CO_2 concentration has increased from 280 ppm to 386 ppm in 2008 (EPA 2009b). Isotopic and inventory-based studies make clear that this rise in the CO_2 concentration is largely a result of combustion of fossil fuels (coal, petroleum, and gas) used to produce electricity, heat buildings, and run motor vehicles and airplanes, among other uses.

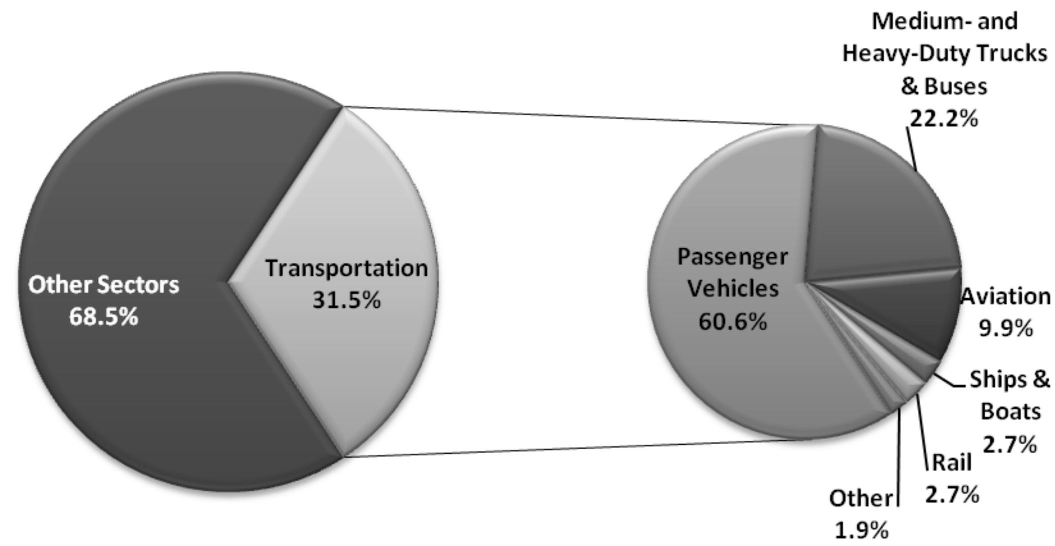
Contributions to the build up of GHGs in the atmosphere vary greatly from country to country, and depend heavily on the level of industrial and economic activity, the population, the standard of living, the character of a country's buildings and transportation system, energy options that are available, and the climate. Emissions from the United States account for about 17.2 percent of total global CO_2 emissions (WRI 2009). The U.S. transportation sector contributed 31.5 percent of total U.S. CO_2 emissions in 2007, with passenger cars and light trucks accounting for 60.6 percent of total U.S. CO_2 emissions from transportation (EPA 2009a). Thus, approximately 19.1 percent of total U.S. CO_2 emissions are from passenger cars and light trucks, and passenger cars and light trucks in the United States account for roughly 3.3 percent of total global CO_2 emissions.[25] Figure 3.4.1-3 shows the proportion of U.S. emissions attributable to the transportation sector and the contribution of each mode to U.S. transportation emissions.

[23] As mentioned above, the IPCC uses standard terms to "define the likelihood of an outcome or result where this can be estimated probabilistically." The term "very likely," cited in italics above and elsewhere in this section, corresponds to a greater than 90-percent probability of an occurrence or outcome, whereas the term "likely" corresponds to a greater than 66-percent probability. This section uses these two terms; Section 4.5 uses and defines a more expansive set of IPCC terminology regarding likelihood.

[24] This calculation is weighted by global warming potential.

[25] Percentages include land-use change and forestry, and exclude international bunker fuels (*i.e.*, international marine and aviation travel).

Figure 3.4.1-3. Contribution of Transportation to U.S. CO_2 Emissions and Proportion Attributable by Mode, 2007



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007

3.4.1.5 Evidence of Climate Change

Observations and studies across the globe are reporting evidence that Earth is undergoing climatic change much more quickly than would be expected from natural variations. The global average temperature is rising, with 8 of the 10 warmest years on record occurring since 2001 (EPA 2009b). Cold-dependent habitats are shifting to higher altitudes and latitudes and growing seasons are becoming longer (EPA 2009b). Sea level is rising, caused by thermal expansion of the ocean and melting of snow and ice. More frequent weather extremes such as droughts, floods, severe storms, and heat waves have also been observed (EPA 2009b, IPCC 2007b). Oceans are becoming more acidic as a result of increasing absorption of CO_2, driven by higher atmospheric concentration of CO_2, (EPA 2009b). Statistically significant indicators of climate change have been observed on every continent (Rosenzweig *et al.* 2008). Additional evidence of climate change is discussed throughout this section.

3.4.1.6 Future Climatic Trends and Expected Impacts

As the world population grows and developing countries industrialize and bring their populations out of poverty, fossil-fuel use and resulting GHG emissions are expected to grow substantially over the 21st century unless there is a significant shift away from deriving energy from fossil fuels. Based on the current trajectory, the IPCC projects that the atmospheric CO_2 concentration could rise to more than three times the pre-industrial level by 2100 (EPA 2009b, IPCC 2007b).

If there is an unchecked rise in the atmospheric CO_2 concentration out to 2100, the average global surface temperature is *likely* to rise by 2.0 to 11.5 °F by that time (EPA 2009b). In addition, EPA (2009b) projects that sea level is *likely* to rise 0.19 to 0.58 meters (0.6 to 1.9 feet) by 2100 due just to thermal expansion and the melting of glaciers and small ice caps; even greater rise is projected if ice streams draining the Greenland and Antarctic ice sheets accelerate. If this happens, and satellite observation suggest such changes are beginning, recent studies indicate that sea-level rise could be even higher, and have estimated ranges of 0.8 to 2 meters (2.6 to 6.6 feet) (Pfeffer *et al*. 2008) and 0.5 to 1.4 meters (1.6 to 4.6 feet) (Rahmstorf 2007) by 2100. In addition to increases in global-average temperature and sea level, climate change is expected to have many environmental, human health, and economic consequences.

For a more in-depth analysis of the future impacts of climate change on various sectors, *see* Section 4.5 of this EIS.

3.4.1.7 Black Carbon

This EIS does not model the climatic impacts of black carbon.[26] Therefore, the direct effects (the radiative properties) and indirect effects (the impacts on clouds and surface snow/ice) of black carbon are qualitatively discussed here.

Black carbon is an aerosol that forms during incomplete combustion of certain fossil fuels (primarily coal and diesel) and biomass (primarily fuel wood and crop waste). Developing countries are the primary emitters of black carbon because they depend more heavily on biomass-based fuel sources for cooking and heating and on diesel vehicles for transport, and have less stringent air emission control standards and technologies. The United States contributes about 7 percent of the world's black carbon emissions, with about 19 percent of those emissions coming from on-road vehicles (or just over 1 percent of the world total) (Battye *et al.* 2002, Bond *et al.* 2004).[27]

While black carbon has been an air pollutant of concern for years due to its direct human health effects, climate change experts are now paying attention to it for its influence on climate change (EPA 2009b). Black carbon has a warming effect on the climate by (1) absorbing solar radiation, (2) reducing the albedo[28] of clouds while suspended in the air, and (3) reducing the albedo of snow and ice when it falls onto snow and ice fields (EPA 2009b; Ramanathan and Carmichael 2008).

The scientific literature is far from conclusive as to what effect black carbon has on the climate. In the IPCC Fourth Assessment Report (IPCC 2007b), the scientific knowledge level of black carbon's effect on the climate was classified as medium to low (CCSP 2008b). Another study estimates that there is a 50-percent uncertainty in global emissions estimates, while the uncertainty in regional emissions estimates can range from factors of two to five (Ramanathan and Carmichael 2008). Although emission estimates are uncertain, recent studies suggest that black carbon might be a major contributor to climate change.

In a recent study, black carbon was estimated to have more than half of the positive radiative forcing effect of CO_2, and a larger forcing than from other GHGs, including CH_4 and N_2O (Ramanathan

[26] Black carbon is often referred to as "soot" or "particulate matter," when in fact it is only one *component* of soot, and one *type* of particulate matter. It is sometimes referred to as "elemental carbon," although it is actually a slightly impure form of elemental carbon. As noted by Andreae and Gelencser (2006), "black carbon" is often used interchangeably with other terms that are similar, but whose definitions are slightly different. Furthermore, definitions across literature sources are not always consistent.

[27] Battye *et al.* (2002) calculated total U.S. (433 Gg) and U.S. motor vehicle (81 Gg) black carbon in fine particles ($PM_{2.5}$) from EPA's 2001 National Emission Inventory (NEI) database. Bond *et al.* (2004) estimated global black carbon emissions (in $PM_{2.5}$) to be 6.5 Tg. (Note that the same year of data was not available – Bond used fuel data from 1996, while EPA calculated black carbon emissions for 2001. So these calculations assume black carbon emissions in the 2 years were equivalent.)

[28] Surfaces on Earth reflect solar radiation back to space. This reflective characteristic, known as *albedo*, indicates the proportion of incoming solar radiation that the surface reflects. High albedo has a cooling effect because the surface reflects rather than absorbs most solar radiation. Black carbon can reduce the albedo of water and ice in clouds and snow and ice on the ground.

and Carmichael 2008). Recent research indicates that black carbon has contributed approximately 0.5 to 1.4 °C (0.9 to 2.52 °F) to Arctic warming since 1890 (Shindell and Faluvegi 2009). Other research suggests that black carbon might have a played a role in droughts in the northern part of China and floods in the southern part of China (Menon *et al.* 2002).

Some aerosols suppress formation of larger cloud drops, which can extend the lifetime of the cloud and increase cloud cover (Ramanathan and Carmichael 2008). Black carbon, on the other hand, radiatively warms the surrounding air, which leads to evaporation of cloud drops and reduces cloud cover (Ramanathan and Carmichael 2008). An important issue, which can vary by region, is whether the non-black carbon aerosols or the black carbon aerosols dominate in cloud effects (Ramanathan and Carmichael 2008). Meanwhile, it is also believed that black carbon-related warming might induce convection and ultimately lead to cloud formation (Rudich *et al.* 2003 in Ramanathan and Carmichael 2008).

Black carbon has a much shorter atmospheric lifespan than GHGs. CCSP (2009) estimates the lifetime of black carbon in the atmosphere as being between 5.3 and 15 days, generally depending on the meteorological situation. Because the atmospheric loading of black carbon depends on being continually replenished, reductions in black-carbon emissions can have an almost immediate effect on radiative forcing. Meanwhile, the lifespan of CO_2 in the atmosphere is hundreds of years. Therefore, due to the long lifespan of CO_2, mitigation of its emissions in the short-term will have long-lasting impacts.

The impact that the new CAFE standards will have on black carbon emissions is uncertain. Historically, diesel vehicles have emitted more black carbon than gasoline vehicles on a per-mile basis. Thus, a shift to diesel vehicles could increase black carbon emissions, resulting in increased warming. Widespread deployment of recent, more effective control technologies for particulate-matter emissions from diesel vehicles could minimize any increase in warming due to this shift. NHTSA estimates that the fraction of MY 2016 passenger cars that are diesel-powered would rise from less than 1 percent under the No Action Alternative to about 1 percent under the Preferred Alternative and would reach 7 to 10 percent under those alternatives that would establish the most stringent CAFE standards. At the same time, the agency projects that the diesel fraction of light trucks sold during MY 2016 would rise from less than 1 percent under the No Action Alternative to more than 12 percent under the Preferred Alternative and would range as high as 25 percent under alternatives that would establish the highest CAFE standards.

Using estimates of U.S. on-road emissions of black carbon in fine particles ($PM_{2.5}$) (Battye *et al.* 2002) and global emissions of black carbon in $PM_{2.5}$ (Bond *et al.* 2004), U.S. motor vehicles contribute just over 1 percent of global black carbon emissions. As noted above, the effects of the alternative CAFE standards considered in this analysis on U.S. and global black carbon emissions have not been established. The precise amount by which CAFE standards will increase black carbon emissions depends on the increase in the presence of diesel vehicles in the future U.S. vehicle fleet that results from manufacturers' efforts to comply with higher CAFE standards, particularly under those alternatives that would impose the most stringent standards. It also depends on future improvements in the effectiveness of emissions control technology for diesel vehicles, including both light duty diesel vehicles and the heavy-duty diesel trucks that are used extensively for fuel distribution to retail stations.

3.4.2 Affected Environment

This section describes the affected environment in terms of current and anticipated trends in GHG emissions and climate. Effects of emissions and the corresponding processes that affect climate involve very complex processes with considerable variability, which complicates the measurement and detection of change. Recent advances in the state of the science, however, are contributing to an increasing body of evidence that anthropogenic GHG emissions are affecting climate in detectable and quantifiable ways.

This section begins with a discussion of emissions, and then turns to climate. Both discussions start with a description of conditions in the United States, followed by a description of global conditions. Many themes in the U.S. discussions reappear in the global discussions.[29]

3.4.2.1 Greenhouse Gas Emissions (Historic and Current)

3.4.2.1.1 U.S. Emissions

GHG emissions for the United States in 2007[30] were estimated at 7,150.1 million metric tons of carbon dioxide ($MMTCO_2$)[31] (EPA 2009a), and, as noted earlier, contributes about 18 percent of total global emissions[32] (WRI 2009). Annual U.S. emissions, which have increased 17 percent since 1990 and typically increase each year, are heavily influenced by "general economic conditions, energy prices, weather, and the availability of non-fossil alternatives" (EPA 2009a).

CO_2 is by far the primary GHG emitted in the United States, representing almost 85.4 percent of all U.S. GHG emissions in 2007 (EPA 2009a). The other gases include CH_4, N_2O, and a variety of fluorinated gases, including HFCs, PFCs, and SF_6. The fluorinated gases are collectively referred to as high global warming potential (GWP) gases. CH_4 accounts for 8.2 percent of the remaining GHGs on a GWP-weighted basis, followed by N_2O (4.4 percent), and the high-GWP gases (2.1 percent) (EPA 2009a).

GHGs are emitted from a wide variety of sectors, including energy, industrial processes, waste, agriculture, and forestry. Most U.S. emissions are from the energy sector, largely due to CO_2 emissions from the combustion of fossil fuels, which alone account for 80 percent of total U.S. emissions (EPA 2009a). These CO_2 emissions are due to fuels consumed in the electric power (42 percent of fossil fuel emissions), transportation (33 percent), industry (15 percent), residential (6 percent), and commercial (4 percent) sectors (EPA 2009a). However, when U.S. CO_2 emissions are apportioned by end use, transportation is the single leading source of U.S. emissions from fossil fuels, causing approximately one-third of total CO_2 emissions from fossil fuels (EPA 2009a).

As noted earlier, the U.S. transportation sector contributed 31.5 percent of total U.S. CO_2 emissions in 2007, with passenger cars and light trucks accounting for 60.6 percent of total U.S. CO_2 emissions from transportation. Thus, 19.1 percent of total U.S. CO_2 emissions are from passenger cars and light trucks. With the United States accounting for 17.2 percent of global CO_2 emissions, passenger cars and light trucks in the United States account for roughly 3.3 percent of global CO_2 emissions.[33]

Passenger cars and light trucks, which include SUVs, pickup trucks, and minivans, account for more than half of U.S. transportation CO_2 emissions, and CO_2 emissions from these vehicles have increased by 21 percent since 1990 (EPA 2009a). This increase was driven by two factors – (1) an increase in use of passenger cars and light trucks and (2) relatively little improvement in their average fuel economy. Population growth and expansion, economic growth, and low fuel prices led to more

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[29] For NEPA purposes, it is appropriate for NHTSA to consider global environmental impacts. *See Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html (last visited July 22, 2009) (stating that "agencies must include analysis of reasonably foreseeable transboundary effects of proposed actions in their [NEPA] analysis of proposed actions in the United States").
[30] Most recent year for which an official EPA estimate is available.
[31] Each GHG has a different level of radiative forcing, that is, the ability to trap heat. To compare their relative contributions, gases are converted to carbon dioxide equivalent using their unique global warming potential (GWP).
[32] Based on 2005 data and excludes carbon sinks from forestry and agriculture.
[33] Percentages include land-use change and forestry, and exclude international bunker fuels.

VMT, while the rising popularity of SUVs and other light trucks kept the average combined fuel economy of new passenger cars and light trucks relatively constant (EPA 2009a).

3.4.2.1.2 Global Emissions

Although humans have always contributed to some level of GHG emissions to the atmosphere through activities like farming and land clearing, substantial contributions did not begin until the mid-1700s, with the onset of the Industrial Revolution. People began burning coal, oil, and natural gas to light their homes, power trains and cars, and run factories and industrial operations. Today the burning of fossil fuels is still the predominant source of GHG emissions.

Levels of atmospheric CO_2 have been rising rapidly. For about 10,000 years before the Industrial Revolution, atmospheric CO_2 levels were 280 ppm (+/- 20 ppm). Since the Industrial Revolution, CO_2 levels have risen to 386 ppm in 2008 (EPA 2009b). In addition, the concentrations of CH_4 and N_2O in the atmosphere have increased 149 and 23 percent, respectively (EPA 2009b).

In 2000, gross global GHG emissions were calculated to be 41,638.5 $MMTCO_2$ equivalent, an 8-percent increase since 1990[34] (WRI 2009). In general, global GHG emissions have increased regularly, though annual increases vary according to a variety of factors (weather, energy prices, and economic factors).

As in the United States, the primary GHGs emitted globally are CO_2, CH_4, N_2O, and the fluorinated gases HFCs, PFCs, and SF_6. In 2000, CO_2 emissions comprised 77 percent of global emissions on a GWP-weighted basis, followed by CH_4 (14.5 percent) and N_2O (7.5 percent). Collectively, fluorinated gases represented 1.1 percent of global emissions (WRI 2009).

Various sectors contribute to global GHG emissions, including energy, industrial processes, waste, agriculture, land-use change, and forestry. The energy sector is the largest contributor of global GHG emissions, accounting for 59 percent of global emissions in 2000. In this sector, the generation of electricity and heat accounts for 25 percent of total global emissions. The next highest contributors to emissions are land-use change and forestry (18 percent), agriculture (14 percent), and transportation (12 percent, which is included in the 59 percent for the energy sector) (WRI 2009).

Emissions from transportation are primarily due to the combustion of petroleum-based fuels to power vehicles such as cars, trucks, trains, airplanes, and ships. In 2005, transportation represented 14 percent of total global GHG emissions and 20 percent of CO_2 emissions; in absolute terms, global transportation CO_2 emissions increased 30 percent from 1990 to 2005 (WRI 2009).[35]

3.4.2.2 Climate Change Effects and Impacts (Historic and Current)

3.4.2.2.1 U.S. Climate Change Effects

This section describes observed historical and current climate change effects and impacts for the United States. Much of the material that follows is drawn from the following sources, including the citations therein: *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009b), *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), and

[34] All GHG estimates cited in this section include contributions from land-use change and forestry, unless noted otherwise.
[35] Values in this paragraph exclude land-use change and forestry.

Global Climate Change Impacts in the United States (GCRP 2009). The impacts associated with these observed trends are further discussed in Section 4.5.

Increased Temperatures

The past decade has been the warmest in more than a century of direct observations, with average temperatures for the contiguous United States rising at a rate near 0.58 °F per decade in the past few decades. U.S. average temperatures are now 1.25 °F warmer than they were at the beginning of the 20th Century with an average warming of 0.13 °F per decade over 1895–2008, and the rate of warming is increasing (EPA 2009b).

Since 1950, the frequency of heat waves has increased, although those recorded in the 1930s remain the most severe. There were also fewer unusually cold days in the past few decades with fewer severe cold waves for the most recent 10-year period in the record (GCRP 2009).

Sea-level Rise

Relative sea level is rising 0.8 to 1.2 inches per decade along most of the Atlantic and Gulf Coasts, and a few inches per decade along the Louisiana Coast (due to land subsidence); sea level is falling (due to land uplift) at the rate of a few inches per decade in parts of Alaska (National Science and Technology Council 2008, EPA 2009b). These observations demonstrate that sea level does not rise uniformly across the globe.

Sea-level rise extends the zone of impact from storm surge and waves from tropical and other storms farther inland, causing coastal erosion and other damage. Resulting shoreline erosion is well documented. Since the 1970s, half of the coastal area in Mississippi and Texas has been eroding by an average of 2.6 to 3.1 meters (8.5 to 10.2 feet) per year. In Louisiana, a full 90 percent of the shoreline has been eroding at an average rate of more than 12.0 meters (39 feet) per year (Nicholls *et al.* 2007 in EPA 2009).

Changes in Precipitation Patterns

Higher temperatures cause higher rates of evaporation and plant transpiration, meaning that more water vapor is available in the atmosphere for precipitation events. Depending on atmospheric conditions, increased evaporation means that some areas experience increases in precipitation events, while other areas are left more susceptible to droughts.

Over the contiguous United States, total annual precipitation increased about 6 percent from 1901 to 2005, with the greatest increases in the northern Midwest and the South. Heavy precipitation events also increased, primarily during the last 3 decades of the 20th Century, and mainly over eastern regions (GCRP 2009). Most regions experienced decreases in drought severity and duration during the second half of the 20th Century, although there was severe drought in the Southwest from 1999 to 2008 (EPA 2009b); the Southeast has also recently experienced severe drought (GCRP 2009).

Increased Incidence of Severe Weather Events

It is *likely* that the numbers of tropical storms, hurricanes, and major hurricanes each year in the North Atlantic have increased during the past 100 years (CCSP 2008c in National Science and Technology Council 2008) and that Atlantic sea-surface temperatures have increased over the same period. However, these trends are complicated by multi-decadal variability and data-quality issues. In addition, there is evidence of an increase in extreme wave-height characteristics over the past 2 decades, associated with more frequent and more intense hurricanes (CCSP 2008a).

Changes in Water Resources

Melting snow and ice, increased evaporation, and changes in precipitation patterns all affect surface water. Stream flow decreased about 2 percent per decade over the past century in the central Rocky Mountain region (Rood *et al.* 2005 in Field *et al.* 2007), while in the eastern United States it increased 25 percent in the past 60 years (Groisman *et al.* 2004 in Field *et al.* 2007). Annual peak stream flow (dominated by snowmelt) in western mountains is occurring at least a week earlier than in the middle of the 20th Century. Winter stream flow is increasing in seasonal snow-covered basins and the fraction of annual precipitation falling as rain (rather than snow) has increased in the past half century (National Science and Technology Council 2008).

Changes in temperature and precipitation are also affecting frozen surface water. Spring and summer snow cover has decreased in the West. In mountainous regions of the western United States, April snow water equivalent has declined 15 to 30 percent since 1950, particularly at lower elevations and primarily due to warming (Field *et al.* 2007 in National Science and Technology Council 2008). However, total snow-cover area in the United States increased in the November-to-January season from 1915 to 2004 (National Science and Technology Council 2008).

Barnett *et al.* (2008) found that human-induced climate change was responsible for 60 percent of the observed changes in river flows, winter air temperature, and snow pack in the western United States.

Annual average Arctic sea ice extent decreased 2.7 (+/- 0.6) percent per decade from 1978 to 2005. In 2007, sea ice extent was approximately 23 percent less than the previous all-time minimum observed in 2005. Average sea ice thickness in the central Arctic *very likely* has decreased by approximately 3 feet from 1987 to 1997. These area and thickness reductions allow winds to generate stronger waves, which have increased shoreline erosion along the Alaskan coast. Alaska has also experienced increased thawing of the permafrost base of up to 1.6 inches per year since 1992 (EPA 2009b, National Science and Technology Council 2008).

Rivers and lakes are freezing over later, at an average rate change of 5.8 (+/- 1.6) days per century, with ice breakup taking place earlier, at an average rate of 6.5 (+/- 1.2) days per century. Loss of glacier mass is occurring in the mountainous regions of the Pacific Northwest and has been especially rapid in Alaska since the mid-1990s (National Science and Technology Council 2008).

Snowpack is also changing. At high elevations that remain below freezing in winter, precipitation increases have resulted in increased snowpack. Warmer temperatures at mid-elevations have decreased snowpack and led to earlier snowmelt, even with precipitation increases (Kundzewicz *et al*. 2007). An empirical analysis of available data indicated that temperature and precipitation impact mountain snowpack simultaneously, with the nature of the impact strongly dependent on factors such as geographic location, latitude, and elevation (Stewart 2009).

3.4.2.2.2 Global Climate Change Effects

In their most recent assessment of climate change, the IPCC states that, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007b). The IPCC concludes that, "At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones" (IPCC 2007b).

This section describes observed historical and current climate-change effects and impacts at a global scale. As with the discussion of effects for the United States, much of the material that follows is drawn from the following studies, including the citations therein: *Summary for Policymakers* (IPCC 2007b), *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009b), *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), and *Global Climate Change Impacts in the United States* (GCRP 2009).

Increased Temperatures

The IPCC states that scientific evidence shows that the increase in GHGs (specifically, CO_2, CH_4, and N_2O) since 1750 has led to an increase in global positive radiative forcing of 2.30 W/m^2 (+/- 0.23 W/m^2) (EPA 2009b). The radiative forcing from increased CO_2 concentrations alone increased by 20 percent between 1995 and 2005, which is the largest increase in the past 200 years (IPCC 2007b).

This increase in radiative forcing results in higher temperatures, which are already being observed. Global temperature has been increasing over the past century. In the past 100 years, global mean surface temperatures have risen by 0.74 +/- 0.18 °C (1.3 +/- 0.32 °F) (EPA 2009b). Temperatures are rising at an increasing rate. The average rate of increase over the past century was 0.07 +/- 0.02 °C (0.13 +/- 0.04 °F) per decade. Over the past 50 years, temperatures have been rising at nearly twice that average rate or 0.13 +/- 0.03 °C (0.23 +/- 0.05 °F) per decade (EPA 2009b). Over the past 30 years, average global temperatures have risen even faster, for an average of 0.29 °F per decade (NOAA 2009 in EPA 2009). Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Temperature increases are more pronounced over land, because air temperatures over oceans are warming at about half the rate as air over land (EPA 2009b).

Extreme temperatures have changed significantly over the past 50 years. Hot days, hot nights, and heat waves have become more frequent; cold days, cold nights, and frost have become less frequent (EPA 2009b).

Weather balloons, and now satellites, have directly recorded increases in temperatures since the 1940s (GCRP 2009). In addition, higher temperatures are also independently confirmed by other global observations. For example, scientists have documented shifts to higher latitudes and elevations of certain flora and fauna habitat. In high and mid latitudes, the growing season increased on average by about 2 weeks during the second half of the 20th Century (EPA 2009b), and plant flowering and animal spring migration patterns are occurring earlier (EPA 2009b). Permafrost top layer temperatures have generally increased since the 1980s (about 3 °C [5 °F] in the Arctic), while the maximum area covered by seasonal frozen ground has decreased since 1900 by about 7 percent in the Northern Hemisphere, with a decrease in spring of up to 15 percent (EPA 2009b).

Some temperature-related climate variables are not changing. The diurnal temperature range has not changed from 1979 to 2004; [36] day- and night-time temperatures have risen at similar rates. Antarctic sea-ice extent shows no substantial average trends, despite inter-annual variability and localized changes, consistent with the lack of warming across the region from average atmospheric temperatures (GCRP 2009).

[36] Diurnal temperature range is a meteorological term that relates to the variation in temperature that occurs from the maximum (high) temperatures of the day to the minimum (lowest) temperatures of nights.

Sea-level Rise

Higher temperatures cause sea level to rise due to both thermal expansion of water and to an increased volume of ocean water from melting glaciers and ice sheets. EPA estimates that between 1993 and 2003, thermal expansion and melting ice were roughly equal in their effect on sea-level rise (EPA 2009b).

Between 1961 and 2003, observations of global ocean temperature indicate that it warmed by about 0.18 °F from the surface to a depth of 700 meters (0.43 mile). This warming contributed an average of 0.4 +/- 0.1 millimeter (0.016 +/- 0.0039 inch) per year to sea-level rise (EPA 2009b), because seawater expands as it warms. Mountain glaciers, ice caps, and snow cover have declined on average, contributing further to sea-level rise. Losses from the Greenland and Antarctic ice sheets have *very likely* contributed to sea-level rise from 1993 to 2003 and satellite observations indicate that they have contributed to sea-level rise in the years since (Shepherd and Wingham 2007). Dynamical ice loss explains most of the Antarctic net mass loss and about half of the Greenland net mass loss; the other half occurred because melting has exceeded snowfall accumulation (IPCC 2007b).

Global average sea level rose at an average rate of 1.8 +/- 0.5 millimeters (0.07 +/- 0.019 inch) per year from 1961 to 2003 with the rate increasing to about 3.1 +/- 0.7 millimeters (0.12 inch +/- 0.027) per year from 1993 to 2003 (EPA 2009b). Total 20th-Century rise is estimated at 0.17 +/- 0.05 meter (0.56 +/- 0.16 foot) (EPA 2009b). However, since the IPCC Fourth Assessment Report was published in 2007, a recent study improved the historical estimates of upper-ocean (300 meters to 700 meters [0.19 to 0.43 mile]) warming from 1950 to 2003 (by correcting for expendable bathy-thermographs instrument bias). Domingues *et al.* (2008) found the improved estimates demonstrate clear agreement with the decadal variability of the climate models that included volcanic forcing. Furthermore, this study estimated the globally averaged sea-level trend from 1961 to 2003 to be 1.5 +/- 0.4 millimeters (0.063 +/- 0.01 inch) per year with a rise of 2.4 millimeters (0.094 inch) per year evident from 1993 to 2003, consistent with the estimated trend of 2.3 millimeters (0.091 inch) per year from tide gauges after taking into account thermal expansion in the upper ocean and deep ocean, variations in the Antarctica and Greenland ice sheets, glaciers and ice caps, and terrestrial storage.

Sea-level rise is not uniform across the globe. The largest increases since 1992 have been in the western Pacific and eastern Indian Oceans; meanwhile, sea level in the eastern Pacific and western Indian Oceans has actually been falling (EPA 2009b).[37]

Changes in Precipitation Patterns

Average atmospheric water vapor content has increased since at least the 1980s over land and the oceans, and in the upper troposphere, largely consistent with air temperature increases. As a result, heavy precipitation events have increased in frequency over most land areas (National Science and Technology Council 2008).

Long-term trends in global precipitation amounts have been observed since 1900. Precipitation has substantially increased in eastern parts of North and South America, northern Europe, and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia. Spatial and temporal variability for precipitation is high, and data are limited for some regions (EPA 2009b).

[37] Note that parts of the United States' West Coast – which is part of the eastern Pacific – are experiencing a rise in sea level (*see* Section 3.4.2.2.1). Local changes in sea-level rise depend on a variety of factors, including land subsidence.

Droughts that are more intense and longer have been observed since the 1970s, particularly in the tropics and subtropics, and were caused by higher temperatures and decreased precipitation. Changes in sea-surface temperatures, wind patterns, and decreased snowpack and snow cover have also been linked to droughts (EPA 2009b).

Increased Incidence of Severe Weather Events

Long-term trends in tropical cyclone activity have been reported, but there is no clear trend in the number of tropical cyclones each year. There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. However, concerns about data quality and multi-decadal variability persist (EPA 2009b). The World Meteorological Organization (WMO) Sixth International Workshop on Tropical Cyclones in 2006 agreed that “no firm conclusion can be made” on anthropogenic influence on tropical cyclone activity because “there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record” (WMO 2006).

There is also insufficient evidence to determine whether there are trends in large-scale phenomena such as the meridional overturning circulation (MOC) (a mechanism for heat transport in the North Atlantic Ocean, where warm waters are carried north and cold waters are carried toward the equator) or in small-scale phenomena such as tornadoes, hail, lightning, and dust storms (IPCC 2007b).

Changes in Ice Cover

Changes in air and ocean temperatures, precipitation onto the ice mass, and water salinity are affecting glaciers and ice sheets. Numerous studies have confirmed that glaciers and ice sheets have significantly shrunk in the past half century. Satellite images have documented the shrinking of the Greenland ice sheet and the West Antarctic ice sheet (NASA 2009); since 1979, the annual average Arctic sea ice area has been declining at a rate of 4.1 percent per decade (EPA 2009b). Additionally, some Arctic ice that previously was thick enough to last through summer has now thinned enough that it melts completely in summer. In 2003, 62 percent of the Arctic’s total ice volume was stored in multi-year ice; in 2008, only 32 percent was stored in multi-year ice (NASA 2009).

Acidification of Oceans

Oceans have absorbed some of the increase in atmospheric CO_2, which lowers the pH of the water. When CO_2 dissolves in seawater, there is an increase in the hydrogen ion concentration of the water, measured as a decline in pH. Relative to the pre-industrial period, the pH of the world’s oceans has dropped 0.1 pH units (EPA 2009b). Because pH is measured on a logarithmic scale, this represents a 30% increase in the hydrogen ion concentration of seawater, a significant acidification of the oceans. Although research on the ultimate impacts of ocean acidification is limited, scientists believe that the acidification is likely to interfere with the calcification of coral reefs and thus inhibit the growth and survival of coral reef ecosystems (EPA 2009b).

3.4.3 Methodology

The methodology NHTSA used to characterize the effects of the alternatives on climate has two key elements, as follows:

1. Analyzing the effects of the proposed action and alternatives on GHG emissions; and
2. Analyzing how GHG emissions affect the climate system (climate effects).

For both effects on GHG emissions and effects on the climate system, this EIS expresses results – for each alternative – in terms of the environmental attribute being characterized (emissions, CO_2 concentrations, temperature, precipitation, and sea level). Comparisons between the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 9) are also presented to illustrate the differences in environmental effects among the alternative CAFE standards. The impact of each action alternative on these results is measured by the difference in its value under the No Action Alternative and its value under that action alternative. For example, the reduction in CO_2 emissions attributable to an action alternative is measured by the difference in emissions under that alternative and emissions under the No Action Alternative.

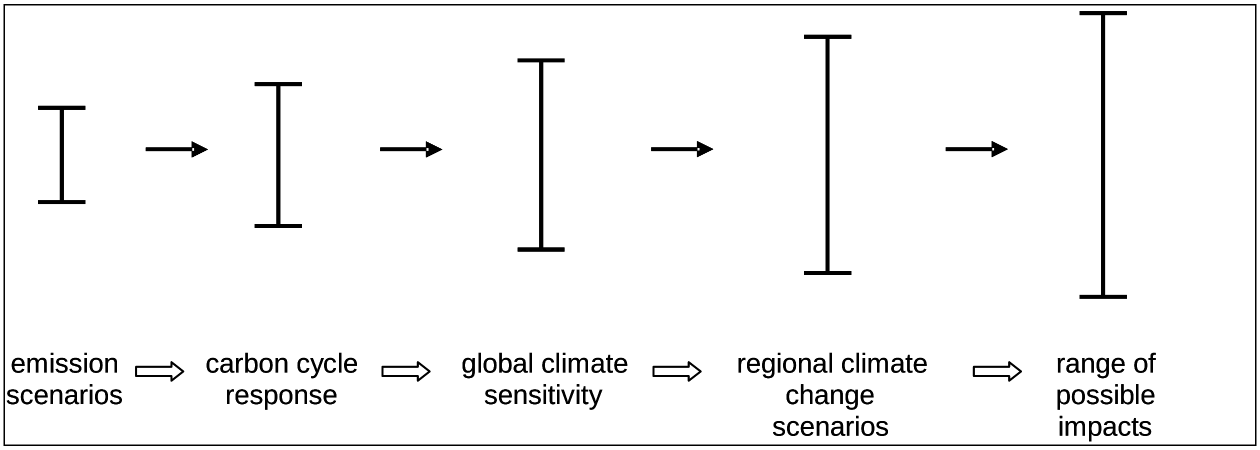
The methods used to characterize emissions and climate effects involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in the transportation sector and other sectors that emit GHGs; changes in the future fuel supply and fuel characteristics that could affect emissions; sensitivity of climate to increased GHG concentrations; rate of change in the climate system in response to changing GHG concentrations; potential existence of thresholds in the climate system (which cannot be predicted or simulated); regional differences in the magnitude and rate of climate changes; and many other factors.

Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change simulations (Figure 3.4.3-1). As indicated in the figure, the emissions estimates used in this EIS have narrower bands of uncertainty than the global climate effects, which are less uncertain than the regional climate change effects. The effects on climate are, in turn, less uncertain than the impacts of climate changes on affected resources (such as terrestrial and coastal ecosystems, human health, and other resources discussed in Section 4.5). Although the uncertainty bands get broader with each successive step in the analytic chain, this is not to say that all values within the bands are equally likely – it is still the case that the mid-range values have the highest likelihood.

Where information in the analysis in this EIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). The scientific understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decisionmaking, evaluating reasonably foreseeable significant adverse impacts on the human environment involves many assumptions and uncertainties. This EIS uses methods and data that represent the best and most up-to-date information available on this topic, and have been subjected to peer-review and scrutiny. In fact, the information cited throughout this section that is extracted from the most recent EPA, IPCC, and CCSP reports on climate change has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The tools used to perform the climate change impacts analysis in this EIS, including MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) and the Representative Concentration Pathway (RCP) and CCSP Final Report of Synthesis and Assessment Product (SAP) 2.1 emissions scenarios described below, are widely available and generally accepted in the scientific community.

CCSP SAP 3.1 on the strengths and limitations of climate models (CCSP 2008d) provides a thorough discussion of the methodological limitations regarding modeling. Readers interested in a detailed treatment of this topic can find the SAP 3.1 report useful in understanding the issues that underpin the modeling of environmental impacts of the proposed action and the range of alternatives on climate change.

Figure 3.4.3-1. Cascade of Uncertainty in Climate Change Simulations a/



a/ Source: Moss and Schneider (2000) – "Cascade of uncertainties typical in impact assessments showing the 'uncertainty explosion' as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses."

3.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

GHG emissions were estimated using the Volpe model, as described in Section 3.1.4. The emissions estimates include global CO_2, CH_4, and N_2O emissions resulting from direct fuel combustion and from the production and distribution of fuel (upstream emissions) in the United States. The Volpe model also accounted for and estimated the following non-GHGs: SO_2, NO_x, CO, and VOCs.

Fuel savings from stricter CAFE standards result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[38] There is a direct relationship among fuel economy, fuel consumption, and CO_2 emissions. Lower fuel consumption reduces CO_2 emissions directly because the primary source of vehicle-related CO_2 emissions is fuel combustion in internal-combustion engines. Therefore, fuel consumption is directly related to CO_2 emissions and CO_2 emissions are directly related to fuel economy. NHTSA estimates reductions in CO_2 emissions resulting from fuel savings by assuming that the carbon content of gasoline, diesel, and other fuels is converted entirely to CO_2 during the combustion process.[39] Specifically, NHTSA estimates CO_2 emissions from fuel combustion as the product of the volume of each type of fuel consumed (in gallons), its mass density (in grams per gallon), the fraction of its total mass represented by carbon (measured as a proportion), and CO_2 emissions per gram of fuel carbon (the ratio of the molecular weights of CO_2 and elemental carbon).

Reduced fuel consumption also lowers CO_2 emissions that result from the use of carbon-based energy sources during fuel production and distribution. NHTSA currently estimates the global reductions in CO_2 emissions during each phase of fuel production and distribution using CO_2 emissions rates obtained from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)

[38] For this rulemaking, NHTSA estimated emissions of vehicular CO_2, CH_4, and N_2O emissions, but did not estimate vehicular emissions of HFCs. CH_4 and N_2O account for 2.2 percent of the tailpipe GHG emissions from passenger cars and light trucks, and CO_2 emissions account for the remaining 97.8 percent. Of the total (including non-tailpipe) GHG emissions from passenger cars and light trucks, tailpipe CO_2 represents about 93.5 percent, tailpipe CH_4 and N_2O represent about 2.1 percent, and HFCs (from air-conditioner leaks) represent about 4.3 percent. (Values calculated from EPA 2009a.)

[39] This assumption results in a slight overestimate of CO_2 emissions, because a small fraction of the carbon content of gasoline is emitted as CO and unburned hydrocarbons. However, the magnitude of this overestimation is likely to be extremely small. This approach is consistent with the recommendation of the IPCC for "Tier 1" national GHG emissions inventories (IPCC 2006).

version 1.8b model using the previous assumptions about how fuel savings are reflected in reductions in activity during each phase of fuel production and distribution. The total reduction in CO_2 emissions from improving fuel economy under each CAFE alternative is the sum of the reductions in motor vehicle emissions from reduced fuel combustion, plus the reduction in upstream emissions from a lower volume of fuel production and distribution.

3.4.3.2 Methodology for Estimating Climate Effects

This EIS estimates and reports on four direct and indirect effects of climate change, driven by alternative scenarios of GHG emissions, as follows:

1. Changes in CO_2 concentrations;
2. Changes in global mean surface temperature;
3. Changes in regional temperature and precipitation; and
4. Changes in sea level.

The change in CO_2 concentration is a direct effect of the changes in GHG emissions and influences each of the other factors.

This EIS uses a simple climate model to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each CAFE alternative and uses increases in global mean surface temperature combined with an approach and coefficients from the IPCC Fourth Assessment Report (IPCC 2007a) to estimate changes in global precipitation. NHTSA used the publicly available modeling software MAGICC 5.3.v2 (Wigley 2008) to estimate changes in key direct and indirect effects. The application of MAGICC 5.3.v2 uses the estimated reductions in emissions of CO_2, CH_4, N_2O, CO, NO_x, SO_2, and VOCs produced by the Volpe model. A sensitivity analysis was completed to examine the relationship among selected CAFE alternatives and likely climate sensitivities, and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of emissions associated with the CAFE alternatives on direct and indirect climate effects.

This section describes MAGICC, the climate sensitivity analysis, and the emissions scenario used in the analysis.

3.4.3.2.1 MAGICC Version 5.3.v2

The selection of MAGICC for this analysis was driven by a number of factors, as follows:

- MAGICC has been used in the peer-reviewed literature to evaluate changes in global mean surface temperature and sea-level rise, including the IPCC Fourth Assessment Report for Working Group I (WGI) (IPCC 2007a) in which it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[40] to estimate the global mean surface temperature and the sea-level rise for global emissions scenarios that the AOGCMs did not run.
- MAGICC is publicly available and was designed for the type of analysis performed in this EIS.
- More complex AOGCMs are not designed for the type of sensitivity analysis performed here and are best used to provide results for groups of scenarios with much greater differences in emissions.

[40] For a discussion of AOGCMs, *see* WGI, Chapter 8 in IPCC (2007a).

- MAGICC has been updated to version 5.3.v2 to incorporate the science from the IPCC Fourth Assessment Report (Wigley 2008).
- EPA is also using MAGICC 5.3.v2 for their vehicle GHG emissions standards Regulatory Impact Analysis (RIA), which accompanies the joint NHTSA and EPA NPRM.

NHTSA assumed that global emissions under the No Action Alternative (Alternative 1) follow the trajectory provided by the RCP 4.5 MiniCAM (Mini Climate Assessment Model) reference scenario. This scenario represents a reference case, in which future global emissions continue to rise unchecked assuming no additional climate policy. It is based on the CCSP SAP 2.1 MiniCAM reference scenario, and has been revised by the Joint Global Change Research Institute to update emission estimates of non-CO_2 gases. Section 3.4.3.3 describes the RCP 4.5 MiniCAM reference scenario.

3.4.3.2.2 Reference Case Modeling Runs

The modeling runs and sensitivity analysis are designed to use information on CAFE alternatives, climate sensitivities, and the RCP 4.5 MiniCAM reference emissions scenario (Clarke *et al.* 2007, Smith and Wigley 2006)[41] to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise likely to result under each alternative.

The modeling runs are based on the results provided for the nine CAFE alternatives, a climate sensitivity of 3 °C (5.4 °F) for a doubling of CO_2 concentrations in the atmosphere, and the RCP 4.5 MiniCAM reference scenario.

The approach uses the following steps to estimate these changes:

1. NHTSA assumed that global emissions under the No Action Alternative follow the trajectory provided by the RCP 4.5 MiniCAM reference scenario.
2. NHTSA assumed that global emissions for the CAFE alternatives are equal to the global emissions from the No Action Alternative minus the emissions reductions from the Volpe model for CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs. (For example, the global emissions scenario under Alternative 2 equaled the RCP 4.5 MiniCAM reference scenario minus the emission reductions from that Alternative). All SO_2 reductions were applied to the Aerosol region 1 of MAGICC, which includes North America.
3. NHTSA used MAGICC 5.3.v2 to estimate the changes in global CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 using the global emissions scenario under each CAFE alternative, developed in Steps 1 and 2 above.
4. NHTSA used the increase in global mean surface temperature, along with factors relating increase in global average precipitation to this increase in global mean surface temperature, to estimate the increase in global averaged precipitation for each CAFE alternative using the RCP 4.5 MiniCAM reference scenario.

Section 3.4.4 presents the results of the model runs for the alternatives.

[41] The use of different emissions scenarios provides insight into the impact of alternative global emissions scenarios on the effect of the CAFE alternatives.

3.4.3.2.3 Sensitivity Analysis

NHTSA conducted a sensitivity analysis to examine the effect of various equilibrium climate sensitivities on the results. Equilibrium climate sensitivity[42] (or climate sensitivity) is the projected responsiveness of Earth's global climate system to forcing from GHG drivers, and is often expressed in terms of changes to global surface temperature resulting from a doubling of CO_2 in relation to pre-industrial atmospheric concentrations (280 ppm CO_2) (NRC 2001 in EPA 2009). In the past 8 years, confidence in climate sensitivity projections has increased significantly (Meehl *et al.* 2007b in EPA 2009). According to IPCC, with a doubling of the concentration of atmospheric CO_2, there is a 66- to 90-percent probability of an increase in surface warming of 2.0 to 4.5 °C (3.6 to 8.1 °F), with 3 °C (5.4 °F) as the single *most likely* surface temperature increase (EPA 2009b, Meehl *et al.* 2007a).

Climate sensitivities of 2.0, 3.0, and 4.5 °C (3.6, 5.4, and 8.1 °F) for a doubling of CO_2 concentrations in the atmosphere were assessed. NHTSA conducted the sensitivity analysis around two of the CAFE alternatives, the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4), as this was deemed sufficient to assess the effect of various climate sensitivities on the results.

The approach uses the following steps to estimate the sensitivity of the results to alternate estimates of the climate sensitivity:

1. NHTSA used the RCP 4.5 MiniCAM reference scenario to represent emissions from the No Action Alternative.
2. Starting with the RCP 4.5 MiniCAM reference scenario from step 1, NHTSA assumed that the reductions in global emissions of CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs resulting from the Preferred Alternative are equal to the global emissions of each pollutant under the No Action Alternative, minus emissions of each pollutant under the Preferred Alternative. All SO_2 reductions were applied to Aerosol region 1 of MAGICC, which includes North America.
3. NHTSA assumed climate sensitivity values consistent with the *likely* range from the IPCC Fourth Assessment Report (IPCC 2007a) of 2.0, 3.0, and 4.5 °C (3.6, 5.4, and 8.1 °F).
4. For each climate sensitivity in step 3, NHTSA used MAGICC 5.3.v2 to estimate the resulting changes in CO_2 concentrations, global mean surface temperature, and sea-level rise through 2100 for the global emissions scenarios in step 1 and 2.

Section 3.4.4.2.5 presents the results of the model runs for the alternatives.

3.4.3.3 Global Emissions Scenarios

As described above, MAGICC uses long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. The RCP 4.5 MiniCAM reference scenario is based on the MiniCAM reference scenario developed for the SAP 2.1 report. This scenario was created as part of the CCSP effort to develop a set of long-term (2000 to 2100) global emissions scenarios that incorporate an update of economic and technology data and utilize improved scenario-development tools compared to the IPCC *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) developed more than a decade ago.

[42] In this document, the term "climate sensitivity" refers to "equilibrium climate sensitivity."

The Strategic Plan for the U.S. Climate Change Science Program (CCSP 2003) called for the preparation of 21 synthesis and assessment products and noted that emissions scenarios are essential for comparative analysis of future climate change and for analyzing options for mitigating and adapting to climate change. The Plan includes Product 2.1, *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application* (Clarke *et al.* 2007), which presents 15 scenarios, five from each of the three modeling groups (IGSM, MiniCAM, and MERGE).[43]

Each climate modeling group independently produced a unique emissions reference scenario based on the assumption that no climate policy would be implemented beyond the current set of policies in place using a set of assumptions about drivers such as population changes, economic growth, land and labor productivity growth, technological options, and resource endowments. In addition, each group produced four additional stabilization scenarios, which are defined in terms of the total long-term radiative impact of the suite of GHGs that includes CO_2, N_2O, CH_4, HFCs, PFCs, and SF_6. These stabilization scenarios represent various levels of implementation of global GHG emissions reduction policies.

The results rely primarily on the RCP 4.5 MiniCAM reference scenario (which is based on the MiniCAM reference scenario developed for SAP 2.1) to represent a reference case emissions scenario; that is, future global emissions assuming no additional climate policy. NHTSA chose the RCP 4.5 MiniCAM reference scenario based on the following factors:

- The RCP 4.5 MiniCAM reference scenario is a slightly updated version of the scenario developed by the MiniCAM Model of the Joint Global Change Research Institute, which is a partnership between the Pacific Northwest National Laboratory and the University of Maryland, and is one of three reference climate scenarios described in the SAP 2.1. The MiniCAM reference scenario is based on a set of assumptions about drivers such as population, technology, and socioeconomic changes in the absence of global action to mitigate climate change.
- In terms of global emissions of CO_2 from fossil fuels and industrial sources, the MiniCAM reference scenario illustrates a pathway of emissions between the IGSM and MERGE reference scenarios for most of the 21st Century. In essence, out of the three SAP 2.1 reference case scenarios, the MiniCAM reference scenario is the “middle ground” scenario.
- CCSP SAP 2.1 is more than a decade newer than the IPCC SRES, and therefore has updated economic and technology data and assumptions and uses improved integrated assessment models that account for advances in economics and science over the past 10 years.
- EPA is also using the RCP 4.5 MiniCAM reference scenario for their vehicle GHG emissions standards RIA, which accompanies the joint NHTSA and EPA NPRM.

The RCP 4.5 MiniCAM reference scenario provides a global context for emissions of a full suite of GHGs and ozone precursors. There are some inconsistencies between the overall assumptions that SAP 2.1 and the Joint Global Change Research Institute used to develop the global emissions scenario and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand. However, these inconsistencies affect the characterization of each CAFE alternative in equal proportion, so the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives.

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[43] IGSM is the Massachusetts Institute of Technology’s Integrated Global System Model. MERGE is A Model for Evaluating the Regional and Global Effects of GHG Reduction Policies.

Each of the alternatives was simulated by calculating the difference between annual GHG emissions under that alternative and emissions under the No Action Alternative, and subtracting this change from the RCP 4.5 MiniCAM reference scenario to generate modified global-scale emissions scenarios, which show the effects of the various regulatory alternatives on the global emissions path. For example, CO_2 emissions from U.S. passenger cars and light trucks in 2020 under Alternative 1, No Action, are 1,810 $MMTCO_2$; the emissions in 2020 under the Alternative 4 (Preferred) are 1,690 $MMTCO_2$ (*see* Table 3.4.4-2). The difference of 120 $MMTCO_2$ represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global emissions for the RCP 4.5 MiniCAM reference scenario in 2020 are 38,020 $MMTCO_2$, which are assumed to incorporate the level of emissions from U.S. passenger cars and light trucks under the No Action Alternative. Global emissions under the Preferred Alternative are thus estimated to be 120 $MMTCO_2$ less than this reference level or 37,900 $MMTCO_2$ in 2020.

Many of the economic assumptions used in the Volpe model (such as fuel price, VMT, U.S. GDP) are based on EIA's Annual Energy Outlook (AEO) 2010 Early Release (EIA 2009a) and International Energy Outlook (IEO) 2009 (EIA 2009b), which forecast energy supply and demand in the U.S. and globally to 2030. Figures 3.4.3-2 to 3.4.3-6 show how the EIA forecasts of global and U.S. GDP, CO_2 emissions from energy use, and primary energy use compare against the assumptions used to develop the SAP 2.1 MiniCAM reference scenario.[44,45] Both forecasts presented here are for reference scenarios.

The GDP growth assumptions for the IEO reference scenario are slightly higher than those in SAP scenarios by about 0.6 percent annually for the world and 0.9 percent annually for the United States (*see* Figure 3.4.3-2).

Despite this IEO assumption of higher economic growth, the growth in primary energy use is similar between the IEO and MiniCAM with the total primary energy use in MiniCAM slightly lower than that of the IEO, as shown in Figure 3.4.3-5. Thus, the global primary liquids energy use in SAP 2.1 and the IEO 2009 compare well. Much of the difference in energy use in the IEO forecast is due to assumptions of higher coal use, which results in higher CO_2 emissions, as shown in Figure 3.4.3-4. Additionally, the IEO reference scenario estimates have a lower share of "other" fuels, which include biomass and renewable fuels, and is likely due to different treatments of non-commercial fuels in the two sets of forecasts.

The primary energy use projections for the United States show a different trend than the global numbers. The AEO 2010 Early Release (EIA 2009a)[46] projection shows an increase in total primary energy use in the United States, but much of the increase is from the use of coal and liquid fuels. On the other hand, the MiniCAM reference scenario has a higher share of natural gas (*see* Figure 3.4.3-6). However, the AEO reference scenario has a greater share of other fuels[47] than the MiniCAM reference scenario, resulting in lower CO_2 emissions (*see* Figure 3.4.3-4).

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[44] The MiniCAM reference scenario from SAP 2.1 uses the same assumptions for GDP, energy use, and CO_2 emissions as the RCP MiniCAM reference scenario.
[45] The IEO 2009 uses energy supply and consumption from the AEO 2009 for the United States and the same forecast for world oil prices. The IEO nuclear primary energy forecast numbers were adjusted to account for differences in reporting primary energy use for nuclear energy and all IEO energy-use estimates were converted to exajoules (EJ).
[46] AEO 2010 Early Release estimates were used for U.S. primary energy consumption.
[47] For AEO reference scenario, "other" includes biomass, hydropower, and other renewable fuels.

Figure 3.4.3-2. Average GDP Growth Rates (1990 to 2030)

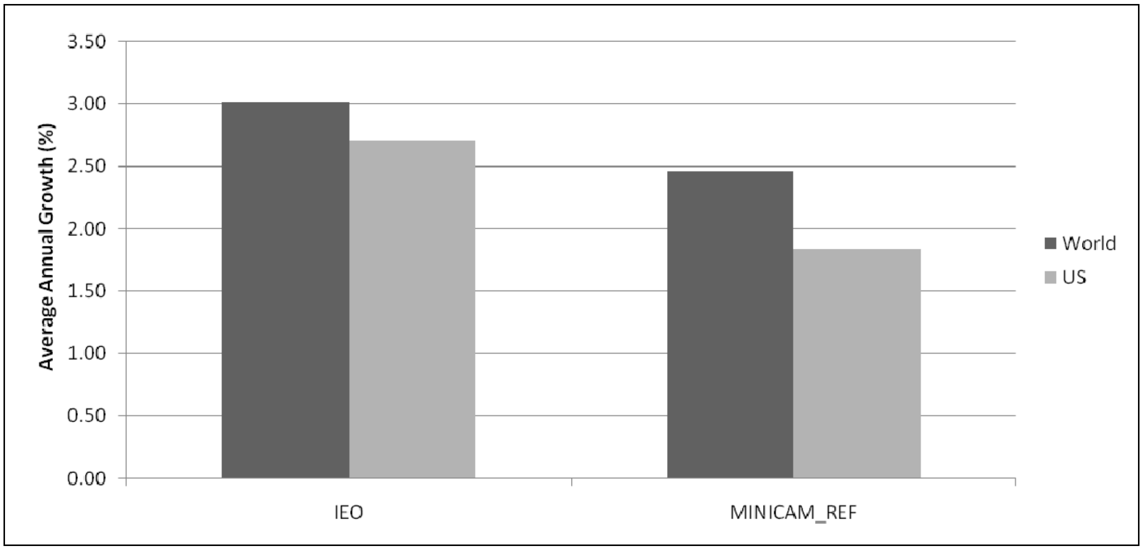


Figure 3.4.3-3. Global CO_2 Emissions from Fossil Fuel Use

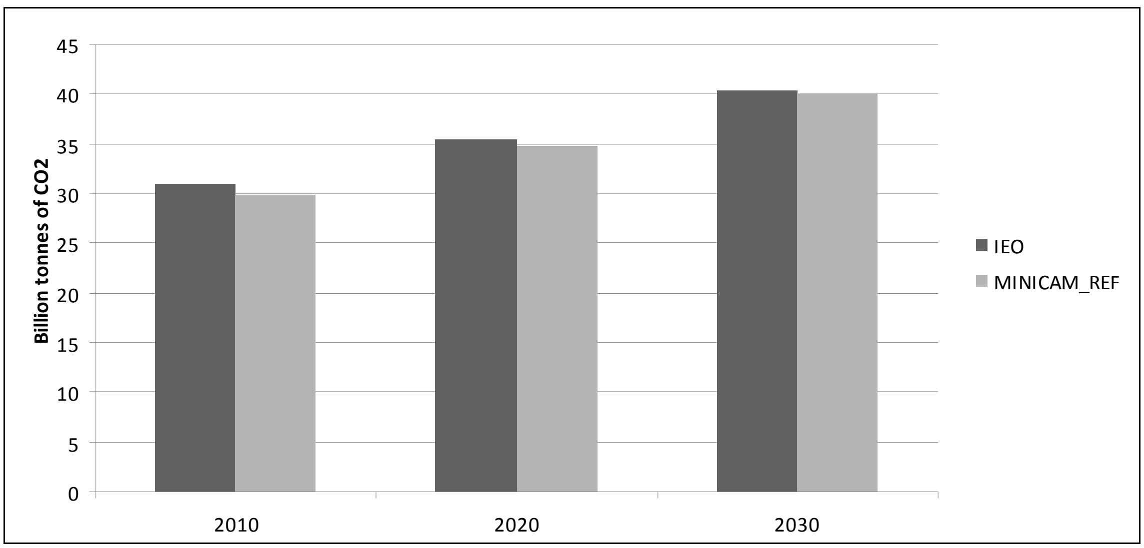


Figure 3.4.3-4. U.S. CO_2 Emissions from Fossil Fuel Use

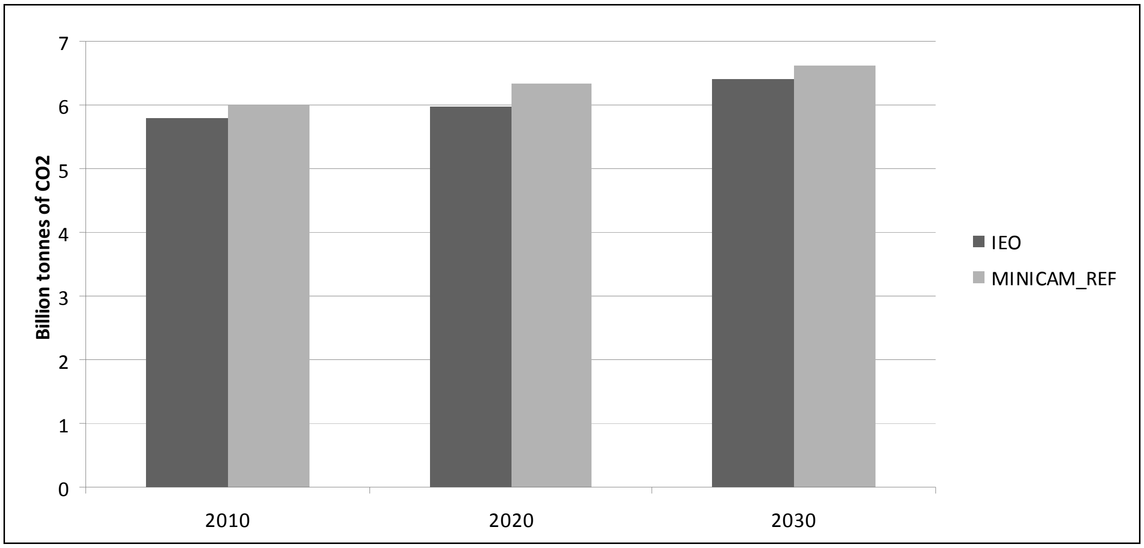


Figure 3.4.3-5. World Primary Energy Use Forecast

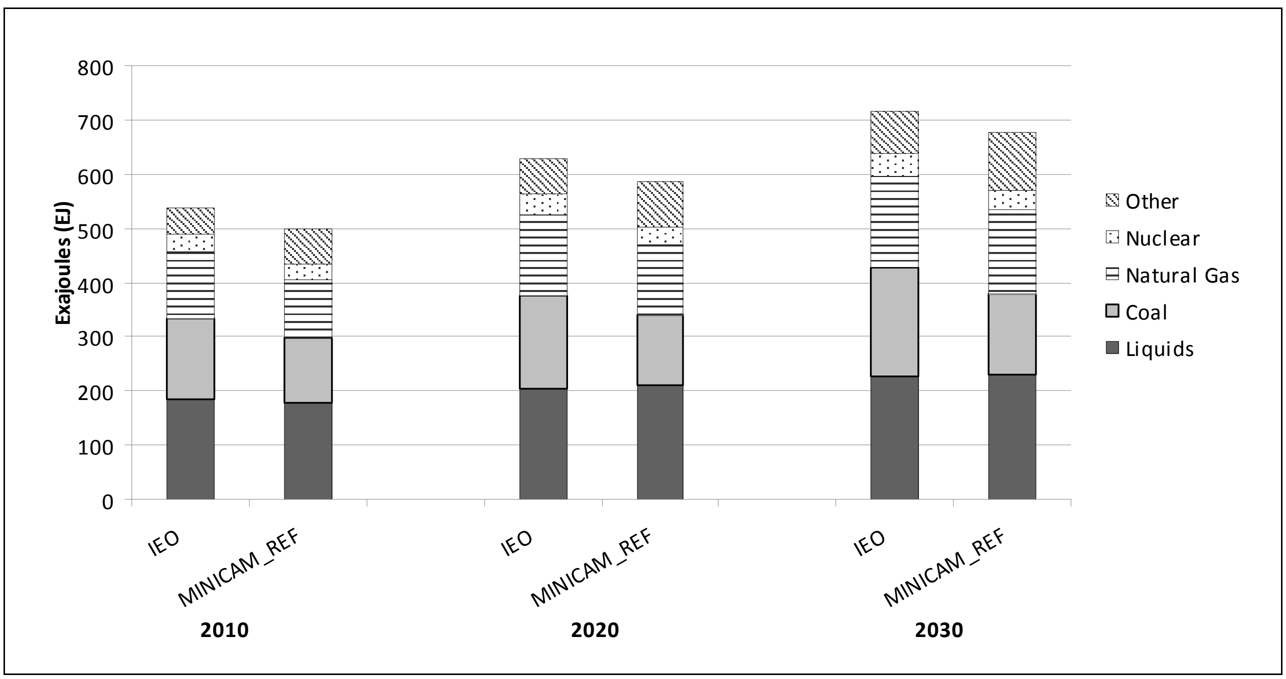
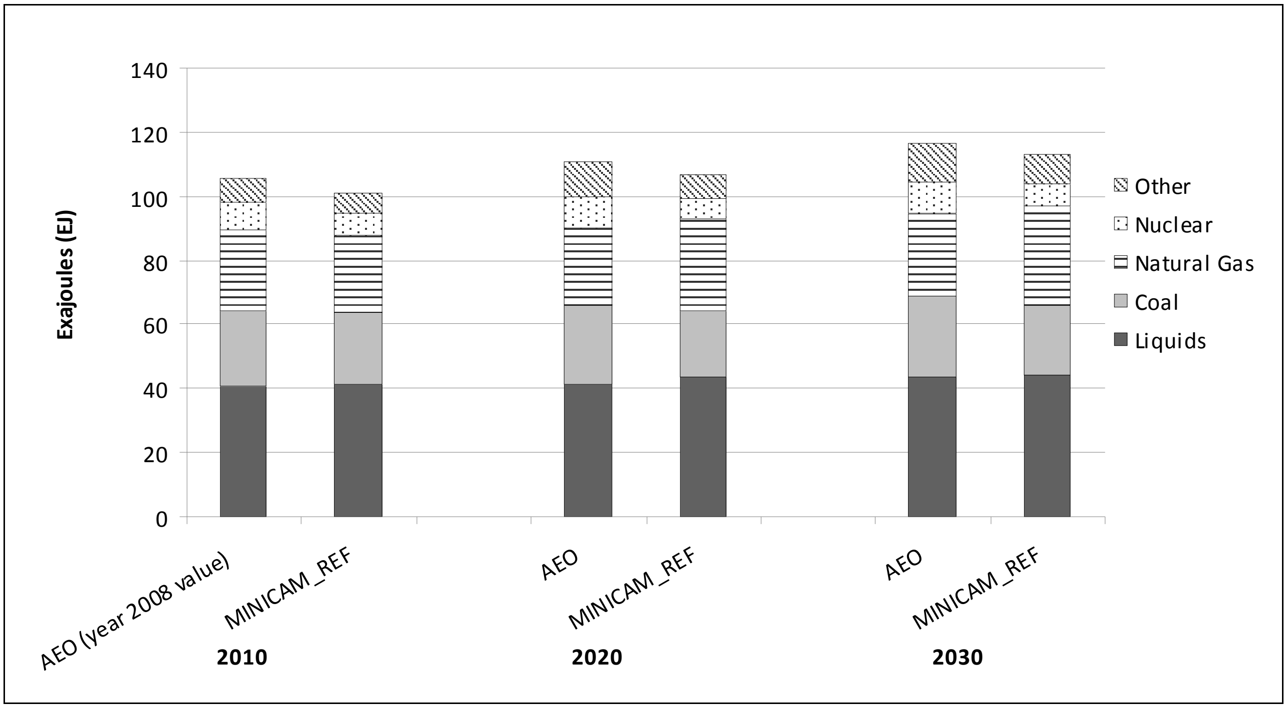


Figure 3.4.3-6. U.S. Primary Energy Use Forecast



Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). In this case, despite the inconsistencies between the MiniCAM assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the emissions estimates for the U.S. transportation sector provided by the Volpe model, the approach used is valid for this analysis. These inconsistencies affect all alternatives equally; therefore, they do not hinder a comparison of the alternatives in terms of their relative effects on climate.

The approaches focus on marginal changes in emissions that affect climate. Thus, the approaches result in a reasonable characterization of climate change for a given set of emissions reductions, regardless of the underlying details associated with those emissions reductions. Section 3.4.4 characterizes projected climate change under the No Action Alternative (Alternative 1) and the action alternatives (Alternatives 2 through 9).

The climate sensitivity analysis provides a basis for determining climate responses to varying climate sensitivities under the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). Section 3.4.3.2.2 discusses the methodology for the sensitivity analysis. Though the MAGICC model does not simulate abrupt climate change processes, some responses of the climate system represented in MAGICC are slightly non-linear, primarily due to carbon cycle feedbacks and the logarithmic response of equilibrium temperature to CO_2 concentration. Therefore, by using a range of emissions cases and climate sensitivities, the effects of the alternatives in relation to different scenarios and sensitivities can be estimated

3.4.3.3.1 Tipping Points and Abrupt Climate Change

The phrase "tipping point" is most typically used, in the context of climate change and its consequences, to describe situations in which the climate system (the atmosphere, oceans, land, cryosphere,[48] and biosphere) reaches a point at which there is a disproportionally large or singular response in a climate-affected system as a result of only a moderate additional change in the inputs to that system (such as an increase in the CO_2 concentration). Exceeding one or more tipping points, which "occur when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause" (NRC 2002 in EPA 2009), could result in abrupt changes in the climate or any part of the climate system. Abrupt climate changes could occur so quickly and unexpectedly that human systems would have difficulty adapting to them (NRC 2002 in EPA 2009).

The methodology used to address tipping points is based on an analysis of climate change science synthesis reports – including the *Technical Support Document for EPA's Endangerment Finding for GHGs* (EPA 2009b), the IPCC WGI report (Meehl *et al.* 2007a) and CCSP SAP 3.4: *Abrupt Climate Change* – and recent literature on the issue of tipping points and abrupt climate change. The analysis identifies vulnerable systems, possible temperature thresholds, and estimates of the likelihood, timing, and impacts of abrupt climate events. While there are methodological approaches to estimate temperatures resulting from a reduction in GHG emissions and associated radiative forcing, the present state of the art does not allow for quantification of how emission reductions from a specific policy or action might affect the probability and timing of abrupt climate change. This is one of the most complex and scientifically challenging areas of climate science, and given the difficulty of simulating the large-scale processes involved in these tipping points – or inferring their characteristics from paleoclimatology – considerable uncertainties remain as to the tipping points and rate of change. Despite the lack of a precise quantitative methodological approach, Section 4.5.9 presents a qualitative and comparative analysis of tipping points and abrupt climate change.[49]

3.4.4 Environmental Consequences

This section describes the environmental consequences of the proposed action and alternatives in relation to GHG emissions and climate effects.

3.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger car and light truck CAFE standards, NHTSA uses the Volpe model (*see* Sections 2.2.1 through 2.2.4 and Section 3.1.4 for descriptions of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total and petroleum energy use, which in turn affects the amount of CO_2 emissions. Reducing fuel use also lowers CO_2 emissions from the use of fossil carbon-based energy during crude-oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHGs emitted during fuel production and use – more than 95 percent, even after accounting for the higher global

[48] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

[49] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

warming potentials of other GHGs – NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel economy.[50]

NHTSA estimated GHG emissions for each alternative using the economic assumptions described in Section 2.2.4. In the discussion and table that follows, emissions reductions represent the differences in total annual emissions by all passenger cars or light trucks in use between their estimated future levels under the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 9). Emissions reductions resulting from the proposed action and alternatives for MYs 2012-2016 passenger cars and light trucks were estimated from 2012 to 2100. For each alternative, all vehicles after MY 2016 were assumed to meet the MY 2016 CAFE standards. Emissions were estimated for all alternatives through 2060, and emissions from 2061 through 2100 were assumed to remain constant at their levels estimated for 2060.[51] Emissions under each action alternative were then compared against those under the No Action Alternative to determine its impact on emissions.

Table 3.4.4-1 and Figure 3.4.4-1 show total emissions and emissions reductions resulting from applying the nine alternative CAFE standards to new passenger cars and light trucks from 2012 to 2100. Emissions for this period range from a low of 227,700 $MMTCO_2$ under the 7%/year Increase (Alternative 8) to 276,000 $MMTCO_2$ under the No Action Alternative (Alternative 1). Compared to the No Action Alternative, projections of emissions reductions over the period 2012 to 2100 due to the MYs 2012-2016 CAFE standards ranged from 20,700 to 48,300 $MMTCO_2$. Compared to cumulative global emissions of 5,293,896 $MMTCO_2$ over this period (projected by the RCP 4.5 MiniCAM reference scenario), this rulemaking is expected to reduce global CO_2 emissions by about 0.4 to 0.9 percent from their projected levels under the No Action Alternative.

Table 3.4.4-1

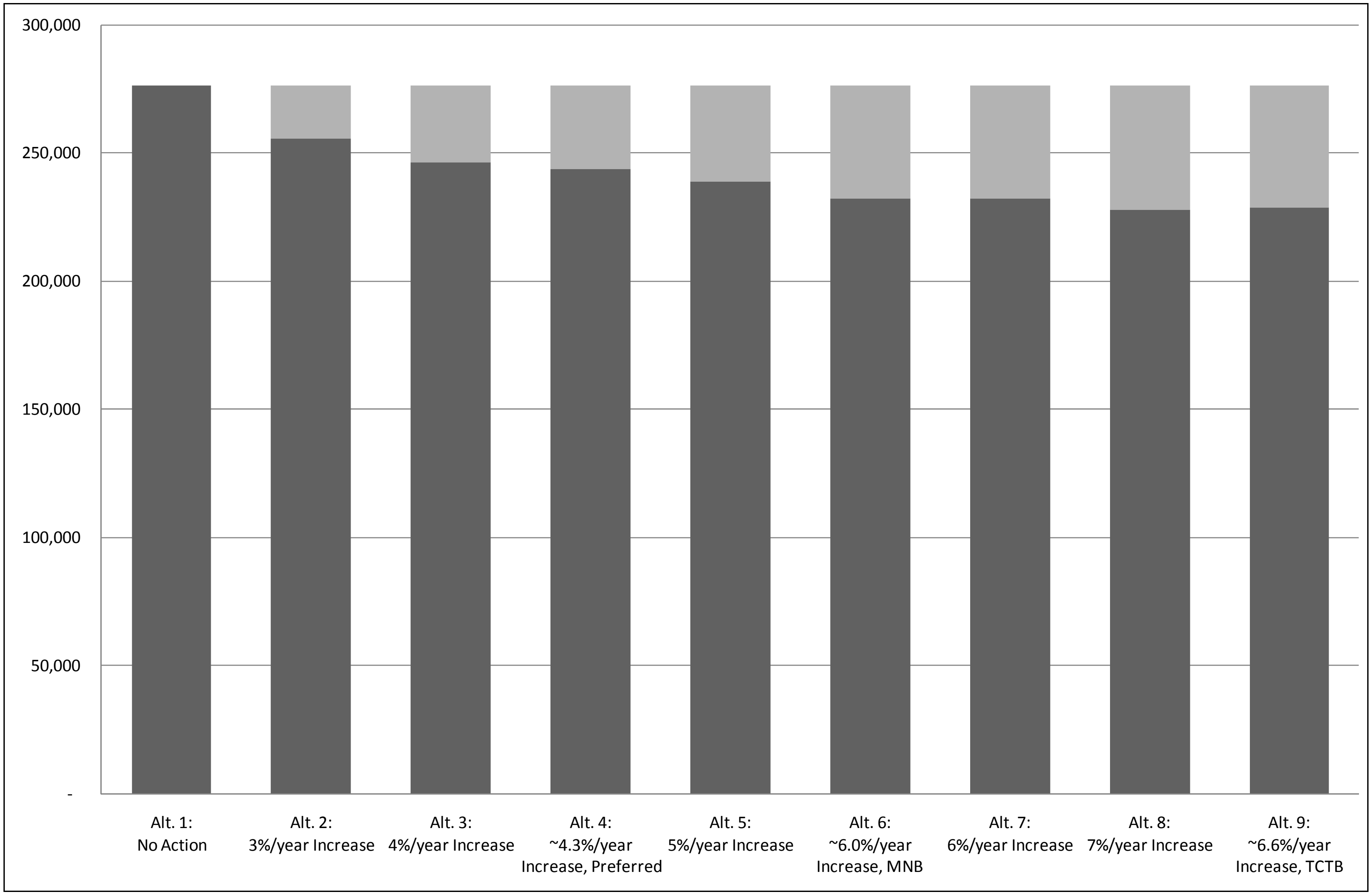
Emissions and Emissions Reductions ($MMTCO_2$) from 2012-2100 by Alternative a/

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	276,000	0
2 3%/year Increase	255,300	20,700
3 4%/year Increase	246,300	29,700
4 ~4.3%/year Increase, Preferred	243,800	32,300
5 5%/year Increase	238,900	37,100
6 ~6.0%/year Increase, MNB	232,200	43,900
7 6%/year Increase	232,100	43,900
8 7%/year Increase	227,700	48,300
9 ~6.6%/year Increase, TCTB	228,700	47,300

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

[50] Although this section includes a discussion of CO_2 emissions only, the climate modeling discussion in Section 3.4.4.4 assesses the direct and indirect effects associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.
[51] *See* Section 3.1.3 for a summary of the scope and parameters of the Volpe model.

Figure 3.4.4-1. Emissions and Emissions Reductions ($MMTCO_2$) from 2012 to 2100 by Alternative



To get a sense of the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from passenger cars and light trucks as a whole and to compare them against emissions projections from the transportation sector, and expected or stated goals from existing programs designed to reduce CO_2 emissions. As mentioned earlier, U.S. passenger cars and light trucks currently account for a significant amount of CO_2 emissions in the United States. With the action alternatives reducing U.S. passenger car and light truck CO_2 emissions by 7.5 to 17.5 percent of cumulative emissions from 2012-2100, they will have a noticeable impact on total U.S. CO_2 emissions. Compared to total U.S. CO_2 emissions in 2100 of 7,886 $MMTCO_2$ projected by the MiniCAM reference scenario (Clarke *et al.* 2007), the action alternatives would reduce total U.S. CO_2 emissions by 3.9 to 9.1 percent in 2100. Figure 3.4.4-2 shows projected annual emissions from passenger cars and light trucks under the MYs 2012-2016 alternative CAFE standards.

As Table 3.4.4-2 shows, total CO_2 emissions accounted for by the U.S. passenger car and light truck fleets are projected to increase substantially after 2020 under the No Action Alternative, which assumes average fuel economy would remain at the 2011 level for all future model years. The table also shows that each of the action alternatives would reduce total passenger car and light truck CO_2 emissions in future years significantly from their projected levels under the No Action Alternative. Progressively larger reductions in CO_2 emissions from their levels under the No Action Alternative are projected to occur during each future year because the action alternatives require successively higher fuel economy levels for MYs 2012-2016 and later passenger cars and light trucks.

Under all of the alternatives analyzed, growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth in total passenger car and light truck travel. This growth in travel overwhelms improvements in fuel economy for each of the alternatives, resulting in projected increases in total fuel consumption by U.S. passenger cars and light trucks over most of the period shown in the table. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger car and light truck fleet represented about 3.3 percent of total global emissions of all CO_2 emissions in 2005 (EPA 2009a, WRI 2009).[52] Although substantial, this source contributes a small percentage of global emissions, and the relative contribution of CO_2 emissions from the U.S. combined passenger car and light truck fleet is expected to decline in the future. This expected decline is due primarily to rapid growth of emissions from developing economies (which result in part from growth in global transportation sector emissions). In the CCSP SAP 2.1 MiniCAM reference scenario, the share of liquid fuel use – mostly oil – from the United States as a percent of total primary energy consumption declines from 40 percent in 2000 to 24 percent in 2100.[53]

As another way to provide context these GHG results, President Obama recently submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020, in association with the Copenhagen Accord,

[52] Includes land-use change and forestry, and excludes international bunker fuels.
[53] The RCP 4.5 MiniCAM reference scenario used in the climate modeling is based on the CCSP SAP 2.1 MiniCAM reference scenario. Both versions of the MiniCAM reference scenario in these models use the same assumptions for GDP, energy use, and CO_2 emissions.

Figure 3.4.4-2. Projected Annual Emissions ($MMTCO_2$) by Alternative

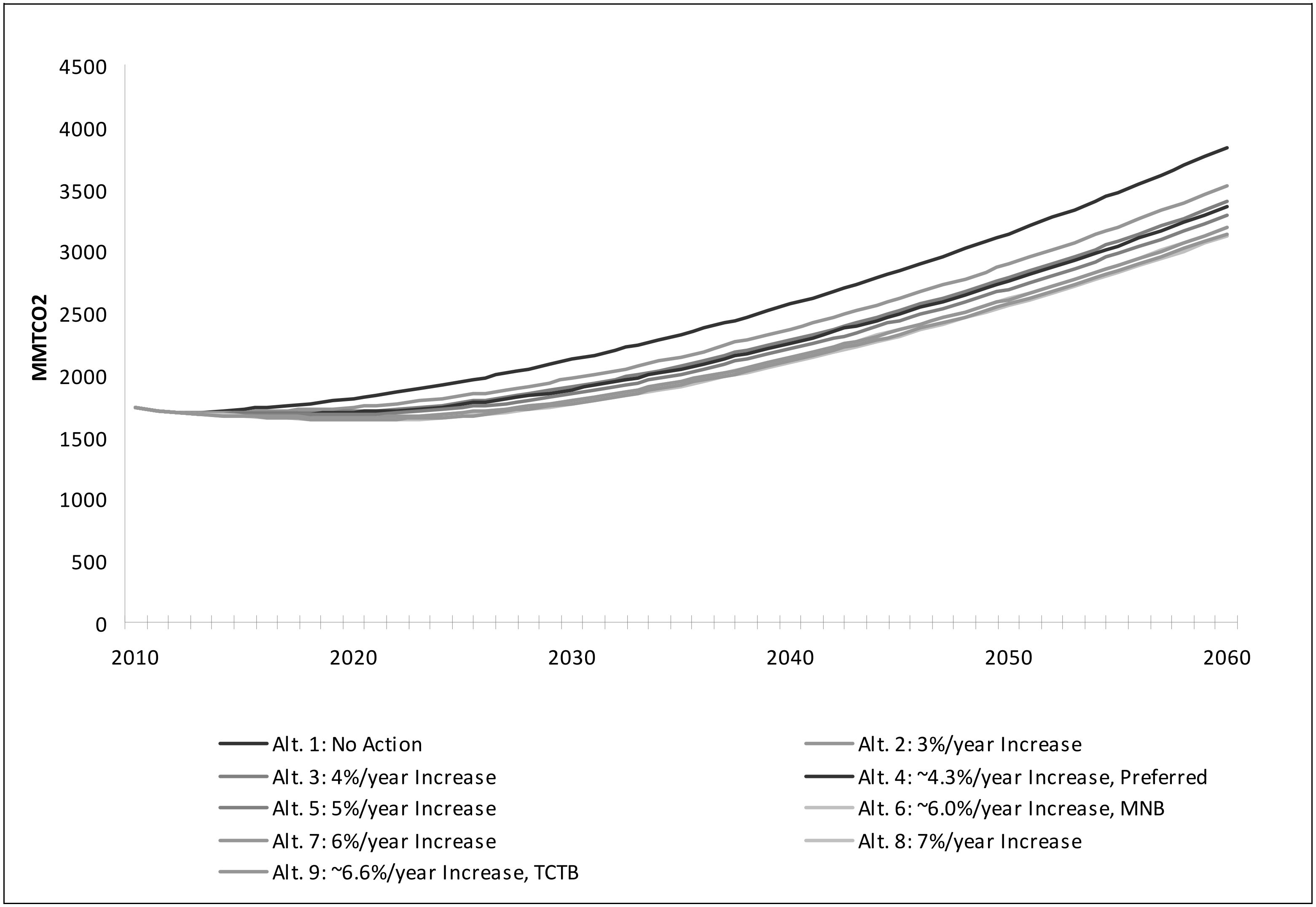


Table 3.4.4-2

Nationwide Emissions of Greenhouse Gases (MMT per Year) from Passenger Cars and Light Trucks by Alternative

GHG and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon dioxide (CO_2)									
2010	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730
2020	1,810	1,730	1,700	1,690	1,670	1,640	1,650	1,630	1,630
2030	2,120	1,970	1,900	1,880	1,840	1,790	1,790	1,760	1,770
2040	2,570	2,360	2,280	2,250	2,200	2,140	2,140	2,100	2,100
2050	3,140	2,890	2,780	2,750	2,690	2,610	2,610	2,550	2,570
2060	3,840	3,530	3,400	3,360	3,280	3,190	3,180	3,120	3,140
Methane (CH_4)									
2010	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
2020	2.11	2.02	1.99	1.97	1.95	1.92	1.92	1.90	1.90
2030	2.48	2.30	2.22	2.20	2.15	2.09	2.09	2.05	2.06
2040	3.00	2.77	2.66	2.64	2.57	2.49	2.49	2.44	2.45
2050	3.66	3.38	3.25	3.22	3.14	3.04	3.04	2.97	2.99
2060	4.48	4.13	3.97	3.93	3.84	3.71	3.71	3.63	3.65
Nitrous oxide (N_2O)									
2010	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2020	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2030	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2040	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
2050	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05
2060	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06

and in conformity with anticipated U.S. energy and climate legislation.[54] While the proposed action contributes to meeting that goal, the action alternatives would result in projected CO_2 emissions from the light duty vehicle sector in 2020 in the range of 0.6 percent above (Alternative 2) to 5.4 below (Alternative 9) 2005 levels. Thus, none of the alternatives considered would reduce 2020 emissions from passenger cars and light trucks by 17 percent from their 2005 level.[55] This occurs because the increases in fuel economy required by even those alternatives that would increase CAFE standards most rapidly (Alternatives 7, 8, and 9) are insufficient to offset the effect on total emissions from projected increases in total VMT by passenger cars and light trucks.

NHTSA emphasizes that the President's stated policy goal outlined above does not specify that every emitting sector of the economy must contribute equally proportional emissions reductions. Significantly, the action of setting fuel economy standards does not directly regulate total emissions from

[54] On January 28, 2010, the U.S. submitted this target to the U.N. Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the [U.N.] in light of enacted legislation." (U.S. Department of State 2010)

[55] A 17% reduction would mean a reduction of 293 $MMTCO_2$ from 2005 levels, or 375 from the No Action baseline.

passenger cars and light trucks. NHTSA's authority to promulgate new fuel economy standards is a limited authority and does not allow NHTSA to regulate other factors affecting emissions, including society's driving habits. Specifically, NHTSA notes that under all of the alternatives analyzed, growth in the number of passenger cars and light trucks in use throughout the U.S., combined with assumed increases in their average use (annual vehicle-miles traveled per vehicle), is projected to result in growth in total passenger car and light truck travel.

This projected growth in travel is expected to more than offset the effect of improvements in fuel economy required under each of the alternatives, resulting in increases in total fuel consumption by U.S. passenger cars and light trucks. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

As Figure 3.4.4-3 shows, NHTSA estimates that the proposed CAFE standards will reduce CO_2 emissions significantly from the future levels that would otherwise be estimated to occur in the absence of the CAFE program. These reductions in emissions are also sufficient to reduce total passenger car and light truck emissions during 2020 below their 2005 levels (for all alternatives except Alternative 2); however, none of the alternatives would reduce emissions sufficiently to achieve the target reduction of 17 percent from 2005 levels. These calculations are meant to present the agency's action as compared to some stated national policy goal to which a decisionmaker or reader might relate.

Figure 3.4.4-4 shows CO_2 reductions from the alternatives in 2016 expressed as equivalent to the number of passenger cars and light trucks that would produce those emissions in that year. The emissions reductions from the action alternatives are equivalent to the annual emissions of between 3.60 million cars (Alternative 2) and 9.70 million cars (Alternative 9) in 2016, as compared to the annual emissions that would occur in the absence of CAFE standards under the No Action Alternative. Emissions reductions in 2016 from the Preferred Alternative (Alternative 4) are equivalent to the annual emissions of 6.26 million cars. Annual CO_2 reductions, their equivalent in vehicles, and differences among alternatives grow larger in future years as older vehicles are increasingly replaced by newer ones meeting the progressively higher CAFE standards required by each alternative.[56]

These emissions reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate Initiative (WCI) to develop regional strategies to address climate change. The WCI stated a goal of reducing 350 $MMTCO_2$ equivalent over the period 2009 to 2020 (WCI 2007a).[57] If this goal is achieved, emissions levels in 2020 would be 33-percent lower than projected 2020 emissions levels under a business as usual scenario, and 15-percent lower than those at the beginning of the WCI action (WCI 2007b). By comparison, the proposed CAFE rulemaking is expected to reduce CO_2 emissions by 290 to 730 $MMTCO_2$ over the same period (depending on alternative), with emissions levels in 2020 representing a 4- to 10-percent reduction from the future baseline emissions for passenger cars and light trucks.

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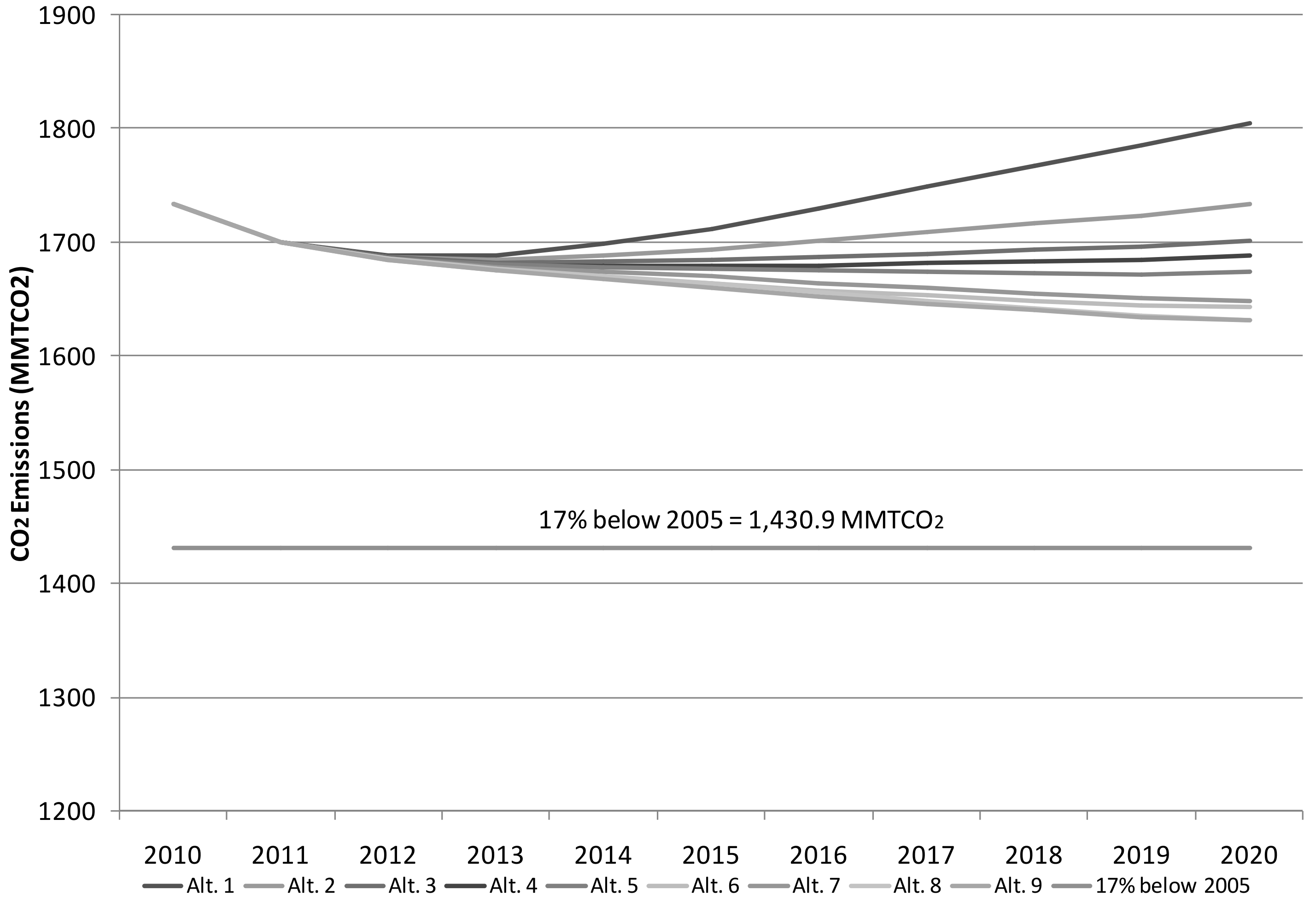
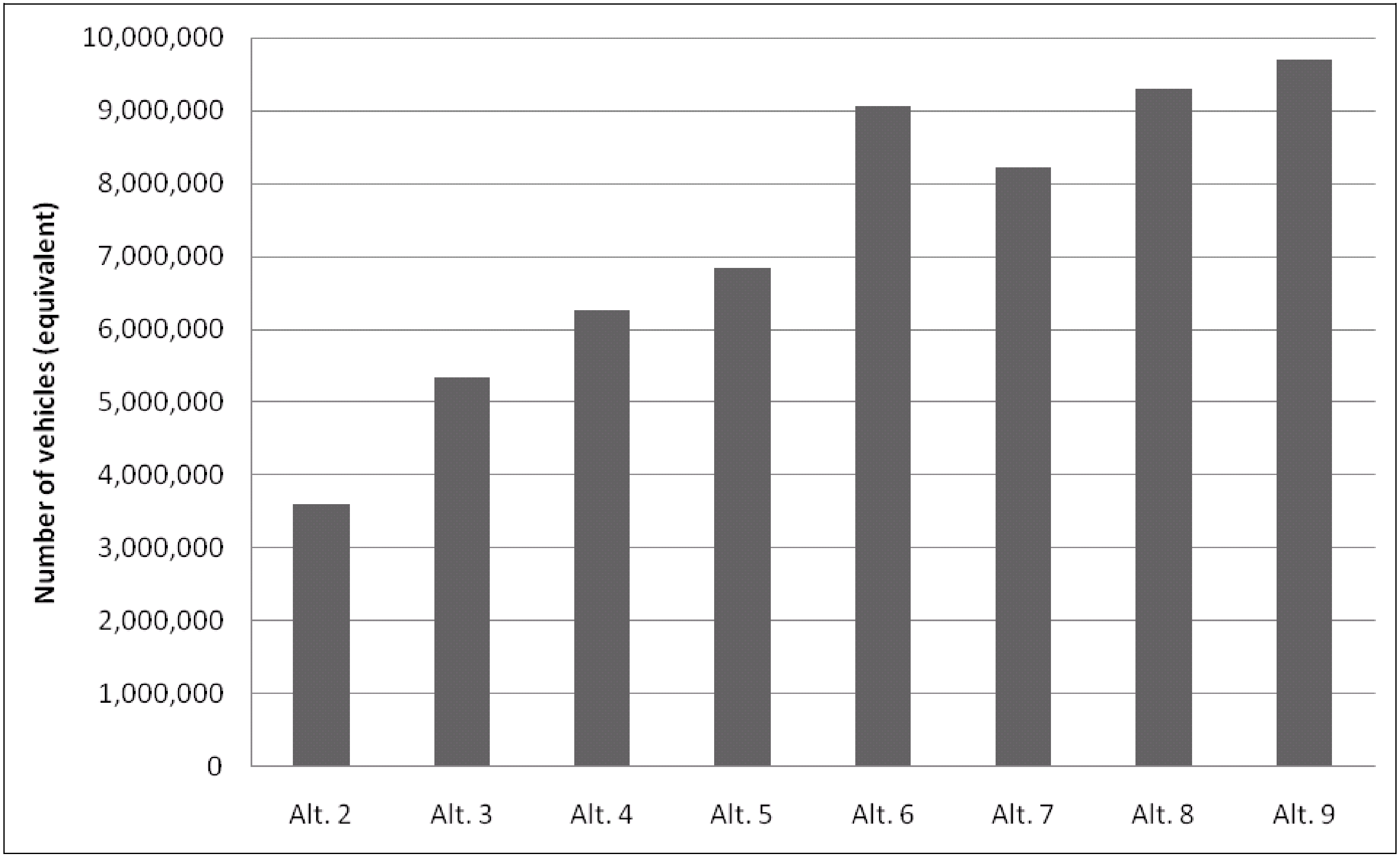
[56] The passenger vehicle equivalency is based on an average per-vehicle emissions estimate, which includes both tailpipe CO_2 emissions and associated upstream emissions from fuel production and distribution. The average light duty vehicle accounts for approximately 7.94 metric tons of CO_2 in the year 2016 based on Volpe model analysis.
[57] Since this goal was initially stated, Montana, Quebec, and Ontario joined the WCI. Thus, the total emissions reduction is likely to be greater than 350 $MMTCO_2$. A revised estimate was not available as of January 25, 2010.

Figure 3.4.4-3. Projected Annual Emissions by Alternative, Compared to 2005 Levels for Cars and Light Trucks



Note: 2005 CO_2 emissions from light-duty vehicles are 1,723.9 $MMTCO_2$.

Figure 3.4.4-4. Number of Passenger Cars and Light Trucks Equivalent to CO_2 Reductions in 2016, Compared to the No Action Alternative



Nine northeast and mid-Atlantic states have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce CO_2 emissions from power plants in the northeast. Emissions reductions from 2006 to 2024 were estimated at 268 $MMTCO_2$ (RGGI 2006).[58] This represents a 23-percent reduction from the future baseline and a 10-percent reduction in 2024 emissions from their levels at the beginning of the action (RGGI 2006). By comparison, NHTSA forecasts that the proposed CAFE rulemaking would reduce CO_2 emissions by 670 to 1,650 $MMTCO_2$ over this period (depending on alternative), with emissions levels in 2024 representing a 6- to 14-percent reduction from the future baseline emissions for passenger cars and light trucks.

Two features of these comparisons are extremely important to emphasize. First, emissions from the sources addressed in the WCI and RGGI plans are projected to decrease compared to the beginning of the action, while emissions from passenger cars and light trucks are projected to increase under all alternatives for this proposed rulemaking due to increases in vehicle ownership and use. Second, these projections are only estimates, and the scope of these climate programs differs from that in the scope of the proposed rulemaking in terms of geography, sector, and purpose.

In 2004, Robert Socolow and Stephen Pacala first introduced the concept of stabilization "wedges" – idealizing a new scheme of dividing necessary emissions reductions to prevent atmospheric CO_2 levels from doubling in the next 50 years (Pacala and Socolow 2004). In 2004, the concentration of atmospheric CO_2 was about 375 ppm. Socolow and Pacala proposed to stabilize atmospheric CO_2 at a maximum concentration of approximately 500 ppm for the next 50 years to prevent the most damaging forms of climate change. Stabilization at 500 ppm would require that emissions be held near the present level of 7 billion tons of carbon[59] per year (GtC/year) for the next 50 years. Socolow and Pacala depicted the necessary reductions in emissions from their projected increase over the next 50 years as a triangle, with progressively larger reductions in emissions from their projected level required during each successive future year (*see* Figure 3.4.4-5).

Socolow and Pacala divided the stabilization triangle into wedges, with each wedge representing an activity that reduces projected growth in carbon emissions by progressively larger amounts each year over a 50-year period ending in 2055, with the reduction reaching 1 billion tons annually in 2055. Socolow and Pacala estimated that approximately seven wedges of this size would be needed to fill the stabilization triangle (*see* Figure 3.4.4-6).

Wedges can be achieved from improvements in energy efficiency, decarbonization of energy sources, decarbonization of fuels, and from forests and agricultural soils. For example, approximately one wedge could be achieved from improvements in either fuel efficiency, reduced reliance on passenger cars, storing CO_2 from power and hydrogen plants, or reduced deforestation. Note that this wedge approach does not assess what the most appropriate global reduction should be, nor does it include an assessment of the economic costs of achieving that goal (whatever it may be), and the wedges could look fundamentally different depending on the approach taken, for example, mandating reductions versus an economy-wide market-based approach.

[58] Emissions reductions were estimated by determining the difference between the RGGI Cap and the Phase III RGGI reference case. These estimates do not include offsets. Offsets are credits that are created by projects outside of the cap system that decrease or sequester emissions in a way that is additional, verifiable, and permanent. Capped/regulated entities can use these offsets for compliance, thus allowing regulated entities to emit more, but allow reductions elsewhere.

[59] Socolow and Pacala present their analysis in terms of carbon, whereas this EIS discusses emissions in terms of CO_2. One ton of carbon equals roughly 3.67 tons of CO_2.

Figure 3.4.4-5. Historical Carbon Emissions with Two Potential Pathways for the Future (Source: Socolow *et al.* 2004)

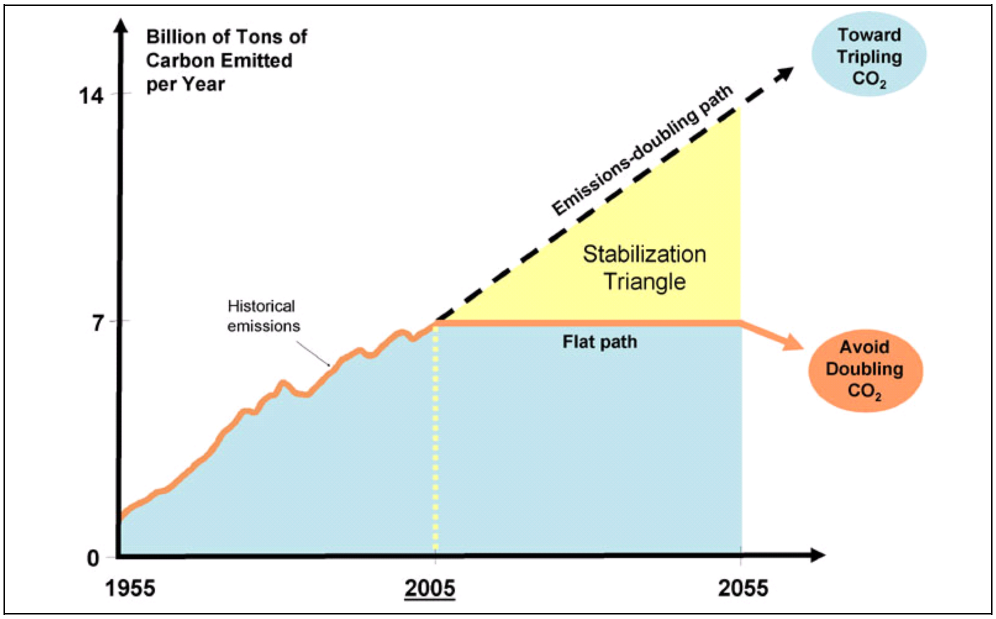
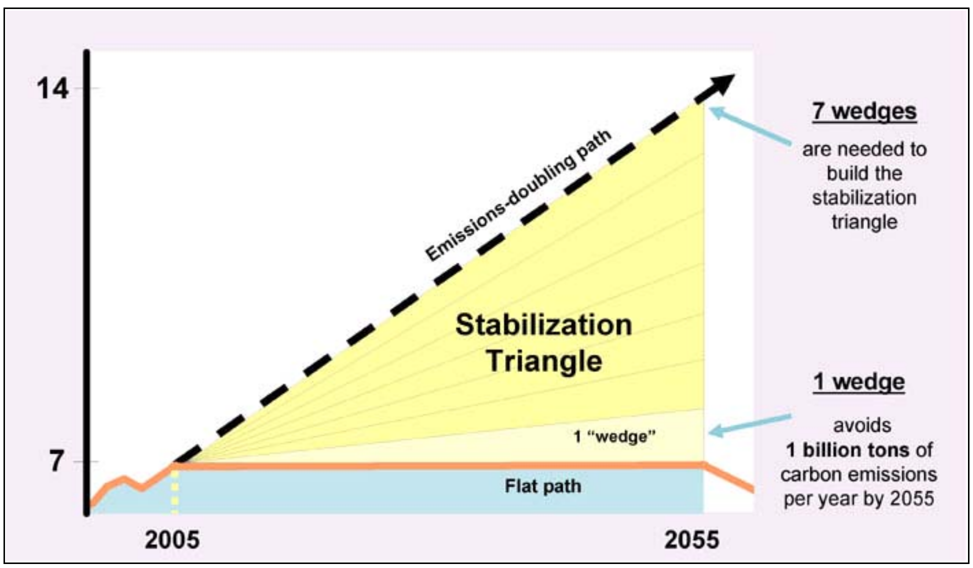


Figure 3.4.4-6. Stabilization Wedges (Source: Socolow *et al.* 2004)



Socolow and Pacala estimate that improving the average fuel economy of the world's combined passenger car and light truck fleet from an average of 30 mpg on conventional fuel to 60 mpg in 50 years (*i.e.*, by 2055) would achieve one wedge.[60] Their estimate is based on a global fleet of approximately 2 billion passenger cars and light trucks, averaging 10,000 miles per year.

[60] *Id.*; *see* also http://www.princeton.edu/~cmi/resources/wedgesumtb.htm (listing 15 examples of potential wedges).

By comparison, NHTSA estimates that the number of passenger cars and light trucks in use throughout the United States will increase to more than 310 million by 2055, the same year Socolow and Pacala analyzed, and that under the No Action alternative these vehicles will be driven an average of almost 22,000 miles. Thus, in total, NHTSA projects that passenger cars and light trucks in the United States will be driven more than 6.8 trillion miles during 2055 under the No Action Alternative. NHTSA estimates that the progressively higher fuel economy levels required by the eight action alternatives considered in this EIS (allowing for the accompanying increases in average vehicle use) would reduce total passenger car and light truck fuel consumption during 2055 by 23 billion gallons (under Alternative 2) to as much as 57 billion gallons (under Alternative 8). As a consequence, CO_2 emissions attributable to U.S. passenger car and light truck use in 2055 would decline by the equivalent of 8 percent (Alternative 2) to 19 percent (Alternative 9) of the emissions reductions corresponding to one "stabilization wedge."[61]

NHTSA emphasizes that the action of setting fuel economy standards does not directly regulate emissions from passenger cars and light trucks. NHTSA's authority to promulgate new fuel economy standards does not allow it to regulate other factors affecting emissions, including society's driving habits. NHTSA does not have the authority to control the increase of vehicles on the road or the amount of miles people drive. NHTSA's authority is to establish average fuel economy standards for each model year at "the maximum feasible average fuel economy that the Secretary decides the manufacturers can achieve in that model year." 49 U.S.C. § 32902(a). NHTSA estimates that the various alternatives being considered will decrease emissions from what they otherwise would be if the agency did not increase CAFE standards. However, due to the continued growth of VMT that the government forecasts, increased efficiency of internal combustion engines will not decrease total emissions from passenger cars and light trucks, although it will significantly slow the rate at which emissions from these vehicles increase, as mentioned above and as illustrated in Figure 3.4.4-2.

Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). In this case, the comparison of emissions reductions from the alternative CAFE standards to emissions reductions associated with other programs is intended to benefit decisionmakers by providing relative benchmarks, rather than absolute metrics, for selecting among alternatives. In summary, the alternatives analyzed herein deliver GHG emissions reductions that are on the same scale as many of the most progressive and ambitious GHG emissions reduction programs underway in the United States.

3.4.4.2 Direct and Indirect Effects on Climate Change

Sections 3.4.4.2.1 through 3.4.4.2.5 describe the direct and indirect effects of the alternatives on four relevant climate change indicators: atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise.

3.4.4.2.1 Atmospheric CO_2 Concentrations

MAGICC 5.3.v2 is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 3.4.4-3.[62] As the table indicates, the results of the model runs developed for this analysis agree relatively well with IPCC estimates for both CO_2 concentrations and surface temperature.

[61] These "wedge equivalents" of the alternative CAFE standards considered in this EIS account for the fact that the emissions reductions they would produce would not begin until 2012, later than the 2005 initial year for emissions reductions assumed in the Socolow Pacala analysis.
[62] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C (5.4 °F).

Table 3.4.4-3

Comparison of MAGICC Modeling Results and Reported IPCC Results (IPCC 2007) a/

	CO_2 Concentration (ppm)		Global Mean Increase in Surface Temperature (°C)		Sea-Level Rise (cm)	
Scenario	**IPCC WGI (2100)**	**MAGICC (2100)**	**IPCC WGI (2080-2099)**	**MAGICC (2090)**	**IPCC WGI (2090-2099) a/**	**MAGICC (2095)**
B1 (low)	550	538.3	1.79	1.81	28	26
A1B (medium)	715	717.2	2.65	2.76	35	35
A2 (high)	836	866.8	3.13	3.31	37	38

a/ The IPCC values represent the average of the 5- to 95-percent range of the rise of sea level between 1980 to 1989 and 2090 to 2099.

A comparison of sea-level rise from MAGICC 5.3.v2 and the IPCC Fourth Assessment Report is presented in the release documentation for MAGICC 5.3.v2 (Wigley 2008). In Table 3 of the documentation, Wigley presents the results for six SRES scenarios, which show that the comparable value for sea-level rise from MAGICC 5.3.v2 (total sea-level rise minus estimates for contributions from non-melt sources such as warming of the permafrost) within 0.01 centimeter in 2095.

As discussed in Section 3.4.3, NHTSA used the RCP 4.5 MiniCAM reference scenario to represent the No Action Alternative in the MAGICC modeling runs. Table 3.4.4-4 and Figures 3.4.4-7 through 3.4.4-10 present the results of MAGICC simulations for the No Action Alternative and the eight action alternatives in terms of CO_2 concentrations and increases in global mean surface temperature in 2030, 2050, and 2100. As Figures 3.4.4-9 and 3.4.4-10 show, the reduction in the increases in projected CO_2 concentrations and temperature from each of the action alternatives amounts to a small fraction of the total increases in CO_2 concentrations and global mean surface temperature. However, the relative impact of the action alternatives is shown by the reduction in increases of both CO_2 concentrations and temperature under Alternative 9. As shown in Figures 3.4.4-9 and 3.4.4-10, the reduction in increase of CO_2 concentrations by 2100 under Alternative 9 is more than twice that of Alternative 2. Similarly, the reduction in increase of temperature under Alternative 9 is more than twice that of Alternative 2.

As shown in Table 3.4.4-4 and Figures 3.4.4-7 through 3.4.4-10, estimated CO_2 concentrations for 2100 range from 778.4 ppm under Alternative 8 to 783.0 ppm under the No Action Alternative. For 2030 and 2050, the corresponding range is even smaller. Because CO_2 concentrations are the key driver of other climate effects (which in turn act as drivers on the resource impacts discussed in Section 4.5), this leads to small differences in these effects. While these effects are small, they occur on a global scale and are long-lived.

Table 3.4.4-4

CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-Level Rise Using MAGICC (RCP MiniCAM Reference) by Alternative a/

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-Level Rise (cm)		
	2030	2050	2100	2030	2050	2100	2030	2050	2100
1 No Action	441.8	514.8	783.0	0.923	1.557	3.136	8.38	15.17	38.00
2 3%/year Increase	441.6	514.3	781.0	0.922	1.554	3.128	8.38	15.16	37.94
3 4%/year Increase	441.5	514.0	780.2	0.922	1.553	3.125	8.38	15.15	37.91
4 ~4.3%/year Increase, Preferred	441.5	514.0	779.9	0.922	1.553	3.124	8.38	15.15	37.90
5 5%/year Increase	441.5	513.8	779.5	0.921	1.552	3.122	8.38	15.15	37.88
6 ~6.0%/year Increase, MNB	441.4	513.7	778.8	0.921	1.551	3.120	8.38	15.14	37.86
7 6%/year Increase	441.4	513.7	778.8	0.921	1.551	3.120	8.38	15.14	37.86
8 7%/year Increase	441.4	513.6	778.4	0.921	1.551	3.118	8.38	15.14	37.84
9 ~6.6%/year Increase, TCTB	441.4	513.6	778.5	0.921	1.551	3.118	8.38	15.14	37.84
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.5	2.0	0.001	0.002	0.007	0.00	0.01	0.06
3 4%/year Increase	0.3	0.8	2.8	0.001	0.003	0.011	0.00	0.02	0.09
4 ~4.3%/year Increase, Preferred	0.3	0.8	3.1	0.001	0.004	0.012	0.00	0.02	0.10
5 5%/year Increase	0.3	1.0	3.5	0.002	0.004	0.014	0.00	0.02	0.12
6 ~6.0%/year Increase, MNB	0.4	1.1	4.2	0.002	0.006	0.016	0.00	0.03	0.14
7 6%/year Increase	0.4	1.1	4.2	0.002	0.006	0.016	0.00	0.03	0.14
8 7%/year Increase	0.4	1.2	4.6	0.002	0.006	0.018	0.00	0.03	0.16
9 ~6.6%/year Increase, TCTB	0.4	1.2	4.5	0.002	0.006	0.017	0.00	0.03	0.16

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

Figure 3.4.4-7. CO_2 Concentrations (ppm)

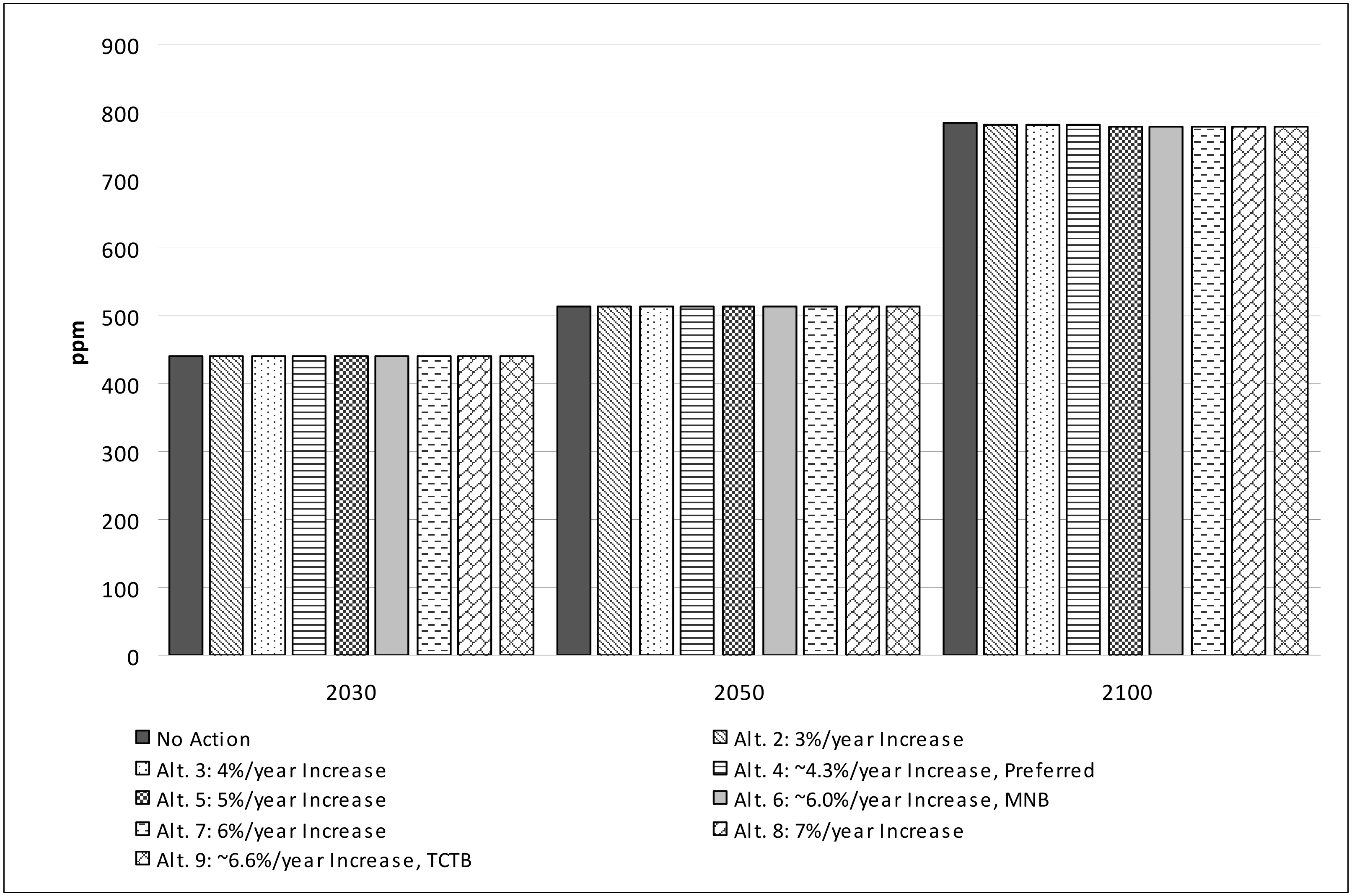


Figure 3.4.4-8. Global Mean Surface Temperature Increase (°C)

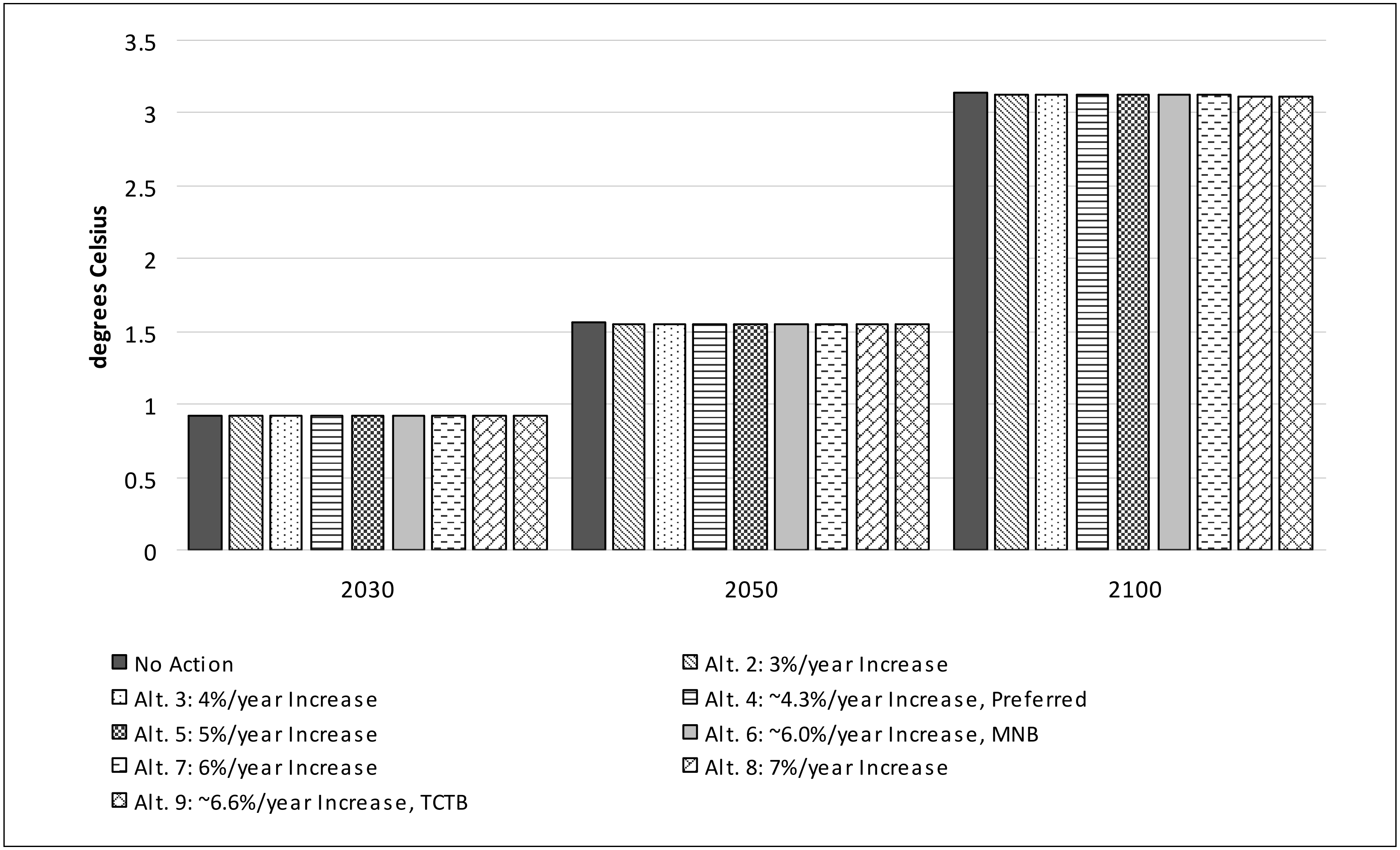


Figure 3.4.4-9. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

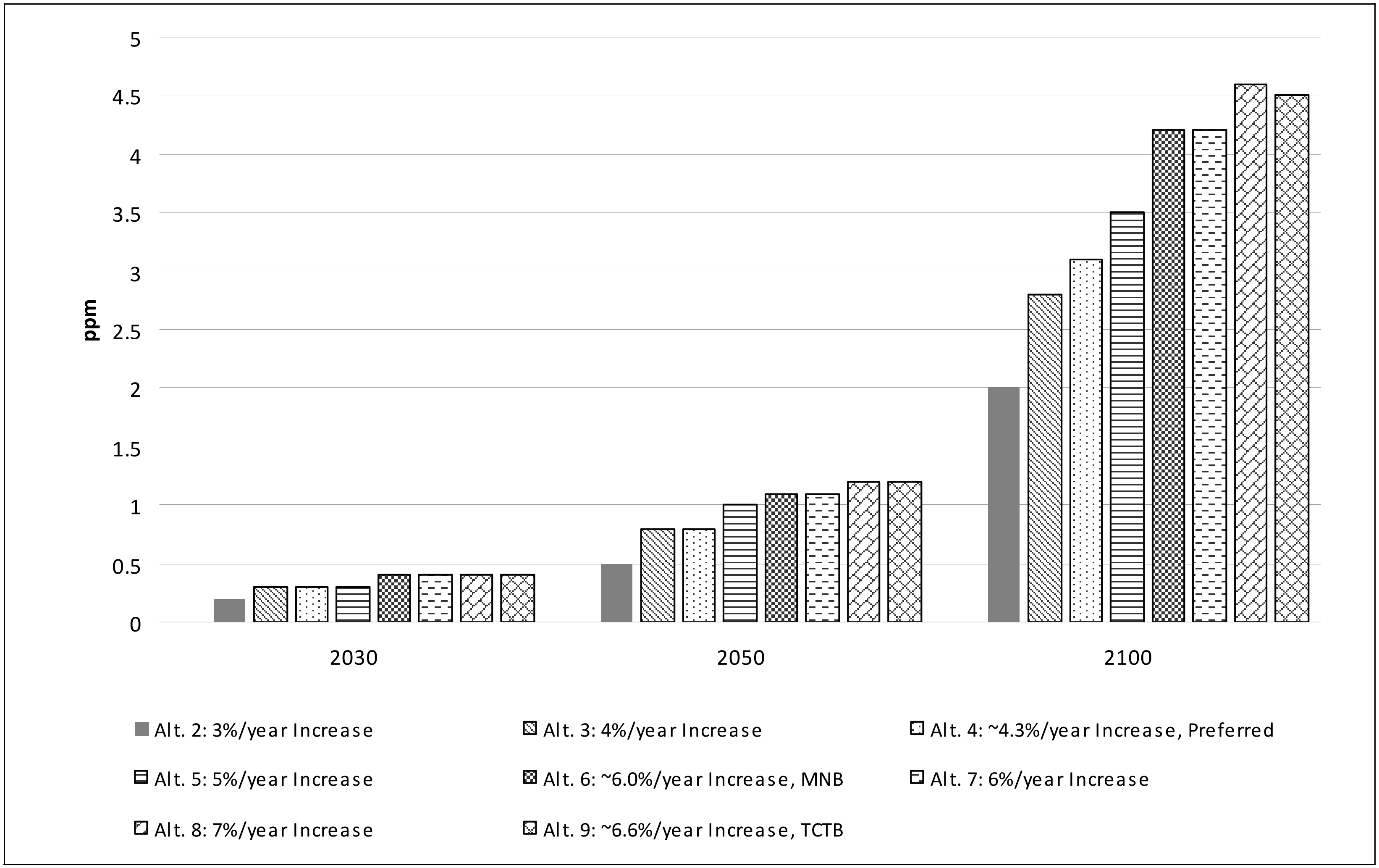
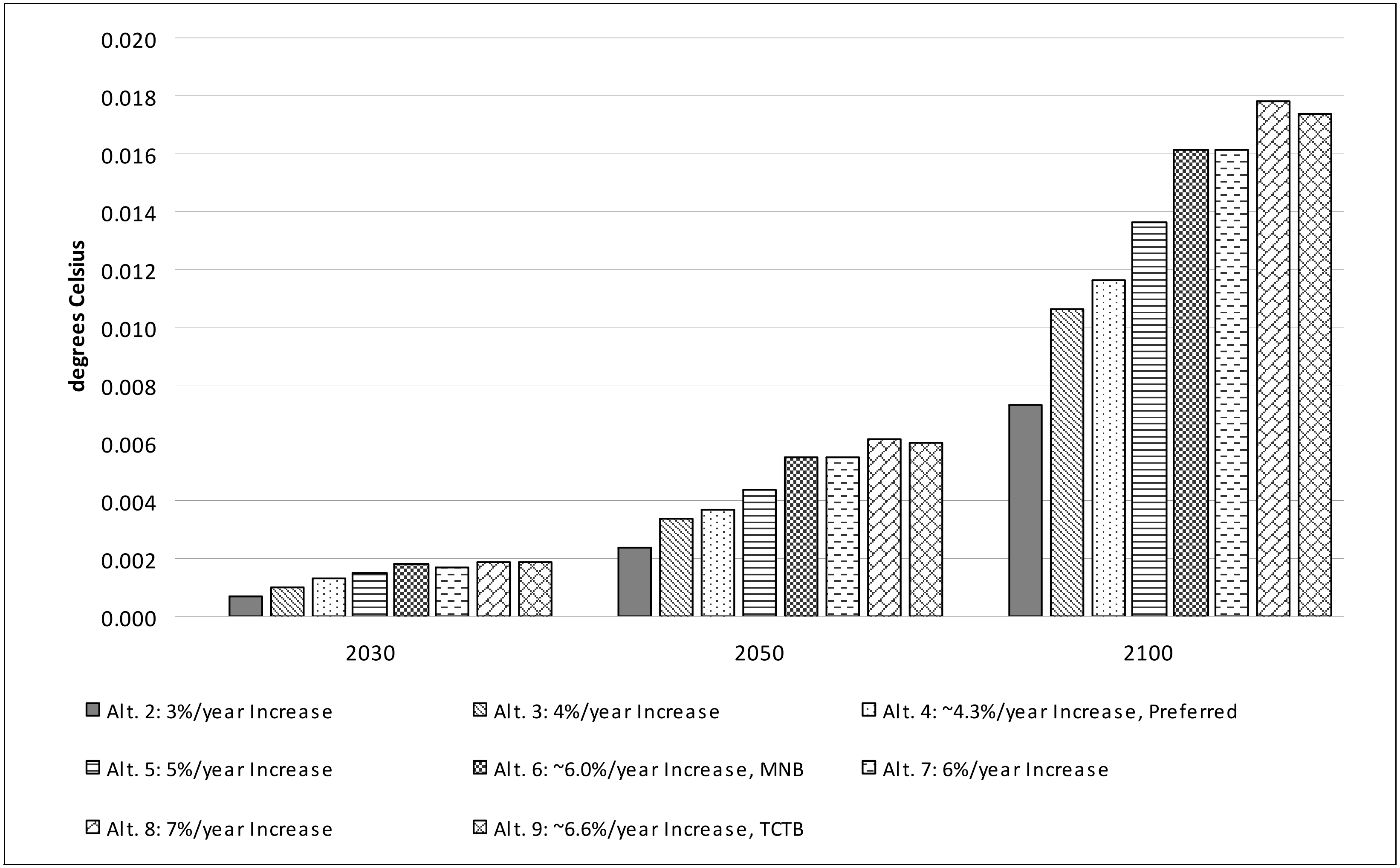


Figure 3.4.4-10. Reduction in Global Mean Temperature Compared to the No Action Alternative



3.4.4.2.2 Temperature

Table 3.4.4.4 lists MAGICC simulations of mean global surface air temperature increases. Under the No Action Alternative, the temperature increase from 1990 is 0.92 °C (1.65 °F) for 2030, 1.56 °C (2.80 °F) for 2050, and 3.14 °C (5.65 °F) for 2100. The differences among alternatives are small. For 2100, the reduction in temperature increase in relation to the No Action Alternative ranges from 0.007 °C (0.013 °F) to 0.018 °C (0.032 °F).

Table 3.4.4-5 summarizes the regional changes in warming and seasonal temperatures presented in the IPCC Fourth Assessment Report. At this time, quantifying the changes to regional climate from the CAFE alternatives is not possible due to the limitations of existing climate models, but the alternatives would be expected to reduce the impacts in proportion to the amount of reduction in global mean surface temperature.

Table 3.4.4-5

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
Africa	Mediterranean area and northern Sahara	*Likely* larger than global mean throughout continent and in all seasons	
	Southern Africa and western margins		
	East Africa		
Mediterranean and Europe	Northern Europe	*Likely* to increase more than the global mean with largest warming in winter	Maximum summer temperatures *likely* to increase more than the average
	Southern and Central Europe		
	Mediterranean area		
Asia	Central Asia	*Likely* to be well above the global mean	
	Tibetan Plateau	*Likely* to be well above the global mean	
	Northern Asia	*Likely* to be well above the global mean	
	Eastern Asia	*Likely* to be above the global mean	*Very likely* that heat waves/hot spells in summer will be longer, more intense, and more frequent *Very likely* fewer very cold days
	South Asia	*Likely* to be above the global mean	*Very likely* fewer very cold days
	Southeast Asia	*Likely* to be similar to the global mean	
North America	Northern regions/Northern North America	*Likely* to exceed the global mean warming	Warming is *likely* to be greatest in winter. Minimum winter temperatures are *likely* to increase more than the average
	Southwest		Warming is *likely* to be greatest in summer Maximum summer temperatures are *likely* to increase more than the average

Table 3.4.4-5 (cont'd)

Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Mean Warming	Maximum Summer Temperatures
	Northeast USA		
	Southern Canada		
	Canada		
	Northernmost part of Canada		
Central and South America	Southern South America	*Likely* to be similar to the global mean warming	
	Central America	*Likely* to be larger than global mean warming	
	Southern Andes		
	Tierra del Fuego		
	Southeastern South America		
	Northern South America		
Australia and New Zealand	Southern Australia	*Likely* comparable to the global mean but less than in the rest of Australia	Increased frequency of extreme high daily temperatures and decreased frequency of cold extremes are *very likely*
	Southwestern Australia	*Likely* comparable to the global mean	
	Rest of Australia	*Likely* comparable to the global mean	
	New Zealand, South Island	*Likely* less than the global mean	
	Rest of New Zealand	*Likely* comparable to the global mean	
Polar Regions	Arctic	*Very likely* to warm during this century more than the global mean	Warming greatest in winter and smallest in summer
	Antarctic	*Likely* to warm	
Small Islands		*Likely* to be smaller than the global annual mean	

MAGICC 5.3.v2 estimates radiative forcing from black carbon, a primary aerosol emitted through the incomplete combustion of fossil fuel and biomass burning. However, emissions trends for black carbon are "hard-wired" in the model to follow emissions of SO_2 and cannot be specified as separate inputs to the model.[63] The radiative forcing of black carbon is difficult to accurately quantify because it is a function of microphysical properties of the geographic and vertical placement, and lifetime

[63] Accurately determining the magnitude of mobile source emissions of black carbon is difficult because the emissions vary with fuel properties and fluctuations in the combustion environment. MOBILE6.2 outputs particulate matter mass that is then incorporated in the Volpe model. This particulate matter is based on tailpipe emissions and therefore includes carbon emissions from the combustion process. Because the carbon emissions are included as part of the particular matter and are not treated independently, the Volpe model does not provide direct results of the impact of the carbon emissions.

of the aerosol; however, it is not clear that black carbon contributes substantially to global warming (Jacobson 2001). Total global black carbon emissions are estimated to be approximately 8 Teragrams of carbon per year (Tg C/yr) (Bond *et al.* 2004 in Forster *et al.* 2007) with estimates of fossil fuel contributions ranging from 2.8 Tg C/yr (Ito and Penner 2005 in Forster *et al.* 2007) to 8.0 Tg C/yr (Haywood and Boucher in Forster *et al.* 2007).[64] In summary, the climate modeling accounts for the effects of black carbon on climate variables.

3.4.4.2.3 Precipitation

In some areas, higher temperatures might increase precipitation. Increases in precipitation are a result of higher temperatures causing greater water evaporation, which causes more water vapor to be available for precipitation (EPA 2009b). Increased evaporation leads to increased precipitation in areas where there is sufficient surface water, such as over oceans and lakes. In drier areas, the increased evaporation can actually accelerate surface drying, which can lead to drought conditions (EPA 2009b). Overall, according to IPCC (Meehl *et al.* 2007a), global mean precipitation is expected to increase under all scenarios. However, there will be considerable spatial and seasonal variations. Generally, precipitation increases are *very likely* to occur in high latitudes, and decreases are *likely* to occur in the sub-tropics (EPA 2009b).

Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). As noted earlier in the methodology section, MAGICC does not directly simulate changes in precipitation, and it was not feasible to undertake precipitation modeling with a full Atmospheric-Ocean General Circulation Model within the time and resources available for this EIS. In this case, the IPCC (Meehl *et al.* 2007a) summary of precipitation represents the most thoroughly reviewed, credible means of producing an assessment of this highly uncertain factor. NHTSA expects that the proposed action and alternatives would reduce anticipated changes in precipitation (i.e., in a reference case with no GHG emission reduction policies) in proportion to the alternatives' effects on temperature.

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (Meehl *et al.* 2007a) is given as the scaled change in precipitation (as a percentage change from 1980 to 1999 averages) divided by the increase in global mean surface warming for the same period (per °C) as shown in Table 3.4.4-6. The IPCC provides scaling factors in the year ranges of 2011 to 2030, 2046 to 2065, 2080 to 2099, and 2180 to 2199. NHTSA used the scaling factors for the RCP 4.5 MiniCAM reference scenario in this analysis because MAGICC does not directly estimate changes in global mean precipitation.[65]

Table 3.4.4-6

Global Mean Precipitation Change (scaled, % per °C) (Meehl *et al.* 2007a)

Scenario	2011-2030	2046-2065	2080-2099	2180-2199
A2 (high)	1.38	1.33	1.45	NA
A1B (medium)	1.45	1.51	1.63	1.68
B1 (low)	1.62	1.65	1.88	1.89

Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the CAFE action alternatives reduce

[64] Bond *et al.* 2004 estimates black carbon in PM_{10} to be 8.0 Tg/yr, with black carbon in $PM_{2.5}$ at 6.5 Tg/yr.
[65] Although MAGICC does not estimate changes in precipitation, SCENGEN does.

temperature increases slightly in relation to the No Action Alternative, they also slightly reduce predicted increases in precipitation, as shown in Table 3.4.4-7 (again based on the A1B [medium] scenario).

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation, as described below (Meehl *et al.* 2007a):

> Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas.

Table 3.4.4-7

Global Mean Precipitation (Percent Change) Based on MiniCAM Reference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % K-1)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (K) for the MiniCAM reference Scenario and Alternative CAFE Standards, Volpe Reference Results			
1 No Action	0.648	1.716	2.816
2 3%/year Increase	0.648	1.713	2.809
3 4%/year Increase	0.648	1.712	2.806
4 ~4.3%/year Increase, Preferred	0.648	1.712	2.806
5 5%/year Increase	0.648	1.711	2.804
6 ~6.0%/year Increase, MNB	0.648	1.709	2.801
7 6%/year Increase	0.648	1.709	2.801
8 7%/year Increase	0.648	1.709	2.800
9 ~6.6%/year Increase, TCTB	0.648	1.709	2.800
Reduction in Global Temperature (K) for Alternative CAFE Standards, Mid-level Results (Compared to No Action Alternative)			
2 3%/year Increase	0.000	0.003	0.006
3 4%/year Increase	0.000	0.004	0.009
4 ~4.3%/year Increase, Preferred	0.000	0.004	0.010
5 5%/year Increase	0.000	0.005	0.012
6 ~6.0%/year Increase, MNB	0.000	0.007	0.014
7 6%/year Increase	0.000	0.007	0.014
8 7%/year Increase	0.000	0.007	0.016
9 ~6.6%/year Increase, TCTB	0.000	0.007	0.016
Volpe Reference level Global Mean Precipitation Change (%)			
1 No Action	0.94%	2.59%	4.59%
2 3%/year Increase	0.94%	2.59%	4.58%
3 4%/year Increase	0.94%	2.58%	4.57%
4 ~4.3%/year Increase, Preferred	0.94%	2.58%	4.57%
5 5%/year Increase	0.94%	2.58%	4.57%
6 ~6.0%/year Increase, MNB	0.94%	2.58%	4.57%
7 6%/year Increase	0.94%	2.58%	4.57%
8 7%/year Increase	0.94%	2.58%	4.56%
9 ~6.6%/year Increase, TCTB	0.94%	2.58%	4.56%

Table 3.4.4-7 (cont'd)

Global Mean Precipitation (Percent Change) Based on MiniCAM Reference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 3%/year Increase	0.00%	0.00%	0.01%
3 4%/year Increase	0.00%	0.01%	0.02%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~6.0%/year Increase, MNB	0.00%	0.01%	0.02%
7 6%/year Increase	0.00%	0.01%	0.02%
8 7%/year Increase	0.00%	0.01%	0.03%
9 ~6.6%/year Increase, TCTB	0.00%	0.01%	0.03%

a/ Note: The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

Regional variations and changes in the intensity of precipitation events cannot be quantified further, primarily due to the unavailability of AOGCMs required to estimate these changes. These models are typically used to provide results among scenarios with very large changes in emissions, such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles would produce results that would be difficult to resolve among scenarios with small changes in emissions. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but inconsistent for other areas.

Table 3.4.4-8 summarizes the regional changes in precipitation from the IPCC Fourth Assessment Report. Quantifying the changes in regional climate from the alternative CAFE standards is not possible at present, but they would be expected to reduce the changes in relation to the reduction in global mean surface temperature.

3.4.4.2.4 Sea-level Rise

IPCC identifies four primary components of sea-level rise: (1) thermal expansion of ocean water, (2) melting of glaciers and ice caps, (3) loss of land-based ice in Antarctica, and (4) loss of land-based ice in Greenland (IPCC 2007b). Ice-sheet discharge is an additional factor that could influence sea level over the long term. Ocean circulation, changes in atmospheric pressure, and geological processes can also influence sea-level rise at a regional scale (EPA 2009b). MAGICC calculates the oceanic thermal expansion component of global mean sea-level rise using a nonlinear temperature- and pressure-dependent expansion coefficient (Wigley 2008). It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded. Neither MAGICC 5.3.v2 nor the IPCC Fourth Assessment Report includes more recent information, suggesting that ice flow from Greenland and Antarctica will be accelerated. The Fourth Assessment Report estimates the ice flow to be between 9 and 17 centimeters (3.5 and 6.7 inches) by 2100 (Wigley 2008).

Table 3.4.4-8

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
Africa	Mediterranean area and northern Sahara	*Very likely* to decrease	
	Southern Africa and western margins	Winter rainfall *likely* to decrease in southern parts	
	East Africa	*Likely* to be an increase in annual mean rainfall	
Mediterranean and Europe	Northern Europe	*Very likely* to increase and extremes are *likely* to increase	*Likely* to decrease.
	Southern and Central Europe		
	Mediterranean area	*Very likely* to decrease and precipitation days are *very likely* to decrease	
Asia	Central Asia	Precipitation in summer is *likely* to decrease	
	Tibetan Plateau	Precipitation in boreal winter is *very likely* to increase	
	Northern Asia	Precipitation in boreal winter is *very likely* to increase Precipitation in summer is *likely* to increase	
	Eastern Asia	Precipitation in boreal winter is *likely* to increase Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	South Asia	Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	Southeast Asia	Precipitation in boreal winter is *likely* to increase in southern parts Precipitation in summer is *likely* to increase in most parts Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
North America	Northern regions/Northern North America		Snow season length and snow depth are *very likely* to decrease
	Southwest	Annual mean precipitation is *likely* to decrease	
	Northeast USA	Annual mean precipitation is *very likely* to increase	
	Southern Canada		
	Canada	Annual mean precipitation is *very likely* to increase	

Table 3.4.4-8 (cont'd)

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report (Christensen *et al.* 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
	Northernmost part of Canada		Snow season length and snow depth are *likely* to increase
Central and South America	Southern South America		
	Central America	Annual precipitation is *likely* to decrease	
	Southern Andes	Annual precipitation is *likely* to decrease	
	Tierra del Fuego	Winter precipitation is *likely* to increase	
	Southeastern South America	Summer precipitation is *likely* to increase	
	Northern South America	Uncertain how rainfall would change	
Australia and New Zealand	Southern Australia	Precipitation is *likely* to decrease in winter and spring	
	Southwestern Australia	Precipitation is *very likely* to decrease in winter	
	Rest of Australia		
	New Zealand, South Island	Precipitation is *likely* to increase in the west	
	Rest of New Zealand		
Polar Regions	Arctic	Annual precipitation is *very likely* to increase. *Very likely* that the relative precipitation increase would be largest in winter and smallest in summer	
	Antarctic	Precipitation *likely* to increase	
Small Islands		Mixed, depending on the region	

The state of the science reflected as of the publication of the IPCC Fourth Assessment Report projects a sea-level rise of 18 to 59 centimeters (0.6 to 1.9 feet) by 2090 to 2099 (EPA 2009b). Several recent studies have found the IPCC estimates of potential sea-level rise might be underestimated regarding ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wignham 2007, Csatho *et al.* 2008) and ice loss from mountain glaciers (Meier *et al.* 2007). Further, IPCC results for sea-level projections might underestimate sea-level rise due to changes in global precipitation (Wentz *et al.* 2007, Zhang *et al.* 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 millimeters per year per degree Centigrade of warming, and a projected sea-level rise of 0.5 to 1.4 meters (1.6 to 4.6 feet) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise over 1 meter (3.3 feet) by 2100 for strong warming scenarios cannot be ruled out." None of these studies takes into account the potential complex changes in ocean circulation that might further influence sea-level rise. Section 4.5.5 discusses sea-level rise in more detail.

Table 3.4.4-4 lists the impacts on sea-level rise under the scenarios and shows sea-level rise in 2100 ranging from 38.00 centimeters (14.96 inches) under the No Action Alternative to 37.84 centimeters (14.89 inches) under the TCTB (Alternative 9), for a maximum reduction of 0.16 centimeters (0.063 inches) by 2100 under the No Action Alternative.

In summary, the impacts of the proposed action and alternatives on global mean surface temperature, precipitation, or sea-level rise are small in relation to the expected changes associated with the emissions trajectories in the RCP 4.5 MiniCAM reference scenario.[66] This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lived.

3.4.4.2.5 Climate Sensitivity Variations

NHTSA examined the sensitivity of projected climate effects to key technical or scientific assumptions used in the analysis. This examination included reviewing the impact of various climate sensitivities on the climate effects due to the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4) with the RCP 4.5 MiniCAM reference scenario. Table 3.4.4-9 lists the results from the sensitivity analysis (3.0 °C [5.4 °F] for a doubling of CO_2 climate sensitivity).

The use of different climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) can affect not only warming but also sea-level rise and CO_2 concentration indirectly.

As shown in Table 3.4.4-9, the sensitivity of the simulated CO_2 emissions in 2030, 2050, and 2100 to changes in climate sensitivity is low; the reduction of CO_2 concentrations from the No Action Alternative to the Preferred Alternative in 2100 is from 3.0 to 3.2 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, as shown in Table 3.4.4-9. In 2030, the impact is low due primarily to the rate at which the global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is larger due not only to the climate sensitivity but also to the change in emissions. In 2100, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative in 2100 ranges from 0.009 ºC (0.016 °F) for the 2.0 °C (3.6 °F) climate sensitivity to 0.015 ºC (0.027 °F) for the 4.5 °C (8.1 °F) climate sensitivity, as listed in Table 3.4.4-9. The impact on global mean surface temperature due to assumptions concerning global emissions of GHG is also important.

The sensitivity of the simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 3.4.4-9. Scenarios with lower climate sensitivities have lower increases in sea-level rise. Also, the reduction in the increase in sea-level rise is lower under the Preferred Alternative compared to the No Action Alternative. Conversely, scenarios with higher climate sensitivities have higher sea-level rise. The reduction in the increase of sea-level rise is greater under the Preferred Alternative compared to the No Action Alternative. The range in reduction of sea-level rise under the Preferred Alternative compared to the No Action Alternative is 0.08 to 0.13 centimeters (0.03 to 0.05 inch), depending on the climate sensitivity.

[66] These conclusions are not meant to be interpreted as expressing NHTSA's views that impacts on global mean surface temperature, precipitation, or sea-level rise are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] of *the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). This analysis fulfills NHTSA's obligations in this regard.

Table 3.4.4-9

CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise (cm) for Varying Climate Sensitivities for Selected Alternatives a/

CAFE Alternative	Climate Sensitivity (°C for $2xCO_2$)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)
		2030	2050	2100	2030	2050	2100	2100
1 No Action								
	2.0	440.2	510.7	765.1	0.699	1.168	2.292	28.68
	3.0	441.8	514.8	783.0	0.923	1.557	3.136	38.00
	4.5	443.6	519.5	805.3	1.168	1.991	4.132	48.67
4 Preferred								
	2.0	439.9	509.9	762.1	0.698	1.166	2.283	28.60
	3.0	441.5	514.0	779.9	0.922	1.553	3.124	37.90
	4.5	443.3	518.7	802.1	1.166	1.987	4.118	48.54
Reduction compared to No Action								
	2.0	0.3	0.8	3.0	0.001	0.003	0.009	0.08
	3.0	0.3	0.8	3.1	0.001	0.004	0.012	0.10
	4.5	0.3	0.8	3.2	0.001	0.005	0.015	0.13

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

3.5 OTHER POTENTIALLY AFFECTED RESOURCE AREAS

This section describes the affected environment and environmental consequences of the proposed action and alternatives on water resources (Section 3.5.1), biological resources (Section 3.5.2), land use and development (Section 3.5.3), safety and other impacts to human health (Section 3.5.4), hazardous materials and regulated wastes (Section 3.5.5), land uses protected under U.S. Department of Transportation Act Section 4(f) (Section 3.5.6), historic and cultural resources (Section 3.5.7), noise (Section 3.5.8), and environmental justice (Section 3.5.9). These sections describe the current and projected future threats to those resources from non-global climate change impacts relevant to the CAFE alternatives and provide primarily qualitative assessments of any potential consequences of the alternatives, positive or negative, on these resources.

This section does not describe the affected environment in relation to, or address potential environmental consequences resulting from, global climate change. For a description of potential impacts resulting from global climate change, *see* Chapter 4.

3.5.1 Water Resources

3.5.1.1 Affected Environment

Water resources include surface water and groundwater. Surface waters are water bodies open to the atmosphere, such as rivers, streams, lakes, oceans, and wetlands; surface waters can contain either fresh or salt water. Groundwater is found in natural reservoirs or aquifers below Earth's surface. Sources of groundwater include rainfall and surface water, which penetrate the ground and recharge the water table. Sections 3.5.1.1.1 through 3.5.1.1.3 describe existing and projected future threats to these resources from non-global climate change impacts related to the proposed action. The production and combustion of fossil fuels, the production of biofuels, and shifts in the location of mining activities are the identified relevant sources of impact. Section 3.5.2 describes relevant aspects of surface water resources from a habitat perspective. For a discussion of the effects of global climate change on freshwater and coastal systems, *see* Sections 4.5.3 and 4.5.5.

Impacts to water resources during recent decades have come from a number of sources, including increased water demand for human and agricultural use, pollution from point and non-point sources, and climatic changes. One of the major human-caused impacts to water quality has been the extraction, refining, and combustion of petroleum products, or oil.

3.5.1.1.1 Oil Extraction and Refining

Oil refineries, which produce gasoline and diesel fuel, and the motor vehicles that combust petroleum-based fuels, are major sources of VOCs, SO_2, NO_x, CO, and other air pollutants (EPA 1995a, EPA 1997a). In the atmosphere, SO_2 and NO_x contribute to the formation of acid rain (the wet, dry, or fog deposition of SO_2 and NO_x), which enters water bodies either directly or as runoff from terrestrial systems (*see* Section 3.3 for more information on air quality). Once in surface waters, these pollutants can cause acidification of the water body, changing the acidity or alkalinity (commonly called pH) of the system and affecting the function of freshwater ecosystems (Van Dam 1996, Baum 2001, EPA 2007). An EPA survey of sensitive freshwater lakes and streams (those with a low capacity to neutralize or buffer against decreases in pH) found that 75 percent of the lakes and 50 percent of the streams had experienced acidification as a result of acid rain (EPA 2007). EPA has identified the areas of the United States most sensitive to acid rain as the Adirondacks and Catskill Mountains in New York State, the mid-Appalachian highlands along the east coast, the upper Midwest, and mountainous areas of the western United States (EPA 2007).

Water quality might also be affected by petroleum products released during the refining and distribution process. Oil spills can lead to contamination of surface water and groundwater and can result in impacts to drinking water and marine and freshwater ecosystems (*see* Section 3.5.2.1.1). EPA estimates that, of the volume of oil spilled in “harmful quantities,” as defined under the CAA, 83.8 percent was deposited in internal/headland waters and within 3 miles of shore, with 17.5 percent spilled from pipelines, often in inland areas (EPA 2004). The environmental impacts to and recovery time for individual waterbodies vary based on several factors (*e.g.*, salinity, water movement, wind, temperature), with locations of faster-moving and warm water recovering more quickly (EPA 2008a).

During oil extraction, the primary waste product is highly saline liquid called “produced water,” which can contain metals and other potentially toxic components (*see* Section 3.5.5.1.1 for more on produced water). Produced water and other oil extraction wastes are most commonly disposed of by reinjecting them to the well, which increases pressure and can force out more oil. Potential impacts from these wastes generally occur when large amounts are spilled and they enter surface waters, when decommissioned wells are improperly sealed, or when saline water from the wells intrudes into fresh surface water or groundwater (Kharaka and Otton 2003).

Water quality impacts also occur as a result of contamination by VOCs. A nationwide USGS study of groundwater aquifers found VOCs in 90 of 98 major aquifers sampled (Zogorski *et al.* 2006). The study concluded that “…[t]he widespread occurrence of VOCs indicates the ubiquitous nature of VOC sources and the vulnerability of many of the Nation’s aquifers to low-level VOC contamination.” Several of the most commonly identified VOCs were a gasoline additive (gasoline oxygenate – methyl tertiary butyl ether [MTBE]) and a gasoline hydrocarbon (toluene). USGS notes, however, that only 1 to 2 percent of the well samples had concentrations of VOCs at levels that would be of potential concern to human health; none of the VOCs found in potentially hazardous quantities were primarily used in the manufacture of fuels or as fuel additives (Zogorski *et al.* 2006). Section 3.5.5 describes toxic chemicals released during fuel production and combustion.

3.5.1.1.2 CO_2 Emissions

Oceanic concentrations of CO_2 from anthropogenic (human-made) sources, primarily the combustion of fossil fuels, have increased since the Industrial Revolution and will likely continue to increase. In addition to its role as a GHG, atmospheric CO_2 plays a key role in the biogeochemical cycle of carbon. Atmospheric CO_2 concentrations influence the chemistry of natural waters.

Atmospheric concentrations of CO_2 are in equilibrium with aqueous (dissolved in water) carbonic acid, which in turn influences the aqueous concentrations of bicarbonate ion and carbonate ion. In natural waters, the carbonate system controls pH, which in turn controls the availability of some nutrients and toxic materials in freshwater and marine systems.

One of the large-scale non-climatic effects of an increase in CO_2 emissions is the potential for ocean acidification. The ocean exchanges huge quantities of CO_2 with the atmosphere, and when atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere into the oceans. This decreases the pH of the oceans, reducing the availability of calcium. According to Richardson and Poloczanska (2008), “declines in ocean pH may impact calcifying organisms, from corals in the tropics to pteropods (winged snails) in polar ecosystems, and will take tens of thousands of years to reequilibrate to preindustrial conditions.” Section 4.7 provides more information on the non-climate effects of CO_2 on plant and animal communities.

3.5.1.1.3 Biofuel Cultivation and Mining Activity

The need to supply agricultural products for a growing population will continue to affect water resources; future irrigation needs are likely to include increased production of both food and biofuel crops (Simpson *et al.* 2008). Global demand for water is increasing as a result of population growth and economic development and irrigation currently accounts for around 70 percent of global water withdrawals (Shiklomanov and Rodda 2003 in Kundzewicz *et al.* 2007). EPA states that "[d]emand for biofuels is also likely to have impacts on water including increasing land in agricultural production, resulting in increased risk of runoff of sediments, nutrients, and pesticides…[p]roduction of biofuels also uses significant amounts of water" (EPA 2008b). Runoff from agricultural sources often contains nitrogen, phosphorus, and other fertilizers and chemicals that harm water quality and can lead to eutrophication (the enrichment of a water body with plant-essential nutrients that can ultimately lead to oxygen depletion) (Vitousek *et al.* 1997, as in Fischlin *et al.* 2007). If biofuel production in the United States continues to be based on input-intensive crops like corn and soybeans, projected expansions to meet demand likely will result in significantly increased runoff of fertilizer and sediment (Simpson 2008).

Shifts toward fuel-saving lighter vehicles, either as a result of consumer preference for fuel-efficient vehicles or downweighting-design decisions by manufacturers, might result in changes in mining land-use patterns with resulting impacts to water quality (*see* Section 3.5.3.1.1). Metal mining results in impacts to water resources via run-off sedimentation from cleared mining sites and degradation of groundwater quality or quantity due to excavation and extraction activities (EPA 1995a). Shifts in demand for lighter vehicles could mean that areas with iron deposits would experience less mining activity, while areas where commonly used light-weight metals (such as aluminum or magnesium) might experience an increase in mining and related water impacts.

3.5.1.2 Environmental Consequences

As discussed in Section 3.3, each action alternative is generally expected to decrease the amount of VOCs, SO_2, NO_x, and other air pollutants in relation to No Action Alternative (Alternative 1) levels. Reductions in these pollutant levels would be the result of lower petroleum fuel consumption by passenger cars and light trucks, and a potential for reduced extraction, transportation, and refining of crude oil. NHTSA expects that lower pollutant emissions would decrease the formation of acid rain in the atmosphere compared to the No Action Alternative, which in turn would have a beneficial impact on the quality of freshwater by decreasing eutrophication[67] and acidification. As discussed in Section 3.4, the impact of the alternative CAFE standards on CO_2 is relatively small compared to global emissions of CO_2. The U.S. passenger car and light truck fleet represents less than 4 percent of the global emissions of CO_2 from passenger cars and light trucks, and this contribution is projected to decline in the future, due primarily to rapid growth of emissions from developing countries.

Each alternative could lead to an indirect increase in the use of more light-weight materials in vehicles, depending on the mix of methods manufacturers use to meet the increased CAFE standards, economic demand, and technological capabilities. If manufacturers opted for increased production of downweighted vehicles, shifts in the location of metal extraction could alternatively benefit water quality in locations of decreased activity, while negatively affecting it in areas of increased activity. However, due to uncertainty about how manufacturers would meet the new requirements, and the fact that none of

[67] Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants and weeds). This enhanced plant growth reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. *See* http://toxics.usgs.gov/definitions/eutrophication.html (last visited Jul. 22, 2009).

the alternative CAFE standards prescribe vehicle downweighting, these potential impacts are not quantifiable. Section 3.5.4 provides additional information on vehicle downweighting.

3.5.2 Biological Resources

3.5.2.1 Affected Environment

Biological resources include vegetation, wildlife, and special status species (those classified as "threatened" or "endangered" under the Endangered Species Act). The U.S. Fish and Wildlife Service has jurisdiction over terrestrial and freshwater special status species and the National Marine Fisheries Service has jurisdiction over marine special status species. States and federal agencies, such as the Department of the Interior's Bureau of Land Management, also have species of concern to which they have assigned additional protections. Sections 3.5.2.1.1 through 3.5.2.1.3 describe the existing and projected future threats to these biological resources from non-global climate change impacts related to the proposed action and alternatives. As discussed below, the production and combustion of fossil fuels, the cultivation and production of biofuels from agricultural crops, and shifts in the location of mining activities are the identified relevant sources of impacts to biological resources. Section 4.5 describes the effects of global climate change on ecosystems.

3.5.2.1.1 Petroleum Extraction and Refining

Oil extraction activities could impact biological resources through habitat destruction and encroachment, raising concerns about their effects on the preservation of animal and plant populations and their habitats. Oil exploration and extraction result in intrusions into onshore and offshore natural habitats and can involve construction within natural habitats. "The general environmental effects of encroachment into natural habitats and the chronic effects of drilling and generating mud and discharge water on benthic (bottom-dwelling) populations, migratory bird populations, and marine mammals constitute serious environmental concerns for these ecosystems" (Borasin *et al.* 2002, in O'Rourke and Connolly 2003).

Oil extraction and transportation can also result in spills of oil and hazardous materials. Oil contamination of aquatic and coastal habitats can directly smother small species and is dangerous to animals and fish if ingested or coated on their fur, skin, or scales. Oil refining and related activities result in chemical and thermal pollution of water, both of which can be harmful to animal and plant populations (Borasin *et al.* 2002, in O'Rourke and Connolly 2003). Offshore and onshore drilling and oil transport can lead to spills, vessel or pipeline breakage, and other accidents that release petroleum, toxic chemicals, and highly saline water into the environment and affect plant and animal communities.

Oil extraction, refining, and transport activities, and the combustion of fuel during motor-vehicle operation, result in air emissions that affect air quality and can contribute to the production of acid rain. These effects can result in negative impacts to plants and animals. Once present in surface waters, air pollutants can cause acidification of waterbodies, changing the pH of the system and affecting the function of freshwater ecosystems. EPA (2009) states:

> …plants and animals living within an ecosystem are highly interdependent…Because of the connections between the many fish, plants, and other organisms living in an aquatic ecosystem, changes in pH or aluminum levels affect biodiversity as well. Thus, as lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease.

Acid rain has also been shown to affect forest ecosystems negatively, both directly and indirectly. These impacts include stunted tree growth and increased mortality, primarily as a result of the leaching of calcium and other soil nutrients (Driscoll *et al.* 2001, DeHayes *et al.* 1999, Baum 2001). Declines in biodiversity of aquatic species and changes in terrestrial habitats likely have ripple effects on other wildlife that depend on these resources.

The combustion of fossil fuels and certain agricultural practices have lead to a disruption in the nitrogen cycle (the process by which gaseous nitrogen from the atmosphere is used and recycled by organisms) with serious repercussions for biological resources. Nitrogen-cycle disruption has occurred through the introduction of large amounts of anthropogenic nitrogen in the form of ammonium and nitrogen oxides to aquatic and terrestrial systems (Vitousek 1994). Increased availability of nitrogen in these systems is a major cause of eutrophication in freshwater and marine waterbodies. Eutrophic systems typically contain communities dominated by phytoplankton (free-floating microscopic plants). Eutrophication can ultimately result in the death of fish and other aquatic animals, as well as harmful algal blooms. Acid rain enhances eutrophication of aquatic systems through the deposition of additional nitrogen (Lindberg 2007).

3.5.2.1.2 CO_2 Emissions

Ocean acidification as a result of increasing concentrations of atmospheric CO_2, primarily from the combustion of fossil fuels, is expected to affect calciferous marine organisms. In conjunction with rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Hoegh-Guldberg *et al.* (2007) state that “[u]nder conditions expected in the 21st century, global warming and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on reef systems. The result will be less diverse reef communities and carbonate reef structures that fail to be maintained.”

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2 concentrations in the atmosphere could increase the productivity of terrestrial systems, because plants use CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report states that “[o]n physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising CO_2, called CO_2 fertilization” (Denman *et al.* 2007).

Under bench-scale and field-scale experimental conditions, several investigators have found that higher concentrations have a “fertilizer” effect on plant growth (*e.g.*, Long *et al.* 2006, Schimel *et al.* 2000). IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing NPP [net primary productivity] increases of 23 to 25 percent (Norby *et al.* 2005), but much smaller increases for grain crops (Ainsworth and Long 2005)…Overall, about two-thirds of the experiments show positive response to increased CO_2 (Ainsworth and Long 2005, Denman *et al.* 2007). Since saturation of CO_2 stimulation due to nutrient or other limitations is common (Dukes *et al.* 2005, Körner *et al.* 2005, both in Denman *et al.* 2007), it is not yet clear how strong the CO_2 fertilization effect actually is.

The CO_2 fertilization effect could mitigate some of the increase in atmospheric CO_2 concentrations by resulting in more storage of carbon in vegetation.

Increased atmospheric CO_2, in conjunction with other environmental factors and changes in plant communities, could alter growth, abundance, and respiration rates of some soil microbes (Lipson *et al.*

2005, Chung *et al.* 2007, Lesaulnier *et al.* 2008). Section 4.7 provides more information on the non-climate effects of CO_2 on plant and animal communities.

3.5.2.1.3 Land Disturbances Due to Biofuel Production and Mining

Future demands for biofuel production are predicted to require increased commitments of land to agricultural production (EPA 2008b). Placing additional land into agricultural production or returning marginal agricultural land to production to grow perennial grass or trees for use in cellulosic ethanol production would decrease the area available as natural habitat. A decrease in habitat and potential habitat for plants and animal species would likely result in negative impacts to certain species. Increased agriculture production would also likely result in increased surface runoff of sediments and fertilizers. Additional fertilizer inputs to water could increase eutrophication and associated impacts. Sediment runoff can settle to the bottom of waterbodies and degrade essential habitat for some species of aquatic organisms, bury food sources and areas used for spawning, and kill benthic organisms (EPA 2000a).

As stated in Section 3.5.1.1.3, a shift toward lighter vehicles would likely result in changes to mining land-use patterns and impacts to water quality; such changes could affect aquatic and terrestrial ecosystems. EPA notes that mining activities could result in the destruction of terrestrial habitat, loss of fish populations due to water-quality impacts, and a loss of plants due to increased dust (EPA 1995a). As previously stated, such a shift would likely be beneficial in areas of decreased activity and detrimental in areas of increased activity.

3.5.2.1.4 Endangered Species

Off-shore drilling, on-shore oil and gas drilling, and roads created to access remote extraction sites through habitats used by threatened or endangered species may be relevant considerations for these plants and animals both directly, through loss of individual animals or habitat, and indirectly, through water-quality degradation or cumulative impacts with other projects. Loss of potential habitat to the production of biofuels could also result in issues for some species (*e.g.*, diminished potential for habitat expansion, increased runoff-related issues).

Increased anthropogenic inputs of nitrogen to terrestrial, aquatic, and microbial communities containing rare plants and animals could also be relevant considerations for threatened and endangered species. In ecosystems with certain vegetation and soil types, this increased nitrogen availability can result in reduced biodiversity or the exclusion of certain endemic species in favor of those adapted to make use of these nutrients to their competitive advantage (Bobbink *et al.* 1998, Fenn *et al.* 2003, Weiss 1999). For example, the decline of certain nutrient-poor native grasslands in California, which serve as critical habitat for the Bay checkerspot butterfly, is likely partially due to an increase in invasive grass species made possible by such nutrient inputs (Weiss 1999).

3.5.2.2 Environmental Consequences

The decrease in overall fuel consumption by passenger cars and light trucks, anticipated under all of the alternatives except the No Action Alternative, could lead to reductions in oil exploration, extraction, transportation, and refining. NHTSA expects that a reduction in these activities would result in decreased impacts to on- and off-shore habitat and plant and animal species. This decrease could have a small overall benefit to plants and animals, primarily through decreased levels of direct ground disturbance and releases of oil and hazardous materials. Reductions in the rate of fuel consumption increase under all of the alternatives compared to the No Action Alternative would lead to overall decreases in the release of SO_2 and NO_x. Reductions in acid rain and anthropogenic nutrient deposition could lower levels of eutrophication in surface waters and could slow direct impacts to ecosystems and to soil leaching.

Reductions in the rate of fuel consumption increase would also lead to a decrease in the release of CO_2 compared to the No Action Alternative. Lower levels of atmospheric CO_2 could slow projected effects to terrestrial plant growth, calciferous marine organisms, and microorganisms. However, as discussed in Section 3.5.1.2, the reduction in CO_2 as a result of the proposed action and alternatives would be relatively small compared to current and projected global CO_2 releases (*see* Chapter 2 and Section 3.3).

The alternatives could lead to an increase in mining for light-weight raw materials, depending on the mix of methods manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. Depending on these factors, increased mining land-disturbance activities could affect aquatic health due to increased sedimentation. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the alternatives analyzed prescribe vehicle downweighting, these potential effects are not quantifiable. It would be speculative to associate any of these potential general impacts to any particular location or to any particular biological resource.

NHTSA has carefully considered the requirements of the Endangered Species Act and determined that Section 7(a)(2) consultation is not required for this action. *See* Appendix G for more information.

3.5.3 Land Use and Development

3.5.3.1 Affected Environment

Land use and development refers to human activities that alter land (*e.g.*, industrial and residential construction in urban and rural settings, clearing of natural habitat for agricultural or industrial use) and could affect the amount of carbon or biomass in existing forest or soil stocks in the affected areas. For purposes of this analysis, shifts in agricultural and mining production and changes to manufacturing plants that produce passenger cars and light trucks are the identified relevant sources of impact.

3.5.3.1.1 Changes in Agricultural Production and Mining

Biofuel production is predicted to require increased devotion of land to agricultural production (EPA 2008b, Keeney and Hertel 2008). Converting areas into cropland would decrease the overall land area kept in a natural state and the potential area available for other uses (such as commercial development or pastureland) (Keeney and Hertel 2008). There is uncertainty regarding how much additional land could be required to meet projected biofuel needs in the United States, and how an increase in biofuel production could affect other land uses (Keeney and Hertel 2008).

Shifts toward fuel-saving lighter vehicles, either as a result of consumer preference for fuel-efficient vehicles or downweighting design decisions by manufacturers, might result in changes in mining land-use patterns. Mining for the minerals needed to construct these lighter vehicles (primarily aluminum and magnesium) could shift some metal-extraction activities to areas rich in these resources. Schexnayder *et al.* (2001) noted that such a shift in materials "could reduce mining for iron ore in the United States, but increase the mining of bauxite for aluminum, magnesium, titanium, and other materials in such major countries as Canada, China, and Russia and in many small, developing countries, such as Guinea, Jamaica, and Sierra Leone."

3.5.3.1.2 Manufacturing Changes

Recent shifts in consumer demand in the United States away from less-fuel-efficient vehicles have begun to change the types of vehicles produced and the manufacturing plants where they are made. Sharp decreases in demand for trucks and SUVs have recently resulted in plant closures and production shifts to plants where small cars and gas-electric hybrid vehicles are made (WWJ News Radio 2008, Keenan and Mckenna 2008, Bunkley 2008).

3.5.3.2 Environmental Consequences

Depending on how manufacturers achieve reductions in vehicle weight, downweighted vehicles could result in shifts in mining from areas containing iron to those containing aluminum and magnesium, and shifts from facilities that process iron ore (for iron and steel) to those that process bauxite (for aluminum) and brine (for magnesium). These changes would have implications for environmental issues associated with land use and development, and material processing. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the analyzed alternatives prescribe vehicle downweighting (much less specific engineering and materials shifts to reduce vehicle mass), these potential environmental impacts are not quantifiable. *See* Section 3.5.4 for more information on vehicle downweighting.

Major changes to manufacturing facilities, such as those occurring with the apparent shift in consumer demand toward more fuel-efficient vehicles, might have implications for environmental issues associated with land use and development. However, NHTSA's review of existing and available technologies and capabilities shows that the CAFE standards under all the action alternatives can be met by existing and planned manufacturing facilities. Because of the availability of sufficient existing and planned capacity, and because none of the alternatives prescribe particular technologies for meeting these standards, the various alternatives are not projected to force changes in product mixes that would result in plant changes.

3.5.4 Safety and Other Impacts to Human Health

NHTSA has analyzed how future improvements in fuel economy might affect human health and welfare through vehicle safety performance and the rate of traffic fatalities. The agency also considered how the new standards might affect energy concerns, which could have ramifications for family health and welfare. For more details on this analysis, *see* Section IV of the joint preamble and Chapter 9 of the RIA.

3.5.5 Hazardous Materials and Regulated Wastes

3.5.5.1 Affected Environment

Hazardous wastes are defined here as solid wastes, which also include certain liquid or gaseous materials, that because of their quantity and concentration, or their physical, chemical, or infectious characteristics, could cause or contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or could pose a substantial hazard to human health or the environment when improperly treated, stored, used, transported, disposed of, or otherwise managed. Hazardous wastes are generally designated as such by individual states or EPA under the Resource Conservation and Recovery Act of 1976. Additional federal and state legislation and regulations, such as the Federal Insecticide, Fungicide, and Rodenticide Act, determine handling and notification standards for other potentially toxic substances. For purposes of this analysis, hazardous materials and wastes generated during the oil-extraction and refining processes and by agricultural production and mining activities are the identified relevant sources of impact.

3.5.5.1.1 Wastes Produced during the Extraction Phase of Oil Production

The primary waste created during the extraction of oil is “produced water,” highly saline water pumped from oil and gas wells during mining (American Petroleum Institute 2000, EPA 2000b). In 1995, the onshore oil and gas industry produced approximately 15 billion barrels of produced water (American Petroleum Institute 2000). Produced water is generally “highly saline (total dissolved solids may exceed 350,000 milligrams per liter [mg/L]), may contain toxic metals, organic and inorganic components, and radium-226/228 and other naturally occurring radioactive materials” (Kharaka and Otton 2003). Drilling wastes, primarily mud and rock cuttings, account for 149 million barrels of extraction wastes. “Associated wastes,” generally the most hazardous wastes produced during extraction (often containing benzenes, arsenic, and toxic metals), account for another 22 million barrels (The American Petroleum Institute 2000, EPA 2000b).

Wastes produced during oil and gas extraction have been known to have serious environmental effects on soil, water, and ecosystems (Kharaka and Otton 2003, O’Rourke and Connolly 2003). Onshore environmental effects result “primarily from the improper disposal of large volumes of saline water produced with oil and gas, from accidental hydrocarbon and produced water releases, and from abandoned oil wells that were not correctly sealed” (Kharaka and Otton 2003). Offshore effects result from improperly treated produced water released into the waters surrounding the oil platform (EPA 2000b).

3.5.5.1.2 Wastes Produced during the Refining Phase of Oil Production

Wastes produced during the petroleum-refining process are primarily released to the air and water, accounting for 75 percent (air emissions) and 24 percent (wastewater discharges) of the total (EPA 1995a). EPA defines a release as the “on-site discharge of a toxic chemical to the environment… emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells” (EPA 1995a). EPA reports that nine of the 10 most common toxic substances released by the petroleum-refining industry are volatile chemicals, highly reactive substances prone to state changes or combustion, that include benzene, toluene, ethylbenzene, xylene, cyclohexane, 1,2,4-trimethylbenzene and ethylbenze (EPA 1995a). These substances are present in crude oil and in finished petroleum products. Other potentially dangerous substances commonly released during the refining process include ammonia, gasoline additives (methanol, ethanol, and MTBE), and chemical feedstocks (propylene, ethylene, and napthalene) (EPA 1995a). Spent sulfuric acid is by far the most commonly produced toxic substance; however, it is generally reclaimed instead of released or transferred for disposal (EPA 1995a).

Wastes released during the oil-refining process can cause environmental impacts to water quality, air quality, and human health. The volatile chemicals released during the refining process are known to react in the atmosphere and contribute to ground-level ozone and smog (EPA 1995a). Several of the produced volatile chemicals are also known or suspected carcinogens and many others are known to cause respiratory problems and impair internal-organ functions, particularly in the liver and kidneys (EPA 1995a). Ammonia is a form of nitrogen and can contribute to eutrophication in surface waters.

3.5.5.1.3 Agricultural Materials

Agricultural production, especially of the type required to grow the corn and soybeans most commonly used to produce biofuels in the United States, also results in the release of potentially hazardous materials and wastes. Wastes from agricultural production can include pesticide (insecticides, rodenticides, fungicides, and herbicides) and fertilizer runoff and leaching, wastes used in the maintenance and operation of agricultural machinery (used oil, fuel spills, organic solvents, metal machining wastes, spent batteries), and other assorted process wastes (EPA 2000c).

Agricultural wastes in the form of runoff from agricultural fields can cause environmental impacts to water and human health. Fertilizers can run off into surface waters and cause eutrophication, while pesticides can directly affect beneficial insects and wildlife (EPA 2000c). A National Renewable Energy Lab report concludes that the negative environmental impacts on soil and water due to impacts of increased biofuel production are likely to occur disproportionately in the Midwest, where most of these crops are grown (Powers 2005). Human health can also be affected by improperly handled or applied pesticides, with potential effects ranging from minor respiratory or skin inflammation to death (EPA 2000c). Nitrogen fertilizer runoff to drinking-water sources can lead to methemoglobinemia, the potentially fatal binding of a form of nitrogen to hemoglobin in infants (Powers 2005).

Ethanol, as a biofuel additive to gasoline, is suspected of enhancing the plume size after a gasoline-blended ethanol spill and might decrease degradation of the spilled hydrocarbon and related compounds, such as benzene (Powers *et al.* 2001, Deeb *et al.* 2002, Williams *et al.* 2003).

3.5.5.1.4 Automobile Production and Assembly

Motor vehicles and the motor vehicle equipment industry, and businesses engaged in the manufacture and assembly of cars, trucks, and buses produce hazardous materials and toxic substances. EPA reports that solvents (xylene, methyl ethyl ketone, acetone, *etc.*) are the most commonly released toxic substances it tracks for this industry (EPA 1995a). These solvents are used to clean metal and in the vehicle-finishing process during assembly and painting (EPA 1995a). Other industry wastes include metal paint and component-part scrap.

In addition, studies have suggested that the substitution of lighter-weight materials (such as aluminum, magnesium, titanium, or plastic) for steel and iron to increase fuel efficiency could increase the total waste stream resulting from automobile manufacturing (Schexnayder *et al.* 2001). Mining wastes generated during the extraction of these lighter raw materials would likely increase substantially, primarily due to aluminum mining, and other production wastes (*e.g.*, from refining of aluminum and plastic manufacturing) could also increase (Schexnayder *et al.* 2001, Dhingra *et al.* 1999). The extraction and processing of these metals and the production of manmade fibers and plastics also generate various hazardous wastes (EPA 1995b, EPA 1997b). An assessment of the solid and hazardous wastes generated during the production of three light-weight concept cars concluded the net generation of waste would increase versus conventional vehicles; however, the study also noted that the generation of most hazardous materials of particular concern to human health (*e.g.*, cadmium, chlorine, lead) emitted during the production of vehicles appeared to decrease in the vehicle models analyzed (Schexnayder *et al.* 2001). Recycling of vehicles at the end of the vehicle life could help to offset some of the projected net increase in waste production versus primarily steel/iron construction vehicles.

3.5.5.1.5 CO_2 Emissions

CO_2 is not classified as a hazardous material or regulated waste. For a discussion of the release of CO_2 relevant to the proposed action and alternatives and its impacts on climate change, *see* Section 3.4. For a discussion of the impacts of CO_2 on water resources, *see* Section 3.5.1.1.2. For a discussion of the impacts of CO_2 on biological resources, *see* Section 3.5.2.1.2.

3.5.5.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the proposed action and alternatives could lead to a reduction in the amount of hazardous materials and wastes created by the oil-extraction and refining industries. NHTSA expects corresponding decreases in the associated environmental and health impacts of these substances. However, these effects would likely be small if they occurred, because of the limited overall effect of the proposed action and alternatives on these areas.

All of the alternatives could lead to the use of more light-weight materials in vehicles, depending on the mix of methods manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. If manufacturers pursued vehicle downweighting, these could be a net increase in the waste stream. However, due to the uncertainty surrounding how manufacturers would meet the new requirements and the fact that none of the alternatives analyzed prescribes vehicle downweighting (or specific means of vehicle downweighting), these potential impacts are not quantifiable. *See* Section 3.5.4 for additional information on vehicle downweighting.

3.5.6 Land Uses Protected under U.S. Department of Transportation Act Section 4(f)

3.5.6.1 Affected Environment

Section 4(f) resources are publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites to which the DOT gives special consideration. Originally included as part of the Department of Transportation Act of 1966, Section 4(f) stipulates that DOT agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless "(1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use." 49 U.S.C. 303.

3.5.6.2 Environmental Consequences

"Section 4(f) only applies where land is permanently incorporated into a transportation facility and when the primary purpose of the activity on the 4(f) resource is for transportation" (FHWA 2005). Because the proposed action in this EIS does not meet these criteria, Section 4(f) does not apply.

3.5.7 Historic and Cultural Resources

3.5.7.1 Affected Environment

The National Historic Preservation Act of 1966 (16 U.S.C. 470 *et seq.*), Section 106, states that agencies of the Federal Government must take into account the impacts of their action to historic properties; the regulations to meet this requirement can be found at 36 CFR Part 800. This process, known as the "Section 106 process," is intended to support historic preservation and mitigate impacts to significant historical or archeological properties through the coordination of federal agencies, states, and other affected parties. Historic properties are generally identified through the *National Register of Historic Places,* which lists properties of significance to the United States or a particular locale because of their setting or location, contribution to or association with history, or unique craftsmanship or materials. National Register-eligible properties must also be sites "A. That are associated with events that have made a significant contribution to the broad patterns of our history; or B. That are associated with the lives of persons significant in our past; or C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or D. That have yielded, or may be likely to yield, information important in prehistory or history." 36 CFR 60.4. Acid rain as a result of the processing of petroleum products and the combustion of petroleum-based fuels is the identified relevant source of impact to historic and cultural resources for this analysis.

Acid rain, the primary source of which is the combustion of fossil fuels, is one cause of degradation to exposed cultural resources and historic sites. EPA states that "[a]cid rain and the dry deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). These effects substantially reduce the societal value of buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars" (EPA 2007).

3.5.7.2 Environmental Consequences

The projected reduction in fuel production and combustion as a result of the proposed action and alternatives could lead to a minor reduction in the amount of pollutants that cause acid rain. A decrease in the production of such pollutants could result in a corresponding decrease in the amount of damage to historic and other structures caused by acid rain. However, such effects are not quantifiable.

3.5.8 Noise

3.5.8.1 Affected Environment

Excessive amounts of noise, which is measured in decibels, can present a disturbance and a hazard to human health at certain levels. Potential health hazards from noise range from annoyance (sleep disturbance, lack of concentration, and stress) to hearing loss at high levels (Delucchi and Hsu 1998, Geary 1998, Fleming *et al.* 2005). Motor-vehicle noise also affects property values. A study of the impacts of roadway noise on property values estimated this cost to be roughly 3 billion dollars in 1991 dollars (Delucchi and Hsu 1998). The noise from motor vehicles has been shown to be one of the primary causes of noise disturbance in homes (OECD 1988, in Delucchi and Hsu 1998, and Geary 1998). Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property.

3.5.8.2 Environmental Consequences

As a result of the rebound effect (the increase in VMT as the cost per mile for fuel decreases), NHTSA predicts that there will be increased vehicle use under all of the alternatives; higher overall VMT would result in increases in vehicle road noise. However, location-specific analysis of noise impacts is not possible based on available data. Noise levels are location specific, meaning factors such as the time of day at which increases in traffic occur, existing ambient noise levels, the presence or absence of noise abatement structures, and the location of schools, residences, and other sensitive noise receptors all influence whether there will be noise impacts.

All of the alternatives could lead to an increase in use of hybrid vehicles, depending on the mix of methods manufacturers use to meet the new CAFE standards, economic demands from consumers and manufacturers, and technological developments. An increased percentage of hybrid vehicles could result in reduced road noise, potentially offsetting some of the increase in road noise predicted to result from increased VMT. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, the fact that none of the alternatives prescribes increased production of hybrid vehicles, and the location-specific nature of noise impacts, these potential impacts are not quantifiable.

3.5.9 Environmental Justice

3.5.9.1 Affected Environment

Federal agencies must identify and address disproportionately high and adverse impacts to minority and low-income populations in the United States (Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*). DOT Order 5610.2 establishes the process the Department uses to "incorporate environmental justice principles (as embodied in the Executive Order) into existing programs, policies, and activities." The production and use of fossil fuels and the production of biofuels are the identified relevant sources of impact to environmental populations for this analysis. For a discussion of the effects of climate change on environmental justice populations, *see* Section 4.6.

Numerous studies have noted that there appears to be a historic and ongoing relationship between the environmental impacts of petroleum extraction, processing, and use and environmental justice populations (Pastor *et al.* 2001, O'Rourke and Connolly 2003, Lynch *et al.* 2004, Hymel 2007, Srinivasan *et al.* 2003).

Potential impacts of the oil exploration and extraction process on environmental justice communities include "human health and safety risks for neighboring communities and oil industry workers, and displacement of indigenous communities" (O'Rourke and Connolly 2003). Subsistence-use activities (collecting plants or animals to fulfill basic needs for food, clothing, or shelter) can also be affected by extraction and exploration through the direct loss of subsistence-use areas or impacts to culturally/economically important plants and animals as a result of a spill or hazardous-material release (O'Rourke and Connolly 2003, Kharaka and Otton 2003).

It has been shown that minority and low income populations often disproportionately reside near high-risk polluting facilities, such as oil refineries (Pastor *et al.* 2001, Graham *et al.* 1999, O'Rourke and Connolly 2003), and "mobile" sources of air toxins and pollutants, as in the case of populations residing near highways (Morello-Frosch 2002, Jerrett *et al.* 2001, O'Neill *et al.* 2003). Populations near refineries could be disproportionately affected by exposure to potentially dangerous petroleum and by-products of the refining process, such as benzene (Borasin *et al.* 2002). Exposure to the toxic chemicals associated with refineries, primarily by refinery workers, has been shown to be related to increases in certain diseases and types of cancer (Pukkala 1998, Chan *et al.* 2006); the precise nature and severity of these health impacts are still under debate. Pollutants emitted primarily by transportation sources, such as NO_x and CO, are often found in higher concentrations near roadways and other emission sources (Zhou and Levy 2007). These pollutants have been reported in higher concentrations in areas with high fractions of disadvantaged populations, such as minorities and low-income groups (Jerret *et al.* 2001, Morello-Frosch 2002). Recent reviews by health and medical researchers indicate a general consensus that proximity to high-traffic roadways could result in adverse cardiovascular and respiratory effects, among other possible impacts (HEI 2010; Heinrich and Wichmann, 2004; Salam *et al.*, 2008; Adar and Kaufman, 2007). The exact nature of the relationship between these health impacts, traffic-related emissions, and the influence of confounding factors or modifying factors such as traffic noise are not fully understood at this time (Samet 2007; HEI 2010).

The production of biofuels could, depending on the mix of agricultural crops or crop residues used in its production, affect food prices. The International Food Policy Research Institute states, "An aggressive biofuel scenario that assumes that current plans for expansion of the sector in Africa, Asia, Europe, and North and South America are actually realized could lead to substantial price increases for some food crops by 2020 – about 80 percent for oilseeds and about 40 percent for maize – unless new technologies are developed that increase efficiency and productivity in both crop production and biofuel processing" (von Braun and Pachauri 2006). Such an increase in food prices would disproportionately affect low income populations, because these groups typically spend a larger share of their incomes on food.

3.5.9.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the action alternatives could lead to a minor reduction in the amount of direct land disturbance as a result of oil exploration and extraction, and the amount of air pollution produced by the oil refineries. There could be corresponding decreases in impacts on environmental justice populations as a result of the alternatives, but the effects of any such decreases are not quantifiable and would likely be minor, if they occurred.

As discussed in Section 3.3, the overall decrease in emissions predicted to occur as a result of the proposed new CAFE standards is not evenly distributed due to the increase in VMT from the rebound effect and regional changes in upstream emissions. As a result, some criteria and toxic air pollutants are predicted to increase in some air quality nonattainment areas. The large size of each nonattainment area and the minor emissions increases in affected nonattainment and other areas make it unlikely that there would be disproportionate effects to environmental justice populations.

3.6 UNAVOIDABLE IMPACTS AND IRREVERSIBLE AND IRRETRIEVABLE RESOURCE COMMITMENT

3.6.1 Unavoidable Adverse Impacts

The National Highway Traffic Safety Administration (NHTSA) proposed action is to implement new Corporate Average Fuel Economy (CAFE) standards for model years (MYs) 2012-2016. Under Alternative 1 (No Action), neither NHTSA nor EPA would issue a rule regarding fuel economy or GHG emissions for MYs 2012-2016. Each of the eight action alternatives (Alternatives 2 through 9) would result in a decrease in carbon dioxide (CO_2) emissions and associated climate change effects and a decrease in energy consumption as compared to the No Action Alternative. However, total energy consumption and CO_2 emissions by U.S. passenger cars and light trucks are projected to continue to increase under all of the alternatives as a result of projected increases in the number of these vehicles in use and the total number of miles they are driven each year (as measured by vehicle miles traveled, or VMT).

Based on NHTSA's current understanding of global climate change, certain effects are likely to occur as a consequence of accumulated total greenhouse gas (GHG) emissions in Earth's atmosphere. Neither the proposed action nor its alternatives would prevent these effects. As described in Section 3.4.4.2, each of the action alternatives could contribute to reductions in global GHG emissions from the levels that would occur if average fuel economy were to continue at its current levels, thus diminishing these anticipated changes in the global climate.

Oxides of nitrogen (NO_x), particulate matter ($PM_{2.5}$), oxides of sulfur (SO_x), volatile organic compounds (VOCs), benzene, 1,3-butadiene, and diesel particulate matter (DPM) exhibit decreases in emissions for all action alternatives and analysis years as compared to their levels under the No Action Alternative. Any negative health impacts associated with these emissions are expected to be similarly reduced, and there would be no unavoidable negative impacts of these emissions.

According to NHTSA's analysis, emissions of carbon monoxide (CO) acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde could increase under certain alternatives from the levels that are projected under the No Action Alternative. Thus, the potential for unavoidable impacts depends on the selection of the final standards. The CO increases would occur only under Alternatives 2 through 4 and would be approximately 0.7 percent or less over the No Action Alternative. The increases in emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde could occur under any of the action alternatives depending on the pollutant and analysis year. The maximum projected increases in emissions, compared to the No Action Alternative, are 0.9 percent for acetaldehyde (under Alternative 8 in 2020), 18.4 percent for acrolein (under Alternative 8 in 2030), 0.7 percent for 1,3-butadiene (under Alternative 3 in 2030), and 9.4 percent for formaldehyde (under Alternative 8 in 2030). Under the Preferred Alternative (Alternative 4) the increases in emissions in 2030 compared to the No Action Alternative would be 50 tons (0.6 percent) for acetaldehyde, 6 tons (1.5 percent) for acrolein, 25 tons (0.7 percent) for 1,3-butadiene, and 33 tons (0.4 percent) for formaldehyde.

Increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the action alternatives, largely due to increases in vehicle miles traveled. These increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards.

3.6.2 Short-term Uses and Long-term Productivity

The eight action alternatives (Alternatives 2 through 9) would result in a decrease in energy (crude oil) consumption and reductions in CO_2 emissions and associated climate change impacts compared to those of Alternative 1, No Action. Manufacturers would need to apply various technologies to the production of passenger cars and light trucks to meet the MYs 2012-2016 CAFE standards under the eight action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the eight action alternatives; however, NHTSA estimates that existing technologies and existing vehicle production facilities can be applied to meet the standards under the eight action alternatives. Some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the CAFE standards. Such short-term uses of resources by vehicle manufacturers to meet the CAFE standards would enable the long-term reduction of national energy consumption and would enhance long-term national productivity.

3.6.3 Irreversible and Irretrievable Commitment of Resources

Energy consumption in the United States would decrease under all the action alternatives compared to the No Action Alternative. Tables 3.2.3-1, 3.2.3-2 and 3.2.3-3 (*see* Section 3.2 of this EIS) summarize fuel consumption under each alternative. For the Preferred Alternative (Alternative 4) the fuel savings[68] over the No Action Alternative in 2060 would be 21.9 billion gallons for passenger cars and another 13.1 billion gallons for light trucks.

As discussed in Section 3.6.2, manufacturers would need to apply various technologies to the production of passenger cars and light trucks to meet the MYs 2012-2016 CAFE standards under the eight action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the eight action alternatives. Existing technologies and existing vehicle production facilities can be applied to meet the CAFE standards under the eight action alternatives. However, some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the standards. The specific amounts and types of irretrievable resources (such as electricity and other energy consumption) manufacturers would expend in meeting the CAFE standards would depend on the specific methods and technologies manufacturers choose to implement. Commitment of resources for manufacturers to comply with the CAFE standards would tend to be offset by the fuel savings from implementing the standards.

[68] Fuel savings are expressed as the sum of the number of gallons of diesel fuel and gasoline without adjustment for the energy content per gallon of each fuel.

3.7 EPA PROPOSED ACTION AND ANALYSIS

3.7.1 Overview

As explained in Chapter 1, in a joint rulemaking being issued in parallel with this EIS, NHTSA and EPA are proposing a strong and coordinated federal greenhouse gas and fuel economy program for light-duty vehicles (passenger cars, light-duty trucks, and medium-duty passenger), referred to as the National Program. This rule proposes to increase vehicle fuel economy and reduce vehicle GHG emissions. NHTSA is proposing CAFE standards under EPCA, as amended by EISA 2007, and EPA is proposing its first-ever GHG emissions standards under the CAA. This joint proposal is consistent with the President's announcement on May 19, 2009 of a National Fuel Efficiency Policy that will improve fuel economy and reduce greenhouse gas emissions for all new cars and light-duty trucks sold in the United States, and the Notice of Upcoming Joint Rulemaking issued by DOT and EPA on that date.[69]

This section of the EIS presents EPA's proposal analysis of its proposed action under the CAA, and attempts to place EPA's proposed action in context of NHTSA's proposed action (setting CAFE standards) and the National Program. Section 1501.6 of CEQ regulations emphasize agency cooperation early in the NEPA process and allow a lead agency (in this case, NHTSA) to request the assistance of other agencies that either have jurisdiction by law or have special expertise regarding issues considered in an EIS. NHTSA invited EPA to be a cooperating agency, pursuant to CEQ regulations, because of its special expertise in the areas of climate change and air quality.[70] On May 12, 2009, the EPA accepted NHTSA's invitation and agreed to become a cooperating agency.

In developing their respective proposals, NHTSA and EPA considered many of the same issues. Given differences in their respective statutory authorities, however, the agencies' proposals include some important differences. Significantly, under the CO_2 fleet average standard proposed under CAA section 202(a), EPA expects manufacturers to take advantage of the option to generate CO_2-equivalent credits by reducing emissions of hydrofluorocarbon (HFC) refrigerant and CO_2 through improvements to their air conditioner systems. EPA accounted for these reductions in developing its proposed CO_2 standard. However, EPCA does not permit NHTSA to consider air conditioning credits in developing a proposed CAFE standard for passenger cars. CO_2 emissions due to air conditioning operation are not measured by the test procedure mandated by statute for use in establishing and enforcing CAFE standards for passenger cars. As a result, improvements in the efficiency of passenger car air conditioners would not be considered as a possible control technology for the purposes of CAFE.

In addition, in its analysis of the impacts of the program, EPA took into consideration three compliance flexibilities that are proposed with the program: full transfer of credits between car and truck fleets; flex fueled vehicle credits; and the Temporary Lead-time Allowance Alternative Standards

[69] *See* Notice of Upcoming Joint Rulemaking To Establish Vehicle GHG Emissions and CAFE Standards, 74 FR 24007 (May 22, 2009).

[70] 40 CFR § 1501.6. NHTSA takes no position on whether EPA's proposed rule on GHG emissions could be considered a "connection action" under the Council of Environmental Quality's regulations at 40 CFR § 1508.25. For the purposes of this EIS, however, NHTSA has decided to treat EPA's proposed rule as if it were a "connected action" under those regulations to ensure coordination under the National Program and because we believe such treatment will prove beneficial and add value to the EIS. NHTSA is aware that Section 7(c) of the Energy Supply and Environmental Coordination Act of 1974 (15 U.S.C. § 793(c)(1)) expressly exempts EPA actions under the Clean Air Act from NEPA's requirements. NHTSA's discussion in this EIS of EPA's proposed GHG regulation should not be construed as a waiver of EPA's express NEPA exemption and places no obligation on EPA to comply with NEPA in promulgating this or any other rule covered by the exemption.

program. NHTSA's CAFE program has its own compliance flexibilities, and as discussed below, NHTSA's analysis accounts for the potential that some manufacturers (*e.g.*, most European OEMs) would pay civil penalties rather than complying with CAFE standards. However, because EPCA prohibits NHTSA from considering CAFE credits compliance flexibilities when determining the stringency of CAFE standards, NHTSA did not attempt to do so when it developed standards it has considered for this action. [71]

Finally, under the proposed EPA GHG emissions standards, there is no ability for a manufacturer to intentionally plan to pay a set fine in lieu of meeting the standard. However, under EPCA, automotive manufacturers are allowed to pay a fine for every 0.1 mpg they fall short of meeting the CAFE standard as a method of compliance. In NHTSA's analysis prepared for this EIS, there is some level of voluntary fine payment reflected in the impacts which reduce the estimated benefits of the alternative CAFE standards analyzed. Since intentional noncompliance is not permitted under the CAA, this consideration justifies proposing more stringent GHG emissions standards, and is not reflected in EPA's impacts analysis.

For the above reasons, the proposed CAFE standards (under the Preferred Alternative) are somewhat lower than the proposed EPA GHG standard. However, together, NHTSA's proposed CAFE standards and EPA's GHG emissions standards would represent a harmonized and consistent National Program under each agency's respective statutory framework. They require vehicles to meet an estimated combined average emissions level of 250 grams of CO_2 per mile in MY 2016 under EPA's GHG program, and 34.1 mpg in MY 2016 under NHTSA's CAFE program. Under the National Program, the overall light-duty vehicle fleet would reach 35.5 mpg in MY 2016, if all reductions were made through fuel economy improvements and result in significant reductions in both greenhouse gas emissions and oil consumption. For more details, *see* the NHTSA and EPA joint preamble and the EPA Draft Regulatory Impact Analysis (DRIA) (*see* Appendix E) and the NHTSA Preliminary Regulatory Impact Analysis (*see* Appendix D) associated with the joint proposal.

3.7.2 Summary of EPA Proposal Impact Analysis

The action EPA is proposing as a part of the National Program would reduce GHG emissions emitted directly from vehicles due primarily to reduced fuel use and secondarily to improved air conditioning systems. In addition to these "downstream" emissions, reducing CO_2 emissions through reducing fuel use translates directly to reductions in the emissions associated with the processes involved in getting petroleum to the pump, including the extraction and transportation of crude oil, and the production and distribution of finished gasoline (termed "upstream" emissions). Reductions from tailpipe GHG standards grow over time as the fleet turns over to vehicles affected by these standards, meaning the benefit of the standards will continue as long as the oldest vehicles in the fleet are replaced by newer, lower CO_2 emitting vehicles.

As detailed in the EPA DRIA (*see* Appendix E), EPA estimated calendar year tailpipe CO_2 reductions based on pre- and post-control CO_2 gram per mile levels from EPA's vehicle technology and cost model (which relates manufacturer technology choices and GHG emission reductions) and VMT

[71] As documented in NHTSA's regulatory impact analysis, NHTSA did perform analysis accounting for the potential that some manufacturers would earn credits for the production of flexible fuel vehicles (FFVs), and would use these credits toward compliance with CAFE standards.

projections described in the draft Joint Technical Support Document.[72] These estimates reflect the CO_2 emissions reductions projected for the entire U.S. vehicle fleet in a specified calendar year.

As in NHTSA's analysis, EPA projected expected changes in both "downstream" (vehicle tailpipe) and "upstream" (fuel production and distribution) emissions, including the effects of additional driving ("VMT rebound"). EPA analyzed the expected effects of the standards on emissions of the vehicle-related greenhouse gases: CO_2, air conditioning related emissions of HFC refrigerant and CO_2, N_2O, and CH_4. EPA also analyzed the effect of the proposed program on "criteria" air pollutants and precursors (including CO, $PM_{2.5}$, SO_x, VOC, NO_x); and air toxics (including benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein).

EPA developed downstream emission impacts using a spreadsheet analysis based on data from two EPA models. EPA derived computation algorithms and achieved CO_2 levels from EPA's vehicle model, coupled with non-CO_2 emission rates from EPA's MOVES.

EPA calculated upstream emission changes resulting from the decreased fuel consumption using a spreadsheet model based on emission factors from Argonne National Laboratory's GREET Model.

EPA and NHTSA shared common data inputs for their parallel analyses, as described in the Joint Technical Support Document associated with the proposed National Program. For full details of EPA's subsequent analyses and results, please refer to Chapter 5 of EPA's DRIA, also associated with the proposed National Program.

In addition, EPA estimated changes in projected global mean surface temperature and sea-level rise to 2100 using the MiniCAM integrated assessment model coupled with the MAGICC, version 5.3 climate model. MiniCAM was used to create the globally and temporally consistent set of emission scenarios required for running MAGICC. MAGICC was then used to estimate the change in the global mean surface temperature and sea-level rise over time (at five-year time steps). Given the magnitude of the estimated emissions reductions associated with the proposal, a simple climate model such as MAGICC is reasonable for estimating the climate response.

To capture some key uncertainties in the climate system with the MAGICC model, the changes in projected temperatures and sea level were estimated across the most current IPCC range of climate sensitivities, 1.5 °C to 6.0 °C.[73] To compute the change in temperature and sea-level rise attributable to the proposal, the output from the proposal's emissions scenario were subtracted from an existing MiniCAM emission scenario. Details about the models used, reference case scenario, and how the emissions reductions were applied to generate the proposal scenario can be found in chapter 7.4 of EPA's DRIA (*see* Appendix E).

3.7.2.1 Energy

EPA anticipates its proposal would create significant fuel savings as compared to the baseline. Projected fuel savings are shown in Table 3.7.2-1.

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[72] Both NHTSA's and EPA's regulatory impact analyses can be found in appendices to this EIS. They can also be found in the docket for this rulemaking, along with the Joint Technical Support Document.

[73] In IPCC reports, equilibrium climate sensitivity refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. The IPCC states that climate sensitivity is "likely" to be in the range of 2 °C to 4.5 °C, "very unlikely" to be less than 1.5 °C, and "values substantially higher than 4.5 °C cannot be excluded." IPCC (2007).

In calendar year 2030, EPA analysis projects its proposal to reduce light-duty fuel consumption approximately 17 percent relative to the reference scenario.

Table 3.7.2-1

Impacts of Proposed Standards on Fuel Savings

Calendar Year	Annual Fuel Savings due to Proposed Standards (Billion Gallons Of Gasoline Equivalent)	No Action Fuel Consumption (Billion Gallons Of Gasoline Equivalent)
2020	13.4	142.2
2030	26.2	161.9
2040	33.9	196.2
2050	42.6	244.1

3.7.2.2 Air Quality

EPA estimates that its proposed standards would result in emission reductions of NO_x, VOC, $PM_{2.5}$ and SO_x, but would slightly increase CO emissions. The overall impact of its proposal would be relatively small compared to total U.S. inventories across all sectors for these pollutants. In 2030, its proposed standards would reduce these total NO_x, PM and SO_x inventories by 0.2 to 0.3 percent and reduce the VOC inventory by 1.2 percent, while increasing the total national CO inventory by 0.4 percent.

EPA estimates that the proposed GHG standards would result in mixed impacts on air toxic emissions. Again, the overall impact of the proposal would be relatively small for these pollutants compared to total U.S. inventories across all sectors. In 2030, EPA estimates that its standards would reduce total acrolein, benzene, and formaldehyde emissions by less than 0.1 percent. Total 1,3-butadiene and acetaldehyde emissions would increase by 0.1 to 0.2 percent.

Table 3.7.2-2 presents the impacts of the proposed standards on each of the non-GHG pollutants that EPA analyzed.

For its final rule, EPA will perform a national-scale air quality modeling analysis to analyze the impacts of the proposed vehicle GHG standards on $PM_{2.5}$, ozone, and selected air toxics (*i.e.*, benzene, formaldehyde, acetaldehyde, acrolein and 1,3-butadiene). The length of time needed to prepare the necessary emissions inventories, in addition to the processing time associated with the modeling itself, has precluded EPA from performing air quality modeling for the proposed rule.

The atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone and air toxics is very complex, and making predictions based solely on emissions changes is extremely difficult. However, based on the magnitude of the emissions changes predicted to result from the proposed vehicle GHG standards, EPA expects that there will be an improvement in ambient air quality, pending a more comprehensive analysis for the final rule.

Table 3.7.2-2

Impacts of Proposed Standards on Non-GHG Emissions (Short Tons Per Year)

Pollutant	Calendar Year	% Change vs.	Calendar Year	% Change vs.

	2020	2020 Reference	2030	2030 Reference
Δ Carbon Monoxide	70,614	0.13%	227,832	0.38%
Δ NO_x	-17,206	-0.14%	-27,726	-0.23%
Δ $PM_{2.5}$	-2,856	-0.08%	-5,431	-0.16%
Δ SO_x	-16,307	-0.18%	-31,965	-0.34%
Δ VOC	-73,739	-0.60%	-142,347	-1.17%
Δ 1,3-Butadiene	11.5	0.07%	36.8	0.22%
Δ Acetaldehyde	16.8	-0.04%	60.6	0.13%
Δ Acrolein	0.2	-0.00%	1.8	-0.03%
Δ Benzene	-83.6	-0.04%	-77.5	-0.04%
Δ Formaldehyde	-28.3	-0.03%	-15.7	-0.02%

3.7.2.3 Climate Change

The results, in both Figures 3.7.2-1 and 3.7.2-2, of EPA's climate change modeling analysis show a small, but quantifiable, reduction in projected global mean surface temperature and sea level as a result of this proposal across all climate sensitivities. Global mean temperature is projected to be reduced by approximately 0.007–0.016 °C by 2100 and global mean sea-level rise is projected to be reduced by approximately 0.06–0.15 cm by 2100. The reductions are small relative to the IPCC's 2100 "best estimates" for global mean temperature increases (1.8–4.0 ºC) and sea-level rise (0.20–0.59 m) for all global GHG emissions sources for a range of emissions scenarios. These projected reductions are proportionally representative of changes to U.S. GHG emissions in the transportation sector.

As a substantial portion of CO_2 emitted into the atmosphere is not removed by natural processes for millennia, each unit of CO_2 not emitted into the atmosphere avoids essentially permanent climate change on centennial time scales. While not formally estimated for the joint proposed rule, a reduction in projected global mean temperature and sea-level rise implies a reduction in the adverse risks associated with climate change. Both figures illustrate that the distribution for projected global mean temperature and sea-level rise increases has shifted downward as a result of the proposal.

Figure 3.7.2-1. Estimated Projected Reductions in Global Mean Surface Temperatures from Baseline for Climate Sensitivities Ranging from 1.5–6 °C

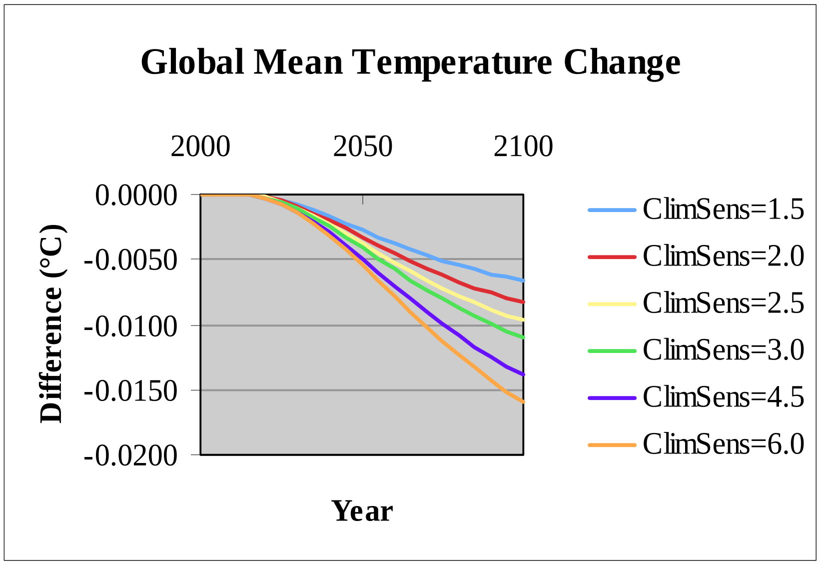
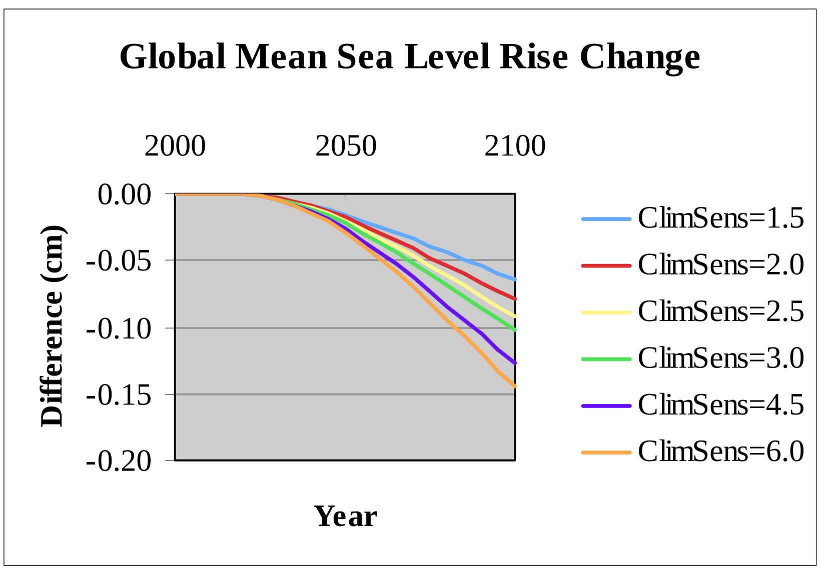


Figure 3.7.2-2. Estimated Projected Reductions in Global Mean Sea-Level Rise from Baseline for Climate Sensitivities Ranging from 1.5–6 °C



Chapter 4 Cumulative Impacts

4.1 INTRODUCTION

The Council on Environmental Quality (CEQ) identifies the impacts federal agencies must address and consider in satisfying the requirements of the National Environmental Policy Act (NEPA). This includes permanent, short-term and long-term direct, indirect, and cumulative impacts.

CEQ NEPA implementing regulations at 40 CFR § 1508.7 define cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions." Cumulative impacts should be evaluated along with the overall impacts of each alternative. The range of alternatives considered should include a No Action Alternative as a baseline against which to evaluate cumulative effects. The range of actions to be considered includes not only the proposed action but all connected and similar actions that could contribute to cumulative effects. Connected actions should be addressed in the same analysis. CEQ recommends that an agency's analysis accomplish the following:

- Focus on the effects and resources within the context of the proposed action.
- Present a concise list of issues that have relevance to the anticipated effects of the proposed action or eventual decision.
- Reach conclusions based on the best available data at the time of the analysis.
- Rely on information from other agencies and organizations on reasonably foreseeable projects or activities that are beyond the scope of the analyzing agency's purview.
- Relate to the geographic scope of the proposed project.
- Relate to the temporal period of the proposed project.

A cumulative impacts analysis involves assumptions and uncertainties. Monitoring programs and research can be identified to supplement the available information and thus enhance analyses for the future. The absence of an ideal database should not prevent the completion of a cumulative effects analysis.

Chapter 4 addresses areas of the quantitative analyses presented in Chapter 3, with particular attention to energy, air, and climate, and describes the indirect cumulative effects of climate change on a global scale. This chapter is organized according to the conventions of the climate change literature rather than the conventions of an Environmental Impact Statement (EIS) format. To assist the reader, the table on the following page maps topics found in U.S. Department of Transportation (DOT) NEPA documents (DOT Order 5610.1C) to the sections in this EIS.

Typical NEPA Topics	EIS Subsections
Water	4.4 Climate; 4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Ecosystems	4.5.3 Freshwater Resources; 4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.6 Food, Fiber, and Forest Products; 4.7 Non-climate Cumulative Impacts of CO_2
Threatened and endangered species	4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.7 Non-climate Cumulative Impacts of CO_2
Publicly owned parklands, recreational areas, wildlife and waterfowl refuges, and historic sites, Section 4(f) related issues	4.5.3 Freshwater Resources; 4.5.4 Terrestrial Ecosystems; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.7 Industries, Settlements, and Society
Properties and sites of historic and cultural significance	4.5.7 Industries, Settlements, and Society
Considerations relating to pedestrians and bicyclists	4.5.7 Industries, Settlements, and Society
Social impacts	4.5.7 Industries, Settlements, and Society; 4.6 Environmental Justice
Noise	4.5.7 Industries, Settlements, and Society
Air	4.3 Air Quality
Energy supply and natural resource development	4.2 Energy; 4.5.4 Terrestrial Ecosystems; 4.5.6 Food, Fiber, and Forest Products; 4.5.7 Industries, Settlements, and Society
Floodplain management evaluation	4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Wetlands or coastal zones	4.5.3 Freshwater Resources; 4.5.5 Coastal Systems and Low-lying Areas
Construction impacts	4.3 Air Quality; 4.4 Climate; 4.5.7 Industries, Settlements, and Society; 4.5.8 Human Health
Land use and urban growth	4.4 Climate; 4.5.6 Food, Fiber, and Forest Products; 4.5.7 Industries, Settlements, and Society
Human environment involving community disruption and relocation	4.3 Air Quality; 4.4 Climate; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.7 Industries, Settlements, and Society; 4.5.8 Human Health; 4.6 Environmental Justice

4.1.1 Approach to Scientific Uncertainty and Incomplete Information

4.1.1.1 CEQ Regulations

CEQ regulations recognize that many federal agencies confront limited information and substantial uncertainties when analyzing the potential environmental impacts of their actions under NEPA. 40 CFR § 1502.22. Accordingly, the regulations provide agencies with a means to formally acknowledge incomplete or unavailable information in NEPA documents. Where "information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known," the regulations require an agency to include in its NEPA document:

1. A statement that such information is incomplete or unavailable;

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

3. A summary of existing credible scientific evidence that is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

4. The agency's evaluation of such impacts based on theoretical approaches or research methods generally accepted in the scientific community.

Relying on these provisions is appropriate when an agency is performing a NEPA analysis that involves potential environmental impacts resulting from carbon dioxide (CO_2) emissions (*e.g.*, *Mayo Found. v. Surface Transp. Bd.*, 472 F.3d 545, 555 (8th Cir. 2006). CEQ regulations at 40 CFR § 1502.21 also authorize agencies to incorporate material into a NEPA document by reference to "cut down on bulk without impeding agency and public review of the action."

Throughout this EIS, the National Highway Transportation Safety Administration (NHTSA) uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas for which the agency cannot develop a credible estimate of the potential environmental impacts of the standards or reasonable alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of CO_2 and other greenhouse gases (GHGs) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. In this EIS, NHTSA often relies on the EPA Technical Support Document entitled *Endangerment and Cause or Contribution Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009), the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report by Working Group II (WGII) entitled *Climate Change 2007 – Impacts, Adaptation, and Vulnerability* (IPCC 2007), and the U.S. Climate Change Science Program (CCSP) Synthesis and Assessment Product (SAP) reports as a recent "summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment." *See* 40 CFR § 1502.22(b)(3).

4.1.2 Temporal and Geographic Boundaries

When evaluating cumulative effects, the analysis must consider expanding the geographic study area beyond that of the proposed action, and expanding the temporal (time) limits to consider past, present, and reasonably foreseeable future actions that might affect the environmental resources of concern. The timeframe for this cumulative impacts analysis extends through 2050 for the air quality analysis and through 2100 for energy and climate change. The analysis considers potential cumulative impacts on a national and global basis.

4.1.3 Reasonably Foreseeable Future Actions

The methodology for evaluating cumulative effects includes the reasonably foreseeable future actions of projected average annual passenger car and light truck mile-per-gallon (mpg) estimates from 2016 through 2030 that differ from mpg estimates reflected in the Chapter 3 analysis. The Chapter 3 analysis reflects the direct impacts of fuel economy requirements for model years (MYs) 2012 through 2016 under each of the action alternatives, assuming no further increases in average new passenger car or light truck mpg after 2016. For Chapter 3, this is a reasonable assumption because Chapter 3 is intended to show the direct and indirect effects *of the proposed action*. The Chapter 3 analysis does not show the environmental effects of fuel economy improvements beyond those made under the proposed action by MY 2016.

However, the Chapter 4 evaluation of cumulative effects projects ongoing gains in average new passenger car and light truck mpg consistent with Annual Energy Outlook (AEO) 2010 Early Release (EIA 2009) Reference Case projections because those projected gains are reasonably foreseeable future actions. AEO Reference Case projections are regarded as the official U.S. Government energy projections by both the public and private sector. Chapter 3, Section 3.2.1 provides an expanded description of the AEO. In general, the AEO Reference Case projections tend to fall in the middle of similar publicly available projections. The AEO projections for average new passenger car and light truck mpg assume that combined new passenger cars and light trucks surpass an average of 35 mpg in 2019, and reach 35.5 mpg in 2020, slightly exceeding the Energy Independence and Security Act (EISA) 2007 requirement of 35 mpg in 2020. The AEO Reference Case projections also anticipate an average annual percentage gain of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg from 2019 through 2030, due to consumer demand and technology advances associated with ongoing increases in fuel prices through 2030. The analysis of cumulative effects in this chapter reflects these AEO mpg projections as reasonably foreseeable future actions, associated with future government actions as needed to achieve the EISA 2007 requirement of 35 mpg in 2020, and future consumer and industry actions that result in ongoing mpg gains through 2030. Table 4.1.3-1 shows the AEO projected total and annual percentage increases for fuel economy.

Table 4.1.3-1

AEO 2019-2030 Projected Gains in Fuel Economy Reflected in Analysis of Cumulative Impacts

	2019-2030 Total % Increase in Fuel Economy	2019-2030 Average Annual % Increase in Fuel Economy
New Passenger Car	6.8	0.49
New Light Truck	8.8	0.68

The specific manner in which the AEO mpg projections are applied varies across the action alternatives to ensure that all action alternatives achieve the EISA 2007 requirement of 35 mpg in 2020. The increase in fuel economy from 2016 to 2030 is expected to be at least equal to a gain of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg under all action alternatives. Also, an even faster rate of mpg gain is expected from 2016 to 2020 for two action alternatives that would have to increase mpg at a faster rate after 2016 to achieve the EISA 2007 requirement of 35 mpg in 2020. Alternatives 4 through 9 would exceed the EISA requirement of 35 mpg in 2020, with an average annual percentage gain of 0.51 percent in passenger car mpg and 0.86 percent in light truck mpg after 2016. Therefore, the analysis of cumulative impacts projects annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg for 2016 through 2030 under Alternatives 4 through 9. Alternatives 2 and 3 would require larger percentage gains in mpg from 2016 to 2020 to achieve the EISA requirement of 35 mpg in 2020. Therefore, the analysis of cumulative impacts projects annual gains in mpg from 2016 to 2020 under Alternatives 2 and 3 that are large enough to achieve the EISA requirement of 35 mpg in 2020. The projected actual achieved mpg in 2020 (fleet-wide average) actually slightly exceeds 35 mpg in 2020 (consistent with the AEO projection) under Alternatives 2 and 3 (and under other action alternatives) because some manufacturers would exceed the EISA requirement of 35 mpg in 2020. The analysis of cumulative impacts also projects annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg under Alternatives 2 and 3 from 2020 through 2030.

The assumption that all Action Alternatives reach the EISA 35 mpg target by 2020, with mpg growth at the AEO forecast rate from 2020 to 2030, results in estimated cumulative impacts for Alternatives 2, 3, and 4 that are substantially equivalent, with any minor variation in cumulative impacts across these Alternatives due to the specific modeling assumptions used to ensure that each Alternative achieves at least 35 mpg by 2020. Therefore, the cumulative impacts analysis in Chapter 4 adds substantively to the analysis of direct impacts in Chapter 3 when comparing cumulative impacts between Alternatives 4 through 9, but not when comparing cumulative impacts between Alternatives 2 through 4.

Another important difference in the methodology for evaluating cumulative effects is that the No Action Alternative (Alternative 1) also reflects projected annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg for 2016 through 2030, whereas the Chapter 3 analysis assumed no increases in average new passenger car or light truck mpg after 2016 under any alternative, including the No Action Alternative. Chapter 2 explained that the No Action Alternative (Alternative 1) assumes no action occurs under the National Program (*i.e.*, NHTSA and EPA do not act, and in the absence of standards, manufacturers continue to meet the NHTSA MY 2011Corporate Average Fuel Economy (CAFE) standards), so average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011. The No Action Alternative, by definition, would not satisfy the Energy Conservation and Policy Act (EPCA) (as updated by EISA) requirement to set standards such that the combined fleet of passenger cars and light trucks achieves a combined average fuel economy of at least 35 mpg for MY 2020 (nor would it satisfy the EPCA, as updated by EISA, requirement to adopt annual fuel economy standard increases).[1] The evaluation of cumulative effects in this chapter is consistent in that the projected annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg for 2016 through 2030 under the No Action Alternative still do not reflect any action under the National Program, but only the annual AEO projected gain in mpg through 2030 due to consumer demand and technology advances associated with ongoing increases in fuel prices.

Even with this projected annual percentage gain in mpg for 2016 through 2030, the No Action Alternative would still not achieve the EISA requirement of 35 mpg in 2020. The annual AEO projected gain in mpg through 2030 due to consumer demand and technology advances is applied to the No Action Alternative and to each of the action alternatives so that the difference between fuel use, emissions, and other projections under the No Action Alternative and the action alternatives can be meaningfully compared (*e.g.*, by calculating fuel saved by any action alternative in relation to the No Action Alternative).

NHTSA also considered other reasonably foreseeable actions that would affect greenhouse gas emissions (GHGs). Section 4.4.3.3 discusses these actions and their incorporation into the analysis.

[1] Although EISA's recent amendments to EPCA direct NHTSA to increase CAFE standards and do not permit the agency to take no action on fuel economy, CEQ regulations mandate analysis of a no action alternative. *See* 40 CFR § 1502.14(d). CEQ has explained that "the regulations require the analysis of the no action alternative *even if the agency is under a court order or legislative command to act*." *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 FR 18026 (1981) (emphasis added). The MY 2011 fuel economy level represents the standard NHTSA believes manufacturers would continue to abide by, assuming NHTSA does not issue a rule.

4.2 ENERGY

A NEPA analysis must consider the cumulative impacts of the proposed action. For this EIS, such considerations include evaluating the cumulative fuel consumption of the vehicle fleet from the onset of the proposed new CAFE standards.

4.2.1 Affected Environment

According to the Energy Information Administration (EIA), net imports of total liquid fuels, including crude oil, refined products, and biofuels, which in 2007 amounted to 58 percent of total consumption, will fall to 48 percent of total consumption in 2020 and then fall further to 45 percent of consumption in 2035 (EIA 2009). This change is attributed in part to expected changes in the CAFE standards and to the increased use of biofuels. The steep decline predicted in imports by 2025 is also driven by the surge in U.S. domestic crude-oil production in the previous decade. After 2025, imports of crude oil and biofuels are forecasted to grow slowly through 2035, although imports of finished products continue to decline. The predicted shift in crude oil imports in the period leading up to 2030 could have some effect on the global price of crude oil, but the United States is a price taker not a pricemaker when it comes to petroleum. In addition, over time the U.S. share of global demand for liquid fuels will decline due to rapid increases in demand in developing economies, including China and India, reducing the relative impact of the CAFE standards on global markets. EIA projections show that U.S. consumption of petroleum liquids amounted to 24 percent of global liquid consumption in 2007 and falls to 20 percent by 2035 (EIA 2009).

Over time, a larger share of liquid fuels is expected to be produced from unconventional sources such as biofuels, shale oil, coal-to-liquids, and gas-to-liquids. These alternative sources would affect CO_2 and other emissions reductions from the CAFE alternatives. This shift would be driven by changes to the Renewable Fuels Standard (RFS) in EISA, which forecasts that 36 billion gallons of renewable fuels will be required by 2022 for use primarily in the transportation sector. The EIA AEO 2010 forecasts that domestic production of non-hydro renewable energy (biomass, landfill gas, biogenic municipal waste, wind, photovoltaic, and solar thermal sources) will increase from just over 4 quadrillion British thermal units in 2007 to almost 14 quadrillion British thermal units in 2035 (EIA 2009). In the United States, liquid fuels from gas, coal, and biomass are projected to increase from 0.00 quadrillion British thermal units in 2007 to 1.18 quadrillion British thermal units by 2035.

Changes to the CAFE standards are unlikely to affect domestic production, given the level of crude oil imports. Impacts on production would occur outside of the United States, and would be determined by the balance between the decline in U.S. imports and the increase in demand from developing countries. Impacts on petroleum products would be mixed. U.S. imports of petroleum products are often targeted for specific product requirements, for logistical reasons, or to optimize the inputs and outputs from refineries. Petroleum imports depend on specific product demands and the mix of crudes processed in the refineries, which are projected to change considerably over time. Consequently, any decline in demand for petroleum products is likely to have some effect on both overseas and domestic refineries.

4.2.2 Methodology

As explained in Section 4.1.3, AEO mpg projections through 2030 are reflected in the analysis of cumulative impacts. In particular, this analysis projects annual gains in mpg from 2016 to 2020 under Alternatives 2 and 3 large enough to achieve the EISA requirement of 35 mpg combined for passenger cars and light trucks in 2020. Additionally, the analysis projects annual percentage gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg from 2019 through 2030 under Alternatives 2 and 3, and from 2016 through 2030 under the No Action Alternative and Alternatives 4 through 9. The compound annual gains of 0.49 percent in passenger car mpg and 0.68 percent in light truck mpg through 2030 reflect the total percentage gains projected by AEO from 2019 through 2030 (*see* Table 4.1.3-1 in Section 4.1.3).

4.2.3 Environmental Consequences

Implementing alternative CAFE standards would result in different future levels of fuel use, total energy, and petroleum consumption, which in turn would have an impact on emissions of GHGs and criteria air pollutants. An important measure of the impact of alternative CAFE standards is the impact on the fuel consumption of the vehicle fleet from the onset of the new standards. Passenger cars and light trucks are considered separately; total fuel consumption encompasses gasoline and diesel. CAFE standards for MYs 2012-2020 are assumed to apply to all subsequent additions to the vehicle fleet.

Table 4.2.3-1 shows the fuel consumption of passenger cars under the No Action Alternative (Alternative 1) and the eight action alternatives (Alternatives 2 through 9), as described in Section 2.3. By 2060, fuel consumption reaches 193.2 billion gallons under the No Action Alternative. Consumption falls across the alternatives from 167.2 billion gallons under Alternatives 3 and 4 to 156.3 and 157.2 billion gallons under Alternatives 8 and 9, representing a fuel savings of 26.0 to 36.9 billion gallons in 2060.

Table 4.2.3-2 shows the fuel consumption of light trucks under the CAFE alternatives examined. Fuel consumption by 2060 reaches 103.8 billion gallons under the No Action Alternative. Consumption declines across the alternatives, from 92.2 billion gallons under Alternative 2 to 84.6 billion gallons under Alternative 8. This represents a fuel savings of 11.5 to 19.1 billion gallons in 2060.

Table 4.2.3-1

Cumulative Effects of Passenger Car Annual Fuel Consumption and Fuel Savings (billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	73.8	69.4	68.4	68.0	67.3	66.0	66.2	65.4	65.4
2030	100.4	88.0	87.6	87.5	86.0	83.6	83.6	81.9	82.3
2040	127.0	110.0	109.9	109.9	108.1	104.9	104.9	102.7	103.3
2050	157.5	136.4	136.3	136.3	134.1	130.2	130.1	127.5	128.2
2060	193.2	167.3	167.2	167.2	164.5	159.6	159.6	156.3	157.2
Fuel Savings Compared to No Action									
2020	--	4.4	5.5	5.8	6.5	7.8	7.6	8.4	8.4
2030	--	12.4	12.8	12.9	14.4	16.8	16.8	18.5	18.1
2040	--	17.0	17.1	17.1	18.9	22.0	22.1	24.2	23.7
2050	--	21.2	21.2	21.2	23.4	27.4	27.4	30.1	29.4
2060	--	26.0	26.0	26.0	28.7	33.6	33.6	36.9	36.0

Table 4.2.3-2

Cumulative Effects of Light Truck Annual Fuel Consumption and Fuel Savings (billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	75.6	72.8	72.2	71.7	71.2	70.0	70.2	69.6	69.6
2030	69.4	63.4	63.2	62.5	61.5	59.8	59.9	58.9	59.0
2040	73.1	65.4	65.4	64.7	63.5	61.5	61.4	60.2	60.5
2050	85.6	76.2	76.2	75.3	73.9	71.5	71.4	70.0	70.3
2060	103.8	92.2	92.3	91.2	89.4	86.6	86.4	84.6	85.1
Fuel Savings Compared to No Action									
2020	--	2.7	3.4	3.9	4.4	5.6	5.3	6.0	6.0
2030	--	6.0	6.3	6.9	7.9	9.6	9.6	10.6	10.4
2040	--	7.7	7.7	8.5	9.7	11.6	11.7	12.9	12.6
2050	--	9.4	9.4	10.3	11.7	14.1	14.2	15.6	15.3
2060	--	11.5	11.5	12.6	14.3	17.2	17.3	19.1	18.7

Table 4.2.3-3 summarizes the fuel consumption and savings for both passenger cars and light trucks. Fuel consumption reaches 297.0 billion gallons under the No Action Alternative in 2060 and declines across the alternatives, from 259.5 billion gallons under Alternative 2 to 241.0 billion gallons under Alternative 8. This represents a fuel savings of 37.5 to 56.0 billion gallons in 2060.

As a result of the assumptions in fuel economy growth after 2016, annual fuel consumption is reduced compared to the fuel consumption results reported in the direct and indirect effects analysis in Section 3.2.3. Fuel savings for Alternatives 2 and 3 are greater in this analysis than in Section 3.2.3. Alternatives 2 and 3 have a fast annual growth in mpg from 2016 to 2020 in order to achieve the EISA requirement of 35 mpg whereas the No Action Alternative increases at a rate consistent with AEO projections. Alternative 4 through 9 show reduced fuel savings as compared to the analysis in Section 3.2.3 because the No Action Alternative, from which the fuel savings is calculated, has lower fuel consumption due to the growth in mpg assumed in this analysis.

Table 4.2.3-3

Cumulative Effects of Combined Passenger Car and Light Truck Annual Fuel Consumption and Fuel Savings a/
(billion gallons of gasoline equivalent)

Calendar Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Fuel Consumption									
2020	149.4	142.2	140.5	139.7	138.5	136.0	136.4	135.0	135.0
2030	169.9	151.5	150.7	150.0	147.6	143.4	143.5	140.8	141.4
2040	200.1	175.4	175.3	174.6	171.6	166.4	166.3	163.0	163.8
2050	243.1	212.5	212.5	211.7	208.0	201.7	201.5	197.4	198.4
2060	297.0	259.5	259.5	258.4	253.9	246.2	246.0	241.0	242.2
Fuel Savings Compared to No Action									
2020	--	7.1	8.9	9.7	10.9	13.4	13.0	14.4	14.4
2030	--	18.4	19.1	19.9	22.3	26.4	26.4	29.1	28.5
2040	--	24.7	24.8	25.5	28.5	33.7	33.8	37.1	36.3
2050	--	30.6	30.6	31.5	35.2	41.4	41.6	45.7	44.7
2060	--	37.5	37.5	38.5	43.1	50.8	51.0	56.0	54.7

a/ Some of the values shown for car & light truck fuel consumption in this table vary slightly from the sum of values shown separately for passenger cars and light trucks in previous tables due to rounding error.

4.3 AIR QUALITY

4.3.1 Affected Environment

Section 3.3.1 describes the air quality affected environment.

4.3.2 Methodology

4.3.2.1 Overview

The analysis methodology for air quality cumulative impacts and consequent health outcomes is the same as described in Section 3.3.2, except that the cumulative impacts analysis assumes annual average percentage gains in average fuel economy from 2016 through 2030 consistent with the AEO 2010 Early Release (EIA 2009) Reference Case projections, with all action alternatives exceeding the combined EISA target of 35 mpg in 2020 (*see* Section 4.1.3). These AEO mpg projections reflect reasonably foreseeable future government actions as needed to achieve the EISA 2007 requirement, and future consumer and industry actions that result in ongoing mpg gains through 2030. Because there are no valid projections that go past calendar year 2030, the average fuel economy estimates for MYs 2030-2050 remain constant. NHTSA analyzed the cumulative air quality impacts of the action alternatives by calculating the emissions from passenger cars and light trucks that would occur under each alternative, including the effects of percentage gains in mpg from 2016 through 2030 consistent with AEO projections, and assessing the changes in emissions in relation to the No Action Alternative, to which the AEO forecasted fuel economy increases were also applied.

This analysis considers the following cumulative impacts of alternative CAFE standards for MYs 2012-2016 *and* other reasonably foreseeable actions projected to affect fuel economy through 2030, as described in Section 4.1.3. Because CAFE standards and ongoing mpg gains apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles with higher average mpg are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet the mpg projection for new passenger cars and light trucks in 2030. To account for these effects on emissions beyond calendar year 2030, NHTSA analyzed cumulative impacts through 2050. Because the cumulative impacts analysis assumes that new vehicles in model years beyond MY 2016 have a higher fleet average fuel economy based on AEO fuel economy projections, these assumptions result in emissions reductions and fuel savings that continue to grow as these new, more fuel efficient vehicles are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet have these higher mpg levels. Because of this, NHTSA analyzed the air emissions through 2050, when most of the fleet would achieve the average fuel economy levels the agency projects in 2030 (based on AEO fuel economy forecasts).[2] For comparison, the Chapter 3 analysis only examines the direct and indirect effects of the proposed MYs 2012-2016 standards and analyzes the effect of this rule through 2030.

4.3.2.2 Treatment of Incomplete or Unavailable Information

As noted in Section 3.3.2, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, projections of vehicle miles traveled (VMT), emissions

[2] By 2050, 98 percent of passenger cars and 88 percent of light trucks will have been produced in 2030 or later. Because newer vehicles are utilized more than older ones, the fraction of total passenger car and light truck VMT that these vehicles account for would be even higher – 99 percent for passenger cars and 94 percent for light trucks.

from fuel refining and distribution, and economic factors. NHTSA used screening-level estimates of health outcomes in the form of cases per ton of criteria pollutant emissions reduced, and of monetized health benefits in the form of dollars per ton of criteria pollutant emissions reduced, to approximate the health benefits associated with each alternative. The use of such dollar-per-ton numbers, however, does not account for all potential health and environmental benefits because the information necessary to monetize all potential health and environmental benefits is unavailable (*e.g.*, health effects per ton of emissions of pollutants other than PM, values of property damage, and effects on vegetation), which leads to an underestimate of total criteria pollutant benefits. Reductions in emissions of toxic air pollutants should result in health benefits as well, but scientific data are not available that would allow quantification and monetization of these benefits.

Where information in the analysis included in this EIS is incomplete or unavailable, the agency has relied on CEQ regulations regarding incomplete or unavailable information. 40 CFR § 1502.22(b). NHTSA used the best available models and supporting data in preparing this EIS. The models used have been scientifically reviewed and have been approved by the agencies that sponsored their development. NHTSA believes that the assumptions in this EIS regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis.

4.3.2.3 Photochemical Air Quality Modeling and Risk Assessment

The national-scale photochemical air quality modeling and health risk assessment, Appendix F, was also conducted with the cumulative impacts data from the DEIS. The analysis methodology for the photochemical modeling and risk assessment of cumulative impacts is the same as described in Section 3.3.2, except that the cumulative impacts analysis assumes annual average percentage gains in average fuel economy from 2016 through 2030 as described in Section 4.3.2.1. The analysis showed comparable results to the health and economic effects calculated in the DEIS.

4.3.3 Environmental Consequences

4.3.3.1 Results of Emissions Analysis

The Clean Air Act (CAA) has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and the U.S. Environmental Protection Agency (EPA) projects that they will continue to decline. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternative CAFE standards. The analysis by alternative in this section shows that the alternative CAFE standards will lead to both reductions and increases in emissions from passenger cars and light trucks (depending on the pollutant), compared to current trends (*i.e.*, the No Action Alternative). The amounts of the reductions and increases would vary by pollutant, calendar year, and alternative. The more restrictive alternatives generally would result in greater emissions reductions compared to the No Action Alternative. This trend is shown in the analysis of the MYs 2012-2016 CAFE standards in Section 3.3.3.

4.3.3.2 Alternative 1: No Action

4.3.3.2.1 Criteria Pollutants

Under the No Action Alternative, average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011. Average fuel economy is assumed to increase from 2012 through 2030 due to projected rising demand for fuel economy, consistent with AEO projections (*see* Section 4.1.3). Current trends in the levels of emissions from vehicles would continue through 2030, with emissions continuing to decline due to the EPA emissions standards, despite a growth in total VMT. By 2050, however, VMT growth more than offsets decreases due to emission standards and total emissions increase. The EPA vehicle emissions standards regulate all criteria pollutants except sulfur dioxide (SO_2), which is regulated through the fuel sulfur content. The No Action Alternative would not change the MY 2011 CAFE standards; therefore, any change in criteria pollutant emissions in nonattainment and maintenance areas throughout the United States would be attributable to current emissions regulatory programs and the assumed future trends in fuel economy increases in accordance with the AEO projections.

Table 4.3.3-1 summarizes the total national emissions of criteria pollutants from passenger cars and light trucks under the No Action Alternative. Figure 4.3.3-1 illustrates this information. Table 4.3.3-1 lists the action alternatives (Alternatives 2 through 9) left to right in order of generally increasing fuel economy requirements. In the case of particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), sulfur oxides (SO_x), nitrogen oxides (NO_x), and volatile organic compounds (VOCs), the No Action Alternative results in the highest emissions, and emissions generally decline as fuel economy standards increase across alternatives. Due to the interaction of VMT, fuel economy, and the share of VMT accrued by diesel vehicles, there are some exceptions to this declining trend (emissions increase from one individual alternative to the next higher fuel economy alternative), although emissions of these pollutants would remain below the levels under the No Action Alternative. These exceptions are NO_x under Alternative 7, and under Alternative 9 in 2020, 2030, and 2050; $PM_{2.5}$ under Alternatives 5 through 8; SO_x under Alternative 3 in 2050, Alternative 5, and Alternative 7 in 2016 and 2020; and VOCs under Alternative 7, and under Alternative 9 in 2020, 2030, and 2050. Despite these individual increases, emissions of $PM_{2.5}$, SO_x, NO_x, and VOCs remain below the levels under the No Action Alternative. In the case of CO, emissions under Alternatives 2 through 4 are slightly higher than under the No Action Alternative, and are lower than under the No Action Alternative for Alternatives 5 through 9. Appendix C presents cumulative emissions of criteria pollutants for each nonattainment area.

Total emissions are composed of four components: tailpipe emissions and upstream emissions for passenger cars, and tailpipe emissions and upstream emissions for light trucks. To show the relationship among these four components for criteria pollutants, Table 4.3.3-2 breaks down the total emissions of criteria pollutants by component for calendar year 2030.

Table 4.3.3-3 lists the net changes in nationwide cumulative emissions from passenger cars and light trucks as compared to the No Action Alternative for each criteria pollutant and analysis year. The table lists Alternatives 2 through 9 from left to right in order of generally increasing fuel economy requirements. The reductions in nationwide cumulative emissions from the No Action Alternative generally increase from left to right, though unevenly, as noted above, due to the interaction of VMT, fuel economy, and the share of VMT accrued by diesel vehicles. There are some increases in CO emissions under Alternatives 2 through 4, as noted above, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

As discussed in Section 3.3.3.2.1, one of the ways that the Volpe model projects vehicle manufacturers can achieve higher fuel economy is to increase the share of new vehicles that use diesel engines. The resulting increase in the use of diesel fuel as mpg standards become more stringent across action alternatives can interact with other factors, such as changes in VMT, the car and light truck shares, and the shares of other technologies such as hybrids, to affect emissions of different pollutants in different ways across Alternatives. Another result of increasing forecasted use of diesel engines can be that

Table 4.3.3-1

Cumulative Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
2016	20,380,537	20,393,938	20,394,480	20,383,598	20,272,923	20,182,256	20,228,025	20,168,102	20,173,726
2020	19,133,013	19,178,024	19,177,706	19,155,494	18,860,312	18,609,878	18,704,744	18,527,238	18,568,972
2030	20,569,714	20,730,187	20,711,222	20,662,019	19,890,055	19,242,112	19,400,043	18,904,057	19,071,598
2050	28,943,491	29,227,165	29,179,262	29,098,748	27,809,337	26,721,219	26,941,788	26,099,919	26,408,318
Nitrogen oxides (NO_x)									
2016	2,210,405	2,207,302	2,205,558	2,204,404	2,201,606	2,197,765	2,199,718	2,197,430	2,196,989
2020	1,755,985	1,746,692	1,744,016	1,742,112	1,733,189	1,723,506	1,727,191	1,720,739	1,721,297
2030	1,417,997	1,395,535	1,393,715	1,391,027	1,364,556	1,338,602	1,344,552	1,325,627	1,331,170
2050	1,736,474	1,699,529	1,697,706	1,693,875	1,649,549	1,606,445	1,614,485	1,582,550	1,593,216
Particulate matter ($PM_{2.5}$)									
2016	68,793	68,374	68,122	68,024	68,424	68,603	68,606	68,737	68,605
2020	68,785	67,443	67,057	66,925	67,672	68,003	68,049	68,373	68,137
2030	82,714	79,237	79,031	78,919	80,004	80,289	80,448	80,932	80,653
2050	123,444	117,742	117,605	117,478	118,957	119,187	119,450	120,068	119,763
Sulfur oxides (SO_x)									
2016	176,518	173,665	172,306	171,666	172,232	171,378	171,729	171,422	170,947
2020	183,552	174,936	172,914	172,039	172,820	171,669	171,805	171,336	170,802
2030	208,630	186,377	185,643	184,922	186,154	184,521	184,182	183,444	183,012
2050	298,565	261,582	261,779	261,029	262,851	260,415	259,761	258,601	258,142
Volatile organic compounds (VOCs)									
2016	2,505,277	2,491,567	2,484,860	2,480,794	2,470,902	2,455,914	2,461,292	2,453,075	2,452,838
2020	2,160,591	2,120,074	2,109,903	2,103,946	2,079,646	2,050,297	2,056,326	2,037,883	2,041,620
2030	1,848,278	1,746,212	1,741,205	1,734,534	1,680,701	1,623,692	1,629,059	1,589,318	1,602,520
2050	2,157,634	1,988,851	1,986,963	1,978,405	1,892,334	1,803,021	1,808,713	1,745,102	1,767,929

Figure 4.3.3-1. Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative

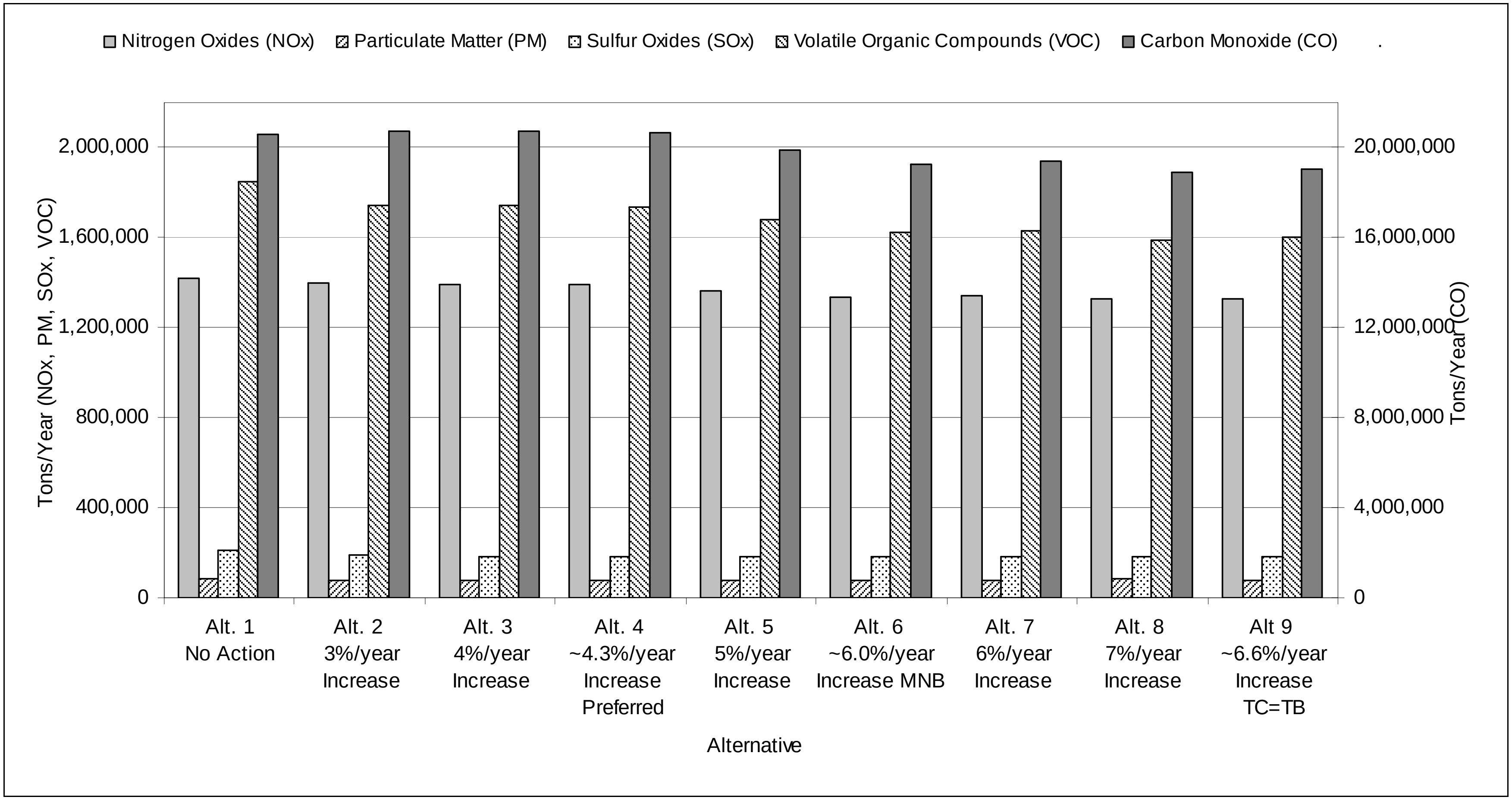


Table 4.3.3-2

Cumulative Nationwide Criteria Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Poll. and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
Car Tailpipe	16,600,120	16,696,233	16,735,859	16,722,906	16,237,744	15,938,196	15,879,787	15,553,277	15,648,485
Car Upstream	85,473	74,450	74,308	74,357	74,945	73,966	74,106	73,717	73,810
Truck Tailpipe	12,211,183	12,415,064	12,327,431	12,260,170	11,454,514	10,666,524	10,945,836	10,430,623	10,644,181
Truck Upstream	46,714	41,418	41,664	41,315	42,133	42,533	42,059	42,301	41,842
Total	28,943,491	29,227,165	29,179,262	29,098,748	27,809,337	26,721,219	26,941,788	26,099,919	26,408,318
Nitrogen oxides (NO_x)									
Car Tailpipe	588,874	592,580	593,895	593,465	577,426	567,584	565,648	554,881	558,023
Car Upstream	267,576	232,825	232,448	232,575	233,465	229,789	230,142	228,371	228,809
Truck Tailpipe	733,930	744,512	741,099	738,733	707,841	677,887	688,775	669,164	677,347
Truck Upstream	146,095	129,611	130,264	129,102	130,816	131,185	129,921	130,134	129,037
Total	1,736,474	1,699,529	1,697,706	1,693,875	1,649,549	1,606,445	1,614,485	1,582,550	1,593,216
Particulate matter ($PM_{2.5}$)									
Car Tailpipe	38,294	39,167	39,059	39,095	40,552	41,586	41,750	42,790	42,491
Car Upstream	36,435	31,749	31,685	31,707	32,010	31,625	31,690	31,554	31,586
Truck Tailpipe	28,795	29,169	29,092	29,051	28,377	27,738	27,987	27,567	27,743
Truck Upstream	19,921	17,658	17,769	17,624	18,019	18,237	18,023	18,156	17,942
Total	123,444	117,742	117,605	117,478	118,957	119,187	119,450	120,068	119,763
Sulfur Oxides (SO_x)									
Car Tailpipe	29,513	25,434	25,459	25,446	24,571	23,541	23,490	22,730	22,929
Car Upstream	163,612	142,602	142,307	142,410	143,897	142,254	142,557	142,021	142,143
Truck Tailpipe	15,966	14,246	14,198	13,998	13,319	12,457	12,544	12,007	12,234
Truck Upstream	89,475	79,301	79,816	79,175	81,063	82,163	81,171	81,844	80,836
Total	298,565	261,582	261,779	261,029	262,851	260,415	259,761	258,601	258,142
Volatile organic compounds (VOCs)									
Car Tailpipe	441,191	445,208	445,814	445,617	438,503	434,412	433,530	428,876	430,243
Car Upstream	893,064	766,825	768,339	767,652	730,099	691,833	689,276	659,851	667,596
Truck Tailpipe	341,942	346,317	345,099	344,301	333,296	322,707	326,643	319,695	322,586
Truck Upstream	481,437	430,501	427,712	420,835	390,437	354,068	359,264	336,679	347,504
Total	2,157,634	1,988,851	1,986,963	1,978,405	1,892,334	1,803,021	1,808,713	1,745,102	1,767,929

Table 4.3.3-3

Cumulative Nationwide Criteria Pollutant Emission Changes (tons/year) from Passenger Cars and Light Trucks by Alternative Compared to No Action Alternative a/ b/

Poll. and Year	Alt. 1 No Action c/	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon monoxide (CO)									
2016	0	13,402	13,943	3,062	-107,614	-198,280	-152,511	-212,434	-206,811
2020	0	45,011	44,693	22,481	-272,701	-523,135	-428,268	-605,774	-564,041
2030	0	160,473	141,508	92,306	-679,658	-1,327,602	-1,169,671	-1,665,657	-1,498,116
2050	0	283,674	235,771	155,258	-1,134,154	-2,222,272	-2,001,703	-2,843,572	-2,535,173
Nitrogen oxides (NO_x)									
2016	0	-3,103	-4,847	-6,001	-8,799	-12,640	-10,687	-12,976	-13,416
2020	0	-9,294	-11,969	-13,873	-22,796	-32,479	-28,795	-35,246	-34,689
2030	0	-22,462	-24,282	-26,970	-53,441	-79,395	-73,445	-92,370	-86,827
2050	0	-36,945	-38,767	-42,599	-86,925	-130,029	-121,989	-153,924	-143,258
Particulate matter ($PM_{2.5}$)									
2016	0	-420	-672	-770	-369	-191	-187	-57	-189
2020	0	-1,342	-1,728	-1,861	-1,114	-783	-736	-412	-648
2030	0	-3,477	-3,683	-3,795	-2,710	-2,425	-2,266	-1,782	-2,061
2050	0	-5,701	-5,838	-5,966	-4,486	-4,256	-3,993	-3,375	-3,681
Sulfur oxides (SO_x)									
2016	0	-2,853	-4,212	-4,852	-4,286	-5,140	-4,788	-5,096	-5,571
2020	0	-8,616	-10,638	-11,513	-10,732	-11,883	-11,747	-12,216	-12,750
2030	0	-22,253	-22,987	-23,708	-22,475	-24,109	-24,447	-25,185	-25,617
2050	0	-36,983	-36,786	-37,537	-35,715	-38,151	-38,804	-39,964	-40,423
Volatile organic compounds (VOCs)									
2016	0	-13,710	-20,417	-24,484	-34,375	-49,363	-43,985	-52,202	-52,439
2020	0	-40,518	-50,688	-56,645	-80,946	-110,295	-104,265	-122,708	-118,971
2030	0	-102,066	-107,073	-113,743	-167,577	-224,585	-219,218	-258,960	-245,758
2050	0	-168,783	-170,670	-179,228	-265,299	-354,612	-348,921	-412,532	-389,704

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

differing upstream emission rates might change pollutant emissions estimates, as compared to those rates for gasoline-fueled engines. Projected changes in the share of diesel vehicles appear to be a factor in the results for CO that show increases in cumulative emissions compared to the No Action Alternative under Alternatives 2 through 4 and decreases in cumulative emissions compared to the No Action Alternative under Alternatives 6 through 9.

Cumulative emissions in 2016 would be equivalent to the noncumulative emissions in all cases. Cumulative emissions of NO_x, $PM_{2.5}$, SO_2, and VOCs in 2020 and 2030 would be less than noncumulative emissions for the same combination of pollutant, year, and alternative because of differing changes in VMT and fuel consumption under the cumulative case compared to the noncumulative case (*i.e.*, because of the impact of projected higher average fuel economy in the cumulative analysis). Cumulative emissions of CO in 2020 and 2030 would be greater than the corresponding noncumulative emissions.

4.3.3.2.2 Toxic Air Pollutants

As with the criteria pollutants, current trends in the levels of toxic air pollutant emissions from vehicles would continue, with emissions of most toxic air pollutants continuing to decline through 2050, despite a growth in total VMT, as a result of the EPA emission standards. By 2050, however, VMT growth more than offsets decreases due to emission standards and total emissions increase. In addtion, with current trends, emissions of diesel particulate matter (DPM) nationwide would increase in 2020, 2030, and 2050 over 2016 levels under the No Action Alternative. Nationwide emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde would decrease in 2020, 2030, and 2050 from 2016 levels under the No Action Alternative. Cumulative emissions would increase in at least one nonattainment area in each year for each toxic air pollutant.

Table 4.3.3-4 summarizes the cumulative national toxic air pollutant emissions from passenger cars and light trucks under each alternative for each toxic air pollutant and analysis year. The table lists Alternatives 2 through 9 from left to right in order of generally increasing fuel economy requirements. Figure 4.3.3-2 lists the total national emissions of toxic air pollutants from passenger cars and light trucks by alternative. Emissions of most toxic air pollutants would increase in each alternative as compared to the No Action Alternative. The exceptions are acetaldehyde emissions, which would decrease under Alternative 2 in 2016, Alternatives 6 through 9 in 2030, and Alternatives 5 though 9 in 2050; acrolein emissions, which would remain the same under alternatives 2 and 3 in 2016; benzene emissions, which would decrease under all alternatives and years; 1,3-butadiene emissions, which would increase under all alternatives and years except Alternatives 5 through 9 in 2030 and 2050; DPM emissions, which would decrease under all alternatives in all years; and formaldehyde emissions, which would decrease under Alternative 2 in all years and under Alternative 3 in 2016 and 2020. The changes in toxic air pollutant emissions, positive or negative, would generally be small (less than 10 percent) in relation to the No Action Alternative emissions levels. The exceptions are acrolein emissions, which would increase by more than 10 percent under Alternatives 6 through 9 in 2030 and Alternatives 5 through 9 in 2050; DPM emissions, which would decrease by more than 10 percent under all action alternatives in 2030 and 2050; and formaldehyde emissions, which would increase by more than 10 percent under Alternatives 8 and 9 in 2050. Appendix C presents the cumulative emissions of toxic air pollutants for each nonattainment area for the No Action Alternative.

As discussed in Section 3.3.3.2.2, one of the ways that the Volpe model projects vehicle manufacturers can achieve higher fuel economy is to increase the share of new vehicles that use diesel engines. The resulting increase in the use of diesel fuel as mpg standards become more stringent across action alternatives can interact with other factors, such as changes in VMT, the car and light truck shares, and the shares of other technologies such as hybrids, to affect emissions of different pollutants in different ways across Alternatives. Another result of increasing forecasted use of diesel engines can be that differing upstream emission rates might change pollutant emissions estimates, as compared to those rates for gasoline-fueled engines. Projected changes in the share of diesel vehicles appear to be a factor in the results for acetaldehyde and 1,3-butadiene that show increases in cumulative emissions compared to the No Action Alternative under Alternatives 2 through 4 and decreases in cumulative emissions compared to the No Action Alternative under Alternatives 6 through 9.

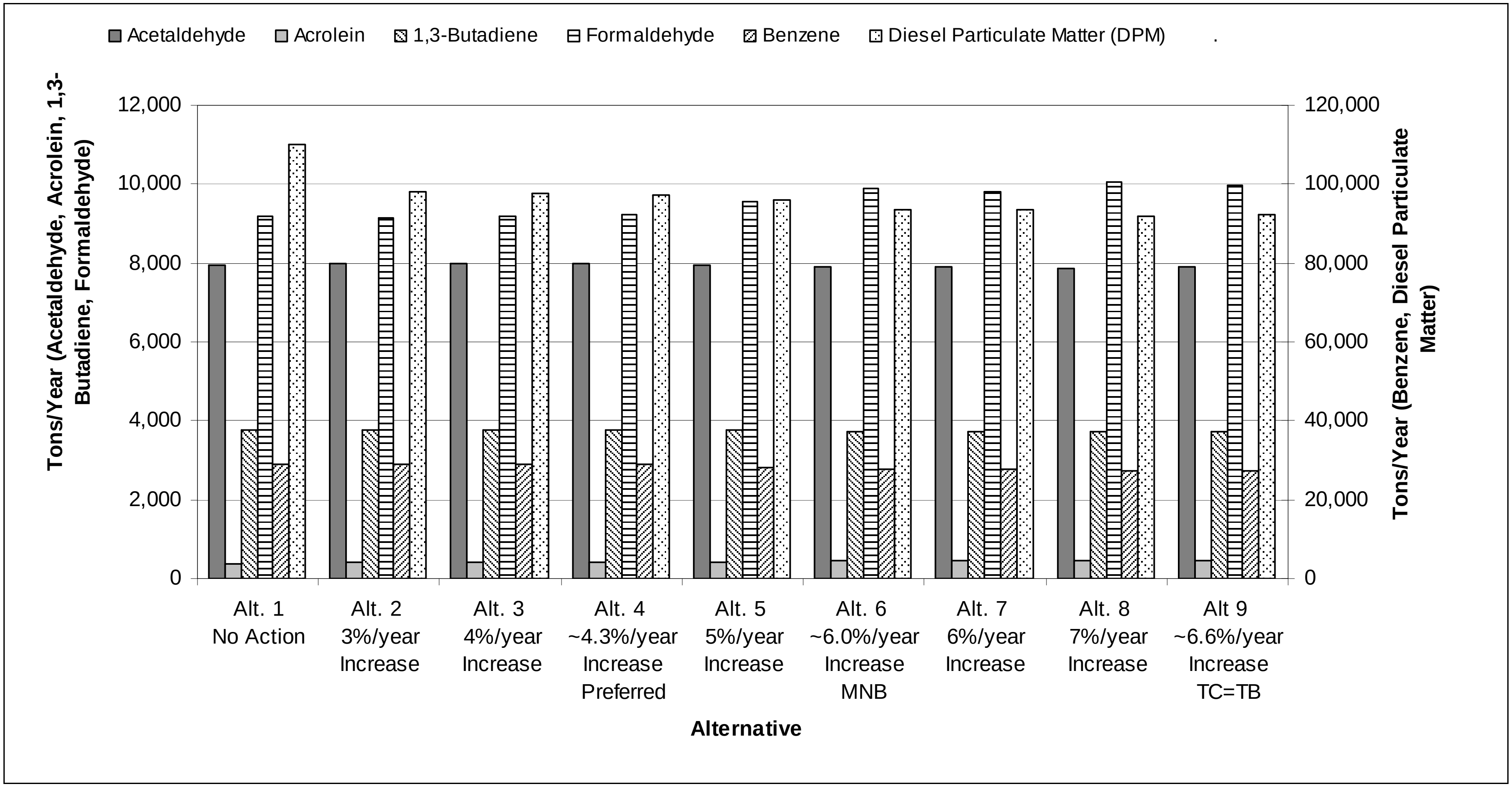
Cumulative emissions after 2016 would be lower than noncumulative emissions for acrolein under Alternative 9 in 2020 and 2030, benzene, DPM, and formaldehyde because of differing changes in VMT and fuel consumption under the cumulative case compared to the noncumulative case (*i.e.*, because of the impact of projected higher fuel economy in the cumulative analysis). Cumulative emissions after 2016 would be the same or higher than noncumulative emissions for acetaldehyde, acrolein under Alternatives 1 through 8, and 1,3-butadiene.

Table 4.3.3-4

Cumulative Nationwide Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Acetaldehyde									
2016	10,921	10,919	10,924	10,928	10,955	10,976	10,960	10,977	10,977
2020	9,025	9,028	9,037	9,041	9,069	9,099	9,085	9,105	9,098
2030	7,939	7,978	7,987	7,989	7,940	7,916	7,912	7,882	7,889
2050	10,061	10,138	10,144	10,143	10,024	9,951	9,947	9,871	9,894
Acrolein									
2016	561	561	561	562	569	576	572	577	576
2020	455	456	456	458	472	486	482	491	486
2030	392	395	396	398	425	449	445	464	449
2050	494	500	501	504	547	585	579	609	585
Benzene									
2016	56,184	56,162	56,150	56,139	56,080	56,019	56,045	56,008	56,010
2020	43,117	43,061	43,043	43,020	42,836	42,665	42,725	42,609	42,631
2030	28,927	28,843	28,826	28,782	28,174	27,645	27,760	27,361	27,491
2050	29,272	29,163	29,128	29,057	28,000	27,082	27,243	26,539	26,794
1,3-butadiene									
2016	6,100	6,101	6,102	6,103	6,107	6,112	6,109	6,113	6,112
2020	4,874	4,880	4,881	4,882	4,883	4,887	4,888	4,891	4,889
2030	3,758	3,784	3,784	3,782	3,753	3,729	3,739	3,722	3,727
2050	4,376	4,426	4,422	4,418	4,359	4,310	4,325	4,289	4,304
Diesel particulate matter (DPM)									
2016	93,117	91,618	90,856	90,463	90,213	89,313	89,679	89,227	89,075
2020	96,724	92,177	91,025	90,479	89,807	88,252	88,565	87,719	87,726
2030	109,888	98,126	97,596	97,096	95,875	93,354	93,454	92,024	92,369
2050	157,271	137,711	137,612	137,050	135,284	131,578	131,581	129,470	130,085
Formaldehyde									
2016	13,700	13,685	13,692	13,707	13,833	13,937	13,874	13,948	13,943
2020	10,978	10,951	10,966	10,988	11,222	11,433	11,350	11,497	11,456
2030	9,179	9,154	9,182	9,213	9,571	9,904	9,810	10,044	9,957
2050	11,476	11,456	11,491	11,534	12,063	12,550	12,425	12,772	12,638

Figure 4.3.3-2. Cumulative Nationwide Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative



Most emissions changes with the cumulative analysis (compared to the No Action Alternative) would be the same as or greater than the corresponding emissions changes with the noncumulative analysis for most toxic air pollutants. The exceptions are acetaldehyde in 2020 under Alternatives 4 and 5, and in 2030 under Alternative 5; acrolein in 2020 under Alternative 9, and in 2030 under Alternatives 5 through 7 and 9; benzene in 2030 under Alternatives 4 through 9; 1,3-butadiene in 2030 under Alternative 4; DPM under Alternatives 5 through 9 in 2020, and under Alternatives 4 through 9 in 2030; and formaldehyde under Alternative 3 in 2030.

Total emissions are composed of four components: tailpipe emissions and upstream emissions for passenger cars, and tailpipe emissions and upstream emissions for light trucks. To show the relationship among these four components for air toxic pollutants, Table 4.3.3-5 breaks down the total emissions of air toxic pollutants by component for calendar year 2030.

Table 4.3.3-6 lists the net changes in nationwide cumulative emissions from passenger cars and light trucks compared to Alternative 1 (No Action) for each toxic air pollutant and analysis year. The table lists Alternatives 2 through 9 left to right in order of generally increasing fuel economy requirements.

4.3.3.2.3 Health Outcomes and Monetized Benefits

Under Alternative 1 (No Action), average fuel economy would remain at the 2011 level until 2016, increase as projected by AEO until 2030, and then remain at the 2030 level through 2050. Emissions of criteria pollutants and toxic air pollutants would change as described above. Human health effects of emissions are tied to specific pollutants, and will vary as emissions of these pollutants vary. The No Action Alternative would result in no other increase or decrease in human health effects throughout the United States compared to current trends because the No Action Alternative represents maintaining the status quo (*i.e.*, no action by either NHTSA or the EPA).

The economic value of health impacts would vary proportionally with changes in health outcomes under the methodology defined in Section 3.3.2.4.2. The monetized health benefits analyzed here are the result of changes in ambient PM concentrations caused by changes in the precursor criteria pollutants NO_x, VOCs, SO_2, and $PM_{2.5}$. Alternative 1 (No Action) would result in no other change in health-related impacts throughout the United States, compared to current trends because the No Action Alternative represents maintaining the status quo (*i.e.*, no action by either NHTSA or EPA).

4.3.3.3 Alternative 2: 3-Percent Annual Increase

4.3.3.3.1 Criteria Pollutants

Under the 3-Percent Alternative (Alternative 2), generally the CAFE standards would require increased fuel economy compared to the No Action Alternative (Alternative 1). Alternative 2 would increase fuel economy less than Alternatives 3 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 2 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.1 to 2.1 percent, $PM_{2.5}$ emissions would be reduced 0.6 to 4.6 percent, SO_x emissions would be reduced 1.6 to 12.4 percent, and VOC emissions would be reduced 0.5 to 7.8 percent, compared to emissions projected under the No Action Alternative. There would be increases of CO emissions. CO emissions would increase 0.1 to 1.0 percent under Alternative 2, depending on the year, compared to emissions projected under the No Action Alternative.

Table 4.3.3-5

Cumulative Nationwide Toxic Air Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Pollutant and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Acetaldehyde									
Car Tailpipe	5,771	5,822	5,831	5,828	5,728	5,670	5,658	5,592	5,611
Car Upstream	95	82	82	82	81	79	78	77	77
Truck Tailpipe	4,143	4,188	4,186	4,187	4,171	4,159	4,168	4,160	4,164
Truck Upstream	52	46	46	45	45	43	43	42	42
Total	10,061	10,138	10,144	10,143	10,024	9,951	9,947	9,871	9,894
Acrolein									
Car Tailpipe	272	281	279	280	300	315	317	331	315
Car Upstream	13	11	11	11	11	11	11	11	11
Truck Tailpipe	202	202	204	207	230	253	246	261	253
Truck Upstream	7	6	6	6	6	6	6	6	6
Total	494	500	501	504	547	585	579	609	585
Benzene									
Car Tailpipe	15,004	15,109	15,139	15,130	14,766	14,546	14,502	14,259	14,330
Car Upstream	1,933	1,664	1,666	1,665	1,600	1,528	1,524	1,470	1,484
Truck Tailpipe	11,291	11,457	11,394	11,347	10,770	10,208	10,409	10,041	10,194
Truck Upstream	1,044	933	929	915	864	801	808	769	786
Total	29,272	29,163	29,128	29,057	28,000	27,082	27,243	26,539	26,794
1,3-butadiene									
Car Tailpipe	2,511	2,541	2,543	2,542	2,530	2,526	2,525	2,518	2,520
Car Upstream	21	18	18	18	18	18	18	18	18
Truck Tailpipe	1,833	1,856	1,851	1,848	1,800	1,755	1,772	1,742	1,755
Truck Upstream	11	10	10	10	10	11	11	11	11
Total	4,376	4,426	4,422	4,418	4,359	4,310	4,325	4,289	4,304
Diesel particulate matter (DPM)									
Car Tailpipe	22	442	314	356	2,020	3,134	3,326	4,485	4,150
Car Upstream	101,917	88,002	88,042	88,017	85,674	82,554	82,441	80,210	80,793
Truck Tailpipe	94	37	107	169	820	1,468	1,249	1,672	1,498
Truck Upstream	55,238	49,229	49,149	48,508	46,771	44,423	44,565	43,104	43,645
Total	157,271	137,711	137,612	137,050	135,284	131,578	131,581	129,470	130,085

Table 4.3.3-5 (cont'd)

Cumulative Nationwide Toxic Air Pollutant Emissions (tons/year) in 2030 from Passenger Cars and Light Trucks, by Vehicle Type and Alternative

Pollutant and Source	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Formaldehyde									
Car Tailpipe	5,967	6,077	6,068	6,071	6,192	6,282	6,296	6,384	6,359
Car Upstream	715	619	619	619	610	593	593	581	584
Truck Tailpipe	4,405	4,414	4,458	4,502	4,924	5,349	5,211	5,487	5,374
Truck Upstream	389	346	346	342	336	327	326	320	321
Total	11,476	11,456	11,491	11,534	12,063	12,550	12,425	12,772	12,638

Table 4.3.3-6

Cumulative Nationwide Changes in Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks by Alternative Compared to No Action Alternative a/ b/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
Poll. and Year	No Action c/	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
Acetaldehyde									
2016	0	-2	3	7	33	55	39	56	56
2020	0	3	12	16	44	74	60	80	73
2030	0	39	48	49	0	-24	-27	-57	-51
2050	0	78	84	82	-36	-110	-114	-190	-166
Acrolein									
2016	0	0	0	1	8	15	11	16	15
2020	0	0	1	3	17	30	26	36	30
2030	0	3	4	6	34	58	53	72	58
2050	0	6	7	10	54	91	86	115	91
Benzene									
2016	0	-21	-33	-45	-104	-165	-139	-175	-174
2020	0	-56	-74	-97	-281	-451	-392	-507	-486
2030	0	-84	-101	-145	-753	-1,282	-1,167	-1,566	-1,436
2050	0	-109	-144	-215	-1,271	-2,190	-2,028	-2,733	-2,478
1,3-butadiene									
2016	0	1	2	3	7	12	10	13	13
2020	0	6	7	8	9	13	14	17	15
2030	0	26	26	25	-5	-28	-19	-36	-30
2050	0	50	46	42	-17	-66	-51	-87	-73
Diesel particulate matter (DPM)									
2016	0	-1,499	-2,261	-2,654	-2,904	-3,804	-3,438	-3,890	-4,042
2020	0	-4,547	-5,699	-6,246	-6,917	-8,472	-8,159	-9,006	-8,998
2030	0	-11,762	-12,292	-12,792	-14,013	-16,534	-16,434	-17,864	-17,519
2050	0	-19,559	-19,659	-20,220	-21,986	-25,693	-25,690	-27,801	-27,185
Formaldehyde									
2016	0	-15	-7	8	134	237	175	249	243
2020	0	-27	-12	10	244	455	372	519	478
2030	0	-25	3	34	392	725	631	865	778
2050	0	-20	15	58	586	1,074	949	1,296	1,162

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.

Emissions in individual nonattainment areas might follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of VMT and fuel usage. Compared to Alternative 1, cumulative emissions of SO_x and VOCs under Alternative 2 would decrease in all nonattainment areas. In contrast, CO emissions would increase in almost all nonattainment areas, while NO_x and PM emissions would decrease in some nonattainment areas and increase in others. Tables in Appendix C list emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 2, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs are lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 2 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 2 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs. For CO, emissions increases under Alternative 2 cumulative analysis would be greater than the corresponding emissions increases under Alternative 2 noncumulative analysis.

Tables in Appendix C list the emissions reductions for each nonattainment area. Table 4.3.3-7 summarizes the criteria air pollutant results by nonattainment area.

Table 4.3.3-7

Cumulative Criteria Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative a/

Criteria Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
CO	Maximum Increase	13,975	2050	2	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-132,472	2050	8	Los Angeles South Coast Air Basin, CA
NO_x	Maximum Increase	291	2050	2	Dallas-Fort Worth, TX
	Maximum Decrease	-6,860	2050	8	Houston-Galveston-Brazoria, TX
$PM_{2.5}$	Maximum Increase	105	2050	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-663	2050	4	Houston-Galveston-Brazoria, TX
SO_x	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-2,732	2050	4	Chicago-Gary-Lake Co, IL-IN
VOCs	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-13,344	2050	8	Houston-Galveston-Brazoria, TX

a/ Emissions changes have been rounded to the nearest whole number.

4.3.3.3.2 Toxic Air Pollutants

Under Alternative 2, cumulative emissions of acetaldehyde, acrolein (except in 2020), and 1,3-butadiene would be greater than noncumulative emissions for the same combinations of pollutant and year. Cumulative emissions of acrolein (in 2020), benzene, DPM, and formaldehyde would be less than noncumulative emissions for the same combinations of pollutant and year.

Alternative 2 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2016), benzene, DPM, and formaldehyde, and would increase emissions of acetaldehyde (except in 2016), acrolein (except in 2016), and 1,3-butadiene. Compared to Alternatives 3 through 9, Alternative 2 would result in lower emissions of acetaldehyde (except under Alternatives 5 through 9 in 2030 and 2050), acrolein (except under Alternative 3 in 2016 and 2020), 1,3-butadiene (except in 2030 and 2050), and formaldehyde (in all years). Alternative 2 would result in higher emissions of benzene (in all years) and DPM (in all years) compared to Alternatives 3 through 9.

Emissions changes (compared to the No Action Alternative) under the Alternative 2 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 2 noncumulative analysis for all toxic air pollutants.

Nationwide, the reduction in upstream emissions of toxic air pollutants tends to offset the increase in VMT and emissions due to the rebound effect. However, as noted above, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. There can be net emission reductions if the reduction in upstream emissions in the nonattainment area more than offsets the increase within the area due to the rebound effect. Under Alternative 2, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.3.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 2 would result in 410 fewer mortalities and 44,853 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*. (2002); reductions would be 156 percent greater using the Laden *et al*. (2006) benefit-per-ton values.

Table 4.3.3-8 lists the net changes in health outcomes due to nationwide cumulative emissions in each analysis year. The table lists Alternatives 1 through 9 left to right in order of generally increasing fuel economy requirements. The health impacts of vehicle emissions decrease successively (*i.e.*, the benefits increase) in each analysis year, and generally decrease across more stringent alternatives through Alternative 4, with mixed results under Alternatives 5 through 7, and decreasing again under Alternatives 8 and 9.

Table 4.3.3-8 expresses the health impacts of each alternative in terms of changes in health outcomes compared to the No Action Alternative. The health impacts of each alternative represent predicted changes from the baseline incidence (or prevalence) rates. To provide context for the estimated health impacts given in Table 4.3.3-8, it is helpful to compare the impacts to sample baseline incidence rates. These sample baseline incidence rates provide an estimate of the typical prevalence rates of each outcome nationwide under the No Action Alternative. The EPA Report to Congress on The Benefits and Costs of the Clean Air Act 1990 to 2010 (EPA 1999) estimated baseline rates for particulate matter (PM)-related mortality and morbidity for 2010. Generally, the EPA extrapolated these baseline rates from the health effect concentration-response function, or estimated them using hospital admissions rates for respiratory and cardiovascular conditions. The EPA analysis estimated the following mean baseline incidence rates (cases per year) for PM-related effects nationwide in 2010: 2.3 million cases of premature mortality, 640,000 cases of chronic bronchitis, 870,000 hospital emergency room visits for asthma, and 440 million work loss days.

Table 4.3.3-9 lists the nationwide changes in monetized health impacts from cumulative emissions from passenger cars and light trucks. Results for each analysis year are shown for the No Action Alternative in the left column, and for the other alternatives from left to right in order of generally increasing fuel economy requirements. Monetized health impacts follow the trends established with health outcomes above, generally decreasing (*i.e.*, benefits increasing) across more stringent alternatives through Alternative 4, with mixed results under Alternatives 5 through 7, and decreasing again under Alternatives 8 and 9.

Table 4.3.3-8

Cumulative Nationwide Changes in Health Outcomes (cases/year) from Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
Out. and Year	**No Action b/**	**3%/year Increase**	**4%/year Increase**	**~4.3%/year Increase Preferred**	**5%/year Increase**	**~6.0%/year Increase MNB**	**6%/year Increase**	**7%/year Increase**	**~6.6%/year Increase TCTB**
Mortality (ages 30 and older)									
Pope *et al.* 2002									
2016	0 **a/**	-23 **b/**	-36	-42	-31	-32	-29	-29	-34
2020	0	-75	-95	-104	-87	-90	-85	-82	-90
2030	0	-221	-233	-242	-227	-249	-239	-243	-248
2050	0	-410	-417	-430	-415	-466	-449	-465	-465
Laden *et al.* 2006									
2016	0	-60	-93	-107	-80	-83	-75	-73	-87
2020	0	-193	-245	-266	-224	-230	-217	-210	-231
2030	0	-566	-596	-619	-580	-638	-611	-622	-635
2050	0	-1,048	-1,067	-1,098	-1,062	-1,192	-1,147	-1,188	-1,190
Chronic Bronchitis									
2016	0	-16	-25	-29	-21	-22	-20	-19	-23
2020	0	-51	-65	-71	-60	-61	-58	-56	-61
2030	0	-145	-153	-159	-149	-165	-157	-160	-164
2050	0	-260	-265	-273	-265	-298	-286	-297	-297
Emergency Room Visits for Asthma									
2016	0	-22	-34	-40	-30	-31	-29	-28	-33
2020	0	-72	-91	-99	-83	-86	-82	-80	-87
2030	0	-202	-212	-220	-204	-221	-214	-217	-222
2050	0	-362	-366	-376	-358	-394	-383	-394	-396
Work Loss Days									
2016	0	-3,047	-4,750	-5,510	-4,110	-4,201	-3,821	-3,708	-4,430
2020	0	-9,663	-12,301	-13,391	-11,232	-11,543	-10,859	-10,515	-11,543
2030	0	-26,037	-27,455	-28,551	-26,834	-29,566	-28,261	-28,812	-29,409
2050	0	-44,853	-45,691	-47,074	-45,648	-51,374	-49,365	-51,187	-51,231

a/ Negative changes indicate reductions; positive emissions changes are increases.
b/ Changes in health outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which emissions under the action alternatives are compared.

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 2 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 2 would be $3.7 billion annually using a 3-percent discount rate and estimates from Pope *et al.* (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less. Alternative 2 would result in less health and economic benefit than other more stringent alternatives.

Table 4.3.3-9

Cumulative Nationwide Monetized Health Benefits (U.S. million dollars/year) from Changes in Criteria Air Pollutant Emissions from Passenger Cars and Light Trucks by Alternative a/

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
Disc. and Year	No Action b/	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~6.0%/year Increase MNB	6%/year Increase	7%/year Increase	~6.6%/year Increase TCTB
3-% Discount Rate									
Pope *et al.* 2002									
2016	0 **a/**	-196 **b/**	-304	-353	-264	-272	-248	-241	-287
2020	0	-653	-830	-903	-758	-779	-735	-713	-782
2030	0	-1,965	-2,070	-2,152	-2,017	-2,216	-2,123	-2,161	-2,208
2050	0	-3,709	-3,775	-3,888	-3,760	-4,219	-4,061	-4,205	-4,212
Laden *et al.* 2006									
2016	0	-480	-746	-865	-648	-666	-607	-591	-704
2020	0	-1,599	-2,032	-2,211	-1,856	-1,909	-1,801	-1,746	-1,915
2030	0	-4,815	-5,073	-5,273	-4,942	-5,429	-5,201	-5,295	-5,409
2050	0	-9,091	-9,253	-9,529	-9,214	-10,339	-9,952	-10,305	-10,322
7-% Discount Rate									
Pope *et al.* 2002									
2016	0	-178	-276	-320	-240	-247	-225	-219	-260
2020	0	-592	-753	-819	-688	-707	-667	-647	-709
2030	0	-1,782	-1,878	-1,952	-1,830	-2,010	-1,926	-1,961	-2,003
2050	0	-3,364	-3,424	-3,526	-3,410	-3,827	-3,683	-3,814	-3,820
Laden *et al.* 2006									
2016	0	-433	-674	-781	-585	-602	-549	-534	-636
2020	0	-1,444	-1,836	-1,997	-1,677	-1,724	-1,627	-1,578	-1,730
2030	0	-4,349	-4,582	-4,763	-4,464	-4,904	-4,698	-4,783	-4,885
2050	0	-8,211	-8,358	-8,607	-8,322	-9,338	-8,989	-9,307	-9,323

a/ Negative changes indicate monetized health benefits; positive emissions changes indicate monetized health disbenefits.
b/ Changes in outcome for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which impacts under the action alternatives are compared.

4.3.3.4 Alternative 3: 4-Percent Annual Increase

4.3.3.4.1 Criteria Pollutants

Under the 4-Percent Alternative (Alternative 3), the CAFE standards generally would increase fuel economy more than Alternative 2 but less than Alternatives 4 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 3 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.2 to 2.2 percent, $PM_{2.5}$ emissions would be reduced 1.0 to 4.7 percent, SO_x emissions would be reduced 2.4 to 12.3 percent, and VOC emissions would be reduced 0.8 to 7.9 percent, compared to emissions projected under the No Action Alternative. Except for emissions SO_x in 2050, these emissions reductions are generally greater than would occur under Alternative 2. Except for emissions of $PM_{2.5}$ under Alternatives 5 through 9, and SO_x under Alternative 5 in 2030 and 2050, these emissions reductions are generally less than would occur under Alternatives 4 through 9. There would be increases of CO emissions from 0.1 to 0.8 percent, depending on the year, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas might follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel consumption. Compared to Alternative 1, cumulative emissions of SO_x and VOCs under Alternative 3 would decrease in all nonattainment areas. In contrast, CO emissions would increase in almost all nonattainment areas, while NO_x and $PM_{2.5}$ emissions would would decrease in some nonattainment areas and increase in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 3, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs would be lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 3 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs. For CO, emissions increases under the Alternative 3 cumulative analysis would be greater than the corresponding emissions increases under the Alternative 3 noncumulative analysis.

4.3.3.4.2 Toxic Air Pollutants

Alternative 3 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene, DPM, and formaldehyde (in 2016 and 2020), and would increase emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde (in 2030 and 2050) compared to the No Action Alternative. Compared to Alternatives 4 through 9, Alternative 3 would result in higher emissions of benzene and DPM, and lower emissions of acetaldehyde (except under Alternatives 5 through 9 in 2030 and 2050), acrolein, 1,3-butadiene (except in 2030 and 2050), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 3 noncumulative analysis for all toxic air pollutants except formaldehyde (in 2030). For formaldehyde in 2030, emissions changes (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be less than the corresponding emissions changes under the Alternative 3 noncumulative analysis.

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 3, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area. Table 4.3.3-10 summarizes the air toxic results by nonattainment area.

4.3.3.4.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 3 would result in 417 fewer mortalities and 45,691 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*. (2002); reductions would be 156 percent greater under the Laden *et al*. (2006) methodology.

Table 4.3.3-10

Cumulative Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative

Hazardous Air Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	4.78	2050	3	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-13.33	2050	8	Houston-Galveston-Brazoria, TX
Acrolein	Maximum Increase	5.56	2050	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-0.74	2050	8	Beaumont/Port Arthur, TX
Benzene	Maximum Increase	10.64	2050	2	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	-112.2	2050	8	New York-N. New Jersey-Long Island, NY-NJ-CT
1,3-Butadiene	Maximum Increase	2.51	2050	2	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-3.91	2050	8	New York-N. New Jersey-Long Island, NY-NJ-CT
Diesel particulate matter	Maximum Increase	124	2050	8	Atlanta, GA
	Maximum Decrease	-3,177	2050	8	Houston-Galveston-Brazoria, TX
Formaldehyde	Maximum Increase	70	2050	8	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	-58	2050	9	Houston-Galveston-Brazoria, TX

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 3 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 3 would be $3.8 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

4.3.3.5 Alternative 4: Preferred Alternative

4.3.3.5.1 Criteria Pollutants

Under the Preferred Alternative (Alternative 4), the CAFE standards would increase fuel economy more than Alternatives 1 through 3 but less than Alternatives 5 through 9. There would be reductions in nationwide emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs under Alternative 4 compared to the No Action Alternative. Depending on the year, NO_x emissions would be reduced 0.3 to 2.5 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.8 percent, SO_x emissions would be reduced 2.8 to 12.6 percent, and VOC emissions would be reduced 1.0 to 8.3 percent, compared to emissions projected under the No Action Alternative. The emissions reductions for these pollutants are generally greater than would occur under Alternative 3, except for SO_x in 2050 . Emissions reductions of these four pollutants under Alternative 4 would be less than would occur under Alternatives 5 through 9, except for $PM_{2,5}$ in all years, and SO_x under Alternative 5 in all years and Alternative 7 in 2016. There would be increases of CO emissions of 0.02 to 0.5 percent, depending on the year, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas might follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel consumption. Compared to Alternative 1, cumulative emissions of SO_x and VOCs under Alternative 4 would decrease in all nonattainment areas. In contrast, CO emissions would increase in almost all nonattainment areas, while NO_x and PM emissions would decrease in some nonattainment areas and increase in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 4, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs are lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 4 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 4 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs, except for $PM_{2.5}$, SO_2, and VOCs in 2030. For CO, emissions increases under the Alternative 4 cumulative analysis would be greater than the corresponding emissions increases under the Alternative 4 noncumulative analysis, except in 2030.

4.3.3.5.2 Toxic Air Pollutants

Under Alternative 4, cumulative emissions would be less than noncumulative emissions for benzene, DPM and formaldehyde and the same as or greater than noncumulative emissions for acetaldehyde, acrolein, and 1,3-butadiene.

Alternative 4 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene and DPM, and would increase emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde. Compared to Alternatives 5 through 9, Alternative 4 would result in higher emissions of acetaldehyde (in 2030 and 2050), benzene, DPM, and 1,3-butadiene (in 2030 and 2050), and lower emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 4 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 4 noncumulative analysis, for all toxic air pollutants except acetaldehyde (in 2020), and benzene, 1,3-butadiene, and DPM in 2030.

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions would not occur uniformly in all nonattainment areas. Under Alternative 4, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.5.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 4 would result in 430 fewer mortalities and 47,074 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al.* (2002); reductions would be 155 percent greater using the Laden *et al.* (2006) methodology.

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 4 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 4 would be $3.9 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

Compared to more stringent alternatives, health and economic benefits are less than for all successive alternatives.

4.3.3.6 Alternative 5: Five Percent Annual Increase

4.3.3.6.1 Criteria Pollutants

Under the 5-Percent Alternative (Alternative 5), the CAFE standards would increase fuel economy more than Alternatives 1 through 4 but less than Alternatives 6 through 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 5 compared to the No Action Alternative. Reductions under Alternative 5 would be greater than under Alternative 4 (except for $PM_{2.5}$ and SO_x), and less than under Alternative 6 through 9 (except for $PM_{2.5}$ in all years). Depending on the year, CO emissions would be reduced 0.5 to 3.9 percent, NO_x emissions would be reduced 0.4 to 5.0 percent, $PM_{2.5}$ emissions would be reduced 0.5 to 3.6 percent, SO_x emissions would be reduced 2.4 to 12.0 percent, and VOC emissions would be reduced 1.4 to 12.3 percent, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas could follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 5 would decrease in all nonattainment areas. $PM_{2.5}$ results would be mixed, with emissions increasing in some nonattainment areas and decreasing in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 5, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs are lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 5 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 5 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs. For CO, emissions reductions under the Alternative 5 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 5 noncumulative analysis.

4.3.3.6.2 Toxic Air Pollutants

Under Alternative 5, cumulative emissions would be less than noncumulative emissions for benzene, DPM, and formaldehyde ; the same as noncumulative emissions for acetaldehyde in 2020, acrolein in all years, and 1,3-butadiene in 2020; and greater than noncumulative emissions for acetaldehyde and 1,3-butadiene in 2030.

Alternative 5 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde (except in 2050), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative. Compared to Alternatives 6 through 9, Alternative 5 would result in higher emissions of acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and lower emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 5 cumulative analysis would be the same or greater than the corresponding emissions changes under the Alternative 5 noncumulative analysis, for all toxic air pollutants except acetaldehyde (in 2020 and 2030), acrolein (in 2030), enzene (in 2030), and DPM (in 2020 and 2030).

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 5, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.6.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 5 would result in 415 fewer mortalities and 45,648 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*. (2002); reductions would be 156 percent greater using the Laden *et al*. (2006) methodology.

Table 4.3.3-9 lists the corresponding monetized health benefitsunder Alternative 5 compared to the No Action Alternative. Health-related benefits underAlternative 5 in 2050 would be $3.8 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

Compared to Alternative 5, health and economic benefits would be greater under Alternative 6, Alternatives 7 and 8 in 2030 and 2050, and Alternative 9, but less under Alternatives 7 and 8 in 2016 and 2020.

4.3.3.7 Alternative 6: MNB

4.3.3.7.1 Criteria Pollutants

Under the MNB (Alternative 6), the CAFE standards would increase fuel economy more than Alternatives 1 through 4 but less than Alternatives 7 through 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 6 compared to the No Action Alternative. Reductions under Alternative 6 would be greater than under Alternative 5 except for $PM_{2.5}$ for all years. Depending on the year, CO emissions would be reduced 1.0 to 7.7 percent, NO_x emissions would be reduced 0.6 to 7.5 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 3.4 percent, SO_x emissions would be reduced 2.9 to 12.8 percent, and VOC emissions would be reduced 2.0 to 16.4 percent, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas could follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel consumption. Compared to Alternative 1, cumulative emissions of CO,

NO_x, SO_x, and VOCs under Alternative 6 would decrease in all nonattainment areas. $PM_{2.5}$ results are mixed, with emissions increasing in some nonattainment areas and decreasing in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 6, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs would be lower than noncumulative emissions. However, emissions of CO would be higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 6 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 6 noncumulative analysis for for NO_x, $PM_{2.5}$, SO_x, and VOCs. Emissions reductions (compared to the No Action Alternative) under the Alternative 6 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 6 noncumulative analysis for CO in all years

4.3.3.7.2 Toxic Air Pollutants

Under Alternative 6, cumulative emissions would be less than noncumulative emissions for benzene, DPM, and formaldehyde; greater than noncumulative emissions for acetaldehyde in all years, acrolein, and 1,3-butadiene in 2030; and the same as noncumulative emissions for acrolein. Alternative 6 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative. Compared to Alternatives 7 through 9, results for all pollutants under Alternative 6 would be mixed, depending on year, pollutant, and alternative.

Emissions changes (compared to the No Action Alternative) under the Alternative 6 cumulative analysis would be greater than the corresponding emissions changes under the Alternative 6 noncumulative analysis for all toxic air pollutants except acrolein (in 2030), benzene (in 2030), and DPM (in 2020 and 2030).

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 6, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.7.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 6 would result in 466 fewer mortalities and 51,374 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*.; reductions would be 156 percent greater using the Laden *et al*. methodology

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 6 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 6 would be $4.2 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*.

(2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

Compared to Alternative 6, health and economic benefits would be greater under Alternative 9 in 2016 and 2020, but less under Alternatives 7 and 8 in all years, and Alternative 9 in 2030 and 2050.

4.3.3.8 Alternative 7: 6-Percent Annual Increase

4.3.3.8.1 Criteria Pollutants

Under the 6-Percent Alternative (Alternative 7), the CAFE standards would increase fuel economy more than Alternatives 1 through 6 but less than Alternatives 8 and 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 7 compared to the No Action Alternative. Reductions would be less than under Alternative 6 (except for SO_x in 2030 and 2050). Reductions also would be less than under Alternatives 8 and 9 (except for $PM_{2.5}$ under Alternative 8). Depending on the year, CO emissions would be reduced 0.7 to 6.9 percent, NO_x emissions would be reduced 0.5 to 7.0 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 3.2 percent, SO_x emissions would be reduced 2.7 to 13.0 percent, and VOC emissions would be reduced 1.8 to 16.2 percent, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas could follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel consumption. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 7 would decrease in all nonattainment areas. $PM_{2.5}$ results are mixed, with emissions increasing in some nonattainment areas and decreasing in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 7, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs are lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 7 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 7 noncumulative analysis for NO_x, $PM_{2.5}$, SO_x, and VOCs. Emissions reductions (compared to the No Action Alternative) under the Alternative 7 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 7 noncumulative analysis for CO.

4.3.3.8.2 Toxic Air Pollutants

Under Alternative 7, cumulative emissions would be less than noncumulative emissions for benzene, DPM, and formaldehyde, and greater than noncumulative emissions for acetaldehyde in 2020 and 2030, and 1,3-butadiene in 2030, and the same as noncumulative emissions for for acrolein in all years and 1,3-butadiene in 2020.

Alternative 7 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde. Compared to Alternatives 8 and 9, Alternative 7 would result in higher emissions of acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and lower emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 7 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 7 noncumulative analysis for all toxic air pollutants except benzene (in 2020 and 2030) , and DPM (in 2020 and 2030).

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 7, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.8.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 7 would result in 449 fewer mortalities and 49,365 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*. (2002); reductions would be 155 percent greater using the Laden *et al*. (2006) methodology.

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 7 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 7 would be $4.1 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

Compared to Alternative 7, health and economic benefits would be greater under Alternative 8 in 2030 and 2050, and Alternative 9 in all years, but less under Alternative 8 in 2016 and 2020.

4.3.3.9 Alternative 8: 7-Percent Annual Increase

4.3.3.9.1 Criteria Pollutants

Under the 7-Percent Alternative (Alternative 8), the CAFE standards would increase fuel economy more than Alternatives 1 through 7 and also more than Alternative 9. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 8 compared to the No Action Alternative. Reductions would be greater than under Alternative 7 (except for $PM_{2.5}$). Reductions would be greater than under Alternative 9 for CO, NO_x (except in 2016), and VOC (except in 2016). Reductions would be less than under Alternative 9 for NO_x in 2016, $PM_{2.5}$ in all years, SO_x in all years, and VOC in 2016. Depending on the year, CO emissions would be reduced 1.0 to 9.8 percent, NO_x emissions would be reduced 0.6 to 8.9 percent, $PM_{2.5}$ emissions would be reduced 0.1 to 2.7 percent, SO_x emissions would be reduced 2.9 to 13.4 percent, and VOC emissions would be reduced 2.1 ro 19.1 percent, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas could follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 8 would decrease in all nonattainment areas. $PM_{2.5}$ results are mixed, with emissions increasing in some nonattainment areas and decreasing in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected fuel economy in the cumulative case. Under Alternative 8, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs would be lower than noncumulative emissions. However, emissions of CO would be higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 8 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 8 noncumulative analysis for CO in all years. Emissions reductions (compared to the No Action Alternative) under the Alternative 8 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 8 noncumulative analysis for NO_x, $PM_{2.5}$, SO_x, and VOCs in all years.

4.3.3.9.2 Toxic Air Pollutants

Under Alternative 8, cumulative emissions would be less than noncumulative emissions for benzene, DPM, and formaldehyde, and the same or greater than noncumulative emissions for acetaldehyde, acrolein, and 1,3-butadiene.

Alternative 8 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative. Compared to Alternative 9, Alternative 8 would result in the same or higher emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), DPM (in 2016), and formaldehyde, and lower emissions of acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM (in 2020 through 2050).

Emissions changes (compared to the No Action Alternative) under the Alternative 8 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 8 noncumulative analysis for all toxic air pollutants except benzene (in 2020 and 2030), and DPM (in 2020 and 2030).

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 8, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.9.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 8 would result in 465 fewer mortalities and 51,187 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al.* (2002); reductions would be 155 percent greater using the Laden *et al.* (2006) methodology.

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 8 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 8 would be $4.2 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less. Compared to Alternative 9, health and economic benefits would be smaller under Alternative 8.

4.3.3.10 Alternative 9: TCTB

4.3.3.10.1 Criteria Pollutants

Under the TCTB Alternative (Alternative 9), the CAFE standards would increase fuel economy more than Alternatives 1 through 7, but less than Alternative 8. There would be reductions in nationwide emissions of all criteria pollutants under Alternative 9 compared to the No Action Alternative. Emission reductions of all criteria pollutants under Alternative 9 would be greater than with any other alternative for NO_x in 2016, $PM_{2.5}$ and SO_x in all years, and VOCs in 2016. Depending on the year, CO emissions would be reduced 1.0 to 8.8 percent, NO_x emissions would be reduced 0.6 to 8.2 percent, $PM_{2.5}$ emissions would be reduced 0.3 to 3.0 percent, SO_x emissions would be reduced 3.2 to 13.5 percent, and VOC emissions would be reduced 2.1 to 18.1 percent, compared to emissions projected under the No Action Alternative.

Emissions in individual nonattainment areas could follow different patterns from nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions, VMT increases, and diesel share of fuel. Compared to Alternative 1, cumulative emissions of CO, NO_x, SO_x, and VOCs under Alternative 9 decrease in all nonattainment areas. $PM_{2.5}$ results are mixed, with emissions increasing in some nonattainment areas and decreasing in others. Tables in Appendix C list the emissions reductions for each nonattainment area.

Cumulative fuel economy standards would lead to lower emissions of most pollutants compared to noncumulative standards, due to the impact of higher projected average fuel economy in the cumulative case. Under Alternative 9, cumulative emissions of NO_x, $PM_{2.5}$, SO_x, and VOCs are lower than noncumulative emissions. However, emissions of CO are higher under the cumulative case than the noncumulative case, because increases in VMT more than offset declines in CO emission rates and increases in fuel economy.

Emissions reductions (compared to the No Action Alternative) under the Alternative 9 cumulative analysis would be greater than the corresponding emissions reductions under the Alternative 9 noncumulative analysis for CO in all years. Emissions reductions (compared to the No Action Alternative) under the Alternative 9 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 9 noncumulative analysis for NO_x, $PM_{2.5}$, SO_x, and VOCs in all years.

4.3.3.10.2 Toxic Air Pollutants

Under Alternative 9, cumulative emissions would be less than noncumulative emissions for acrolein (in 2020 and 2030), benzene (in 2020 and 2030), DPM (in 2020 and 2030), and formaldehyde (in 2020 and 2030), and the same as greater than noncumulative emissions for acetalehyde and 1,3-butadiene in all years.

Alternative 9 would reduce toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde (in 2030 and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde (in 2016 and 2020), acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative.

Emissions changes (compared to the No Action Alternative) under the Alternative 9 cumulative analysis would be the same as or greater than the corresponding emissions changes under the Alternative 9 noncumulative analysis for acetalehyde, benzene (in 2016 and 2020), 1,3-butadiene, and formaldehyde. Emissions changes (compared to the No Action Alternative) under the Alternative 9 cumulative analysis would be less than the corresponding emissions changes under the Alternative 9 noncumulative analysis for acrolein (in 2020 and 2030), benzene (except in 2016 and 2020), and DPM (except in 2016).

Nationwide, emissions of toxic air pollutants can decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual nonattainment areas. Under Alternative 9, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutant in at least one of the analysis years (*see* Appendix C). However, the emissions increases would be quite small, as shown in Appendix C, and emissions increases would be distributed throughout each nonattainment area.

4.3.3.10.3 Health Outcomes and Monetized Benefits

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 9 would result in 465 fewer mortalities and 51,231 fewer work-loss days in 2050. Mortality benefits are measured according to Pope *et al*. (2002); reductions would be 156 percent greater using the Laden *et al*. (2006) methodology.

Table 4.3.3-9 lists the corresponding monetized health benefits under Alternative 9 compared to the No Action Alternative. In 2050, health-related benefits under Alternative 9 would be $4.2 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, health-related benefits would be 145 percent greater. Using a 7-percent discount rate, health-related benefits would be 9.3 to 9.7 percent less.

4.4 CLIMATE

As noted earlier, a cumulative impact is defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." 40 CFR § 1508.70.

This section on the cumulative impacts of the proposed action and alternatives on climate covers many of the same topics as Section 3.4. However, the analysis in Chapter 4 is broader than the analysis in Chapter 3 because it addresses (1) the effects of the MYs 2012-2016 standards together with those of reasonably foreseeable future actions, including the continuing increases in CAFE standards for MYs 2017-2020 that are necessary under some alternatives to reach the EISA-mandated target of a combined mpg of 35 mpg (*see* Section 4.1.3), and (2) continuing market-driven annual average percentage gains in mpg from 2016 through 2030 consistent with the AEO projections as a reasonably foreseeable future action. These reasonably foreseeable future actions would affect fuel consumption and emissions attributable to passenger cars and light trucks through 2060. Because these mpg projections apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow as new vehicles are added to the fleet in each subsequent year, and as VMT continue to grow. This is the case under the No Action Alternative and each of the action alternatives. Like Chapter 3, Chapter 4 addresses the consequences of emissions and effects on the climate system. However, Chapter 4 goes beyond this to discuss the impacts of changes in the climate system on key resources (*e.g.*, freshwater resources, terrestrial ecosystems, and coastal ecosystems).

Understanding that many readers do not read through an EIS in linear fashion, but instead focus on the sections of most interest, this section repeats some of the information in Section 3.4 with modifications to reflect the slightly different scope (cumulative impacts versus the direct and indirect effects of the proposed action and alternatives). However, this section also refers the reader to Section 3.4 in many cases, to minimize replication of background information on climate science or modeling methodologies.

4.4.1 Introduction – Greenhouse Gases and Climate Change

Section 3.4.1 provides a discussion of the science of climate change, uncertainty within the IPCC framework, and NHTSA's reliance on panel- and peer-reviewed literature for this EIS.

4.4.2 Affected Environment

The affected environment can be characterized in terms of GHG emissions and climate. Section 3.4.2 provides a discussion of both topics, including a description of conditions in the United States as well as globally. Because there is no distinction between the affected environment for purposes of the analysis of direct and indirect effects and the analysis of cumulative impacts, NHTSA refers readers to Section 3.4.2 for a discussion of this topic.

4.4.3 Methodology

The methodology NHTSA used to characterize the effects of the proposed action and alternatives on climate has two key elements: (1) analyzing the effects of the proposed action and alternatives on GHG emissions and (2) analyzing how GHG emissions affect the climate system (climate effects).

This cumulative impacts analysis of each alternative includes the effects of the proposed CAFE standards for MYs 2012-2016 *and* other reasonably foreseeable actions, including ongoing gains in mpg through 2030 consistent with AEO projections (*see* Section 4.1.3). This EIS expresses results for each alternative in terms of the environmental attribute being characterized (emissions, CO_2 concentrations, temperature, precipitation, and sea level). Comparisons between the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 9) illustrate the differences in environmental effects among the alternative CAFE standards. The impact of each action alternative on these results is measured by the difference in its value under the No Action Alternative and its value under that action alternative. For example, the reduction in CO_2 emissions attributable to an action alternative is measured by the difference in emissions under that alternative and emissions under the No Action Alternative.

The methods NHTSA used to characterize emissions and climate-change impacts involve considerable uncertainty. *See* Section 3.4.3 for a discussion of uncertainty in emissions scenarios, the global climate system, and climate models.

4.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

GHG emissions were estimated using the Volpe model, which is described in Section 3.1.4. The methodology for modeling GHG emissions is described in Section 3.4.3.1. This analysis of cumulative impacts uses the Volpe model to estimate GHG emissions, but includes reasonably foreseeable actions beyond this proposed action. *See* Sections 4.1.4 and 4.4.3.3 for a detailed description of these additional actions.

4.4.3.2 Methodology for Estimating Climate Effects

This EIS estimates and reports four direct and indirect effects of climate change driven by alternative scenarios of GHG emissions – changes in CO_2 concentrations, changes in global temperature, changes in regional temperature and precipitation, and changes in sea level.

The change in CO_2 concentration is a direct effect of the changes in GHG emissions, and influences each of the other factors.

This EIS uses a climate model to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each alternative CAFE standard, and uses increases in global mean surface temperature combined with an approach and coefficients from the IPCC Fourth Assessment Report (IPCC 2007) to estimate changes in global precipitation. NHTSA used the publicly available modeling software MAGICC version 5.3.v2 (Wigley 2008) to estimate changes in key direct and indirect effects. MAGICC 5.3.v2 uses the estimated reductions in emissions of CO_2, CH_4, N_2O, CO, NO_x, SO_2, and VOCs produced by the Volpe model. Sensitivity analyses examined the relationship among various CAFE alternatives, likely climate sensitivities, and scenarios of global emissions paths and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of the emissions associated with the regulatory alternatives on direct and indirect climate effects.

Sections 4.4.3.2.1, 4.4.3.2.2, and 4.4.3.2.3 describe MAGICC, the Reference Case modeling runs, the sensitivity analysis, and the emissions scenarios NHTSA used in the analysis.

4.4.3.2.1 MAGICC Version 5.3.v2

The selection of MAGICC for this analysis was driven by a number of factors, as described in Section 3.4.3.2.1.

NHTSA assumed that global emissions consistent under the No Action Alternative (Alternative 1) would follow the trajectory provided by the CCSP SAP 2.1 MiniCAM Level 3 scenario. This scenario represents a Reference Case where future global emissions assume significant global actions to address climate change. Section 4.4.3.2.2 describes the CCSP SAP 2.1 scenarios.

4.4.3.2.2 Reference Case Modeling Runs

The approach for the Reference Case modeling runs was based on the approach described in Section 3.4.3.2.2. For this analysis, NHSTA assumed that global emissions under the No Action Alternative (Alternative 1) follow the trajectories provided by the CCSP SAP 2.1 MiniCAM Level 3 scenario, rather than the RCP 4.5 MiniCAM reference scenario used in Section 3.4.

Section 4.4.4 presents the results of the Reference Case modeling runs.

4.4.3.2.3 Sensitivity Analysis

The approach for the sensitivity analysis was based on the same approach described in Section 3.4.3.2.3. In the Chapter 4 analysis, NHTSA assumed multiple global emissions scenarios that include the SAP 2.1 MiniCAM Level 3 (650 ppm as of 2100); the SAP 2.1 MiniCAM Level 2 (550 ppm as of 2100); and RCP 4.5 MiniCAM reference scenario (783 ppm as of 2100). The Section 3.4 analysis did not assess the sensitivity around different global emissions scenarios. These global emissions scenarios represent various levels of implementation of global GHG emissions reduction policies.

Section 4.4.4.2.5 presents the results of the sensitivity analysis.

4.4.3.3 Global Emissions Scenarios

As described above, MAGICC uses long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. All scenarios used are based on the CCSP effort to develop a set of long-term (2000 to 2100) emissions scenarios that incorporate an update of economic and technology data and utilize improved scenario development tools compared with the IPCC *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) developed more than a decade ago. *See* Section 3.4.3.3 for background on the development of the CCSP scenarios.

The results in this chapter rely primarily on the CCSP SAP 2.1 MiniCAM Level 3 scenario to represent a Reference Case global emissions scenario; that is, future global emissions assuming significant global actions to address climate change. This Reference Case global emissions scenario serves as a baseline against which the climate benefits of the various CAFE alternatives can be measured.[3] NHTSA chose the SAP 2.1 MiniCAM Level 3 scenario to represent reasonably foreseeable actions based on the following factors:

- The SAP 2.1 MiniCAM Level 3 scenario was developed by the MiniCAM Model of the Joint Global Change Research Institute (which is a partnership between the Pacific Northwest National Laboratory and the University of Maryland) and is one of three Level 3 climate

[3] Note that the Reference Case global emissions scenario used in Chapter 4 differs from the global emissions scenario used for the climate change modeling presented in Chapter 3. In Chapter 4, the Reference Case global emission scenario reflects reasonably foreseeable actions in global climate change policy; in Chapter 3, the global emissions scenario used for the analysis assumes that there are no significant global controls or large efforts to mitigate the projected continued growth of global GHG emissions. Given that the climate system is non-linear, the choice of a global emissions scenario could produce different estimates of the benefits of the proposed action and alternatives, if the emissions reductions under the alternatives were held constant.

scenarios described in the SAP 2.1. MiniCAM Level 3 is based on a set of assumptions about drivers such as population, technology, and socioeconomic changes, and global climate policies that correspond to total radiative forcing stabilization by 2100 and associated CO_2 concentrations at roughly 650 parts per million by volume (ppmv), after accounting for the contributions to radiative forcing from the non-CO_2 GHGs. It therefore represents an illustration of a plausible future pathway of global emissions in response to significant global action to mitigate climate change.

- CCSP SAP 2.1 is more than a decade newer than the IPCC SRES, and therefore has updated economic and technology data/assumptions. It also uses improved integrated assessment models that account for advances in economics and science over the past 10 years.

The SAP 2.1 MiniCAM Level 3 scenario assumes a moderate level of global GHG reductions, resulting in a global atmospheric CO_2 concentration of roughly 650 ppmv by 2100. The regional, national, and international initiatives and programs discussed below are those NHTSA has tentatively concluded are reasonably foreseeable past, current, or future actions to reduce GHG emissions. Although many of these actions, policies, or programs are not associated with precise GHG reduction commitments, collectively they illustrate an existing and continuing trend of U.S. and global awareness, emphasis, and efforts toward significant GHG reductions. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA.

Reasonably Foreseeable Actions Included in the Cumulative Impacts Analysis

United States: Regional Actions[4]

- **Regional Greenhouse Gas Initiative (RGGI).** Beginning January 1, 2009, RGGI is the first mandatory, market-based effort in the United States to reduce GHG emissions (RGGI 2009a). Ten Northeastern and Mid-Atlantic states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) have capped annual emissions from power plants in the region at 188 million tons of CO_2 (RGGI 2009b). Beginning in 2015, this cap will be reduced 2.5 percent each year through 2019, for a total of a 10-percent emissions reduction from the 2015 cap from the power sector by 2018 (RGGI 2009c). Thus, the cap is comprised of two phases: the first is a stabilization phase from 2009 to 2014, and the second is a reduction phase from 2015 through 2018.
- **Western Climate Initiative (WCI)** – The WCI includes seven states (Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington) and four Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec). Set to begin on January 1, 2012, the WCI cap-and-trade program will cover emissions of the six main greenhouse gases (CO_2, CH_4, N_2O, HFC's, PFC's, and SF_6) from the following sectors of the economy: electricity generation, including imported electricity; industrial and commercial fossil fuel combustion; industrial process emissions; gas and diesel consumption for transportation; and residential fuel use. Covered entities and facilities will be required to surrender enough allowances to cover emissions that occur within each 3-year "compliance period." This multi-sector program is the most comprehensive carbon-reduction strategy designed to date in the United States. This program is an important component of the WCI comprehensive regional effort to reduce GHG emissions to 15 percent below 2005 levels by 2020. The program will be rolled out in two phases. The first phase will begin on January 1, 2012, and will cover emissions from electricity, including imported electricity, industrial combustion at large sources, and industrial process emissions for which adequate measurement methods exist. The second

[4] Two of the three regional actions include Canadian provinces as participants and observers.

phase begins in 2015, when the program expands to include transportation fuels and residential, commercial, and industrial fuels not otherwise covered (WCI 2009). When fully implemented in 2015, the program will cover nearly 90 percent of greenhouse gas emissions in the 11 WCI Partner states and provinces.

- **Midwestern Greenhouse Gas Reduction Accord** – The Accord includes six states (Illinois, Iowa, Kansas, Michigan, Minnesota, and Wisconsin) and one Canadian province (Manitoba). Signed on November 15, 2007, the Midwestern Greenhouse Gas Reduction Accord serves as a regional strategy to achieve energy security and reduce GHG emissions (Midwestern Governors Association 2009). The Accord will establish GHG-reduction targets and time frames consistent with member states' targets; develop a market-based and multi-sector cap-and-trade mechanism to help achieve those reduction targets; establish a system to enable tracking, management, and crediting for entities that reduce GHG emissions; and develop and implement additional steps as needed to achieve the reduction targets, such as low-carbon fuel standards and regional incentives and funding mechanisms (Midwestern Greenhouse Gas Reduction Accord 2009).

United States: Federal Actions

- **EPA Proposed GHG Emissions Standards.** In a joint NHTSA and EPA notice of proposed rulemaking published concurrently with this Draft EIS, EPA will propose a national CO_2 vehicle emissions standard under Section 202(a) of the Clean Air Act, which will be coordinated and harmonized with NHTSA proposed CAFE standards. These standards would apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles (light-duty vehicles) built in MYs 2012-2016. These vehicle categories are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. EPA is considering proposing standards that would, if made final, achieve an average of 250 grams per mile of CO_2 in MY 2016. The standards would begin with the 2012 model year and the program is intended to reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (EPA 2009d).
- **Cap-and-Trade Bills in the 111th Congress.** H.R. 2454, the American Clean Energy and Security Act of 2009 ("Waxman-Markey Bill"), passed in the House June 26, 2009. The bill amends the Clean Air Act to require the EPA Administrator to promulgate regulations to cap and reduce GHG emissions, annually, to yield GHG emission reductions from capped sources of 17 percent (below 2005 levels) by 2020, 42 percent by 2030, and 83 percent by 2050; and establish a federal GHG registry, among other amendments. In the U.S. Senate, S. 1733, Clean Energy Jobs and American Power Act, ("Kerry-Boxer Bill"), proposes to cut U.S. GHG emissions by 20 percent by 2020, and 83 percent by 2050, when compared to the 2005 baseline. Included in its key elements are: a coordinated approach to geological sequestration of carbon dioxide, new performance standards for coal-fired plants, programs to research furthering of nuclear power use, water-use efficiency programs, and new energy efficiency standards for buildings. The Kerry-Boxer bill passed out of the Senate Environment and Public Works Committee on November 5, 2009.
- **Renewable Fuel Standard (RFS2).** Section 211(o) of the Clean Air Act requires that a renewable fuel standard be determined annually that is applicable to refiners, importers, and certain blenders of gasoline (73 *FR* 70643). On the basis of this standard, each obligated party determines the volume of renewable fuel that it must ensure is consumed as motor vehicle fuel. RFS2 will increase the volume of renewable fuel required to be blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022 (EPA 2009b), and the renewable fuel standard for 2009 is 10.21 percent (73 *FR* 70643). EPA estimates that the

greater volumes of biofuel mandated by RFS2 will reduce life-cycle GHG emissions by an annual average of 150 million tons CO_2 equivalent (EPA 2009c).

- **United States GHG Emissions Target in Association with the Copenhagen Accord**. Building on the pledge made at the December 2009 U.N. climate change conference in Copenhagen (COP-15), President Obama recently submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020, in association with the Copenhagen Accord. This target is in conformity with anticipated U.S. energy and climate legislation, and recognizes that the final target will be reported to the Secretariat in light of enacted legislation. Initial activities toward this goal include an $80 billion investment in clean energy through the American Recovery and Reinvestment Act of 2009, more stringent energy efficiency standards for commercial and residential appliances, and development of wind energy on the Outer Continental Shelf, among other federal initiatives. On January 28, 2010, the U.S. submitted this target to the U.N. Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the [U.N.] in light of enacted legislation" (U.S. Department of State 2010).

International Actions

- **United Nation's Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol, and the December 2009 Conference of the Parties (COP)-15.** UNFCCC is an international treaty signed by many countries around the world (including the United States[5]), which entered into force on March 21, 1994, and sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change (UNFCCC 2002). The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing GHG emissions, which covers more than half of the world's GHG emissions. These amount to an average of 5 percent of 1990 levels over the 5-year period 2008 through 2012 (UNFCCC 2005). At COP-15, and for the first time ever, all major developed and developing countries agreed to pledge specific emission reductions. However, the pledges will not be legally binding, and much remains to be negotiated.
- **The European Union Greenhouse Gas Emission Trading System (EU ETS) -** In January 2005 the EU ETS commenced operation as the largest multi-country, multi-sector Greenhouse Gas Emission Trading System world-wide (European Union 2009). The aim of the EU ETS is to help European Union Member States achieve compliance with their commitments under the Kyoto Protocol (European Union 2005). This trading system does not entail new environmental targets; instead, it allows for less expensive compliance with existing targets under the Kyoto Protocol.

  The scheme is based on Directive 2003/87/EC, which entered into force on October 25, 2003

[5] Although a signatory to the Kyoto Protocol, the United States has neither ratified nor withdrawn from the Protocol. Treaties are nonbinding on the United States unless ratified by the Senate by a two-thirds majority, and neither the Clinton Administration nor the Bush Administration submitted the Kyoto Protocol to the Senate for ratification. On July 25, 1997, before the Kyoto Protocol was finalized, the Senate passed (by a 95-0 vote) the Byrd-Hagel Resolution, which stated the Senate position that the United States should not be a signatory to any treaty that did not include binding targets and timetables for developing nations as well as industrialized nations or "would result in serious harm to the economy of the United States." *See* S. Res. 98, 105th Cong. (1997).

(European Union 2009), and covers over 11,500 energy-intensive installations across the European Union, which represent almost half of Europe's emissions of CO_2. These installations include combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp and paper (European Union 2005).

- **G8 Declaration – Summit 2009.** During the July 2009 G8 Summit in Italy, the group officially recognized the importance of the outcome of COP-15, issuing the following statement regarding GHG emissions reductions: "We recognize the broad scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 °C. Because this global challenge can only be met by a global response, we reiterate our willingness to share with all countries the goal of achieving at least a 50 percent reduction of global emissions by 2050, [recognizing] that this implies that global emissions need to peak as soon as possible and decline thereafter. As part of this, we also support a goal of developed countries reducing emissions of greenhouse gases in aggregate by 80 percent or more by 2050 compared to 1990 or more recent years" (G8 Summit 2009, page 19).
- **Asia Pacific Partnership on Clean Development and Climate.** The Asia-Pacific Partnership on Clean Development and Climate is an effort to accelerate the development and deployment of clean energy technologies. The Asia-Pacific Partnership partners (Australia, Canada, China, India, Japan, Korea, and the United States) have agreed to work together and with private-sector partners to meet goals for energy security, national air pollution reduction, and climate change in ways that promote sustainable economic growth and poverty reduction. These seven partner countries collectively account for more than half of the world's economy, population, and energy use, and they produce about 65 percent of the world's coal, 62 percent of the world's cement, 52 percent of world's aluminum, and more than 60 percent of the world's steel (APP 2009a). The Partnership aims to be consistent with and contribute to the members' efforts under the UNFCCC and will complement, but not replace, the Kyoto Protocol (APP 2009b).

The SAP 2.1 MiniCAM Level 3 scenario provides a global context for emissions of a full suite of GHGs and ozone precursors for a Reference Case harmonious with implementation of the above policies and initiatives. There are some inconsistencies between the overall assumptions used by CCSP in SAP 2.1 (Clarke *et al.* 2007) to develop global emissions scenarios and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand. However, these inconsistencies affect the characterization of each CAFE alternative in equal proportion, so the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives.

NHTSA used the MiniCAM Level 3 scenario as the primary global emissions scenario for evaluating climate effects in the Chapter 4 analysis, but used the MiniCAM Level 2 scenario and the RCP 4.5 MiniCAM reference emissions scenario to evaluate the sensitivity of the results to alternative emissions scenarios. The RCP 4.5 MiniCAM reference emissions scenario assumes that no climate policy would be implemented beyond the current set of policies in place, whereas the SAP 2.1 MiniCAM Level 2 and 3 scenarios correspond to total radiative forcing stabilization by 2100 and associated CO_2 concentrations at roughly 550 ppmv and 650 ppmv, respectively, after accounting for the contributions to radiative forcing from the non-CO_2 GHGs.

Separately, each of the other alternatives was simulated by calculating the difference between annual GHG emissions under that alternative and emissions under the No Action Alternative (Alternative 1), and subtracting this change in the MiniCAM Level 3 scenario to generate modified global-scale emissions scenarios, which show the effect of the various CAFE alternatives on the global emissions path.

For example, emissions from U.S. passenger cars and light trucks in 2020 under the No Action Alternative are 1,800 million metric tons of CO_2 ($MMTCO_2$); emissions in 2020 under the Preferred Alternative (Alternative 4) are 1,680 $MMTCO_2$ (*see* Table 4.4.4-2). The difference of 120 $MMTCO_2$ represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global emissions for the MiniCAM Level 3 scenario in 2020 are 34,060 $MMTCO_2$, which are assumed to incorporate the level of emissions from U.S. passenger cars and light trucks under the No Action Alternative. Global emissions under the Preferred Alternative are thus estimated to be 120 $MMTCO_2$ less than this reference level, or 33,940 $MMTCO_2$ in 2020.

Many of the economic assumptions used in the Volpe model (such as fuel price, VMT, U.S. gross domestic product [GDP]) are based on the EIA Annual Energy Outlook (AEO) 2010 Early Release (EIA 2009a) and International Energy Outlook (IEO) 2009 (EIA 2009b), which forecast energy supply and demand in the United States and globally to 2030. Figures 4.4.3-1 through 4.4.3-5 show how the EIA forecasts of global and U.S. GDP, CO_2 emissions from energy use, and primary energy use compare against the assumptions used to develop the SAP 2.1 MiniCAM scenarios.[6,7] The IEO forecast is for a reference case, while the SAP 2.1 forecasts are for a reference case and two climate policy cases.

The GDP growth assumptions for the IEO reference scenario are slightly higher than those in the SAP scenarios, by about 0.6 percent annually for the world and 0.9 percent annually for the United States (*see* Figure 4.4.3-1).

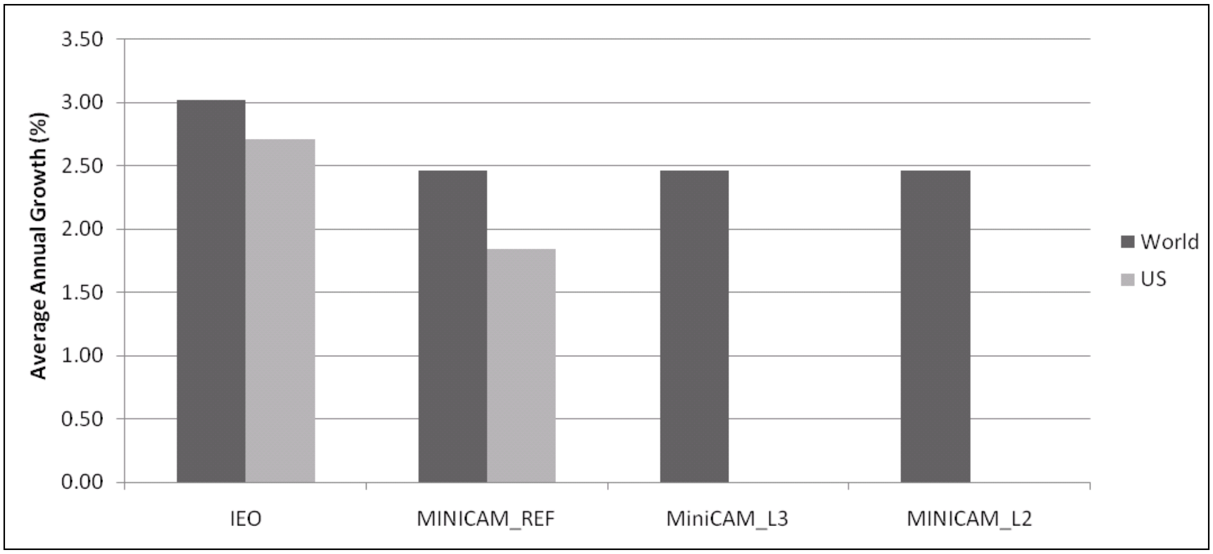
Despite this IEO assumption of higher economic growth, the growth in primary energy use is similar between the IEO and MiniCAM, with the primary energy use in MiniCAM slightly lower than that of the IEO, as shown in Figure 4.4.3-4. The global primary liquids energy use in SAP 2.1 and the IEO 2009 (EIA 2009b) compare well. Much of the difference in energy use in the IEO forecast is due to assumptions of higher coal use that result in higher CO_2 emissions, as shown in Figure 4.4.3-2. Additionally, the IEO reference scenario estimates have a particularly low share of "other" fuels, which includes biomass and renewable fuels, and is likely due to different treatments of non-commercial fuels in the two sets of forecasts.

The primary energy use projections for the United States show a different trend than the global numbers. The AEO 2010 Early Release (EIA 2009a)[8] projection shows an increase in total primary energy use in the United States, but much of the increase is from the use of coal and liquid fuels. On the other hand, the SAP MiniCAM scenarios have a higher share of natural gas (Figure 4.4.3-5). However, the AEO reference scenario has a larger share of other fuels[9] than the SAP MiniCAM scenarios, resulting in lower CO_2 emissions (Figure 4.4.3-3).

The approaches focus on the marginal climate effects of marginal changes in emissions. Thus, they generate a reasonable characterization of climate changes for a given set of emissions reductions, regardless of the underlying details associated with those emissions reductions. The discussion in Section 4.4.4 characterizes projected climate change under the No Action Alternative and the changes associated with each action alternative.

[6] The MiniCAM reference scenario from SAP 2.1 uses the same assumptions for GDP, energy use, and CO_2 emissions as the RCP MiniCAM reference scenario.
[7] The IEO 2009 (EIA 2009b) uses energy supply and consumption from the AEO 2009 for the United States and the same forecast for world oil prices. The IEO nuclear primary energy forecast numbers were adjusted to account for differences in reporting primary energy use for nuclear energy. All IEO energy-use estimates were converted to exajoules.
[8] AEO 2010 Early Release (EIA 2009a) estimates were used for U.S. primary energy consumption.
[9] For the AEO reference scenario, "other" includes biomass, hydropower, and other renewable fuels.

Figure 4.4.3-1. Average GDP Growth Rates (1990 to 2030) a/



a/ GDP growth rates were not available for the United States under MiniCAM Level 3 and MiniCAM Level 2 scenario

Figure 4.4.3-2. Global Annual CO_2 Emissions from Fossil Fuel Use

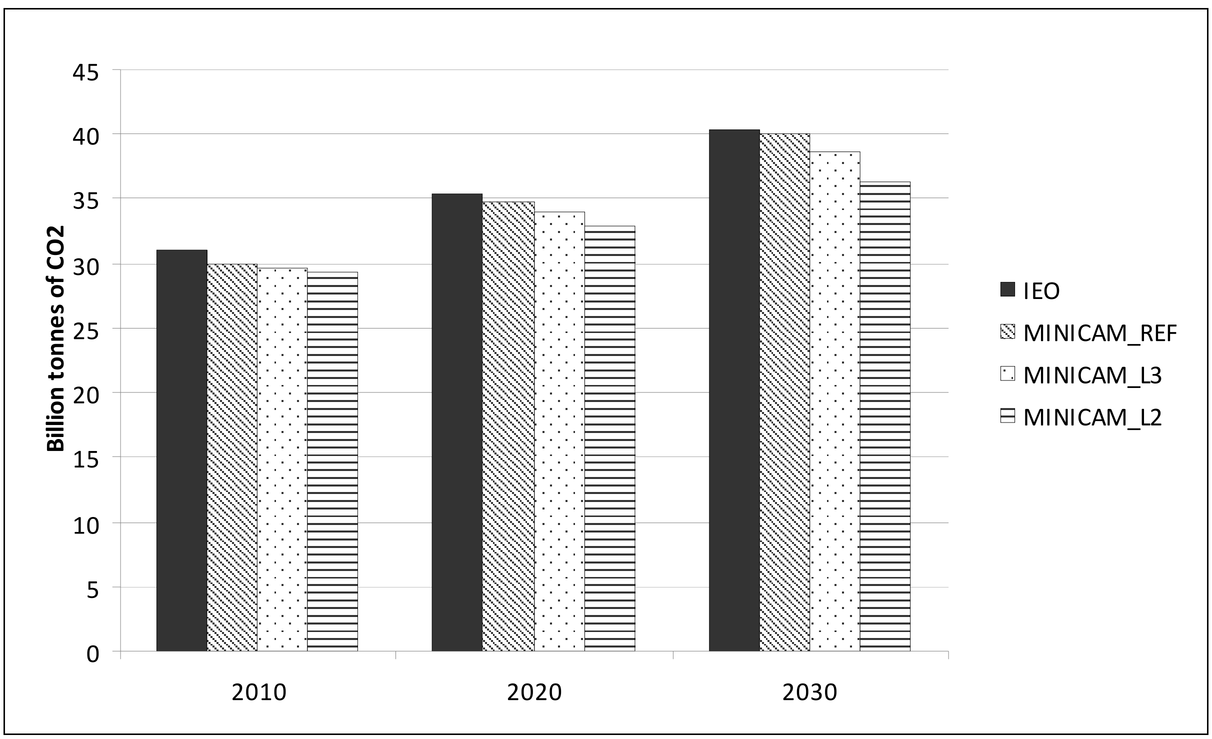


Figure 4.4.3-3. U.S. Annual CO_2 Emissions from Fossil Fuel Use

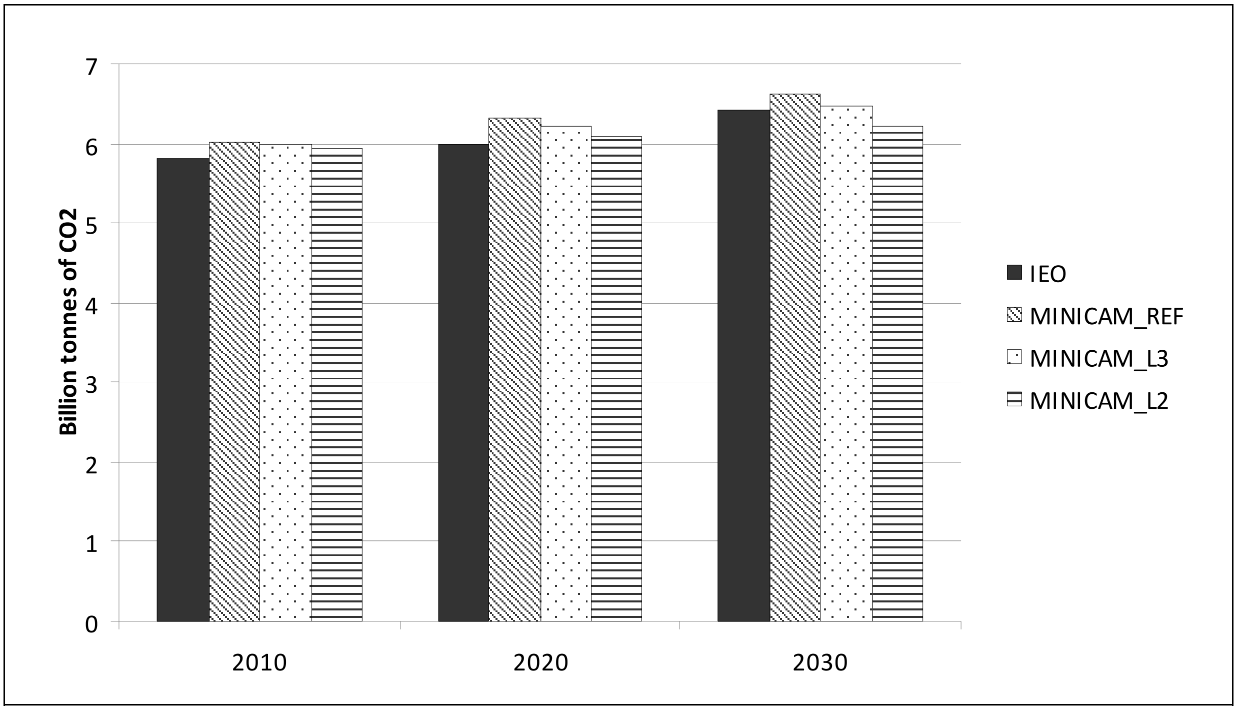


Figure 4.4.3-4. World Primary Energy Use Forecast

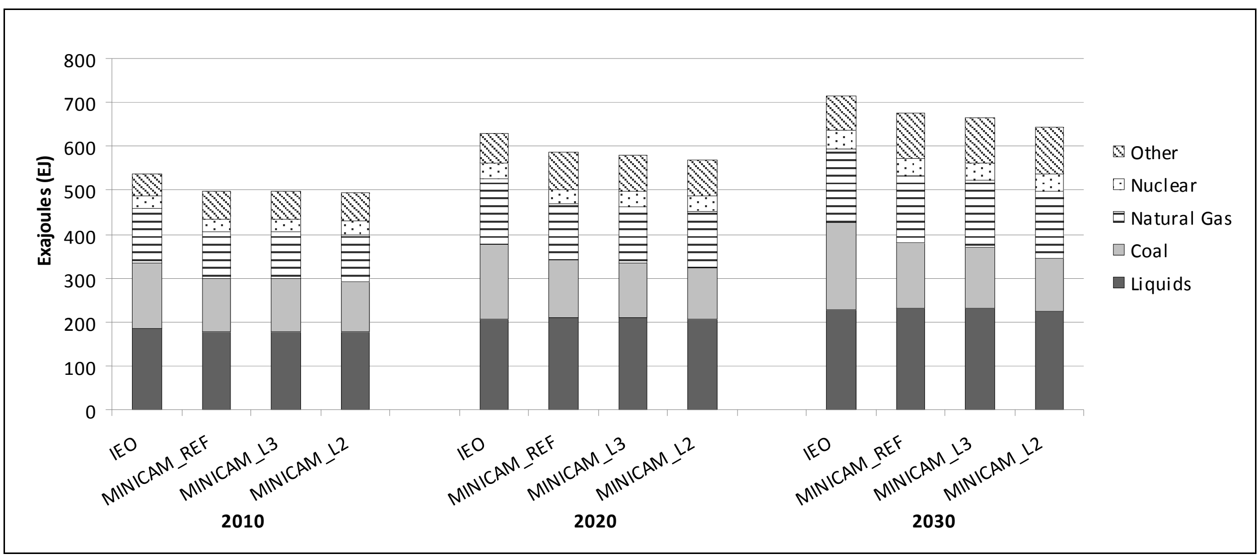
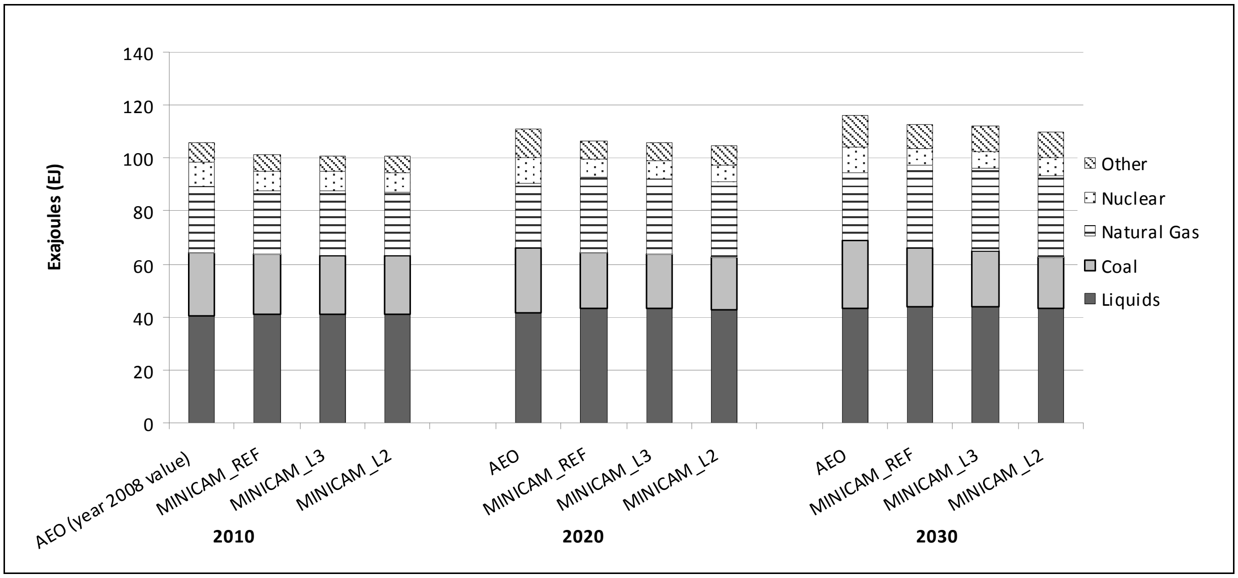


Figure 4.4.3-5. U.S. Primary Energy Use Forecast



The climate sensitivity analysis (*see* Section 4.4.3.2.3) also uses the MiniCAM Level 2 emissions scenario (Clarke *et al.* 2007) and the RCP 4.5 MiniCAM reference emissions scenario as possible global emissions scenarios. This provides a basis for determining climate responses to varying levels of global emissions and climate sensitivities under the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). Some responses of the climate system are believed to be non-linear; by using a range of emissions cases and climate sensitivities, it is possible to estimate the effects of the alternatives in relation to different scenarios and sensitivities.

Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). For this analysis, despite the inconsistencies between the MiniCAM assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the emissions estimates for the U.S. transportation sector provided by the Volpe model, the approach used is valid; these inconsistencies affect all alternatives equally, and thus do not hinder a comparison of the alternatives in terms of their relative effects on climate.

4.4.3.3.1 Tipping Points and Abrupt Climate Change

Tipping points and abrupt climate change are discussed in Section 3.4.3.3.1 and the same conclusions apply to this cumulative impact analysis. A qualitative survey of the current state of climate science on tipping points and abrupt climate change is presented in Section 4.5.9.

4.4.4 Environmental Consequences

This section describes the consequences of the proposed action and alternatives, and other reasonably foreseeable future actions, in relation to GHG emissions and the consequences of global climate change.

4.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger car and light truck CAFE standards, NHTSA uses the Volpe model (*see* Sections 2.2.1 through 2.2.4 and Section 3.1.4 for descriptions of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total energy and petroleum energy use, which in turn affects the amount of CO_2 emissions. These CO_2 emissions estimates also include upstream emissions, which occur from the use of carbon-based energy during crude oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHG emitted during fuel production and use – more than 95 percent, even after accounting for the higher global warming potentials (GWPs) of other GHGs – NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel economy.[10]

NHTSA considers the following measures of the cumulative impact of alternative CAFE standards for MYs 2012-2016 *and* other reasonably foreseeable actions affecting CO_2 emissions:

- CO_2 emissions from MYs 2012-2016 passenger cars and light trucks, which are directly affected by the new CAFE standards;
- CO_2 emissions from MYs 2017-2030 passenger cars and light trucks, assuming annual average percentage gains in mpg consistent with the AEO 2010 Early Release Reference Case projections (EIA 2009a), with all action alternatives exceeding the combined EISA target of 35 mpg in 2020 (*see* Section 4.1.3);
- CO_2 emissions from MYs 2031-2060 passenger cars and light trucks, for which the overall fuel economy of the fleet continues to improve as new vehicles enter the fleet with an average fuel economy equivalent to MY 2030 vehicles,[11] and older vehicles leave the fleet; and
- CO_2 emissions from MYs 2061-2100 passenger cars and light trucks, for which emissions are held constant.[12]

Cumulative emissions reductions from each action alternative increase across alternatives, with Alternative 2 having the lowest cumulative emissions reductions and Alternative 9 having the highest cumulative emissions reductions. Emissions reductions represent the differences in total annual emissions by all passenger cars or light trucks in use between their estimated future levels under the No Action Alternative (baseline), and with each alternative CAFE standard in effect.

Emissions reductions resulting from applying the reasonably foreseeable future actions to the proposed CAFE standards for MYs 2012-2016 passenger cars and light trucks and the eight action alternatives were estimated from 2012 to 2060. Emissions were estimated for all alternatives through 2060, and these emissions were compared against the No Action Alternative (which assumes post-MY 2011 fuel economy levels grow at the rates projected by the AEO fuel economy forecasts) to estimate emissions reductions. Annual emissions reductions from 2061 to 2100 were held constant at 2060 levels. Emissions under each action alternative were then compared against those under the No Action Alternative to determine its impact on emissions.

Table 4.4.4-1 shows total GHG emissions and emissions reductions from new passenger cars and light trucks from 2012-2100 under each of the nine alternatives. Projections of emissions reductions over

[10] Although this section includes only a discussion of CO_2 emissions, the climate modeling discussion in Section 4.4.4.4 assesses the direct and indirect effects associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.

[11] As explained in Section 4.1.3, because AEO fuel economy projections end at 2030, this analysis assumes that all post-2030 vehicles continue to achieve the average fuel economy levels projected for new vehicles in 2030.

[12] The year 2060 is the last year the Volpe model provides estimates of fleet fuel efficiency, fuel use, VMT, and the other factors required to calculate GHG emissions. Because this information is not available post 2060, emissions are held constant after that year.

the 2012 to 2100 period due to the MYs 2012-2016 CAFE standards and other reasonably foreseeable future actions ranged from 30,200 to 45,600 $MMTCO_2$. Compared to cumulative global emissions of 3,919,462 $MMTCO_2$ over this period (projected by the SAP 2.1 MiniCAM Level 3 scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.8 to 1.2 percent from their projected levels under the No Action Alternative.

Table 4.4.4-1

Cumulative Effects of Emissions and Emissions Reductions ($MMTCO_2$) from 2012 to 2100 by Alternative a/

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	259,800	0
2 3%/year Increase	229,600	30,200
3 4%/year Increase	229,300	30,400
4 ~4.3%/year Increase, Preferred	228,400	31,400
5 5%/year Increase	224,700	35,100
6 ~6.0%/year Increase, MNB	218,400	41,400
7 6%/year Increase	218,300	41,500
8 7%/year Increase	214,200	45,600
9 ~6.6%/year Increase, TCTB	215,200	44,600

a/ Note: The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.

To get a sense of the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from passenger cars and light trucks as a whole and to compare them against emissions projections from the United States, and expected or stated goals from existing programs designed to reduce CO_2 emissions. As mentioned earlier, U.S. passenger cars and light trucks currently account for approximately 19.1 percent of CO_2 emissions in the United States. With the action alternatives reducing U.S. passenger car and light truck CO_2 emissions by 11.6. to 17.6 percent over 2012-2100, the CAFE alternatives will have a noticeable impact on total U.S. CO_2 emissions. Compared to total U.S. CO_2 emissions in 2100 projected by the MiniCAM reference scenario of 7,886 $MMTCO_2$ (Clarke *et al.* 2007), the action alternatives would reduce total U.S. CO_2 emissions by 5.7 to 8.5 percent in 2100. Figure 4.4.4-1 shows projected annual emissions from passenger cars and light trucks under MYs 2012-2016 standards and other reasonably foreseeable future actions.

As Table 4.4.4-2 shows, total CO_2 emissions accounted for by the U.S. passenger car and light truck fleets are projected to increase substantially from their level in 2011 under the No Action Alternative, which would assume that passenger cars and light trucks continue to achieve the level of fuel economy required by MY 2011 CAFE standards. The table also shows that each of the action alternatives would reduce total passenger car and light truck CO_2 emissions in future years significantly from their projected levels under the No Action Alternative. Progressively larger reductions in CO_2 emissions from their levels under the No Action Alternative are projected to occur during each future year because the action alternatives require successively higher fuel economy levels for MYs 2012-2016 and later passenger cars and light trucks. For example, Alternative 9 (which results in 37.0 mpg in 2016) will get much larger by 2030 growing at 0.51 percent a year than Alternative 2 (which results in 32 mpg in 2016) will get by 2030 growing at 0.51 percent a year.

Figure 4.4.4-1. Cumulative Annual Emissions Under the MYs 2012-2016 Standards and Other Reasonably Foreseeable Future Actions (MMTCO$_2$)

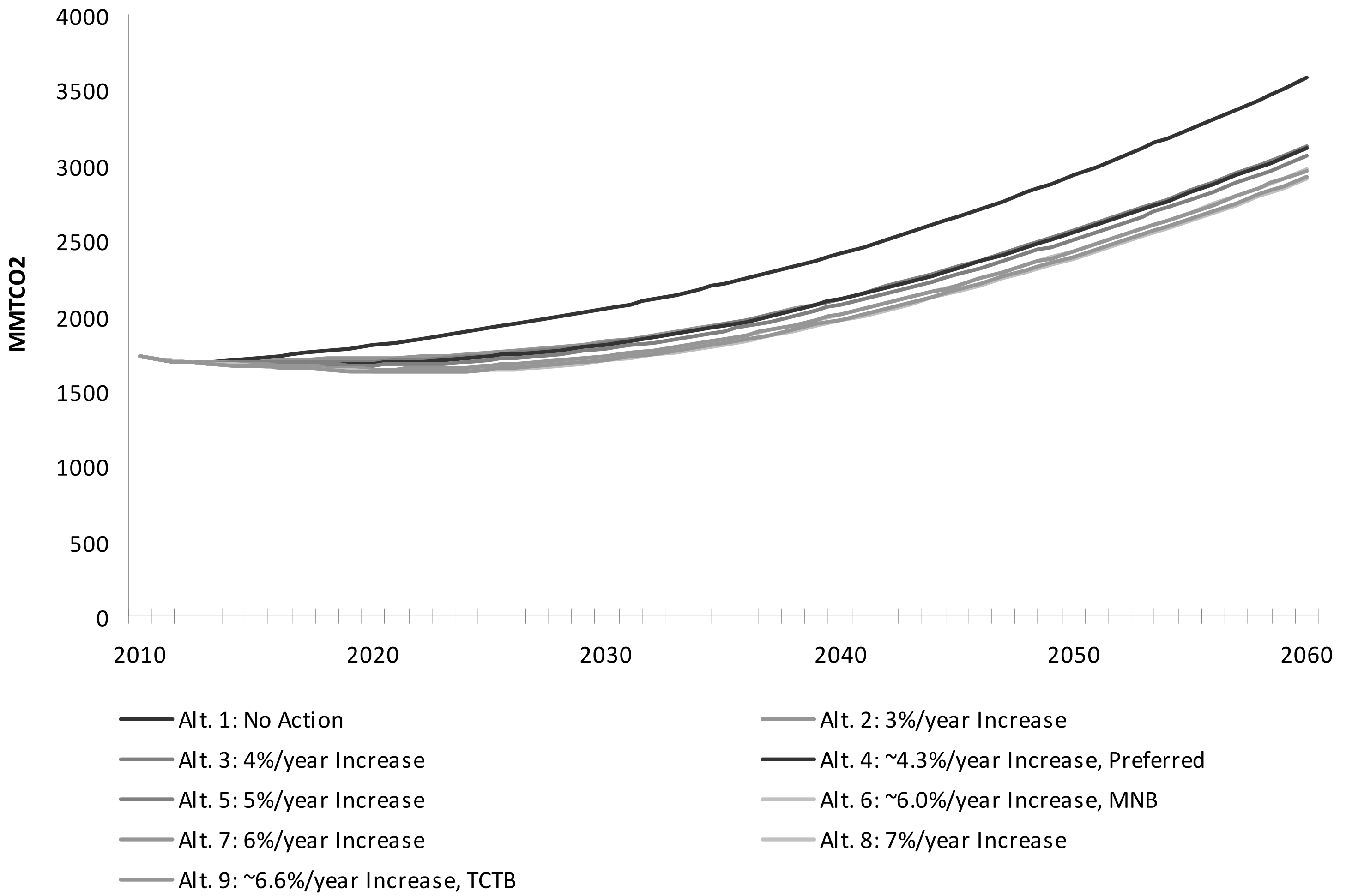


Table 4.4.4-2

Cumulative Effects of Nationwide Emissions of Greenhouse Gases (MMT per year) from Passenger Cars and Light Trucks by Alternative

GHG and Year	Alt. 1 No Action	Alt. 2 3%/year Increase	Alt. 3 4%/year Increase	Alt. 4 ~4.3%/year Increase Preferred	Alt. 5 5%/year Increase	Alt. 6 ~6.0%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.6%/year Increase TCTB
Carbon dioxide (CO_2)									
2010	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730
2020	1,800	1,710	1,690	1,680	1,670	1,640	1,640	1,630	1,630
2030	2,050	1,820	1,820	1,890	1,780	1,730	1,730	1,700	1,700
2040	2,410	2,110	2,110	2,100	2,070	2,010	2,000	1,960	1,970
2050	2,930	2,560	2,560	2,550	2,510	2,430	2,430	2,380	2,390
2060	3,580	3,120	3,130	3,110	3,060	2,970	2,960	2,900	2,920
Methane (CH_4)									
2010	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2020	1.92	2.00	1.98	1.97	1.95	1.91	1.92	1.89	1.90
2030	2.39	2.14	2.13	2.12	2.08	2.02	2.08	1.98	1.99
2040	2.82	2.48	2.48	2.46	2.42	2.34	2.34	2.29	2.30
2050	3.42	3.00	3.00	2.99	2.93	2.84	2.84	2.77	2.79
2060	4.18	3.67	3.65	3.58	3.46	3.46	3.46	3.39	3.41
Nitrous oxide (N_2O)									
2010	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2020	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2030	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2040	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
2050	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05
2060	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06

Under all of the alternatives, projected growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use (VMT per vehicle), is projected to result in growth in total passenger car and light truck travel (VMT). As a result, despite increases in fuel economy, total fuel consumption and CO_2 emissions by U.S. passenger cars and light trucks is projected to increase under each of the action alternatives, as shown in the Figure 4.4.4-1. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger car and light truck fleet represented about 3.3 percent of total global emissions of CO_2 in 2005 (EPA 2009a, WRI 2009).[13] Although substantial, this source is still a small percentage of global emissions. The relative contribution of CO_2 emissions from U.S. passenger cars and light trucks is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions). These conclusions are not meant to be interpreted as expressing NHTSA views that the U.S. vehicle fleet's contribution to global CO_2 emissions is not an area of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). The analysis in this EIS fulfills NHTSA obligations in this regard.

These emissions reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the WCI to develop regional strategies to address climate change. WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent over the period from 2009 to 2020 (WCI 2007) By comparison, this rulemaking is expected to reduce CO_2 emissions by 310 to 730 $MMTCO_2$ over the same period. In the Northeast and Mid-Atlantic, nine states have formed the RGGI to reduce CO_2 emissions from power plants. Emissions reductions from 2006 to 2024 are estimated at 268 $MMTCO_2$ from what they were otherwise projected to be (RGGI 2006).[14] By comparison, NHTSA forecasts that this rulemaking will reduce CO_2 emissions by 820 to 1,630 $MMTCO_2$ over this period.

Two features of these comparisons are extremely important to emphasize. First, emissions from the sources addressed in the WCI and RGGI plans are projected to decrease compared to the beginning of the action, while emissions from passenger cars and light trucks are projected to increase under all alternatives for this rulemaking due to increases in vehicle ownership and use. Second, these projections are only estimates, and the scope of these climate programs differs from that in this rulemaking in terms of geography, sector, and purpose.

Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). I n this case, the comparison of emissions reductions from the action alternatives to emissions reductions associated with other programs is intended to aid decisionmakers by providing relative benchmarks, rather than absolute metrics, for selecting among alternatives. In summary, the alternatives analyzed here deliver GHG emissions reductions that are on a scale similar to many of the most progressive and ambitious GHG emissions reduction programs underway in the United States. However, due to projected increases in VMT, increases in CAFE standards are not projected to provide absolute emissions reductions from today's levels of passenger car and light truck emissions, whereas some regional programs do predict such absolute reductions.

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[13] Includes land-use change and forestry, and excludes international bunker fuels.

[14] Emissions reductions were estimated by determining the difference between the RGGI Cap and the Phase III RGGI Reference Case. These estimates do not include offsets.

4.4.4.2 Cumulative Effects on Climate Change

The approach to estimating the cumulative effects of climate change from the MYs 2012-2016 CAFE standards combined with other reasonably foreseeable future actions mirrors that used to estimate the direct and indirect effects of the MYs 2012-2016 CAFE standards.

Again, because EISA directs NHTSA to increase CAFE standards to reach a combined fleet average CAFE level of at least 35 mpg by MY 2020, MYs 2017-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the MYs 2012-2016 CAFE standards. Many of the action alternatives surpass the target of 35 mpg in 2016. For action alternatives that do not reach 35 mpg by MY 2016 (Alternative 2, Alternative 3, Alternative 4, and Alternative 5), the Chapter 4 cumulative impacts mpg is expected to continue to rise from 2017 to 2020 so that the MY 2020 EISA target 35 mpg is at least met. Once the 35 mpg target is met or exceeded, NHTSA assumes that the overall fuel economy of the fleet continues to improve until 2030 at a pace consistent with the AEO 2010 Early Release Reference Case projections (*see* Section 4.1.3). NHTSA also assumes fuel economy increases consistent with the AEO projections under the No Action Alternative.

Because the CAFE standards apply to new vehicles, this assumption results in emissions reductions and fuel savings that continue to grow after 2030 as new vehicles meeting the 2030 mpg average are added to the fleet in each subsequent year, reaching their maximum values when all passenger cars and light trucks in the U.S. fleet meet the 2030 average mpg. Overall, the emissions reductions for the MYs 2012-2016 CAFE standards have a small impact on climate change. The emissions reductions and resulting climate impacts for the MYs 2012-2016 CAFE standards and other reasonably foreseeable future actions are larger, although they are still relatively small in absolute terms. While these effects are small, they occur on a global scale and are long-lived. These conclusions are not meant to be interpreted as expressing NHTSA views that anthropogenic climate change is not an area of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). The analysis in this EIS fulfills NHTSA obligations in this regard.

Sections 4.4.4.2.1 through 4.4.4.2.4 describe cumulative effects of the alternatives on climate change in terms of atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise.

4.4.4.2.1 Atmospheric Carbon Dioxide Concentrations

MAGICC is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 4.4.4-3.[15] As the table indicates, the model runs developed for this analysis achieve relatively good agreement with IPCC WGI estimates in terms of both CO_2 concentrations and surface temperature.

A comparison of sea-level rise from MAGICC 5.3.v2 and the IPCC Fourth Assessment Report can be found in the release documentation for MAGICC 5.3.v2 (Wigley 2008). In Table 3 of the documentation, Wigley (2008) presents the results for six SRES scenarios that show the comparable value for sea-level rise from MAGICC 5.3.v2 (total sea-level rise minus estimates for contributions from non-melt sources such as warming of the permafrost) within 0.01 centimeters (0.04 inch) in 2095.

[15] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C (5.4 °F)

Table 4.4.4-3

Comparison of MAGICC Results and Reported IPCC Results (IPCC 2007)

Scenario	CO_2 Concentration (ppm) IPCC WGI (2100)	CO_2 Concentration (ppm) MAGICC (2100)	Global Mean Increase in Surface Temperature (°C) IPCC WGI (2080-2099)	Global Mean Increase in Surface Temperature (°C) MAGICC (2090)	Sea-level Rise (cm) IPCC WGI (2090-2099) a/	Sea-level Rise (cm) MAGICC (2095)
B1	550	538.3	1.79	1.81	28	26
A1B	715	717.2	2.65	2.76	35	35
A2	836	866.8	3.13	3.31	37	38

a/ The IPCC values represent the average of the 5- to 95-percent range of the rise of sea level from 1980 to 1989 and from 2090 to 2099.

The MiniCAM Level 3 scenario, which is a radiative forcing stabilization scenario with a corresponding CO_2 concentration level of roughly 650 ppmv in 2100, was used to represent the No Action Alternative (Alternative 1) in the MAGICC runs for this EIS.[16] Table 4.4.4-4 and Figures 4.4.4-2 through 4.4.4-5 show the mid-range results of MAGICC model simulations for Alternative 1 and the eight action alternatives for CO_2 concentrations and increase in global mean surface temperature in 2030, 2050, and 2100. As Figures 4.4.4-2 and 4.4.4-3 show, the reduction impact on the growth in projected CO_2 concentrations and temperature amounts to a small fraction of the total growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the action alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature under the TCTB Alternative (Alternative 9).

As shown in the Table 4.4.4-4 and Figures 4.4.4-2 through 4.4.4-5, there is a fairly narrow band of estimated CO_2 concentrations as of 2100, from 653.4 ppm under Alternative 8 (7%/year increase in fuel economy) to 657.4 ppm under the No Action Alternative (Alternative 1). For 2030 and 2050, the corresponding range is even smaller. Because CO_2 concentrations are the key driver of all other climate effects, this leads to small differences in these effects. Although these effects are small, they occur on a global scale and are long-lived.

4.4.4.2.2 Temperature

MAGICC simulations of mean global surface air temperature increases are shown below in Table 4.4.4-4. For all alternatives, the cumulative global mean surface temperature increase is about 0.80 °C to 0.81 °C (1.44 to 1.46 °F) as of 2030; 1.32 to 1.33 °C (2.38 to 2.39 °F) as of 2050; and 2.59 to 2.61 °C (4.66 to 4.70 °F) as of 2100.[17] The differences among alternatives are small. For 2100, the reduction in temperature increase under the action alternatives in relation to the No Action Alternative is about 0.01 to 0.02 °C (0.02 to 0.04 °F). Although these effects are small, they occur on a global scale and are long-lived.

Quantifying the changes to regional climate from the CAFE alternatives is not possible at this point due to the limitations of existing climate models, but it is expected that the alternatives would reduce the changes in relation to the reduction in global mean surface temperature. Regional changes to warming and seasonal temperatures as described by the IPCC Fourth Assessment Report are summarized in Table 3.4.4-5 in Section 3.4.4.2.2.

[16] The No Action Alternative does not reach a CO_2 concentration level of exactly 650 ppm in 2100 because the MiniCAM Level 3 scenario was developed using an assumed total long-term radiative forcing stabilization level, which includes radiative forcing from other non-CO_2 GHGs. The scientists who designed the scenario are using 650 ppm as convenient shorthand for a condition that is considerably more complicated.

[17] Because the actual increase in global mean surface temperature lags the commitment to warming, the impact on global mean surface temperature increase is less than the impact on the long-term commitment to warming.

Table 4.4.4-4

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (MiniCAM Level 3) by Alternative a/

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
	2030	2050	2100	2030	2050	2100	2030	2050	2100
1 No Action	438.7	498.0	657.4	0.805	1.327	2.611	7.83	13.67	32.84
2 3%/year Increase	438.5	497.2	654.8	0.805	1.323	2.599	7.83	13.65	32.74
3 4%/year Increase	438.5	497.2	654.8	0.804	1.323	2.599	7.83	13.65	32.74
4 ~4.3%/year Increase, Preferred	438.5	497.2	654.7	0.804	1.323	2.599	7.83	13.65	32.73
5 5%/year Increase	438.4	497.1	654.3	0.804	1.322	2.597	7.83	13.65	32.72
6 ~6.0%/year Increase, MNB	438.4	496.9	653.8	0.804	1.321	2.594	7.83	13.64	32.69
7 6%/year Increase	438.4	496.9	653.8	0.804	1.321	2.594	7.83	13.64	32.69
8 7%/year Increase	438.3	496.8	653.4	0.804	1.321	2.592	7.83	13.64	32.68
9 ~6.6%/year Increase, TCTB	438.3	496.8	653.5	0.804	1.321	2.593	7.83	13.64	32.68
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.8	2.7	0.001	0.004	0.012	0.00	0.02	0.10
3 4%/year Increase	0.2	0.8	2.7	0.001	0.004	0.012	0.00	0.02	0.10
4 ~4.3%/year Increase, Preferred	0.2	0.8	2.8	0.001	0.004	0.012	0.00	0.02	0.11
5 5%/year Increase	0.3	0.9	3.2	0.001	0.004	0.014	0.00	0.02	0.12
6 ~6.0%/year Increase, MNB	0.3	1.1	3.7	0.002	0.006	0.017	0.00	0.03	0.15
7 6%/year Increase	0.3	1.1	3.7	0.002	0.005	0.017	0.00	0.03	0.15
8 7%/year Increase	0.4	1.2	4.1	0.002	0.006	0.019	0.00	0.03	0.16
9 ~6.6%/year Increase, TCTB	0.4	1.2	4.0	0.002	0.006	0.018	0.00	0.03	0.16

a/ The numbers in this table have been rounded for presentation purposes. Therefore, the reductions might not reflect the exact difference of the values in all cases.

Figure 4.4.4-2. Cumulative Effects on CO_2 Concentrations

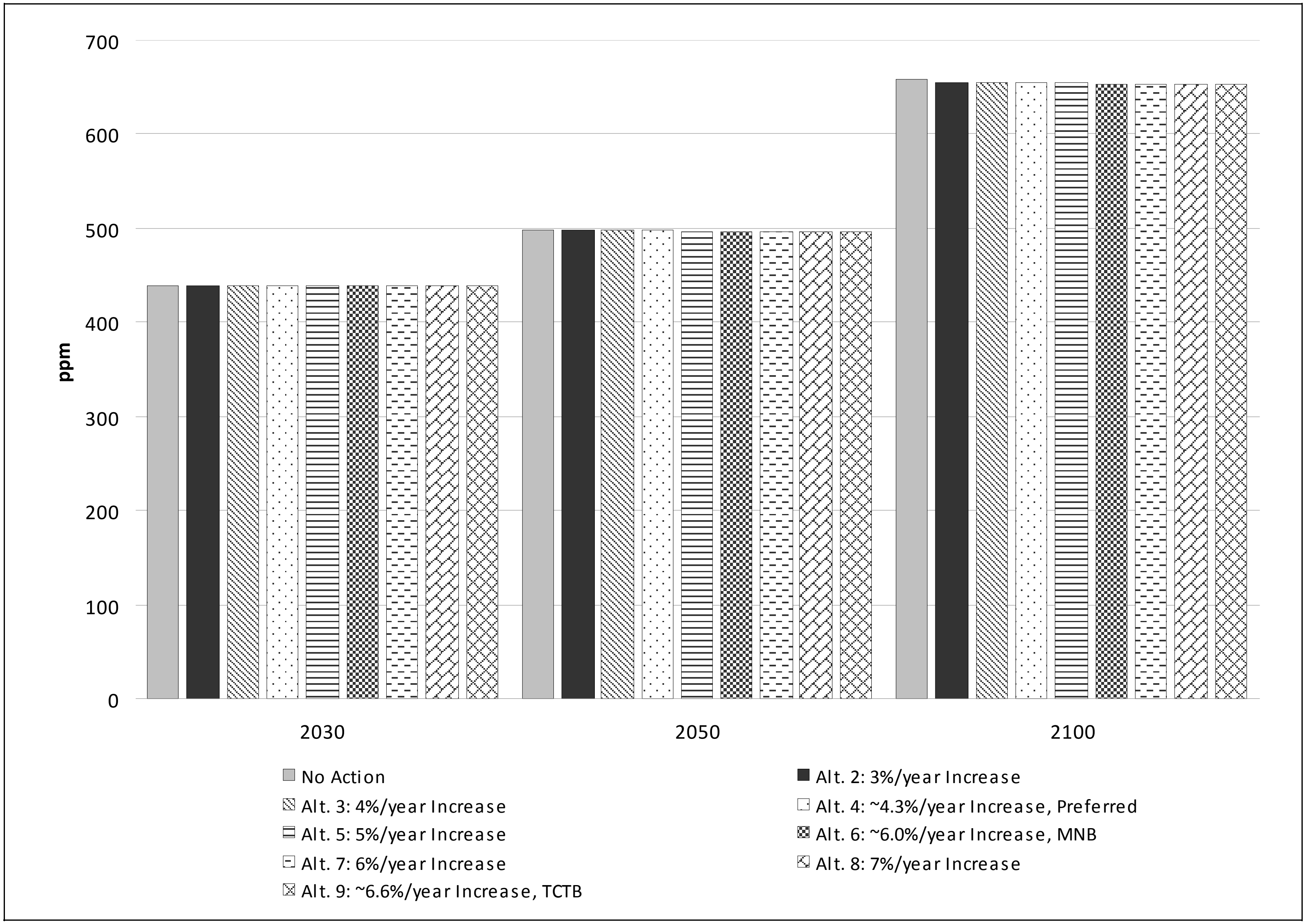


Figure 4.4.4-3. Cumulative Effects on Global Mean Surface Temperature Increase

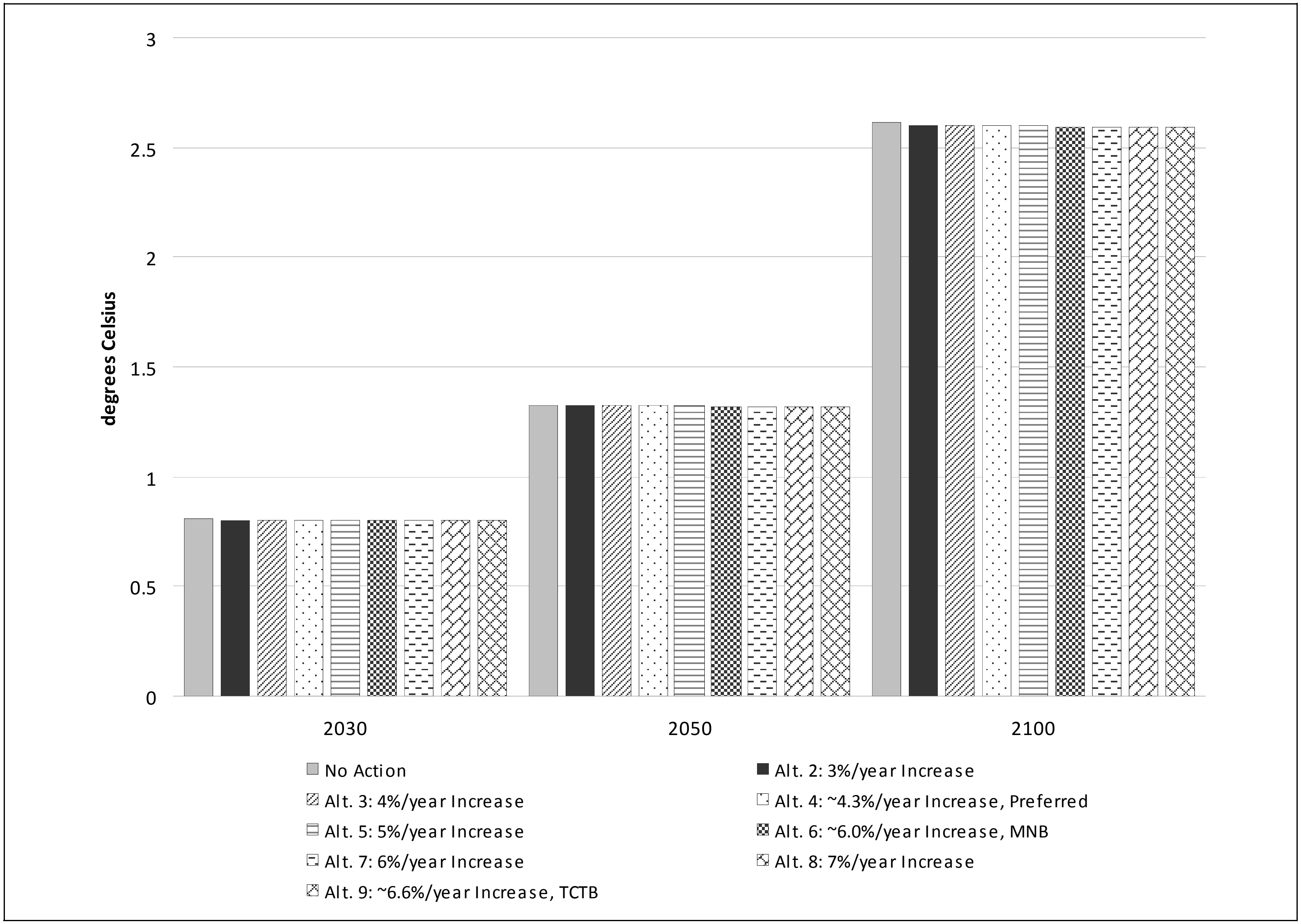


Figure 4.4.4-4. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

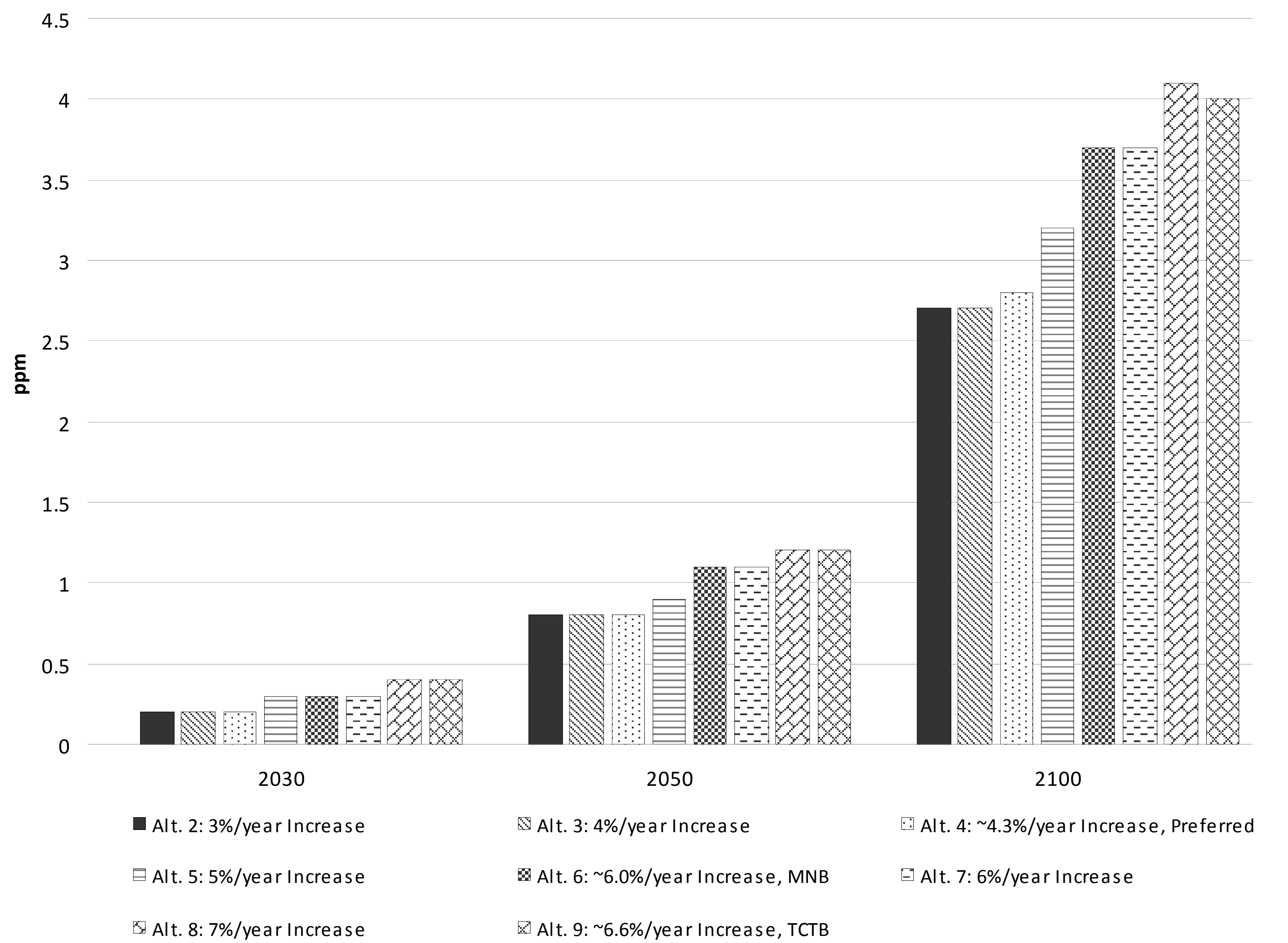
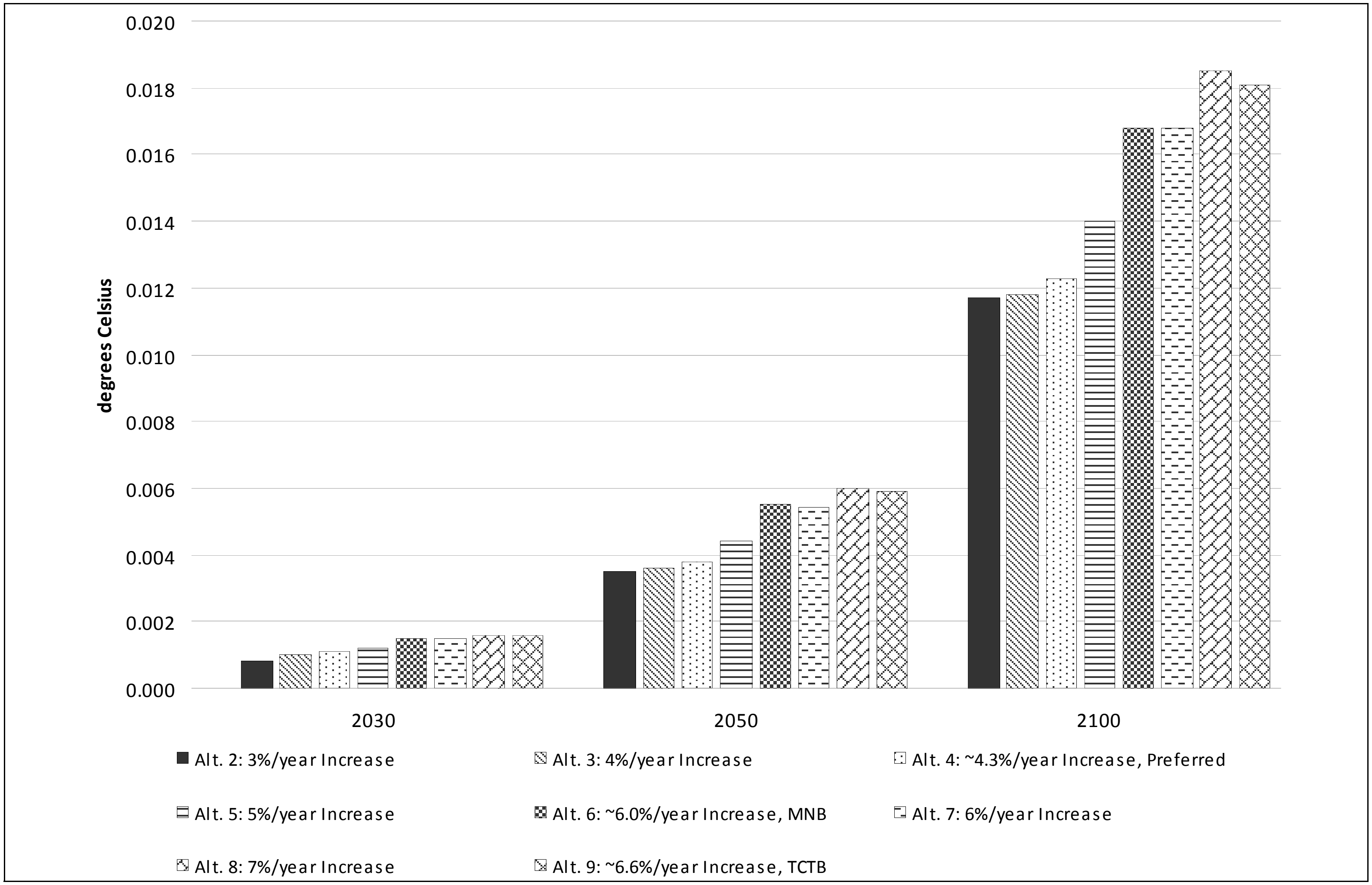


Figure 4.4.4-5. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)



4.4.4.2.3 Precipitation

The effects of higher temperatures on the amount of precipitation and the intensity of precipitation events, as well as the IPCC scaling factors to estimate global mean precipitation change, are discussed in Section 3.4.4.2.3.

Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the action alternatives would reduce temperature increases slightly in relation to the No Action Alternative, they also would reduce predicted increases in precipitation slightly, as shown in Table 4.4.4-5 (again, based on the A1B [medium] scenario).

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This inability is due primarily to the lack of availability of AOGCMS required to estimate these changes. AOGCMS are typically used to provide results among scenarios having very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles produce results that would be difficult to resolve among scenarios having relatively small changes in emissions. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but are inconsistent in others.

Quantifying the changes to regional climate from the action alternatives is not possible at this point, but the action alternatives would reduce the changes in relation to the reduction in global mean surface temperature. Regional changes to precipitation as described by the IPCC Fourth Assessment Report are summarized in Table 3.4.4-8 in Section 3.4.4.2.3.

4.4.4.2.4 Sea-level Rise

The components of sea-level rise, MAGICC treatment of these components, and recent scientific assessments are discussed in Section 3.4.4.2.4.

Table 4.4.4-4 presents the impact on sea-level rise from the scenarios and show sea-level rise in 2100 ranging from 32.84 centimeters (12.93 inches) under the No Action Alternative (Alternative 1) to 32.68 centimeters (12.87 inches) under Alternatives 8 and 9, for a maximum reduction of 0.16 centimeters (0.06 inches) by 2100.

In summary, the impacts of the proposed action and alternatives and other reasonably foreseeable future actions on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the SRES scenarios.[18] This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lived.

[18] These conclusions are not meant to be interpreted as expressing NHTSA views that impacts on global mean surface temperature, precipitation, or sea-level rise are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] of *the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). This analysis fulfills NHTSA obligations in this regard.

Table 4.4.4-5

Cumulative Effects on Global Mean Precipitation (Percent Change) Based on MiniCAM Level 3 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaled, % K-1)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (K) for the MiniCAM reference Scenario and Alternative CAFE Standards, Volpe Reference Results			
1 No Action	0.586	1.466	2.415
2 3%/year Increase	0.586	1.462	2.405
3 4%/year Increase	0.585	1.461	2.405
4 ~4.3%/year Increase, Preferred	0.585	1.461	2.405
5 5%/year Increase	0.585	1.459	2.403
6 ~6.0%/year Increase, MNB	0.585	1.459	2.401
7 6%/year Increase	0.585	1.459	2.401
8 7%/year Increase	0.585	1.459	2.399
9 ~6.6%/year Increase, TCTB	0.585	1.459	2.400
Reduction in Global Temperature (K) for Alternative CAFE Standards, Mid-level Results (Compared to No Action Alternative)			
2 3%/year Increase	0.000	0.004	0.010
3 4%/year Increase	0.000	0.004	0.010
4 ~4.3%/year Increase, Preferred	0.000	0.005	0.011
5 5%/year Increase	0.000	0.005	0.012
6 ~6.0%/year Increase, MNB	0.000	0.007	0.015
7 6%/year Increase	0.000	0.007	0.015
8 7%/year Increase	0.000	0.007	0.016
9 ~6.6%/year Increase, TCTB	0.000	0.007	0.016
Global Mean Precipitation Change (%)			
1 No Action	0.85%	2.21%	3.94%
2 3%/year Increase	0.85%	2.21%	3.92%
3 4%/year Increase	0.85%	2.21%	3.92%
4 ~4.3%/year Increase, Preferred	0.85%	2.21%	3.92%
5 5%/year Increase	0.85%	2.21%	3.92%
6 ~6.0%/year Increase, MNB	0.85%	2.20%	3.91%
7 6%/year Increase	0.85%	2.20%	3.91%
8 7%/year Increase	0.85%	2.20%	3.91%
9 ~6.6%/year Increase, TCTB	0.85%	2.20%	3.91%
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 3%/year Increase	0.00%	0.01%	0.02%
3 4%/year Increase	0.00%	0.01%	0.02%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~6.0%/year Increase, MNB	0.00%	0.01%	0.02%
7 6%/year Increase	0.00%	0.01%	0.02%
8 7%/year Increase	0.00%	0.01%	0.03%
9 ~6.6%/year Increase, TCTB	0.00%	0.01%	0.03%

a/ The numbers in this table have been rounded for presentation purposes. Therefore, the reductions might not reflect the exact difference of the values in all cases.

4.4.4.2.5 Climate Sensitivity Variations

NHTSA examined the sensitivity of climate effects on key assumptions used in the analysis. This examination included reviewing the impact of various climate sensitivities and global emissions scenarios on the climate effects under the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). Table 4.4.4-6 presents the results from the sensitivity analysis.

The use of alternative global emissions scenarios can influence the results in several ways. Emissions reductions can lead to larger reductions in the CO_2 concentrations in later years because more of the anthropogenic emissions can be expected to stay in the atmosphere. The use of different climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) can affect not only warming but also indirectly affect sea-level rise and CO_2 concentration.

As shown in Table 4.4.4-6, the sensitivity of simulated CO_2 emissions in 2030, 2050, and 2100 to assumptions of global emissions and climate sensitivity is low; stated simply, CO_2 emissions do not change much with changes in global emissions and climate sensitivity. For 2030 and 2050, the choice of global emissions scenario has little impact on the results. By 2100, the Preferred Alternative (Alternative 4) has the greatest impact in the global emissions scenario with the highest CO_2 emissions (MiniCAM Reference) and the least impact in the scenario with the lowest CO_2 emissions (MiniCAM Level 2). The total range of the impact of the Preferred Alternative on CO_2 concentrations in 2100 is from 2.6 to 3.1 ppm. The Reference Case using the MiniCAM Level 3 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of 2.8 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, as shown in Table 4.4.4-6. In 2030, the impact is low due primarily to the rate at which global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is large due not only to the climate sensitivity but also to the change in emissions. In 2030, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative is 0.001 to 0.002 °C (0.002 to 0.004 °F) across the climate sensitivities and global emissions scenarios, as shown in Table 4.4.4-9. The impact on global mean surface temperature due to assumptions concerning global emissions of GHG is also important. The scenarios with the higher global emissions of GHGs, such as the MiniCAM Reference, have a lower reduction in global mean surface temperature and the scenarios with lower global emissions have a higher reduction. This is in large part due to the non-linear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are high; therefore, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

The sensitivity of simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 4.4.4-6. Scenarios with lower climate sensitivities have lower increases in sea-level rise; the increase in sea-level rise is lower under the Preferred Alternative (Alternative 4) than it would be under scenarios with higher climate sensitivities. Conversely, scenarios with higher climate sensitivities have higher sea-level rise; the increase of sea-level rise is higher under the Preferred Alternative than it would be under scenarios with lower climate sensitivities. Higher global GHG emissions have higher sea-level rise, but the impact of the Preferred Alternative is less than in scenarios with lower global emissions. Conversely, scenarios with lower global GHG emissions have lower sea-level rise, though the impact of the Preferred Alternative is greater than in scenarios with higher global emissions.

Table 4.4.4-6

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives a/

Emissions Scenario	CAFE Alternative	Climate Sensitivity (°C for $2xCO_2$)	CO_2 concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)
			2030	2050	2100	2030	2050	2100	2100
MiniCAM Level 2									
	1 No Action	2.0	434.5	483.8	553.5	0.613	0.989	1.555	22.40
		3.0	436.0	487.3	565.9	0.813	1.327	2.189	30.03
		4.5	437.6	491.3	581.3	1.035	1.709	2.963	38.88
	4 Preferred	2.0	434.3	482.9	550.9	0.612	0.986	1.545	22.31
		3.0	435.7	486.4	563.1	0.812	1.323	2.175	29.91
		4.5	437.3	490.4	578.5	1.033	1.704	2.946	38.74
	Reduction compared to No Action								
		2.0	0.2	0.9	2.6	0.001	0.003	0.010	0.09
		3.0	0.3	0.9	2.8	0.001	0.004	0.014	0.12
		4.5	0.3	0.9	2.8	0.001	0.005	0.017	0.14
MiniCAM Level 3									
	1 No Action	2.0	437.3	494.5	643.4	0.607	0.990	1.888	24.68
		3.0	438.7	498.0	657.5	0.805	1.327	2.611	32.84
		4.5	440.3	502.0	675.2	1.024	1.706	3.475	42.24
	4 Preferred	2.0	437.0	493.7	640.6	0.606	0.987	1.879	24.59
		3.0	438.5	497.2	654.7	0.804	1.323	2.599	32.73
		4.5	440.0	501.2	672.2	1.023	1.701	3.459	42.10
	Reduction compared to No Action								
		2.0	0.3	0.8	2.8	0.001	0.003	0.009	0.09
		3.0	0.2	0.8	2.8	0.001	0.004	0.012	0.11
		4.5	0.3	0.8	3.0	0.001	0.005	0.015	0.14
MiniCAM Reference									
	1 No Action	2.0	440.2	510.7	765.1	0.699	1.168	2.292	28.68
		3.0	441.8	514.8	783.0	0.923	1.557	3.136	38.00
		4.5	443.6	519.5	805.3	1.168	1.991	4.132	48.67
	4 Preferred	2.0	439.9	509.9	762.2	0.698	1.165	2.284	28.60
		3.0	441.5	514.0	780	0.922	1.553	3.124	37.90
		4.5	443.3	518.7	802.2	1.166	1.987	4.118	48.54
	Reduction compared to No Action								
		2.0	0.3	0.8	2.9	0.001	0.003	0.008	0.08
		3.0	0.3	0.8	3.0	0.001	0.004	0.011	0.10
		4.5	0.3	0.8	3.1	0.002	0.005	0.014	0.13

a/ The numbers in this table have been rounded for presentation purposes. Therefore, the reductions might not reflect the exact difference of the values in all cases.

4.5 HEALTH, SOCIETAL, AND ENVIRONMENTAL IMPACTS OF CLIMATE CHANGE

4.5.1 Introduction

The effects of the proposed action and alternatives on climate as described in Section 4.4 – CO_2 concentrations, temperature, precipitation, and sea-level rise – can translate to impacts to key natural and human resources. Section 4.5.2 describes the methodology NHTSA used to evaluate the cumulative impacts stemming from climate change on key natural and human resources. Sections 4.5.3 through 4.5.8 address cumulative impacts to the following key natural and human resources:

- Freshwater resources (the availability, practices, and vulnerabilities of freshwater as a function of climate);
- Terrestrial and freshwater ecosystems (existing and potential vulnerabilities and benefits of the respective species and communities in response to climate change);
- Marine, coastal systems, and low-lying areas (the interplay between climate, environment, species, and communities within coastal and open-ocean waters, including coastal wetlands and coastal human settlements);
- Food, fiber, and forest products (the environmental vulnerabilities of farming, forestry, and fisheries that could be affected by climate change);
- Industries, settlements, and society (covers a broad range of human institutions and systems, including industrial and service sectors; large and small urban areas and rural communities; transportation systems; energy production; and financial, cultural, and social institutions in the context of how these elements might be affected by climate change; and
- Human health (how a changing climate might affect human mortality and morbidity).

Each section discusses the affected environment, provides an overview of the resource within the U.S. and globally, and addresses the consequences and observed changes of climate change on that resource. The section also includes a discussion of both the beneficial and adverse consequences of climate change, as they are represented in the literature. Although the approach is systematic, these topics do not exist in isolation and there is some overlap between discussions.

The sections generally follow the organization of topic areas in the climate literature, notably by IPCC, which is a key source for much of the information presented in this section, and by EPA and CCSP. These categories do not follow the classification of resources typically found in an EIS. *See* the chart in Section 4.1 to find where specific NEPA topics are covered.

As shown in Section 4.4, although the alternatives could substantially decrease GHG emissions, they would not prevent climate change; instead they would result in reductions to the anticipated increases of global CO_2 concentrations, temperature, precipitation, and sea level. NHTSA's assumption is that these reductions in climate effects would be reflected in reduced impacts to affected resources. However, the magnitude of the changes in climate effects that the alternatives would produce – 4 ppm of CO_2, a few hundredths of a degree Centigrade difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 millimeters of sea-level rise, *see* Section 4.4.4 – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions could be important – very small percentages of huge numbers can yield substantial results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives; rather it provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change. [19]

4.5.2 Methodology

This document primarily draws upon panel-reviewed synthesis and assessment reports from the IPCC and U.S. Global Change Research Program (USGCRP). It also cites EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* – which heavily relied on these panel reports. NHTSA similarly relies on panel reports because they have assessed numerous individual studies in order to draw general conclusions about the state of science; have been reviewed and formally accepted by, commissioned by, or in some cases authored by, U.S. government agencies and individual government scientists and provide NHTSA with assurances that this material has been well vetted by both the climate change research community and by the U.S. government; and in many cases, they reflect and convey the consensus conclusions of expert authors. These reports therefore provide the overall scientific foundation for U.S. climate policy at this time.

This document also refers to new peer-reviewed literature that has not been assessed or synthesized by an expert panel. This new literature supplements but does not supersede the findings of the panel-reviewed reports.

NHTSA's consideration of newer studies and highlighting of particular issues responds to previous public comments received on the scoping document and the prior EIS for the MY 2011 CAFE standard, as well as the Ninth Circuit's decision in *CBD v. NHTSA*, 538 F.3d 1172 (9th Cir. 2008). The level of detail regarding the science of climate change in this draft EIS, and NHTSA's consideration of other studies that show illustrative research findings pertaining to the potential impacts of climate change on health, society, and the environment, are provided to help inform the public and the decisionmaker, consistent with the agency's approach in the prior EIS for the MY 2011 CAFE standards.

NHTSA compiled research on freshwater resources; terrestrial and freshwater ecosystems and biodiversity; marine, coastal, and low-lying areas; industry, settlement, and society; food, fiber, and forest products; and human health. Each section includes an introduction and addresses the impacts anticipated for both the United States and the global environment.

To accurately reflect the likelihood of climate-change impacts for each sector, NHTSA referenced the IPCC uncertainty guidelines (*see* Section 4.4.1.1 and Section 4.5.2.2). This approach provided a consistent methodology to define confidence levels and percent probability of a predicted outcome or impact. More information on the uncertainty guidelines is provided in the *Treatment of Uncertainties in the IPCC's Working Group II Assessment* in Solomon *et al.* (2007). Section 4.5.2.2 summarizes the IPCC treatment of uncertainty.

4.5.2.1 Cumulative Climate-change Impacts

As described in Chapter 3, the proposed action and alternatives result in different periods of CO_2 emissions associated with the operation of U.S. vehicles. These emissions, in combination with U.S.

[19] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ (1984) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

GHG emissions from other sources (such as power plants, natural gas use, and agricultural production) and with emissions of all GHGs globally, would alter atmospheric concentrations of GHGs. As the modeling results presented in Section 4.4 show, different atmospheric concentrations of GHGs will be associated with long-term changes in global climate variables, including global average temperature, precipitation, and rising sea level. In turn, these climate changes would result in changes to a range of natural and human resources and systems, including water supplies, human health, the built environment, and a host of others.

The most common approach to assessing the impacts of climate change is to construct future scenarios that represent combinations of changes in levels, and sometimes patterns or variability, of temperature, precipitation, sea-level rise, and other relevant climatic and related variables (IPCC 2007b). In some cases these scenarios will represent the results of specific climate modeling (the output of General Circulation Models), often downscaled to provide results at a finer level of geographic resolution. In other cases, scenarios might be designed to be representative of the *types* and *ranges* of effects expected to occur under climate change, and not the results of specific models (Parson *et al.* 2007). Impacts associated with these scenarios are then estimated using a variety of techniques, including models of individual systems (specific ecosystems or geographic areas, such as a park) and examination of performance under similar historical conditions.

Climate impacts literature suggests that some regions and sectors will likely experience positive effects of future climate change, particularly at lower levels of temperature change (less than 1 to 3 °C [1.8 to 5.4 degrees Fahrenheit {°F} above 1990 levels), while others will experience negative effects (IPCC 2007b). The IPCC WGII for the Fourth Assessment Report found that, at higher levels of temperature, on balance the net global effects are expected to be negative: "while developing countries are expected to experience larger percentage losses, global mean losses could be 1 to 5 percent GDP for 4 °C [7.2 °F] of warming" (IPCC 2007b). The modeling results presented in Section 4.4 suggest that, for the CAFE alternatives, the cumulative climate effects in terms of temperature rise under a moderate emissions scenario lie in the range of 2.59 to 2.61 °C (4.66 to 4.70 °F) as of 2100.

NHTSA's presumption, consistent with the general literature cited above and reviewed for Section 4.5, is that reducing emissions and concomitant climate effects will reduce the net negative long-term effects that have been projected for climate change. NHTSA has not, however, performed a quantitative comparison of the climate impacts of the alternative CAFE standards on individual resource areas, for several reasons.

First, as indicated above, analyses of impacts often focus on discrete climate scenarios, rather than a continuum of climate outcomes; the information to analyze small changes in climate variables is not, therefore, generally available in the literature. Moreover, as the global climate changes, so will regional and local climates. Changes in global climate variables will be reflected in regional and local changes in average climate variables, and in the variability and patterns of climate, such as seasonal and annual variations, the frequency and intensity of extreme events, and other physical changes, such as the timing and amount of snowmelt. Impacts assessments often rely on highly localized data for both climate and other conditions and circumstances (CCSP 2008d). Thus, changes in impacts due to changes in global average climate, as projected in this analysis, likely will not be adequately represented by a simple scaling of results. Where information in the analysis included in the EIS is incomplete or unavailable, the agency has relied on CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). Information on the effect of very small changes in temperature, precipitation, and sea-level rise (at the scale of the distinctions among the alternative CAFE standards) is not currently available. Nevertheless, NHTSA's qualitative characterization – that the greater the reductions in GHG emissions, the lower the environmental impact – is consistent with theoretical approaches and research methods generally accepted in the scientific community.

Second, there is considerable debate about the likely shape of a global climate impacts damage function. Although many believe the function to be upwardly sloped (so that marginal net damages increase with increasing levels of climate change), fewer agree on its shape, that is, how *rapidly* net climate damages increase as temperature and other variables increase (IPCC 2007b). There is also the important question of whether there are thresholds, that is, stress points at which ecosystems collapse or the negative impacts rapidly accelerate – a topic important enough to warrant attention in a SAP Report for which the USGS is the lead agency (CCSP 2009c). Finally, much of the work on impacts – both global and more localized – is, in and of itself, qualitative and so does not lend itself to further quantification.[20]

4.5.2.2 Treatment of Uncertainties in the Working Group I Assessment

Uncertainties can be classified in several different ways. "Value uncertainties" and "structural uncertainties" are two primary types of uncertainties. When data are inaccurate or do not fully represent the phenomenon of interest, value uncertainties arise. These types of uncertainties are typically estimated with statistical techniques, and then expressed probabilistically. An incomplete understanding of the process that controls particular values or results generates structural uncertainties. These types of uncertainties are described by presenting the authors' collective judgment of their confidence in the correctness of a result. As stated in the WGI assessment, a "careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results" are drawn in the uncertainty guidance provided for the Fourth Assessment Report.

The standard terms used to define levels of confidence are:

Confidence Terminology	Degree of Confidence in Being Correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

The standard terms used to define the likelihood of an outcome or result where the outcome or result can be estimated probabilistically are:

Likelihood Terminology	Likelihood of the Occurrence/Outcome
Virtually certain	Greater than 99% probability
Extremely likely	Greater than 95% probability
Very likely	Greater than 90% probability
Likely	Greater than 66% probability
More likely than not	Greater than 50% probability
About as likely as not	33 to 66% probability
Unlikely	Less than 33% probability
Very unlikely	Less than 10% probability
Extremely unlikely	Less than 5% probability
Exceptionally unlikely	Less than 1% probability

[20] NHTSA's qualitative discussion of these impacts also does not attempt to analyze the consequences that these impacts may have in terms of economic impacts stemming from the differential abilities that different populations may have to adapt to the consequences resulting from climate change. The ability to adapt will vary with sector, country, and how sudden or disruptive the impact.

4.5.3 Freshwater Resources

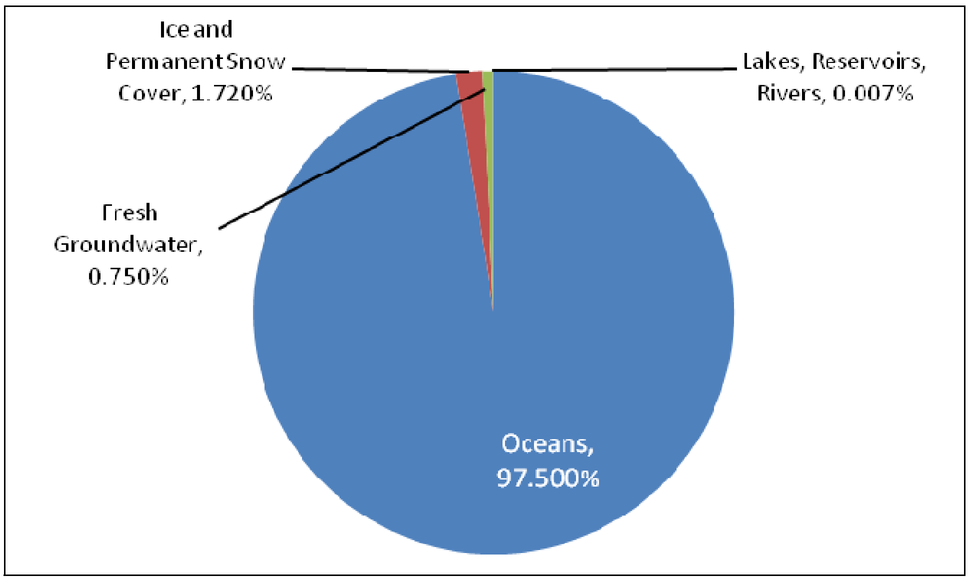
In 2008, IPCC concluded that "Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems" (Bates *et al.* 2008). In the United States, according to EPA (2009b), the vulnerability of these resources varies regionally. This section summarizes current global and U.S. observations of freshwater resources and the most recent projections of future changes.

4.5.3.1 Affected Environment

4.5.3.1.1 Freshwater Systems and Storage

Without water, there would be no life on Earth. Climate change implications for water resources are therefore of fundamental interest. As seen in Figure 4.5.3-1, water covers about 70 percent of Earth's surface, and most of this water (97.5 percent) is contained in the oceans. The remaining 2.5 percent is fresh water, most of which (68.7 percent) is ice and permanent snow cover in the Antarctic, the Arctic, and mountainous regions. Another 29.9 percent is fresh groundwater. Only 0.26 percent of the total amount of fresh water is contained in lakes, reservoirs, and river systems (UNESCO 2003).

Figure 4.5.3-1. Global Allocation of Water



The largest volume of fresh water is stored in the cryosphere, and consists of snow, glaciers, ice, and frozen ground. Most glaciers and ice sheets are found in Antarctica (almost 90 percent), with the remainder found in Greenland (almost 10 percent) and in mountain glaciers. Permafrost extends over northeastern Europe and the northern and northeastern parts of Asia, including the Arctic islands, northern Canada, the fringes of Greenland and Antarctica, and the high-altitude areas of South America (UNESCO 2003).

Groundwater occurs in the pores of soils and fractures of rocks and is the second largest source of fresh water. Groundwater feeds springs, streams, and lakes; supports wetlands; and is a critical source of water for human consumption. Groundwater also includes aquifers, underground strata of water-bearing permeable rock or unconsolidated materials (sand, gravel, and some silts and clays) from which water is extracted by well systems (UNESCO 2003).

Lakes, which can be broadly defined as bodies of water collected in depressions in Earth's surface, are widespread and numerous (there are approximately 15 million) and store the largest volume of fresh surface waters. Reservoirs – human-made lakes – are constructed for the storage of water, and are typically created by damming a river channel in a valley (UNESCO 2003).

Rivers are bodies of flowing water that drain surface runoff from land to the seas and oceans. They begin in higher elevations such as mountains and hills where rainwater and snowmelt collect, forming small tributary streams that flow into larger streams and rivers (UNESCO 2003).

4.5.3.1.2 Non-climate Threats to Freshwater Resources

Freshwater resources during recent decades are threatened by non-climatic and climatic drivers. The non-climate threats include population growth and economic development, which create increasing demands for water from the residential, industrial, municipal, and agricultural sectors. In particular, irrigation of agricultural lands accounts for nearly 70 percent of global freshwater withdrawals and for more than 90 percent of global consumptive use (Bates *et al*. 2008). The extent of irrigated areas, which is expected to expand in areas that are already water-stressed, will determine the effect that this use will have on global water use in the future (EPA 2009b, Bates *et al*. 2008, Kundzewicz *et al*. 2007a).

Other pressures on freshwater resources include infrastructure development (dams, dikes, levees, and river diversions); poor land use (urbanization, conversion to crop or grazing lands, wetland removal or reduction, and deforestation); overexploitation (groundwater aquifer depletion and reduced water levels in lakes, rivers, and wetlands); water pollution from industrial, municipal, and agricultural sources (pathogens and microbial contaminants, pesticides, phosphorus and nitrogen from fertilizers, heavy metals, toxic organic compounds and microorganic pollutants); silt and suspended particles (from soil erosion); acidification (from air pollution); and thermal pollution (from industrial discharges and slow flows caused by dams and reservoirs) (EPA 2009b, Bates *et al*. 2008, Kundzewicz *et al*. 2007a).

4.5.3.2 Environmental Consequences

Although there will be water-supply increases in some areas and decreases in others, there will be an overall net negative impact of climate change on water resources and freshwater ecosystems worldwide. The effects of climate change on freshwater resources will exacerbate the impacts of other stressors, such as increases in population growth, economic activity, land-use change, and urbanization. In some areas, including regions as diverse as the Rhine basin, southeastern Michigan, Pennsylvania, and central Ethiopia, models project that land-use change will have a small effect compared to climate change (Kundzewicz *et al*. 2007a).

Areas in which runoff is projected to decline are likely to face a reduction in the value of the services provided by freshwater resources. The beneficial impacts of increased annual runoff in other areas will be offset to some extent by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (EPA 2009b).

Chemical and microbial inputs, biogeochemical processes, water temperature, and water levels control water quality. Climate changes can affect water quality from increases in temperature or through changes in precipitation and water quantity. Negative impacts from water temperature increases include algal blooms, increased microbial concentrations, and out-gassing of volatile and semi-volatile compounds like ammonia, mercury, dioxins, and pesticides (EPA 2009b). Negative impacts on water quality from changes in water quantity include resuspension of bottom sediments, increased turbidity (suspended solids), pollutant introduction, and reduced dilution. Increased stream flow can dilute pollutant concentrations or transport additional pollutants into surface-water sources, while extreme events – floods and droughts – generally exacerbate water quality problems (EPA 2009b).

In general, consequences of changes in snow, ice, and frozen ground (including permafrost) include (Rosenzweig *et al*. 2007):

- Ground instability in permafrost regions;
- A shorter travel season for vehicles over frozen roads in the Arctic;
- Increase in the number and size of glacial lakes in mountain regions;
- Destabilization of moraines damming glacial lakes;
- Changes in Arctic and Antarctic Peninsula flora and fauna;
- Limitations on mountain sports in lower-elevation alpine areas; and
- Changes in indigenous livelihoods in the Arctic.

4.5.3.2.1 Observed Impacts of Climate Change on Freshwater Resources in the United States

Precipitation and Stream Flow

Conditions across the United States tend to be increasingly dry from east to west. Upslope areas in the Cascade and coastal mountain ranges are more humid, with relatively low precipitation variability. The Intermountain West and Southwest are driest, and the greatest precipitation variability is in the arid and semi-arid West (EPA 2009b, Lettenmaier *et al.* 2008). Stream gauge data show increases in stream flow from 1939 through 1998 in the eastern United States (Mauget 2003 in Lettenmeier *et al.* 2008) and a more or less reverse pattern in the western United States (Lettenmaier *et al.* 2008a, National Science and Technology Council 2008). Stream flow in the eastern United States has increased 25 percent in the past 60 years, and has decreased by about 2 percent per decade in the central Rocky Mountain region over the past century (EPA 2009b). Since 1950, stream discharge in both the Colorado and Columbia River Basins has decreased, while over the same period annual evapotranspiration from the conterminous United States increased by 55mm (2.2 inches) (Walter *et al.* 2004).

The observed impacts to precipitation and streamflow also include:

- In regions with winter snow, warming has shifted the magnitude and timing of hydrologic events (Mote *et al.* 2005, Regonda *et al.* 2005, Stewart *et al.* 2005 in National Science and Technology Council 2008). From 1949 to 2004, the fraction of annual precipitation falling as rain (rather than snow) increased at 74 percent of the weather stations studied in the western mountains of the United States (EPA 2009b).
- Streamflow peaks in the snowmelt-dominated western mountains of the United States occurred 1 to 4 weeks earlier in 2002 than in 1948 (Stewart *et al.* 2005 in National Science and Technology Council 2008).
- Precipitation in the Arctic has increased 8 percent on average over the past century. Much of that increase has occurred as rain (EPA 2009b).

Precipitation variability and subsequent surface-water availability vary regionally across the United States depending on a catchment's (watershed) physical, hydrological, and geological characteristics (National Science and Technology Council 2008). EPA has identified the Great Lakes, Chesapeake Bay, Gulf of Mexico, and Columbia River Basin as large water bodies for which climate change is a particular concern (EPA 2009b).

The IPCC Fourth Assessment Report summarized the current precipitation and water supply trends in the United States as follows (EPA 2009b):

- Annual precipitation has increased throughout most of North America.
- Stream flow has increased in the eastern United States in the last 60 years, but has decreased in the central Rocky Mountain region over the last century.
- Since 1950, stream discharge in both the Colorado and Columbia River basins has decreased.
- In regions with winter snow, warming has shifted the magnitude and timing of hydrologic events.
- The fraction of annual precipitation falling as rain (rather than snow) increased at 74 percent of the weather stations studied in the western mountains of the United States from 1949 through 2004.

Snow Cover

There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks across much of the western United States. Evidence suggests this trend is *very likely* attributable, at least in part, to long-term warming, although decadal-scale variability, including a shift in Pacific Decadal Oscillation (PDO) in the 1970s, might have played some part. Where shifts to earlier snowmelt peaks and reduced summer and fall low flows have already been detected, continuing shifts in this direction are expected and could have substantial impacts on the performance of reservoir systems (EPA 2009b).

Snowpack in the mountainous headwater regions of the western United States generally declined over the second half of the 20^{th} Century, especially at lower elevations and in locations where average winter temperatures are close to or above 0^{o}C (32 °F). These trends toward reduced winter snow accumulation and earlier spring melt are also reflected in a tendency toward earlier runoff peaks in spring, a shift that has not occurred in rainfall-dominated watersheds in the same region (Lettenmaier *et al.* 2008b in National Science and Technology Council 2008).

Spring and summer snow cover has decreased in the western United States (Groisman *et al.* 2004). April snow water equivalent has declined 15 to 30 percent since 1950 in the western mountains of North America, particularly at lower elevations and primarily due to warming rather than changes in precipitation (Mote *et al.* 2003, 2005 and Lemke *et al.* 2007b, all in National Science and Technology Council 2008). Additionally, the break-up of river and lake ice in North America is now occurring earlier, with an advance of 0.2 to 12.9 days over the last century (EPA 2009b).

Groundwater

The effects of climate on groundwater – especially groundwater recharge – is a topic that requires further research to determine current effects from climate change. The available literature (Vaccaro 1992, Loaiciga *et al.* 2000, Hanson and Dettinger 2005, Scibek and Allen 2006, Gurdak *et al.* 2007, all in Lettenmaier *et al.* 2008) implies that groundwater systems generally respond more slowly to climate change than do surface-water. However, a 2.5 °C (4.5 °F) or greater warming scenario is projected to decrease the recharge of the Ogallala aquifer region by 20 percent (EPA 2009b).

Groundwater levels correlate most strongly with precipitation. Temperature is a more important factor for shallow aquifers during warm periods (National Science and Technology Council 2008).

Groundwater and surface water might also be affected by sea-level rise. Saltwater intrusion into aquifers might occur in coastal areas, and increased salinity of ground and estuary water might reduce freshwater availability.

Water Quality

Chemical and microbial inputs, biogeochemical processes, water temperature, and water levels control water quality. Water temperature and water quantity are sensitive to climate change. However, pollution from land use – especially agricultural runoff, urban runoff, and thermal pollution from energy production – have caused most of the observed changes in water quality (National Science and Technology Council 2008).

Rising water temperatures negatively affect aquatic biota, especially certain fish species such as salmon (Bartholow 2005, Crozier and Zabel 2006, both in Lettenmaier *et al.* 2008). Rising temperatures also affect dissolved oxygen, oxidation/reduction potentials, lake stratification, and mixing rates. However, the direction of climate change effects associated with water quantity on water quality is not as evident. Increased streamflow can dilute pollutant concentrations or transport additional pollutants into surface water sources. Extreme events – floods and droughts – generally exacerbate water quality problems.

Extreme Events – Floods and Drought

Extreme events such as floods and drought affect freshwater resources. Climatic phenomena (intense/long-lasting precipitation, snowmelt, ice jams) and non-climatic phenomena (dam failure, landslides) can exacerbate floods and drought.

As previously mentioned, research to date has not provided clear evidence for a climate-related trend in floods during past decades. However, evidence suggests that the observed increase in precipitation intensity and other observed climate changes could have affected floods (National Science and Technology Council 2008).

There is some evidence of long-term drying and increase in drought severity and duration in the West and Southwest (National Science and Technology Council 2008) that is probably a result of decadal-scale climate variability and long-term change (EPA 2009b).

Over-allocation and continuing competition for freshwater resources for agriculture, cities, and industry increases vulnerability to extended drought in North America (EPA 2009b), despite the fact that per-capita water consumption has declined over the past 2 decades in the United States (Lettenmaier *et al.* 2008a).

4.5.3.2.2 Globally Observed Impacts of Climate Change on Freshwater Resources

Trends associated with climate change have already been observed in various inputs, throughputs, and outputs to the global freshwater system, including (Kundzewicz *et al.* 2007a):

- Precipitation – increasing over northern (30 degrees north) latitudes, decreasing over middle (10 degrees south to 30 degrees north) latitudes, increasing in intensity;
- Stream flow – increasing in Eurasian Arctic, measurable increases or decreases in some river basins, earlier spring peak flows and increased winter-based flows in North America and Eurasia;

- Evapotranspiration – increased actual evapotranspiration in some areas;
- Lakes – warming, substantial increases and decreases in some lake levels, and reduction in ice cover;
- Snow cover – decreasing in most regions;
- Glaciers – decreasing almost everywhere; and
- Permafrost – thawing between 0.08 inch per year (Alaska) and 1.8 inches per year (Tibetan plateau).

For other anticipated changes in the freshwater system, data are often insufficient to observe a climate trend, especially when compared to the non-climatic pressures mentioned previously. The lack of an observed trend does not necessarily indicate a lack of sensitivity to climate change. The current hydrologic observing system was not designed specifically for detecting the effects of climate change on water resources (Lettenmaier *et al.* 2008a). In addition, there are large-scale climate variations, such as ENSO events, occurring at the same time as global and regional climate changes. For these reasons, it can be difficult to detect a climate change signal within the climate variability without observations of a decade or longer (Rosenzweig *et al*. 2007).

Snow Cover and Frozen Regions

Temperature increases lead to declines in snow cover, and where most of winter precipitation currently falls as snow, hydrologic impact studies have shown that warming leads to changes in the seasonality of river flows. Areas vulnerable to these changes include the European Alps, the Himalayas, western North America, central North America, eastern North America, the Russian territory, Scandinavia, and Baltic regions (Kundzewicz *et al.* 2007a).

Precipitation is also an important driver of changes in snow cover. At high elevations that remain below freezing in winter, precipitation increases have resulted in increased snowpack. Warmer temperatures at mid-elevations have decreased snowpack and led to earlier snowmelt, even with precipitation increases (Kundzewicz *et al*. 2007a). An empirical analysis of available data indicated that both temperature and precipitation impact mountain snowpack simultaneously, with the nature of the impact strongly dependent on factors such as geographic location, latitude, and elevation (Stewart 2009).

Global warming is increasing glacier melt worldwide and decreasing snow cover in most regions. More than one-sixth of the world's population lives in glacier- or snowmelt-fed river basins and will be affected by a seasonal shift in stream flow, an increase in the ratio of winter to annual flows, and a reduction in low flows caused by decreased glacier extent or snow water storage (Kundzewicz *et al.* 2007a).

Glacier melt sustains many rivers during summer in the Hindu Kush Himalaya and the South American Andes (Singh and Kumar 1997, Mark and Seltzer 2003, Singh 2003, Barnett *et al.* 2005 in Kundzewicz *et al.* 2007,). The mass of some northern hemisphere glaciers is projected to decrease up to 60 percent by 2050 (Schneeberger *et al.* 2003 in Kundzewicz *et al.* 2007).

From 2010 to 2015, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it did from 1950 to 1979. The maximum ice cover is also expected to be 20 to 40 percent thinner (Vuglinsky and Gronskaya 2005 in Kundzewicz *et al.* 2007).

Permafrost is thawing in many regions, with variations among regions in the degree of thawing. In Alaska, permafrost is declining 0.08 inch per year, while permafrost melting is 1.8 inches per year on the Tibetan plateau (Kundzewicz *et al.* 2007a).

Surface Waters

A recent analysis of streamflow records for 925 of the world's largest ocean-discharging rivers from 1948 through 2004 indicated significant trends for about one-third of the top 200 rivers. There were significant downward trends in annual streamflow in low- and mid-altitude regions, consistent with the general drying trend over global lands for the past half-century, whereas there was a large upward trend for annual discharge into the Arctic Ocean. The data also indicated that ENSO events are important for rivers discharging into the Atlantic, Pacific, Indian and global oceans as a whole, but not for the Arctic Ocean and the Mediterranean and Black Seas. Significantly, the effect of human activities on annual stream flow and streamflow trends was found to be small for most of the world's large rivers compared to the influence of climate change (Dai *et al*. 2009).

Climate models consistently project precipitation increases in high latitudes and parts of the tropics, and decreases in lower mid-latitude regions (Milly *et al*. 2005c, Nohara *et al*. 2006 in Ebi *et al.* 2008). Projections for the area in between remain highly uncertain (Kundzewicz *et al*. 2007a). Data from 24 climate model runs generated by 12 different general circulation models generally agreed that by 2050 annual average river runoff and water availability will increase by 10 to 40 percent at high latitudes (North America, Eurasia) and in some wet tropical areas, and decrease by 10 to 30 percent over some dry regions at mid-latitudes and in the dry tropics (Milly *et al.* 2005a).

Semi-arid and arid areas are particularly vulnerable to precipitation declines. Many of these areas are water stressed, including the Mediterranean, southern Africa, and northeastern Brazil. In southeastern Australia and southern India, climate change has the potential to exacerbate reductions in runoff caused by forestation (Bates *et al*. 2008, Kundzewicz *et al.* 2007a).

In snow-dominated basins, where most precipitation occurs in winter in the form of snow, it is projected that winter snows will be reduced and snowmelt will occur earlier, resulting in reduced spring runoff and summer flows (Bates *et al*. 2008). Projections for rain-fed basins describe higher flows in the peak-flow season, with either lower flows in low-flow seasons or extended dry periods (Kundzewicz *et al.* 2007a).

Water Quality

A brief overview of the effects of climate change on the availability and quality of drinking water is provided by Epstein *et al.* (2005). Many countries are experiencing water-quality issues in their water and wastewater treatment plants. Increased filtration is required in drinking water plants to address microorganism outbreaks following intense rain, thus increasing some operating costs by 20 to 30 percent (AWWA 2006 in Kundzewicz 2007). Other stressors on water quality noted by the IPCC include (Kundzewicz *et al.* 2007a):

- More water impoundments for hydropower (Kennish 2002 in Kundzewicz *et al.* 2007, Environment Canada 2004 in Fischlin *et al.* 2007);
- Stormwater drainage operation and sewage disposal disturbances in coastal areas resulting from sea-level rise (Haines *et al.* 2000);
- Increasing water withdrawals from low-quality sources;

- Greater pollutant loads resulting from increased infiltration rates to aquifers or higher runoff to surface waters (resulting from high precipitation);
- Water infrastructure malfunctioning during floods (GEO-LAC 2003); and
- Increased amounts of polluted storm water.

Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate existing water pollution, with impacts on ecosystems, human health, water system reliability, and operating costs. Pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt, and thermal pollution. Rising temperatures also have adverse effects on dissolved oxygen levels, oxidation/reduction potentials, and lake stratification and mixing rates (EPA 2009b, Kundzewicz *et al.* 2007a).

4.5.3.2.3 Projected Impacts of Climate Change on Freshwater Resources in the United States

Most freshwater resource analyses are keyed either to climate scenarios (what happens if temperature increases by 6 °F and precipitation declines by 10 percent) or to global climate model outputs pegged to IPCC-reported emission scenarios. This section summarizes the projected impacts resulting from such analyses, current sensitivities, and potential vulnerabilities (including extreme events).

The climate-change impacts on freshwater resources in the United States are described by National Science and Technology Council (2008), Lettenmaier *et al.* (2008a), and Field *et al.* (2007a). "In regards to the hydrologic observing systems on which these sections are based, Lettenmaier *et al.* (2008a) found that the current hydrologic observing system was not designed specifically for the purpose of detecting the effects of climate change on water resources. In many cases, the resulting data are unable to meet the predictive challenges of a rapidly changing climate" (National Science and Technology Council 2008).

Precipitation

Recent climate model simulations reported by the IPCC indicate that, in general, current patterns will continue, with increases in runoff over the eastern United States, gradually transitioning to little change in the Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior West (Colorado and Great Basin) (Bates *et al*. 2008, Kundzewicz *et al*. 2007a). Many areas in the western and southwestern United States already stressed are expected to suffer from additional decreases in precipitation and runoff from future climate changes (EPA 2009b). In eastern North America, meanwhile, precipitation may increase. Under a mid-range scenario, daily precipitation so heavy that it now occurs only every 20 years is likely to occur every 8 years by 2100 (EPA 2009b).

Additionally, several recent state and regional studies have examined specific climate-change impacts on freshwater resources. For example, many impacts on freshwater resources described above have been projected for New Jersey (EPA 1997). "Projections for the western mountains of the United States suggest that warming, and changes in the form, timing, and amount of precipitation will *very likely* lead to earlier melting and significant reductions in snowpack by the middle of the 21st Century (*high confidence*). In mountainous snowmelt-dominated watersheds, projections suggest advances in the timing of snowmelt runoff, increases in winter and early spring flows (raising flooding potential), and substantially decreased summer flows. Heavily utilized water systems of the western United States that rely on capturing snowmelt runoff, such as the Columbia River system, will be especially vulnerable" (Field *et al.* 2007b in National Science and Technology Council 2008).

Although uncertainties in climate model projections of precipitation changes make future projections of stream flow uncertain, watersheds dominated by spring and summer snowmelt are an exception. In mountainous snowmelt-dominated watersheds, projections suggest advances in the timing of snowmelt runoff, increases in winter and early spring flows (raising flooding potential), and substantially decreased summer flows (Stewart 2009).

Snowpack

Trends in declining snowpack are perhaps best illustrated from studies conducted for California. Reduced snowpack has been identified as a major concern for the State (California Energy Commission 2006 in National Science and Technology Council 2008). Several authors anticipate a coming crisis in water supply for the western United States (Barnett *et al.* 2008), and have projected that Lake Mead (on the Colorado River system) might go dry (Barnett and Pierce 2008 in CCSP 2008). While these studies focus on issues already identified in the literature, their findings suggest that freshwater resources might be more sensitive to climate change than previously projected. A recent article by Rauscher *et al.* (2008) used a high-resolution nested climate model to investigate future changes in snowmelt-driven runoff over the western United States and modeled increases in seasonal temperature of approximately 3 to 5 °C (5.4 to 9 °F) by 2100, which could cause snowmelt-driven runoff to occur as much as 2 months earlier than at present – twice as early as other projections – affecting reservoir water storage and hydroelectric generation, and impacting land use, agriculture, and water management.

In the western United States, where water supplies are already strained, continuing shifts toward drier conditions will have significant implications for water supplies and water management (Brekke *et al*. 2009, Lettenmaier *et al.* 2008a). Projections for the western mountains of the United States suggest that warming, and changes in the form, timing, and amount of precipitation will very likely lead to earlier melting and significant reductions in snowpack by the middle of the 21st Century. Heavily utilized water systems of the western United States that rely on capturing snowmelt runoff, such as the Columbia River system, will be especially vulnerable (EPA 2009b).

Snowpack is also decreasing in Alaska. Snow cover in that area is expected to decrease 10 to 20 percent by the 2070s (EPA 2009b).

Groundwater

Future groundwater supplies will depend on both climate-related changes in recharge rates and withdrawals for human uses. Many parts of the United States depend on groundwater supplies for drinking water, irrigating agriculture, and a variety of residential uses, and increased demands due to population growth, increased temperature, and reduced precipitation could draw down groundwater supplies faster than it can be recharged (GCRP 2009). In arid and semi-arid regions, groundwater supplies are more vulnerable than elsewhere, and in some areas it might not be possible to rely on groundwater to make up declines in surface-water supplies resulting from climate change and other stressors. Projections for the Ogallala aquifer, for example, indicate a 20 percent decrease in groundwater recharge based on simulations of future warming using a number of different climate models (EPA 2009b).

Water Quality

Climate change will make achieving existing water quality goals more difficult. Historically, agricultural runoff, urban runoff, and thermal pollution from energy production have caused most of the observed changes in water quality in the United States (Kundzewicz *et al.* 2007a, The National Science and Technology Council 2008). EPA cites siltation, excess nutrients, and metals (*e.g.*, mercury) as the main pollutants in U.S. waters, primarily because of nonpoint source pollution from runoff from urban and agricultural lands (EPA 2000, EPA 2007).

Based on simulations, phosphorus remediation targets for the Bay of Quinte (Lake Ontario) and the surrounding watershed could be compromised as 5.4 to 7.2 °F warmer water temperatures contribute to 77 to 98 percent increases in summer phosphorus concentrations in the Bay (Nicholls 1999, in National Science and Technology Council 2008), and as changes in precipitation, streamflow, and erosion lead to increases in average phosphorus concentrations in streams of 25 to 35 percent (Walker 2001 in Field *et al.* 2007).

Projected impacts on water quality also include (National Science and Technology Council 2008):

- Changes in precipitation could increase nitrogen loads from rivers in the Chesapeake and Delaware Bay regions by up to 50 percent by 2030 (Kundzewicz *et al.* 2007a).
- Decreases in snow cover and increases in winter rain on bare soil will *likely* lengthen the erosion season and enhance erosion intensity. This will increase the potential for sediment-related water quality impacts in agricultural areas (Field *et al.* 2007a).
- Increased precipitation amounts and intensities will lead to greater rates of erosion in the United States and in other regions unless protection measures are taken (Kundzewicz *et al.* 2007a). Soil-management practices (crop residue, no-till) in some regions (*e.g.*, the Corn Belt) might not provide sufficient erosion protection against future intense precipitation and associated runoff (Field *et al.* 2007a).
- For the Midwest, simulations project that the low flows used to develop pollutant discharge limits (Total Maximum Daily Loads) would decrease by more than 60 percent were there to be a 25 percent decrease in mean precipitation; adding on irrigation demand, the effective decline is projected to reach 100 percent (Eheart *et al.* 1999 in National Science and Technology Council 2008).
- Based on simulations, phosphorus remediation targets for the Bay of Quinte (Lake Ontario) and the surrounding watershed could be compromised as 5.4 to 7.2 °F warmer water temperatures contribute to 77 to 98 percent increases in summer phosphorus concentrations in the Bay (Nicholls 1999 in National Science and Technology Council 2008), and as changes in precipitation, streamflow, and erosion lead to increases in average phosphorus concentrations in streams of 25 to 35 percent (Walker 2001 in Field *et al.* 2007).

Kundzewicz *et al.* (2007a) also concluded (*high confidence*) that climate change is *likely* to make achieving existing water quality goals for North America more difficult (National Science and Technology Council 2008).

Extreme Events – Floods and Drought

Climate change is expected to increase the frequency and intensity of extreme events such as floods and drought. Research to date has not provided clear evidence for a climate-related trend in floods in the United States during past decades. However, evidence suggests that the observed increase in precipitation intensity and other observed climate changes could have affected floods (National Science and Technology Council 2008). Climatic phenomena (intense/long-lasting precipitation, snowmelt, ice jams) and non-climatic phenomena (dam failure, landslides) can exacerbate floods and droughts. In the United States, the frequency of heavy precipitation events was at a minimum in the 1920s and 1930s, and then increased during most of the rest of the 20th Century (Field *et al*. 2007a).

Because the intensity and mean amount of precipitation is projected to increase across the United States at middle and high latitudes, the risk of flash flooding and urban flooding will increase in these areas (EPA 2009b). At the same time, greater temporal variability in precipitation increases the risk of drought (Christensen *et al.* 2007a). There is some evidence of long-term drying and increase in drought severity and duration in the West and Southwest (National Science and Technology Council 2008) that is probably a result of decadal-scale climate variability and long-term change (EPA 2009b).

Water Availability and Water Use

Regionally, the IPCC concluded that large changes in irrigation water demand are *likely* due to climate change (Kundzewicz *et al.* 2007a). Irrigation continues to be the largest use of water, accounting for 70 percent of global water use and 90 percent of consumptive use. Over-allocation and continuing competition for freshwater resources for agriculture, cities, and industry increases vulnerability to climate changes. Federal agencies have identified a number of areas, mostly in the western half of the United States, where there could be conflicts over growing water shortages in a changing climate (U.S. DOI 2005, Brekke *et al.* 2009). For example, in southern California, 41 percent of the water supply will be vulnerable by the 2020s due to loss of snowpack in the Sierra Nevada and Colorado River Basin (EPA 2009b).

4.5.3.2.4 Projected Impacts of Climate Change on Global Freshwater Resources

The IPCC report is the most recent, comprehensive, and peer-reviewed summary of impacts on global freshwater resources available. Kundzewicz *et al.* (2007a) summarized the conclusions from the freshwater resources and management chapter as follows:

- The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level, and precipitation variability (*very high confidence*).
- More than one-sixth of the world's population lives in glacier- or snowmelt-fed river basins and will be affected by the seasonal shift in streamflow, an increase in the ratio of winter to annual flows, and possibly the reduction in low flows caused by decreased glacier extent or snow-water storage (*high confidence*).
- Sea-level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas (*very high confidence*).
- Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas (*high confidence*).
- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (*high confidence*).
- Many of these areas (Mediterranean basin, western United States, southern Africa, and northeastern Brazil) will suffer a decrease in water resources due to climate change (*very high confidence*).
- Efforts to offset declining surface-water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed regions (*high confidence*), where vulnerability is often exacerbated by the rapid increase in population and water demand (*very high confidence*).

- Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water-system reliability, and operating costs (*high confidence*).
- These pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt, and thermal pollution.
- Climate change affects the function and operation of existing water infrastructure and water management practices (*very high confidence*).
- Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land use change, and urbanization (*very high confidence*).
- Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence; regionally, large changes in irrigation water demand as a result of climate change are *likely* (*high confidence*).
- Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems (*very high confidence*).
- Improved incorporation of current climate variability into water-related management would make adaptation to future climate change easier (*very high confidence*).
- Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (the Caribbean, Canada, Australia, Netherlands, United Kingdom, United States, and Germany) that have recognized projected hydrological changes with related uncertainties (*very high confidence*).
- Since the IPCC Third Assessment, uncertainties have been evaluated, their interpretation has improved, and new methods (*e.g.*, ensemble-based approaches) are being developed for their characterization (*very high confidence*).
- Nevertheless, quantitative projections of changes in precipitation, river flows, and water levels at the river-basin scale remain uncertain (*very high confidence*).
- The negative impacts of climate change on freshwater systems outweigh its benefits (*high confidence*).
- All IPCC regions (*see* Chapters 3 through 16 of the IPCC report) show an overall net negative impact of climate change on water resources and freshwater ecosystems (*high confidence*).
- Areas in which runoff is projected to decline are *likely* to face a reduction in the value of the services provided by water resources (*very high confidence*).
- The beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (*high confidence*).

Observed global climate-related trends affecting freshwater resources were identified previously. The following discussion identifies key projected impacts to surface waters, groundwater, extreme events, and water quality.

Surface Water

Data from 24 climate model runs generated by 12 different general circulation models (Milly *et al.* 2005b in Kundzewicz *et al.* 2007) generally agreed that by 2050:

- Annual average river runoff and water availability will increase by 10 to 40 percent at high latitudes (North America, Eurasia) and in some wet tropical areas.
- Annual average river runoff and water availability will decrease by 10 to 30 percent over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas (Mediterranean, southern Africa, and western United States/northern Mexico).

Hydrological impact studies have shown that warming leads to changes in the seasonality of river flows where much winter precipitation currently falls as snow, including the European Alps, the Himalayas, western North America, central North America, eastern North America, the Russian territory, Scandinavia, and Baltic regions. Winter flows will increase, summer flows will decrease, and peak flow will occur at least 1 month earlier in many cases (Kundzewicz *et al.* 2007a).

Higher temperatures increase glacier melt. Glacier melt sustains many rivers during summer in the Hindu Kush Himalaya and the South American Andes (Singh and Kumar 1997, Mark and Seltzer 2003, Singh 2003, Barnett *et al.* 2005, all in Kundzewicz *et al.* 2007). The mass of some northern hemisphere glaciers is projected to decrease up to 60 percent by 2050 (Schneeberger *et al.* 2003 in Kundzewicz *et al.* 2007).

Projections for rain-fed basins describe higher flows in peak-flow season with either lower flows in low-flow season or extended dry periods (Kundzewicz *et al.* 2007a).

Lake levels are determined by river and rain water inputs and evaporation outputs. By the end of the 21st Century, water levels are projected to change between −4.5 feet and +1.15 feet in the Great Lakes (Lofgren *et al.* 2002, Schwartz *et al.* 2004, both in Kundzewicz *et al.* 2007) and to drop about 29.5 feet in the Caspian Sea (Elguindi and Giorgi 2006 in Kundzewicz *et al.* 2007).

From 2010 to 2015, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it did from 1950 to 1979. The maximum ice cover is also expected to be 20 to 40 percent thinner (Vuglinsky and Gronskaya 2005 in Kundzewicz *et al.* 2007).

A combination of land-use changes and climate change could affect annual runoff. Land-use changes are projected by model studies to have a small effect compared to climate change in the Rhine basin, southeastern Michigan, Pennsylvania, and central Ethiopia. In southeastern Australia and southern India, projections are comparable, with climate change having the potential to exacerbate reductions in runoff caused by afforestation (Kundzewicz *et al.* 2007a).

Evapotranspiration (water loss from plant leaves) responds to increases in carbon dioxide in two distinct ways. First, higher CO_2 concentrations cause leaf stomata to close, reducing evapotranspiration. Second, CO_2 fertilization encourages plant growth, increasing total leaf area and subsequent evapotranspiration. Considering these vegetation effects, global mean runoff has been projected to increase by 5 percent for a doubling of CO_2 concentration (Betts *et al.* 2007, Leipprand and Gerten 2006, both in Kundzewicz *et al.* 2007) compared to a 5 to 17 percent increase under climate change alone (Kundzewicz *et al.* 2007a).

Small islands are especially vulnerable to future change in water availability. Most small islands already have limited availability of freshwater, and changes in their hydrologic cycle can pose serious threats for their water supply (EPA 2009b).

Groundwater

Climate change will mainly affect groundwater recharge rates, although very little research has been done on the issue. Groundwater levels could change as a result of thawing permafrost, vegetation changes, changes in river level (where hydraulic connection is adequate), and changes in floods. Global hydrological models project that globally averaged groundwater recharge will increase less (2 percent) than total runoff (9 percent) in the 2050s compared to recharge and runoff rates from 1961 to 1990. In northeastern Brazil and southwestern Africa, and along the southern Mediterranean coast, groundwater recharge is projected to decrease by more than 70 percent. In contrast, recharge is projected to increase by more than 30 percent in the Sahel, Near East, northern China, Siberia, and the western United States (Döll and Flörke 2005 in Kundzewicz *et al.* 2007). Projected impacts on individual aquifers return very site-specific results.

Any decrease in groundwater recharge will exacerbate the effect of saltwater intrusion. Saltwater intrusion has been projected for a sea-level rise of 0.33 foot on two coral islands off the Indian coast – the thickness of the freshwater lens decreasing from 82 feet to 32 feet and from 118 feet to 92 feet (Bobba *et al.* 2000 in Kundzewicz *et al.* 2007). Saltwater intrusion from sea-level rise might also affect groundwater/aquifer water supplies on similar small islands.

Some areas might try to offset decreases in surface water availability by increasing withdrawals of groundwater. However, decreases in groundwater discharge will hamper such efforts (EPA 2009b).

Extreme Events – Floods and Droughts

Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas, and extreme floods and extreme droughts are projected to become more frequent (EPA 2009b). The proportion of total rainfall from heavy precipitation events is likely to increase over most areas, particularly in tropical and high-latitude regions, while droughts are expected to increase in subtropical and mid-latitude regions. Precipitation changes between these regions are uncertain (Bates *et al.* 2008). More floods are projected for northern and northeastern Europe, while more drought is projected for southern and southeastern Europe (Lehner *et al.* 2005 in Kundzewicz *et al.* 2007).

Projections of climate-change impacts on flood magnitude and frequency can be both positive and negative, depending on the global climate model used, snowmelt contributions, catchment characteristics, and location (Reynard *et al.* 2004 in Kundzewicz *et al.* 2007). Up to 20 percent of the world's population lives in river basins at risk from increased flooding (Kleinen and Petschel-Held 2007 in Kundzewicz *et al.* 2007). The area flooded in Bangladesh is projected to increase by 23 to 29 percent with a global temperature rise of 3.6 °F (Mirza 2003 in Kundzewicz *et al.* 2007).

A recent study by Allen and Soden (2008) using a combination of satellite observations and model simulations showed a link between rainfall extremes and temperature. The observed amplification of rainfall extremes was larger than other model projections, leading the authors to infer that "projections of future changes in rainfall extremes due to anthropogenic global warming may be underestimated."

Globally, it is projected that by the 2090s, there will be an increase in drought-affected areas, with the land area in extreme drought at a given time expected to be ten times what it is today (Bates *et al.* 2008, Kundzewicz *et al.* 2007a). By the 2090s, the proportion of the total land surface in extreme drought is projected to increase ten-fold, from the current rate of 1 to 3 percent to 30 percent; extreme drought events per 100 years are projected to double; and mean drought duration is projected to increase by a factor of six (Burke *et al.* 2006a in Kundzewicz *et al.* 2007).

Water Quality

Higher water temperatures and runoff variations are *likely* to affect water quality negatively (Patz 2001, Lehman 2002, O'Reilly *et al.* 2003, Hurd *et al.* 2004, all in Kundzewicz *et al.* 2007). Negative impacts on water quality from changes in water quantity include resuspension of bottom sediments, increased turbidity (suspended solids), pollutant introduction, and reduced dilution. Negative impacts from water temperature include algal blooms, increased microbial concentrations, and out-gassing of volatile and semi-volatile compounds like ammonia, mercury, dioxins, and pesticides (Kundzewicz *et al.* 2007a).

Acidic atmospheric deposition is projected to increase acidification in rivers and lakes (Ferrier and Edwards 2002, Gilvear *et al.* 2002, Soulsby *et al.* 2002, all in Kundzewicz *et al.* 2007a).

Salt concentration is expected to increase in estuaries and inland reaches under decreasing streamflows. For example, salinity is projected to increase in the tributary rivers above irrigation areas in Australia's Murray-Darling Basin by 13 to 19 percent by 2050 and by 21 to 72 percent by 2100 (Kundzewicz *et al.* 2007a).

No quantitative studies projecting the impact of climate change on microbiological water quality for developing countries are cited by the IPCC. However, climate change will be an additional stressor affecting water quality and public health. Potential impacts include increased waterborne disease with increases in extreme rainfall, and great incidence of diarrheal and water-related diseases in regions with increased drought (Kundzewicz *et al.* 2007a). A brief overview of the effects of climate change on the availability and quality of drinking water is provided by Epstein *et al.* (2005).

Developed countries are also experiencing water-quality issues in their water and wastewater treatment plants. Increased filtration is required in drinking water plants to address microorganism outbreaks following intense rain, thus increasing some operating costs by 20 to 30 percent (AWWA 2006 in Kundzewicz *et al.* 2007a). Other stressors on water quality include (Kundzewicz *et al.* 2007a):

- More water impoundments for hydropower (Kennish 2002 in Kundzewicz *et al.* 2007, Environment Canada 2004 in Fischlin *et al.* 2007);
- Stormwater drainage operation and sewage disposal disturbances in coastal areas resulting from sea-level rise (Haines *et al.* 2000);
- Increasing water withdrawals from low-quality sources;
- Greater pollutant loads resulting from increased infiltration rates to aquifers or higher runoff to surface waters (resulting from high precipitation);
- Water infrastructure malfunctioning during floods (GEO-LAC 2003); and
- Increased amounts of polluted storm water.

In many regions, there is no alternative supply even as water quality declines, and reusing wastewater (*e.g.*, to irrigate crops) can introduce other public health problems.

4.5.4 Terrestrial and Freshwater Ecosystems

This section addresses climate-related impacts on terrestrial and freshwater ecosystems, including non-coastal wetlands. An ecosystem is defined as a complex of biological communities (plants, animals, and microorganisms) and their non-living environments, which act together as a unit (MA 2005c in Lettenmeier *et al.* 2008 and MA 2005b in Fischlin *et al.* 2007). By definition, relationships within an ecosystem are strong, while relationships with components outside the ecosystem boundaries are weak (MA 2005b in Fischlin *et al.* 2007). Ecosystems are critical, in part, because they supply humans with services that sustain life and are beneficial to the functioning of society (Fischlin *et al.* 2007).

In addition to anthropogenic stressors, such as extraction of natural resources and changes in land use (Bush *et al*. 2004 in Fischlin *et al*. 2007), climate change poses a threat to the wellbeing of ecosystems. Many terrestrial and freshwater ecosystems have demonstrated resilience to historical changes in climate; however, their ability to maintain resilience in response to more rapid and profound changes in climate, such as those expected to occur over the next century, is uncertain (Chapin *et al*. 2004, Jump and Peñuelas 2005, both in Fischlin *et al*. 2007). Projected climate change and other ecosystem stressors generated by humans in the next century are "virtually certain to be unprecedented" (Forster *et al*. 2007 in Fischlin *et al*. 2007). While some climate-change impacts are expected to exacerbate existing ecosystem stressors, others represent entirely new stressors. For example, increasing surface temperatures or changes in snow cover will sometimes result in a mismatch in timing between predators and their prey, constraining the ability of populations to sustain themselves via a limited food supply (EPA 2009b, UNEP 2006). Impacts projected for species biodiversity "are significant and of key relevance, since global losses in biodiversity are irreversible (*very high confidence*)" (EPA 2009b).

4.5.4.1 Affected Environment

Earth's biosphere is an interconnected network of individuals, populations, and interacting natural systems, referred to as ecosystems. Ecosystems provide society benefits such as *supporting services*, such as biodiversity, "a resource that…sustain[s] many of the goods and services that humans enjoy from ecosystems"; *provisioning services*, such as food and building/clothing materials; *regulating services*, such as the sequestration of carbon, regulation of climate and water, and protection from natural hazards (floods, landslides, pest regulation); and *cultural services*, which allow humans the opportunity to appreciate the aesthetics of ecosystems components (Hassan *et al*. 2005b in Fischlin *et al*. 2007). The focus of this section is on *non-marine* ecosystems only. Section 4.5.5 addresses marine and coastal ecosystems.

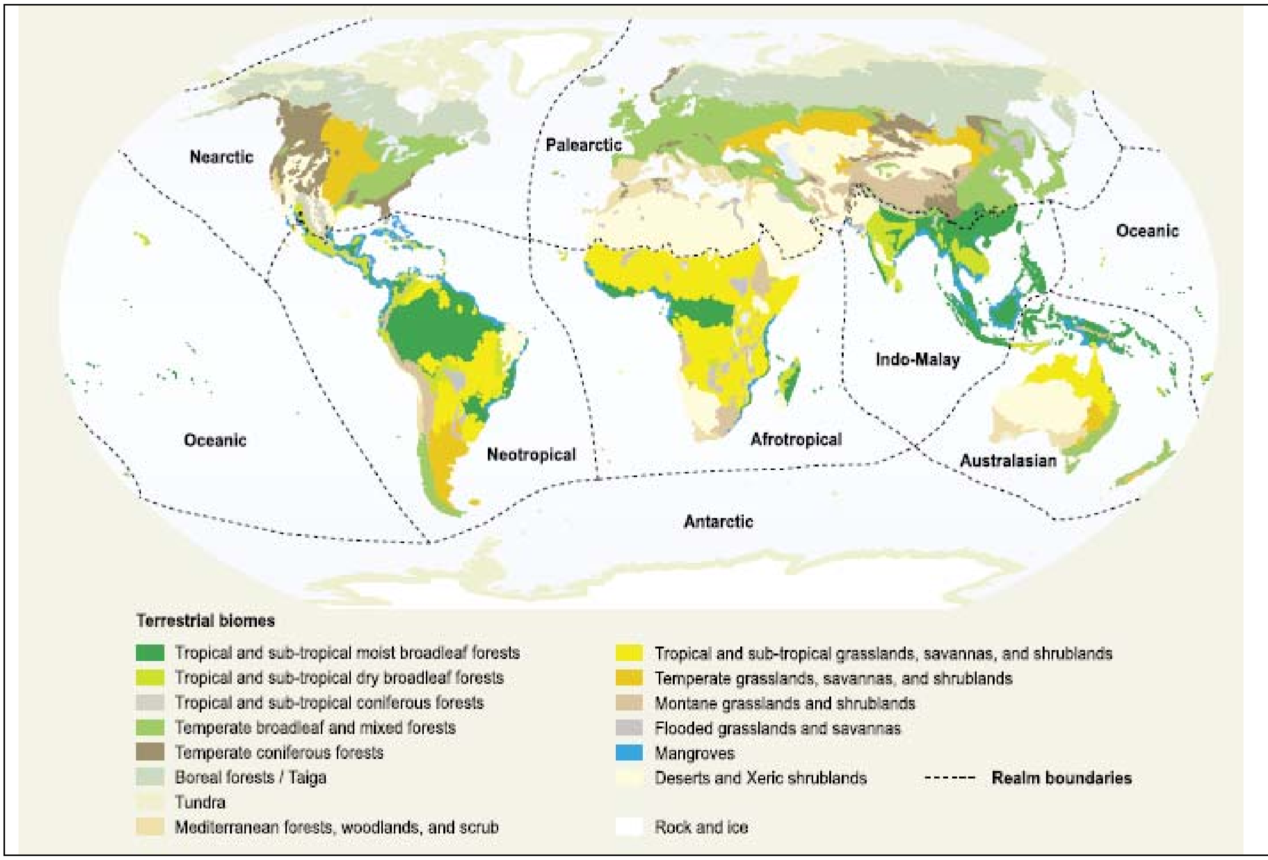
Ecosystems addressed in this section include (EPA 2009b, EPA 2001) terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra; aquatic communities, such as rivers, lakes, and ponds; and freshwater wetlands, such as marshes, swamps, and bogs.

4.5.4.1.1 Global Ecoregions and Ecozones

<u>Terrestrial Communities</u>

The World Wildlife Fund (WWF) has developed a widely accepted classification scheme for global terrestrial ecosystems; the classification includes ecozones, biomes, and ecoregions. Similar to the classification of Miklos Udvary's (1975) biogeographical realm, the ecozone is the biogeographic division of Earth's surface at the largest scale. Terrestrial ecozones follow the floral and faunal boundaries that separate the world's major plant and animal communities. The WWF has identified eight terrestrial ecozones, as indicated in Figure 4.5.4-1.

Figure 4.5.4-1. Terrestrial Ecozones and Biomes of the World (Source: MA 2005c in Lettenmeier *et al*. 2008)



Biomes are climatically and geographically defined areas of ecologically similar communities of plants, animals, and microorganisms. These habitat types are defined by factors such as plant structures, leaf types, plant spacing, and climate. The land classification system developed by WWF identifies 14 major terrestrial habitat types, which can be further divided into 825 smaller, more distinct terrestrial ecoregions (WWF 2008a).

The 14 primary terrestrial habitats recognized by WWF are as follows:

- *Tundra* is a treeless polar desert found at high latitudes in the Polar Regions, primarily in Alaska, Canada, Russia, Greenland, Iceland, and Scandinavia, and sub-Antarctic islands. These regions are characterized by long, dry winters, months of total darkness, and extremely frigid temperatures. The vegetation is composed of dwarf shrubs, sedges and grasses, mosses, and lichens. A wide variety of animals thrive in the tundra, including herbivorous and carnivorous mammals and migratory birds.

- *Boreal Forests and Taiga* are forests found at northerly latitudes in inland Alaska, Canada, Sweden, Finland, Norway, and Russia, and parts of the extreme northern continental United States, northern Kazakhstan, and Japan. Annual temperatures are low and precipitation ranges from 15 to 40 inches per year and can fall mainly as snow. Vegetation includes coniferous and deciduous trees, lichens, and mosses. Herbivorous mammals and small rodents are the predominant animal species; however, predatory birds and mammals also occupy this habitat type.

- *Temperate coniferous forests* are found predominantly in areas with warm summers and cool winters. Plant life varies greatly across temperate coniferous forests. In some forests, needleleaf trees dominate, while others consist of broadleaf evergreen trees or a mix of both tree types. Typically, there are two vegetation layers in a temperate coniferous forest: an understory dominated by grasses and shrubs and an overstory of large tree species.

- *Temperate broadleaf and mixed forests* experience a wide range of variability in temperature and precipitation. In regions where rainfall is distributed throughout the year, deciduous trees are mixed with evergreens. Species such as oak, beech, birch, and maple typify the tree composition of this habitat type. Diversity is high for plants, invertebrates, and small vertebrates.

- *Mediterranean forests, woodlands, and shrub* ecoregions are characterized by hot and dry summers, while winters tend to be cool and moist. Most precipitation arrives during winter. Only five regions in the world experience these conditions: the Mediterranean, south-central and southwestern Australia, the fynbos of southern Africa, the Chilean matorral, and the Mediterranean ecoregions of California. These regions support a tremendous diversity of habitats and species.

- *Tropical and subtropical coniferous forests* are found predominantly in North and Central America and experience low levels of precipitation and moderate variability in temperature. These forests are characterized by diverse species of conifers, whose needles are adapted to deal with the variable climate conditions. These forests are wintering ground for a variety of migratory birds and butterflies.

- *Tropical and subtropical moist broadleaf forests* are generally found in large, discontinuous patches centered on the equatorial belt and between the Tropics of Cancer and Capricorn. They are characterized by low variability in annual temperature and high levels of rainfall. Forest composition is dominated by semi-evergreen and evergreen deciduous tree species. These forests are home to more species than any other terrestrial ecosystem. A square kilometer can support more than 1,000 tree species. Invertebrate diversity is extremely high, and dominant vertebrates include primates, snakes, large cats, amphibians, and deer.

- *Tropical and subtropical dry broadleaf forests* are found in southern Mexico, southeastern Africa, the Lesser Sundas, central India, Indochina, Madagascar, New Caledonia, eastern Bolivia, central Brazil, the Caribbean, valleys of the northern Andes, and along the coasts of Ecuador and Peru. Deciduous trees predominate in most of these forests and they are home to a wide variety of wildlife, including monkeys, large cats, parrots, various rodents, and ground-dwelling birds.

- *Temperate grasslands, savannas, and shrublands* are known as prairies in North America, pampas in South America, veld in southern Africa, and steppe in Asia. They differ from tropical grasslands in species composition and the annual temperature regime under which they thrive. These regions are devoid of trees, except for riparian or gallery forests associated with streams and rivers. Biodiversity in these habitats includes a number of large grazing mammals and associated predators, burrowing mammals, numerous bird species, and a diversity of insects.

- *Tropical and subtropical grasslands, savannas, and shrublands* are found in the large expanses of land in the tropics that do not receive enough rainfall to support extensive tree cover. However, there could be great variability in soil moisture throughout the year.

Grasses dominate the species composition of these ecoregions, although scattered trees can be common. Large mammals that have evolved to take advantage of the ample forage typify the biodiversity associated with these habitats.

- *Montane grasslands and shrublands* include high-elevation grasslands and shrublands, such as the puna and paramo in South America, subalpine heath in New Guinea and East Africa, steppes of the Tibetan plateaus, and other similar subalpine habitats around the world. Montane grasslands and shrublands are tropical, subtropical, and temperate. Mountain ecosystem services such as water purification and climate regulation extend beyond the geographical boundaries of the grasslands and shrublands and affect all continental mainlands (Woodwell 2004). Characteristic plants of these habitats display features such as rosette structures, waxy surfaces, and abundant pilosity (WWF 2008b).

- *Deserts and xeric shrublands* across the world vary greatly with respect to precipitation and temperature. Generally, rainfall is less than 10 inches annually and evaporation exceeds precipitation. Temperature variability is also extremely diverse in these remarkable lands. Many deserts, such as the Sahara, are hot year-round, but others, such as Asia's Gobi, become quite cold in winter. Woody-stemmed shrubs and plants evolved to minimize water loss characterize vegetation in these regions. Animal species are equally well-adapted to the dry conditions, and species are quite diverse.

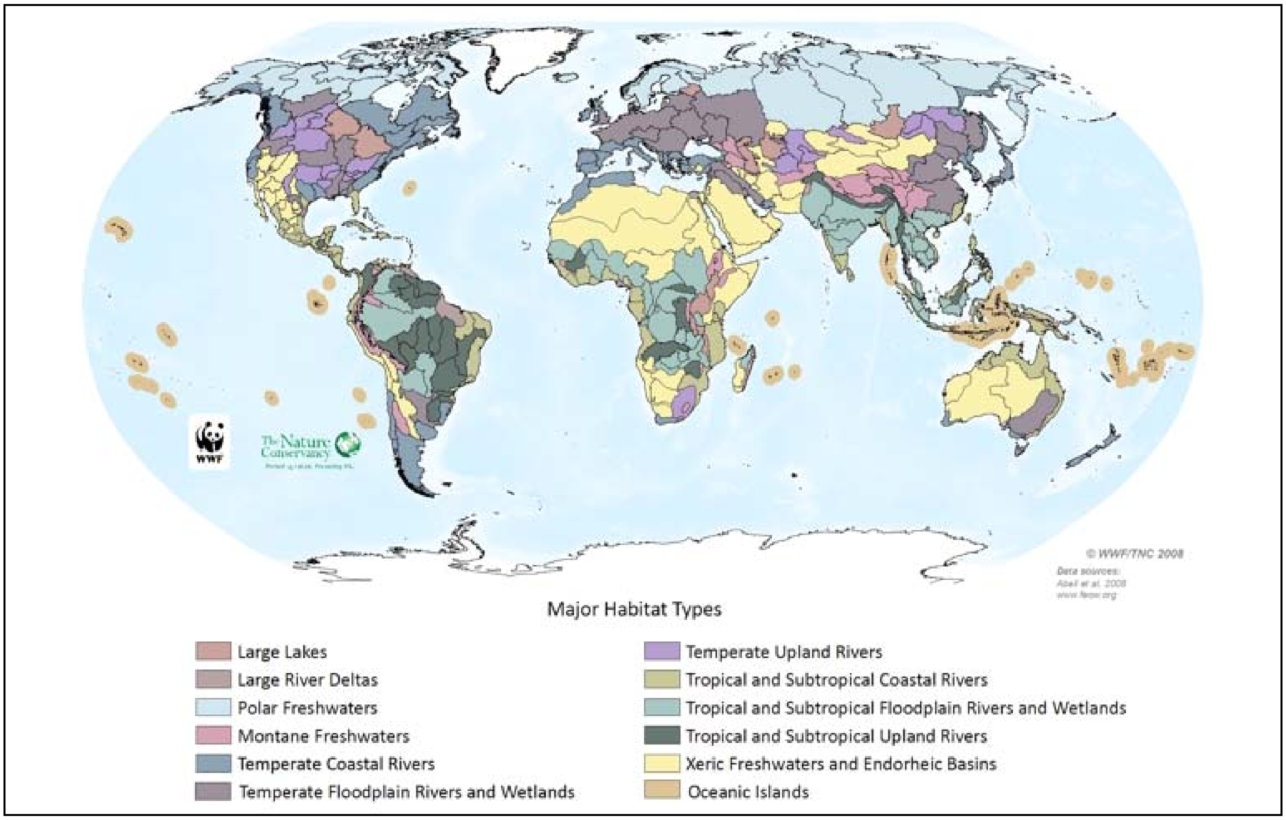
- *Mangroves* occur in the waterlogged, salty soils of sheltered tropical and subtropical shores, where they stretch from the intertidal zone to the high tide mark. Associated with these tree species is a whole host of aquatic and salt-tolerant plants. Mangroves provide important nursery habitats for a vast array of aquatic animal species.

- *Flooded grasslands and savannas* are common to four continents. These vast areas support numerous plants and animals adapted to the unique hydrologic regimes and soil conditions. Large congregations of migratory and resident water birds can be found in these regions. Ecosystem services include breeding habitat and the buffering of inland areas from the effects of wave action and storms (MA 2005c in Lettenmeier *et al.* 2008).

Freshwater Aquatic Communities

According to the Freshwater Ecoregions of the World (FEOW) project, although freshwater biodiversity is more imperiled overall than terrestrial biodiversity, conservation efforts have largely focused on terrestrial ecosystems. This is due, in large part, to a lack of comprehensive data on freshwater species distribution (FEOW 2009). FEOW has worked to identify and classify Earth's many freshwater habitats into larger, more manageable groupings. From the 426 freshwater ecoregions identified in Abell *et al*. (2008), FEOW has defined 12 Major Habitat Types (MHTs), which represent groups of "ecoregions with similar biological, chemical, and physical characteristics and are roughly equivalent to biomes for terrestrial systems" (FEOW 2009). These are presented in Figure 4.5.4-2 and are described below.

Figure 4.5.4-2. Freshwater Major Habitat Types (MHTs) (Source: FEOW 2009)



The 12 MHTs recognized by FEOW are as follows (FEOW 2009):

- *Large lakes* are dominated and defined by lentic (still or standing water) systems. Ecosystems in this MHT include areas of in-flow and out-flow from rivers and adjacent wetlands in addition to the lakes themselves. These regions include large tropical, temperate, and polar lakes.

- *Large river deltas* contain deltaic features such as those from tidal influences and their associated fish species, which are different from those found upstream. Regions containing deltaic features, but that aren't defined by specific fish species, are not included in these ecoregions.

- *Montane freshwaters* are composed on streams, rivers, lakes or wetlands at higher elevations. Included are high gradient, fast-flowing streams, and complexes of higher elevation wetlands and lakes.

- *Xeric freshwaters and endorheic (closed) basins* contain freshwater systems found in arid, semi-arid, or sub-humid environments. They usually contain plant and animal species that are adapted to ephemeral regimes, intermittent flooding, or lower levels of water periodically throughout the year.

- *Temperate coastal rivers* usually contain small to medium coastal basins at middle latitudes. While characterized by river systems, they can also include wetlands, small lakes, and lagoons. Migratory animal species that live in both fresh and marine ecosystems may be present. Island ecoregions with these characteristics are included here.

- *Temperate upland rivers* include non-floodplain rivers at middle latitudes, along with headwater drainages and tributaries of large rivers. These rivers typically flow over moderate gradients and do *not* flood cyclically.

- *Temperate floodplain rivers and wetland complexes* each contain a single large river system at a middle latitude, including its associated sub-basins, which are or have historically been cyclically flooded. These regions can contain wetland complexes with deltas, swamps, and marshes.

- *Tropical and subtropical coastal river* ecoregions contain several tropical small or medium coastal basins that drain into the ocean. The areas are characterized by river systems but can also contain lakes, lagoons, and wetlands. Islands with these characteristics are included here.

- *Tropical and subtropical upland rivers* contain non-floodplain rivers in the tropics, including headwater drainages and tributaries of larger rivers. These rivers flow over moderate gradients.

- *Tropical and subtropical floodplain rivers and wetland complexes* are characterized by a single tropical large river and include that river's main stem drainage and its sub-basins, which are or have historically been cyclically flooded. Internal deltas, marshes, and swamps may be included in these areas.

- *Polar freshwaters* are high-latitude ecoregions that contain the entire drainage from the headwaters to the mouth of the system. The Yukon in Alaska is one example of this MHT.

- *Oceanic islands* include the ecoregions of one or more islands, and above high tide. The plant and animal species found here are freshwater, but have evolved from marine ancestors.

Freshwater Wetlands

As the barriers between terrain and water, wetlands are typically not only rich sources of biodiversity, but also provide services critical to humans, such as mitigation of flooding and storm runoff, erosion control, and filtration of pollutants from water and sediments. The roles of particular wetlands vary depending on the location and main water source of the wetland. Those that are dominated by precipitation supply water to streams and replenish groundwater reservoirs while riparian wetlands are dominated by surface flow and may remove, store, or release water, nutrients, and sediments. Types of wetlands, excluding those associated with marine systems or estuaries (which are addressed in Section 4.5.5), are as follows (EPA 2001):

- Precipitation-dominated Wetlands

  - *Bogs* form where peat accumulates at a faster rate than it decomposes. These receive little to no surface water in-flow due to their elevation above surrounding areas due to the peat accumulation. Due to this lack of in-flow, they have low rates of primary productivity. The dominant plant matter in bogs, Sphagnum moss, releases organic acids, usually resulting in acidification of the bogs, with a pH as low as 3.0. Also found in bogs are evergreen trees and shrubs. This environment has produced unique plants that evolved to thrive in conditions that are acidic and lacks nutrients.

- *Vernal pools* are low-lying areas in grasslands and forests that are underlain by clay or bedrock, which acts to pool the water, rather than allowing any accumulated water to drain away. While covered by shallow water during some periods, they can be completely dry during some months of the summer and fall.

- *Playas* are small, low-lying marshlike ponds that collect rainfall and storm runoff from surrounding areas. These form in arid regions such as the Southern Great Plains in the United States.

- *Prairie potholes* are holes generated by past glacial events in northern North America that subsequently fill up with rainwater and snowmelt. The potholes contribute to groundwater recharge, at times.

- *Wet meadows* are grasslands formed in poorly drained areas that get waterlogged after precipitation events, such as basins and depressions, between marshes and upland areas. They are often dry during summer months.

- *Wet prairies* are similar to wet meadows but remain waterlogged longer than do wet meadows. Additionally, they receive water not only from precipitation but also from groundwater and intermittent streams.

• Groundwater-dominated Wetlands

  - *Fens* form in low-lying areas or near slopes where groundwater meets the soil surface. These wetlands accumulate peat, similar to bogs, but are supplied with groundwater, rather than precipitation and, as such, are provided with a year-round water supply. Fens are typically found at higher latitudes and in previously-glaciated locations.

• Surface Water-dominated Wetlands

  - *Freshwater marshes* are formed in depressions around lakes and rivers and can contain permanent or periodic shallow water with little or no accumulation of peat. They usually have the greatest biodiversity of the types of wetlands (along with tidal marshes). Much of a marsh's water is from surface sources, but some is from groundwater. They are dominated by floating-leaf plants, such as lilies, and soft-stemmed plants like cattails.

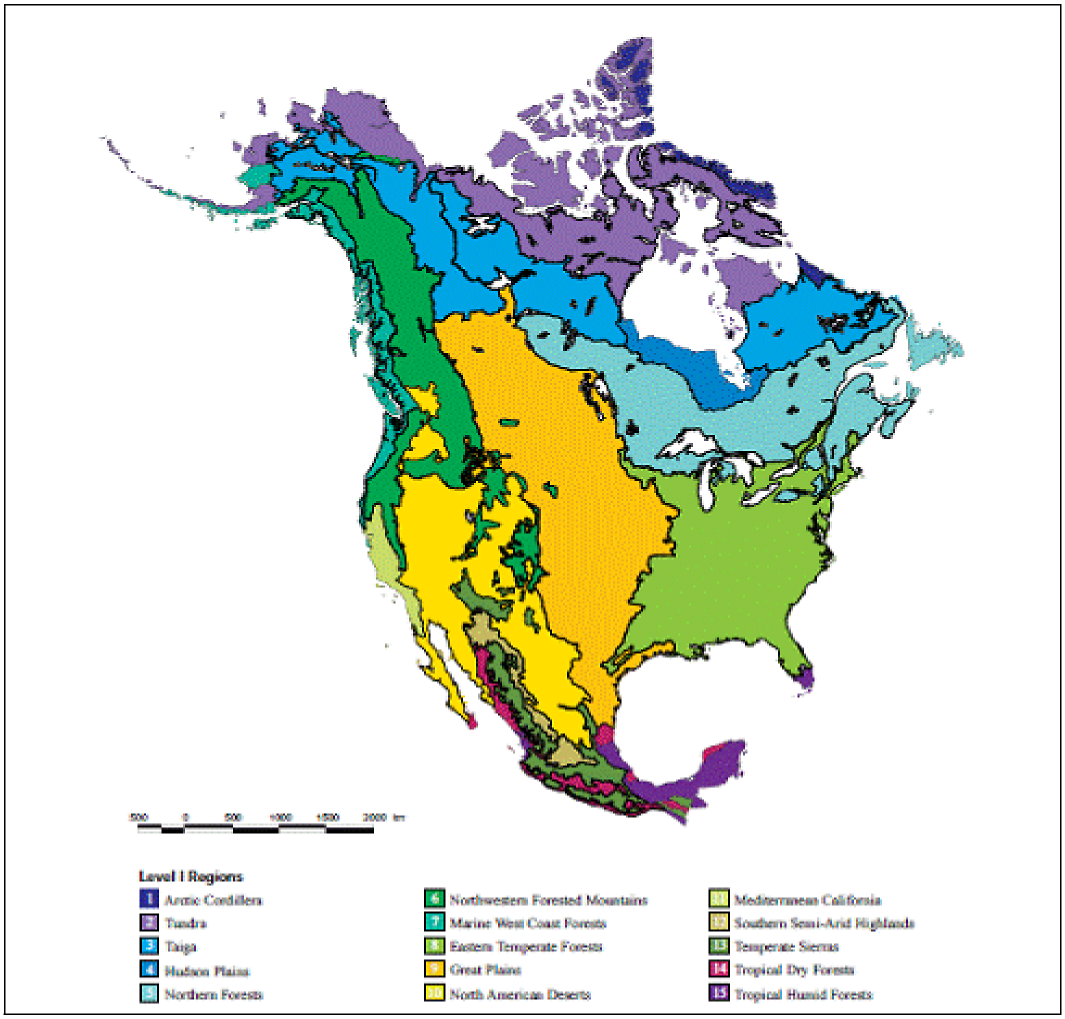
  - *Riparian forested wetlands (swamps)* are linear systems formed along rivers and lakes. They are typically saturated during the winter while plants are dormant and evapotranspiration is low. During the summer, they are usually dry, except during periods of flooding. The pH and nutrient load of riparian wetlands vary, depending on the inputs, but they are almost always very productive ecosystems. Many bird and fish species are known to be solely dependent on riparian wetlands.

  - *Tidal freshwater marshes* are influenced by tides only in terms of water levels, and receive little, if any, saline water from the ocean. These are found upstream from estuarine systems and receive most water from upstream sources, with some additional input from storm runoff and precipitation. These marshes have very high primary productivity and are known for their rich biodiversity. A key function performed by tidal freshwater marshes is the prevention of nitrogen entering in to estuaries; they can filter out as much of 50 percent of the nitrogen that enters the marsh.

4.5.4.1.2 Ecosystems in the United States

Published in 1976, *Ecoregions of the United States* represented one of the first attempts to systematically divide the Country's terrestrial ecosystems into more manageable regions. Subsequently, Bailey (1980) provided, for each region, a brief description of the dominant physical and biological characteristics based on land-surface form, climate, vegetation, soils, and fauna. Bailey defined four major domains, 12 divisions, and 30 provinces. Since then, the terrestrial ecoregions of North America have been further refined by the international working group of the Commission of Environmental Cooperation (CEC 1997). Their system divides the continent into 15 broad level I ecoregions, 52 level II ecoregions, and approximately 200 level III ecoregions. The level I terrestrial ecoregions present in the United States include tundra, taiga, northern forests, northwestern forested mountains, marine west coast forests, eastern temperate forests, great plains, North American deserts, Mediterranean California, southern semi-arid highlands, temperate sierras, and tropical humid forests (*see* Figure 4.5.4-3).

Figure 4.5.4-3. Level I Ecoregions in the North America (Source: CEC 1997)



There are 50 freshwater ecoregions in the United States. These ecoregions are divided among eight of the 12 MHTs recognized in the FEOW project – polar freshwaters (two), temperate coastal rivers (12), temperate upland rivers (12), large lakes (two), temperate floodplain rivers and wetlands (seven), xeric freshwaters and endorheic basins (11), tropical and subtropical coastal rivers (three), and oceanic islands (one) (FEOW 2009). One of the most ecologically valuable freshwater resources in the United States is the Prairie Pothole Region (PPR) of the Great Plains, which falls primarily within the temperate floodplain rivers and wetlands MHT. This region contains as many as eight million acres of wetlands, providing crucial ecosystem services to the Country in addition to habitat critical to waterfowl (EPA 2009b, CCSP 2009c). Almost 90 percent of variation in the mallard duck reproductive variability depends on breeding activities within the PPR (Johnson *et al.* 2005a). Historically, the climate of this area has fluctuated, sometimes between extremes such as devastating droughts and periodic flooding. Both ends of the climate spectrum resulted in widespread tree and grassland mortality (CCSP 2009c). More than 90 percent of the eastern PPR wetlands have been drained for agricultural purposes and, although restoration activities have been underway for more than 20 years, less than 1 percent of drained basins have been restored (Johnson *et al.* 2005a).

The Great Lakes region is an ecologically and economically significant area that spreads across the northern United States and southern Canada in eastern North America. The lakes (Erie, Huron, Michigan, Ontario, and Superior) contain 18 percent of the world's fresh water. They not only supply water to millions of people, but also are home to some of the richest ecosystems on the continent (Kling *et al.* 2003). The lakes themselves provide habitat for large populations of trout, salmon, and other popular game fish, while the surrounding marsh and coniferous forests sustain grey wolves, moose, peregrine falcons, bald eagles, and black bears. The Upper Peninsula of Michigan has a 1,700-mile shoreline and 16,500 square miles of largely intact forests. The Peninsula contains rich populations of both aquatic and terrestrial species, including 300 bird species, of which 25 to 30 percent are year-round residents; the rest are migratory (Kling *et al*. 2003).

Ecosystems are dynamic and can change naturally over time as a result of drivers such as climate change (natural or anthropogenic), geological processes (volcanic eruptions, earthquakes, landslides, erosion, stream migration), fire, disease or pest outbreaks, and evolution. All organisms modify their environment to some extent; however, in the past century and especially in the past 50 years, human population growth and technological innovations have affected ecosystems drastically (Vitousek *et al.* 1997). In fact, the structure of the world's ecosystems have changed more rapidly in the second half of the 20th Century than in any time in recorded human history (MA 2005c in Lettenmeier *et al.* 2008). It is expected that during the course of the 21st Century, the resilience of many ecosystems is likely to be exceeded by anthropogenic pressures (Fischlin *et al.* 2007).

4.5.4.2 Environmental Consequences

This section discusses existing climate and non-climate related impacts that have already been observed, and projected impacts. Climate-change impacts are discussed globally, and with specific attention to impacts in the United States. The EPA *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* was released in 2009 (EPA 2009b), the IPCC WGI *Fourth Assessment Report* (Fischlin *et al.* 2007) was released in 2007, the CCSP report on climate sensitive ecosystems was released in 2008 (CCSP 2008a). The 2009 EPA findings and the 2007 IPCC report are the most comprehensive recent summaries of projected impacts of climate change. Many of the impacts discussed in this section were gathered from these reports, which provide analyses and discussions on both global and U.S. scales. Information about impacts specific to ecosystems in the United States was obtained from the EPA findings and the 2008 CCSP report, along with information from several other recent reports. The projected impacts described in Sections 4.5.4.2.1 through 4.5.4.2.5 were forecast with varying degrees of certainty. Where relevant, the descriptions include the level of certainty as defined by IPCC.

4.5.4.2.1 Non-climate Threats to Terrestrial and Freshwater Ecosystems

The Millennium Ecosystem Assessment (MA), a United Nations research project, focuses on identifying the current inventory and conditions of 10 categories of global ecosystems and projecting changes and trends into the future.

In 2005, the MA released five technical volumes and six synthesis reports, providing a scientific appraisal of the condition and trends in the world's ecosystems (terrestrial, marine, and freshwater) and the services they provide. From 2001 to 2005, the MA involved the work of more than 1,360 experts worldwide. The MA included the following conclusions regarding the current state of global ecosystems (MA 2005c in Lettenmeier *et al.* 2008):

- Cultivated systems now cover one quarter of Earth's terrestrial surface. More than two thirds of the area of two of the world's 14 major terrestrial biomes and more than half of the area of four other biomes had been converted by 1990, primarily to agriculture.
- Across a range of taxonomic groups, for most species, either the population size or range or both is currently declining.
- The distribution of species on Earth is becoming more homogenous; in other words, the set of species in any one region of the world is becoming more similar to the set in other regions primarily as a result of introductions of species, both intentionally and inadvertently in association with increased travel and shipping.
- The number of species on the planet is declining. Over the past few hundred years, humans have increased the species extinction rate by as much as 1,000 times over background rates typical over Earth's history. Some 10 to 30 percent of mammal, bird, and amphibian species are currently threatened with extinction.
- Only four of the 24 ecosystem services examined in this assessment have been enhanced, while 15 have been degraded (Hassan *et al.* 2005a).

The MA concluded that biodiversity changes due to human activities were more rapid in the past 50 years than at any time in human history. Moreover, the forces causing biodiversity loss and leading to changes in ecosystem services are either steady, show no evidence of declining over time, or are increasing in intensity. The MA examined four plausible future scenarios and projected that the rates of biodiversity change will continue or accelerate (MA 2005c in Lettenmeier *et al.* 2008). The changes in ecosystems identified in the MA can have impacts on ecological processes, species composition, and genetic diversity. Ecosystem processes, which include water, nitrogen, carbon, and phosphorous cycling, have all changed more rapidly in the second half of the 20th Century than at any time in recorded human history (MA 2005c in Lettenmeier *et al.* 2008). Human actions have not only changed the structure of ecosystems, but also the processes as functions of the ecosystems.

A change in ecosystem structure also affects the species within the system and vice versa. Historically, the natural processes of evolution and the combination of natural barriers to species migration and local adaptation resulted in substantial phenotypic differences in plant and animal species of different ecosystems. These regional differences are now becoming rare.

Some ecosystem changes have been the inadvertent result of activities unrelated to the use of ecosystem services, such as the construction of roads, ports, and cities and the discharge of pollutants. However, most ecosystem changes were the direct or indirect result of changes made to meet growing demands for food, water, timber, fiber, and fuel (MA 2005c in Lettenmeier *et al*. 2008). In addition to climate change, ecosystem dynamics can be affected by a variety of human and natural drivers, including, land use change, hydrologic modification, wildfires, insect outbreaks, species decline and extinctions, and pollution. These drivers can act independently or in concert with each other (EPA 2009b, Lepers *et al.* 2004), and are summarized below.

Land-use Change

Land-use change represents the anthropogenic replacement of one land use type by another, such as forest converted to cultivated land (or the reverse), and subtle changes of management practices within a given land use type, such as intensification of agricultural practices. Both forms of land-use change are affecting 40 percent of the terrestrial surface (Foley *et al.* 2005 in Easterling *et al.* 2007). Land-use change can lead to habitat loss and fragmentation and is an important driver in ecosystem change (Heywood and Watson 1995 in Fischlin *et al.* 2007, Fahrig 2003 in Fischlin *et al.* 2007). Overall, land transformation represents the primary driving force in the loss of biological diversity (Vitousek *et al.* 1997). In nine of the 14 terrestrial biomes studied by the MA, more than half the area has been transformed, largely by agricultural cultivation (Hassan *et al.* 2005a). Only the biomes that are less suitable for agriculture, such as deserts, boreal forests, and tundra, have remained largely untransformed by human activity.

Virtually all of Earth's ecosystems have now been substantially transformed through human actions (MA 2005c in Lettenmeier *et al.* 2008). Approximately 70 percent of original temperate grasslands and forests and Mediterranean forests were lost by 1950, primarily from conversion to agricultural lands. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (MA 2005a in Kundzewicz *et al.* 2007, Hassan *et al.* 2005a).

Historically, terrestrial ecosystems that have been most substantially altered by human activity include temperate broadleaf forests, temperate grasslands, Mediterranean forests, and tropical dry forests (Hassan *et al.* 2005a). Of these, more than two thirds of the temperate grasslands and Mediterranean forests, and more than half of tropical dry forests, temperate broadleaf forests, and tropical grasslands have been converted to agriculture (Hassan *et al.* 2005a). Forest systems in general have been reduced by half over the past 3 centuries, and have effectively disappeared in 25 countries. Another 29 countries have lost 90 percent or more of their forest cover (Hassan *et al.* 2005a).

Globally, the rate of ecosystem conversion has begun to decelerate, mainly because the rate of expansion of cultivated land has declined. Ecosystems are beginning to return to conditions and species compositions similar to their pre-conversion states. However, rates of ecosystem conversion remain high or are increasing for specific ecosystems and ecoregions (MA 2005c in Lettenmeier *et al.* 2008). Land-use changes and land degradation are important drivers of ecosystem change globally and in the United States. For example, "between 1982 and 1997, 11 million acres of nonfederal grasslands and shrublands were converted to other uses" (The H. John Heinz III Center for Science 2002).

The increase in cultivated land, especially for the purpose of grazing, has led to an increase in desertification. Desertification involves the expansion of deserts into semi-arid and subhumid regions, and the loss of productivity in arid zones. Desertification is characterized by loss of groundcover and soils, replacement of palatable, mesophytic grasses by unpalatable xerophytic shrubs, or both (Ryan *et al.* 2008a). Desertification affects the livelihoods of millions of people, including a large portion of the poor residents of drylands (Hassan *et al.* 2005a). While desertification can certainly be exacerbated by changes in climate, there has been long-standing controversy over the relative contributions of climatic and anthropogenic factors as drivers of desertification (National Science and Technology Council 2008).

Hydrologic Modification

An ongoing and significant threat to freshwater ecosystems is the practice of hydrologic modification, including the damming of lakes and rivers for hydroelectric power and re-routing stream systems for the purposes of agricultural irrigation. At present, there are 45,000 large dams (more than about 50 feet high) and as many as 800,000 smaller dams around the world (MA 2005a in Kundzewicz *et al.* 2007). These practices can negatively impact migratory patterns of aquatic species, interfering with reproductive patterns, for example. The tight control of waterways through damming, though partially intended to help prevent the damages from periodic flooding, has also worked to prevent the positive impacts of flooding, such as the replacement of soil nutrients to agricultural lands and terrestrial ecosystems (Heino *et al*. 2008, MA 2005a in Kundzewicz *et al.* 2007). In recent years, decisionmakers in the United States have realized the damages to aquatic ecosystems and the surrounding landscape caused by such modifications. Therefore, fewer dams are being constructed and some are being dismantled. However, most remain intact.

Wildfires

Fire influences ecosystem structure by promoting species that tolerate fire or even enhance the spread of fire, resulting in a relationship between the relative flammability of a species and its relative abundance in a particular community (Bond and Keeley 2005). Intensified and increasing wildfire occurrences appear to be changing vegetation structure and composition in some ecoregions (Kasischke and Turetsky 2006).

Insect Outbreaks

Invasive alien species represent a major threat to endemic or native biodiversity in terrestrial and aquatic systems. Invasions of alien species also interact with other drivers, sometimes resulting in unexpected outcomes. The impact of insect damage is substantial and can exceed the impacts of fire in some ecosystems, but especially in boreal forests (EPA 2009b, Logan *et al.* 2003). For example, spruce budworm defoliated more than 20 times the area burned in eastern Ontario between 1941 and 1996 (Fleming *et al.* 2002). Fires tended to occur 3 to 9 years after a spruce budworm outbreak (Fleming *et al.* 2002), suggesting that insect outbreaks can be a driver of increased fire events.

Species Decline and Extinction

Although extinction is a natural part of Earth's history, observed modern rates of extinction are not part of natural cycles. Over the past few hundred years, humans have increased the extinction rate by as much as 1,000 times over the rate expected based on natural history (Hassan *et al.* 2005a). A decrease in global genetic diversity is linked to extinction. The loss of unique populations has resulted in the loss of genetic diversity. The loss of genetic diversity among terrestrial species has also declined among cultivated species as farmers have shifted from locally adapted crop populations to more widely adapted varieties produced through formal breeding practices. For most species across a wide range of taxonomic groups, either the population size, population range, or both is in decline (MA 2005c in Lettenmeier *et al.* 2008).

Pollution

Pollution is another substantial threat to ecosystems. Over the past 4 decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine systems. A known cause is the use of increasing amounts of synthetic nitrogen and phosphorous fertilizers, which can be lost to the environment after application (EPA 2009b).

Consumption of nitrogen fertilizer grew almost 800 percent between 1960 and 2003 (MA 2005c in Lettenmeier *et al.* 2008). In terrestrial ecosystems, excessive nitrogen flows contribute to acidification. Nitrogen also plays a role in ground-level ozone, which can lead to a loss of forest and agricultural productivity (EPA 2009b, MA 2005c in Lettenmeier *et al.* 2008). In aquatic systems, excessive nitrogen and phosphorus loads often result in eutrophication of both surface and deeper waters (Poff *et al.* 2002). As the nutrient enrichment encourages growth of aquatic vegetation in the surface layers of water bodies, the result is that natural processes that occur as the plants die, sink to the lower layers of water, and decay lead to depleted oxygen. The depletion of oxygen makes it more difficult for many species to thrive and sometimes results in large areas of "dead zones," in which no species are able to thrive. In one example, in the 1960s, Lake Erie experienced such significant phosphorus pollution that algal bloom decay used up almost all of the dissolved oxygen in the lake and the lake was almost entirely unable to support any fish and other aquatic life (Kling *et al.* 2003).

4.5.4.2.2 Observed Impacts on Terrestrial and Freshwater Ecosystems in the United States

Changes and impacts on ecosystems in the United States are similar to those occurring globally. During the 20th Century, the United States already had begun to experience the effects of climate change. Precipitation over the contiguous United States increased 6.1 percent over long-term averages (EPA 2009b), while a sea-level rise of 0.08 to 0.12 inch per year has occurred at most of the country's coastlines; the Louisiana coast has experienced an even greater rise in sea level at a rate of 0.36 inches per year (EPA 2009b). It should be noted that while global sea level rise is relatively smooth across the globe, the amount at any particular location can be affected by many factors.

Examples of observed changes to non-marine ecosystems in the United States attributable to anthropogenic climate change include:

- Many plant species are expanding leaves or flowering earlier, for example: earlier flowering in lilac, 1.8 days per decade (Schwartz and Reiter 2000) and honeysuckle, 3.8 days per decade (Cayan *et al.* 2001).
- Warmer springs have led to earlier nesting for 28 migrating bird species on the east coast of the United States and to earlier egg laying for Mexican jays and tree swallows (EPA 2009b).
- In lowland California, 70 percent of 23 butterfly species advanced the date of first spring flights by an average of 24 days over 31 years (Forister and Shapiro 2003 in Easterling *et al.* 2007).
- Many North American plant and animal species have shifted their ranges, typically to the north or to higher elevations (EPA 2009b, Parmesan and Yohe 2003a).
- Edith's checkerspot butterfly has become locally extinct in the southern, low-elevation portion of its western North American range but has extended its range 56 miles north and 394 feet higher in elevation (EPA 2009b, Parmesan 1996, Crozier 2003). Forty percent of the populations below 2,400 feet elevation are now extinct (GCRP 2009).
- The frequency of large forest fires and the length of the fire season in the western United States have increased substantially since 1985. These phenomena are related to the advances in the timing of spring snowmelt and increases in spring and summer air temperatures (EPA 2009b, Westerling *et al.* 2006b in CCSP 2008).
- The vegetation growing season has increased on average by about 2 days per decade since 1948, with the largest increase happening in the West (Easterling 2002, Feng and Hu 2004 in Rosenzweig *et al.* 2007).

- Recently, spruce budworm in Alaska has completed its lifecycle in 1 year, rather than the 2 years previously (EPA 2009b). This allows many more individuals to survive the overwintering period with impacts on the boreal forests of North America.
- Over the past 3 to 5 decades, all the major continental mountain chains exhibited upward shifts in the height of the freezing level (Diaz *et al.* 2003).
- Populations of the American pika, a mountain-dwelling relative of the rabbit, are in decline (EPA 2009b). The pika might be the first North American mammal to become extinct as a result of anthropogenic climate change. Several populations of the pika, in the Rocky Mountain region, appear to have been extirpated as of the 1990s, compared to those that existed in the early 20th Century. One of the important factors in this occurrence is climate change that affected food supply and habitat availability (Janetos *et al*. 2008).
- Reproductive success in polar bears has declined as a result of melting Arctic Sea ice. Without ice, polar bears cannot hunt seals, their preferred prey (Derocher *et al.* 2004). On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species (EPA 2009b), reflecting the loss of sea ice habitat that once encompassed more than 90 percent of the polar bear's habitat range (*Federal Register* 73, 28212-28303, May 15, 2008).
- Between 1970 and 2000, much of Alaska has experienced approximately 10 additional snow-free days. The response to this is variable throughout the state. In northern Alaska, above-ground vegetation is increasing on the tundra while decreasing in the boreal forest regions in the interior of the state (CCSP 2009c).
- Permafrost in Alaska is warming and thawing in some areas and large areas of thermokarst terrain (subsidence from thawing) are observed. Estimates of the surface warming thus far are 0.5 to 1.5 °C (0.9 to 2.7 °F) and the subsidence is averaging 1 to 2 meters, and is as much as 6 meters in some locations (CCSP 2009c).
- In northern Alaska, shrub cover has increased by 16 percent since 1950. In 200 Arctic locations, there has been a 70 percent increase in shrub cover (EPA 2009b). This is already resulting in decreased surface albedo, reinforcing the warming trend (CCSP 2009c). The northward-shifting tree line into the tundra is encroaching on habitat for a number of migratory birds and land mammals, such as caribou (GCRP 2009).
- Northeastern birds that winter in the southern United States arrive home 13 days earlier than they did in the early 20th Century. Those that migrate to South America arrive home 4 days earlier, on average (GCRP 2009).
- In the past decade, the percentage of Rocky Mountain wildflower buds that are exposed to frost has doubled, hindering their reproductive ability (GCRP 2009).
- Since 1906, climate in the PPR has been generally been warmer and wetter. Minimum daily temperatures have been increasing in winter while maximum daily temperatures in the summer have been decreasing. Average annual precipitation over the same time period increased by 9 percent. The moisture gradient (wet in the east, dry in the west) steepened, as well. This trend is threatening the productive are of wetlands (Millett *et al*. 2009).
- There have been major changes in plant species abundance in Thoreau's Walden Woods in Concord, MA. Meticulous records of species have been kept for 150 years. Much of the change is thought due to changes in climate. The mean annual temperature in the Concord area has risen 2.4 °C (4.3 °F) in the last 100 years. Species in the area are now flowering 7 days earlier than they were during Thoreau's record-keeping days (Willis *et al*. 2008).

4.5.4.2.3 Observed Impacts of Climate Change on Terrestrial and Freshwater Ecosystems Globally

Because all ecosystems are defined by the interactions of biotic factors (plants, animals, and microorganisms) and abiotic factors (geology, hydrology, weather), climate is a key factor in determining the different characteristics and distributions of natural systems.

Studies have noted the response of biological and chemical characteristics of ecosystems to climate conditions, especially temperature change. Substantial research has examined the effects of climate change on vegetation and wildlife, leading to the conclusion that the changing climate is already having a real and demonstrable effect on a variety of ecosystem types (EPA 2009b, CCSP 2008b). As noted in the IPCC report, plants and animals can reproduce, grow, and survive only within specific ranges of climate and environmental conditions (EPA 2009b, Fischlin *et al.* 2007). Changes in climate can affect terrestrial ecosystems in any of the following ways (EPA 2009b):

- Shifting the timing of life cycle events such as blooming or migration;
- Shifting range boundaries or densities of individuals within their ranges;
- Changing species morphology (body size, egg size), reproduction, or genetics; and
- Causing extirpation or extinction.

These changes are a result of many factors. Phenology – the timing of seasonal activities of animals and plants – is perhaps the simplest process by which to track changes in the ecology of species in response to climate change (EPA 2009b, Rosenzweig *et al.* 2007). Observed phenological events include spring leaf unfolding, flowering, fruit ripening, autumn leaf coloring, leaf fall of plants, bird migration, chorusing of amphibians, and appearance or emergence of butterflies. Global daily satellite data, available since 1981, indicate an earlier onset of spring by 10 to 14 days over 19 years, particularly across temperate latitudes of the northern hemisphere (EPA 2009b, Lucht *et al.* 2002). Leaf unfolding and flowering in spring and summer have, on average, advanced by 1 to 3 days per decade in Europe, North America, and Japan over the last 30 to 50 years (Fischlin *et al.* 2007). The seasonal timing of bird migration and egg-laying has also changed, associated with the increase of temperature in breeding grounds and migration routes (EPA 2009b). According to IPCC (Rosenzweig *et al.* 2007), "Many small mammals have been observed to come out of hibernation and to breed earlier in the spring than they did a decade ago (Inouye *et al.* 2000, Franken and Hik 2004) and even larger mammals such as reindeer are showing phenological changes (Post and Forchhammer 2002), as are butterflies, crickets, aphids, and hoverflies (Forister and Shapiro 2003 in Easterling *et al.* 2007, Stefanescu *et al.* 2003, Hickling *et al.* 2005, and Newman 2005). Increasing regional temperatures are also associated with earlier calling and mating and shorter time to maturity of amphibians (Gibbs and Breisch 2001, Reading 2003, and Tryjanowski *et al.* 2003)." Frogs have been documented initiating mating calls as many as 10 to 13 days earlier then they were a century ago in some areas (EPA 2009b).

Rapid global warming can directly affect the size of a species' range, the density of individuals within the range, and the abundance of preferred habitat within the range. Climate changes have affected the location of suitable habitat for several species of plants and animals. Changes in the distribution of species have occurred across a wide range of taxonomic groups and geographical locations (Rosenzweig *et al.* 2007). Several different bird species no longer migrate out of Europe in the winter as the temperature continues to warm (Rosenzweig *et al.* 2007). Over the past decades, a poleward extension of various species has been observed, which is probably attributable to increases in temperature (Parmesan and Yohe 2003b in Rosenzweig *et al.* 2007). Many Arctic and tundra communities are affected and have been replaced by trees and dwarf shrubs (Kullman 2002 in Rosenzweig *et al.* 2007, and EPA 2009b). In some mountainous areas of the northern hemisphere, including in Alaska, tree lines have shifted to higher altitudes over the past century (Sturm *et al.* 2001 in Rosenzweig *et al.* 2007).

Decreases in the size of a species' range, the density of individuals within the range, and the abundance of its preferred habitat factors can lower species population size (Wilson *et al.* 2004 in Rosenzweig *et al.* 2007) and can increase the risk of extinction. Examples of declines in populations and subsequent extinction or extirpation are found in amphibians around the world (Alexander and Eischeid 2001, Middleton *et al.* 2001, Ron *et al.* 2003, and Burrowes *et al.* 2004, all in Rosenzweig *et al.* 2007). Increased toad mortality in freshwater systems in recent years has been attributed, in part, to exposure of their eggs to ultraviolet B radiation, which increases susceptibility to certain fungal parasites (EPA 2009b).

Changes in morphology and reproduction rates have been attributed to climate change. For example, the egg sizes of many bird species are changing with increasing regional temperatures (Jarvinen 1996 and Tryjanowski *et al.* 2003). Several studies conducted in Asia and Europe found that some birds and mammals are experiencing increases in body size as temperatures increase, on a regional scale, most likely due to the increasing availability of food (Nowakowski 2002, Yom-Tov 2003, Kanuscak *et al.* 2004, and Yom-Tov and Yom-Tov 2004 in Rosenzweig *et al.* 2007). Many northern insects have a 2-year life cycle, and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. The mountain pine beetle has expanded its range in British Columbia into areas previously considered too cold (Carroll *et al.* 2004) for its survival.

Examples of observed changes to non-marine ecosystems attributable to changes in climate also include:

- In lakes around the world, disruptions of trophic interactions among phytoplankton and zooplankton species with different temperature requirements have been observed (Winder and Schindler, 2004).
- Forest growth has increased over the last several decades due to increasing CO_2 in the atmosphere, an earlier onset of the growing season, and increased atmospheric nitrogen deposition (GCRP 2009).
- Changes in the relative timing of caterpillar food supplies for European woodland birds, including the Great Tit and the Pied Flycatcher, are impacting the reproductive success for those that cannot adjust their phenological timing, accordingly (UNEP 2006).
- In Northern Scotland, some populations of seabirds have had failures of close to 100 percent in recent years, due primarily to warmer waters becoming more hostile to phytoplankton, providing less food to the fish, which are the seabirds' food source (UNEP 2006).
- New species of fish, such as pacific salmon, have been identified in aquatic systems of the Canadian Arctic in recent years as a result of expanded ranges from warming waters (UNEP 2006).

4.5.4.2.4 Projected Impacts of Climate Change on Terrestrial and Freshwater Ecosystems in the United States

The United States is projected to experience changes in average temperature and precipitation over the 21st Century of an even greater magnitude than those experienced in the 20th Century. Although the entire Country is projected to experience some degree of change, particular regions of the United States could experience changes of a greater-than-average magnitude. For example, the greatest changes in temperature are projected for Alaska and the western continental United States (EPA 2009b, CCSP 2008a). In northern Alaska, the average temperatures are projected to increase 5.0 °C (9.0 °F) by the end of the 21st Century. Areas near coasts are projected to witness an increase of approximately 2.0 °C (3.6 °F) over the same period; summer temperatures nationwide could increase 3.0 to 5.0 °C (5.4 to 9.0

°F); and winter temperatures are projected to increase 7.0 to 10.0 °C (12.6 to 18.0 °F) (CCSP 2008a). Additionally, the northeastern United States could experience a rise in sea level that is greater than the projected global average of 0.8 to 2.0 meters (2.6 to 6.6 feet) (EPA 2009b, Pfeffer *et al*. 2008).

Additional expected changes in United States climate include:

- More frequent hot days and hot nights (EPA 2009b);
- Heavier precipitation events, primarily in the form of rain rather than snow (EPA 2009b). Annual precipitation in the northeastern United States is projected to increase while precipitation in the Southwest is expected to decrease (EPA 2009b, Christensen *et al.* 2007a); and
- A decline in spring snow cover, leading to decreased availability of water in reservoirs (EPA 2009b).

Ecosystems across the United States are projected to experience both positive and negative impacts from climate change over the next century. The degree of impacts will vary by region. Wildlife species have already responded to climate change and its effects on migration patterns, reproduction, and geographic ranges (EPA 2009b). Future, more substantial changes in climate are projected to affect many ecosystem services negatively (EPA 2009b, CCSP 2008a). The IPCC WGII has projected, with a *high level of confidence*, "that recent regional changes in temperature have had discernible impacts on many physical and biological systems" (National Science and Technology Council 2008).

The IPCC has determined that areas of the United States that experience temperature increases of 1.5 to 2.5 °C (2.7 to 4.5 °F) are at highest risk for modifications to ecosystem structure and composition (IPCC 2007c in CCSP 2008). Over the next century, it is projected that species could move northward and to higher elevations (Field *et al.* 2007b in National Science and Technology Council, 2008). In one example of possible future threats to ecosystem vegetation, the upward move in elevation of species as the snow and tree line advances suggests that alpine ecosystems could be endangered by the introduction of invasive species (National Science and Technology Council 2008).

Rather than experiencing impacts of climate change directly, most animals could experience the effects of climate change indirectly through changes to their habitat, food sources, and predators (Schneider and Root 1996 in National Science and Technology Council 2008). A changing climate facilitates migration of certain species into non-native habitats, potentially affecting current goods and services (EPA 2009b, CCSP 2008a).

Ecosystems in the United States are projected to experience a variety of climate-change impacts. For example:

- The area of drought-limited ecosystems is projected to expand in the U.S. 11 percent for every 1.0 °C (1.8 °F) (EPA 2009b).
- Changes in hydrology as a result of changes in precipitation patterns could interrupt the breeding cycles of amphibians, which depend on the ability to migrate to breeding ponds. The production of their eggs is also highly dependent on temperature and moisture availability (Fischlin *et al.* 2007 in National Science and Technology Council 2008).
- Changes in climate that occur over at least several years are likely to affect the reproductive success of migratory birds and their ability to survive. A mismatch in timing between the migration and reproduction periods and peak food availability is the potential pathway for such impacts (EPA 2009b).

- The migration of butterflies is highly dependent on spring temperatures, and anthropogenic climate change is likely to lead to earlier spring arrivals. As with migratory birds, an earlier butterfly migration could result in a mismatch with food supply, thus threatening reproduction and survival (Forister and Shapiro 2003 in National Science and Technology Council, 2008).
- Shifts in migration ranges could result in disease entering new areas, for example, avian malaria in Hawaii could move upslope as climate changes (CCSP 2008a).

In one well-publicized example of mammals experiencing the effects of a warming climate, the polar bear is specifically adapted to conditions in a narrow ecological slot niche (an environment with cold temperatures and access to snow, ice, and open water) and depends on this sea ice environment to hunt ice-breeding seals (EPA 2009b). Two thirds of polar bears could be gone from Alaska by the middle of this century (GCRP 2009). Polar bears were listed as threatened under the Endangered Species Act on May 15, 2008, due to the ongoing and projected loss of their sea-ice habitat from global warming (EPA 2009b).

The vegetation of terrestrial ecosystems in the United States is projected to experience a variety of direct impacts from climate change. For example, national forests, which harbor much of the Nation's biodiversity, and national grasslands are expected to experience an exacerbation of preexisting stressors, such as wildfires, invasive species, extreme weather events, and air pollution (CCSP 2008a).

Warmer, drier climates weaken resistance of trees to insect infestation, as they are more likely to be wilted and weakened under those conditions. In a healthy state, trees can typically fight off beetle infestation by drowning them with resin (sap) as they bore through the bark. Drought reduces the flow of resin and beetles that are able to penetrate the bark introduce decay-causing fungus. This problem has already been documented. Since 1994, winter mortality of beetle larvae in Wyoming has been cut due to mild winters (from 80 percent to less than 10 percent mortality). As a result, the beetles have been able to strip four million acres of Wyoming forests (Egan 2002 in Epstein *et al.* 2005). The U.S. Forest Service reports that bark beetles have now impacted over 1.5 million acres in northern Colorado and southern Wyoming, killing lodgepole pines and affecting watersheds, timber production, and wildlife habitats, along with other human activities (USFS 2008).

Additional impacts on vegetation in ecosystems in the United States could include:

- Water management in the West would be complicated by increases in temperatures and changes in precipitation patterns, which lead to reduced snow pack, earlier snowmelt, and modified hydrology (EPA 2009b).
- High latitudes would experience increased vegetation productivity. Regions in the mid-latitudes would experience either increased or decreased productivity, depending on whether the primary impact is more precipitation or higher temperatures (increasing evaporation and dryness) (Bachelet *et al.* 2001b, Berthelot *et al.* 2002, Gerber *et al.* 2004, Woodward and Lomas 2004, all in National Science and Technology Council 2008, EPA 2009b).
- Terrestrial ecosystems in the East would be statistically "likely to become carbon sources, while those in the west would be likely to remain carbon sinks" (Bachelet *et al.* 2004 in National Science and Technology Council 2008).
- The jet stream would move northward with increasing atmospheric temperatures. The consequence of this shift is a drying of the Southeast. Closed-canopy forest ecosystems could be converted to savanna ecosystems, woodlands, or grasslands, measurably increasing the threat of fire occurrence (CCSP 2008a).

- Growing seasons would lengthen, according to several predictive models; this would beneficially act to sustain carbon sinks (EPA 2009b).
- In the Olympic Range, a temperature increase of 2 °C (3.6 °F) would move tree species upwards 0.20 to 0.38 mile. Temperate species would replace subalpine species over 300 to 500 years (Zolbrod and Peterson 1999).

By 2050, coldwater stream fish habitat is projected to decline by 20 percent in the U.S. as a whole and 50 percent in the Rocky Mountain Region (Preston 2006). More than half of the wild trout populations of the southern Appalachian Mountains are projected to disappear as streams warm. Some studies project that losses of western trout populations could exceed 60 percent (Keleher and Rahel 1996 in Poff *et al*. 2002; Rahel *et al*. 1996 in Mohseni *et al*. 2003; Rahel 2002 in Battin *et al*. 2007). Models of Pacific Northwest salmon populations project losses of 20 to 40 percent by 2050 (Battin *et al*. 2007).

The millions of wetlands in the North American Prairie Pothole region, which provide essential breeding habitat to waterfowl, are considered particularly vulnerable to a warmer and drier climate. The wetlands of this region are considered the most productive habitat for waterfowl in the world, and it is estimated that the wetlands in the area support up to 80 percent of North American ducks. Simulations suggest that under a drier climate, the most productive habitat for breeding waterfowl would shift from the center of the region in the Dakotas and southeastern Saskatchewan to the wetter eastern and northern fringes, areas that are less productive or where most wetlands have been drained, resulting in significant declines in productivity (Johnson *et al*. 2005a).

Seasonal migrations of wetland species will be disrupted, with reduced survival and possible extinctions of some species. Boreal peatlands are considered particularly vulnerable (Wrona *et al*. 2006; Heino *et al*. 2008). Declines in abundance and local and global extinctions of arctic fish species are projected for this century.

4.5.4.2.5 Projected Impacts of Climate Change on Global Terrestrial and Freshwater Ecosystems

The IPCC concludes (*very high confidence*) that anthropogenic temperature rises have visibly altered ecosystems (Parry *et al.* 2007). The exact impacts of climate changes are difficult to discern, however, because they are mediated by other stressors and the capabilities of natural systems to adapt to changing climates to some degree (Parry *et al.* 2007).

Some regions of the world are more vulnerable to changes in climate than others. Regions of snow, ice, and tundra have been visibly altered by changes in global temperature. Observations of frozen regions already show larger glacial lakes and the destabilization of glacial debris that dam these lakes; changes in ecosystems at both poles; and increased melting of ice sheets, glaciers, and ice caps (Parry *et al.* 2007).

Ecosystems in all regions of the world are expected to respond to climate-change impacts with poleward and upward shifts of plants and animals; earlier onset of migration of terrestrial species such as birds and butterflies; and localized disappearance of particular species (EPA 2009b).

Additional factors, such as projected growth in human populations, are expected to exacerbate the effects of climate change. For example, river basin ecosystems that are already experiencing high levels of stress are projected, with *medium confidence*, to witness growth in human populations from approximately 1.4 to 1.6 billion in 1995 to roughly 4.3 to 6.9 billion by 2050 (Parry *et al.* 2007). River basins experience the stress of increasing human populations as manifested in increasing demands for water (CCSP 2008b) and more inputs of pollutants. A warmer, drier climate could increase these stressors and reduce access to other water sources (EPA 2009b).

Other projected global impacts of climate change include:

- The hardiness of the world's ecosystems is expected (*high confidence*) to be challenged over the 21st Century with "an unprecedented combination of climate change, associated disturbances (*e.g.*, flooding, drought, wildfire, insects, and ocean acidification), and other global change drivers (especially land use, pollution, and over-exploitation of resources) (Fischlin *et al.* 2007).
- Declines in keystone species populations are projected to be the primary factor in causing ecological cascades, which are "sequential chains of ecological effects, including starvation and death, beginning at the bottom levels of the food chain and ascending to higher levels, including apex predators" (EPA 2009b).
- Eighty-four percent of the species listed in the Convention on Migratory Species could be impacted in some way by climate change: 53 percent are susceptible to changes in water regime, 24 percent to mismatched water supply, 18 percent to sea-level rise, 17 percent to changes in prey range, 17 percent to habitat shifts, and seven percent to increased storm severity. The number of species threatened due to climate change is greater than the total number that are threatened by all other anthropogenic effects (UNEP 2006).
- By 2050, the Amazon forest is likely committed to losing 50 percent of its area. Even if all further forcing were to discontinue, projections indicate that almost all of the Amazon forest would be committed to loss (Jones *et al*. 2009).
- Fifty to 70 percent of the global climate models utilized by IPCC in 2007 project a 20-percent reduction in dry season precipitation in the eastern Amazon region, 40 percent in the central region, and 20 percent in the west. The Amazon forest seems resilient short-term droughts but large tree mortality begins after 3 years of drought (Betts *et al*. 2008).
- Global average temperature increases in excess of 1.5 to 2.5 °C (2.7 to 4.5 °F) are statistically likely to threaten 20 to 30 percent of plant and animal species with extinction by 2100 (GCRP 2009).
- Carbon uptake by ecosystems such as forests and grasslands is statistically likely to peak during the 21st Century and might ultimately even reverse (forests and grasslands would emit carbon, rather than taking it in), which would amplify climate change due to increased atmospheric CO_2 (Fischlin *et al.* 2007 in National Science and Technology Council 2008).

In addition to other anthropogenic stressors, "such as extractive use of goods, and increasing fragmentation and degradation of natural habitats" (Bush *et al.* 2004 in Fischlin *et al.* 2007), climate change poses a threat to the wellbeing of ecosystems. Although many ecosystems have been resilient to historical changes in climate, it is not clear whether their resilience is enough to withstand the more rapid and profound changes that are projected given the buildup of GHGs in the atmosphere (Chapin *et al.* 2004, Jump and Peñuelas 2005 in Fischlin *et al.* 2007). Projected climate change and other anthropogenic stressors are "virtually certain to be unprecedented" (Forster *et al.* 2007 in Fischlin *et al.* 2007). While some of the impacts expected with climate change serve to exacerbate existing stressors on ecosystems, other expected impacts could be altogether new. For example, increasing temperatures could cause some current sinks for GHGs, such as forest vegetation, to actually become sources for these gases (including CO_2 and methane) (Fischlin *et al.* 2007).

Effects of anthropogenic climate change on ecosystems are anticipated at different levels of severity and over varying time scales (decades to centuries) (Lischke *et al.* 2002 in Fischlin *et al.* 2007). Some of the broad impacts on ecosystems associated with climate change are expected to include species extinctions, loss of habitat due to more severe tropical storms (Wiley and Wunderle 1994 in Fischlin *et al.* 2007), changes in the types and abundance of vegetation present in an ecosystem (Schröter *et al.* 2005, Metzger *et al.* 2006, both in Fischlin *et al.* 2007), and increased susceptibility of land to desertification (Burke *et al.* 2006b in Fischlin *et al.* 2007).

Aquatic species will be vulnerable to changes in precipitation, hydrologic regimes, and water temperatures that alter or reduce habitat. Southern species of mammals and waterfowl are among the species groups expected to move north as the climate warms (Wrona *et al*. 2006), with the potential for some extinctions of fishes that are already at the northern limits of their range (Chu *et al.* 2005 in Heino *et al.* 2008). It has been estimated that with a warming of 4.0 °C (7.2 °F), there would be a shift in thermal regimes northward by about 422 miles (Sweeney *et al*. 1992 in Heino *et al*. 2008). Eaton and Scheller (1996) in Mohseni *et al*. 2003 estimated that with this degree of warming, thermally suitable habitat for 57 stream fishes requiring cold or cool water would decline by 50 percent.

Foreseeable pathways of climate change-induced impacts on ecosystems include:

- CO_2 fertilization effects on vegetation (EPA 2009b).
- Higher atmospheric temperatures that could lead to more frequent insect and disease outbreaks (EPA 2009b).
- Increased radiation due to a projected decrease in tropical cloud cover (Nemani *et al.* 2003 in Fischlin *et al.* 2007). This is linked to warming, which can directly affect ecosystems and increase the frequency and severity of storms originating in the tropics.

Increased water temperatures in freshwater systems sometimes make aquatic species more susceptible to pathogens. Increasing evaporation of lakes and stream systems can also increase concentrations of pollutants in water bodies.

Ecological Thresholds

Ecosystems have thresholds, similar to climatic or oceanic system tipping points, over which any small stressors on an ecosystem could result in abrupt changes in the quality or properties of the whole system. “Threshold phenomena are particular nonlinear behaviors that involve a rapid shift from one ecosystem state (or dynamic regime) to another that is the result of, or provokes, instability in any ecosystem” attribute (CCSP 2009c). This kind of instability is associated with some type of positive, runaway feedback, which differentiates a threshold from other types of changes in the ecosystem that are the result of environmental modifications.

Crossing over a threshold, an ecosystem makes a well defined break from previous trends in the system’s behaviors and overall characteristics (CCSP 2009c). An example cited in CCSP (2009a) that illustrates this is the observed impact to grasslands that was the result of interactions between drought and livestock overgrazing. As soon as a component critical to the wellbeing of the grassland ecosystem failed, that failure triggered “runaway desertification…a domino-like cascade of instability that substantially alter[ed] the rest of the system” (Groffman *et al*. 2006 in CCSP 2009c). Another example is that of the previously cited rapid die-off of forests in the southwestern United States. The primary trigger to runaway changes, sudden tree mortality from the drought-bark beetle stressors, led to other nonlinear changes in the ecosystem, such as erosion and the increased incidence of forest fires. Similarly, in the 1990s, southern Alaska experienced a world-record-breaking onslaught of spruce bark beetles, which was linked to a threshold response to observed changes in climate, primarily milder winter seasons that reduced the beetles' winter mortality and allowed the beetles to complete their life cycles in 1 year, rather than the historical 2 years. The beetle outbreak occurred on top of a 9-year drought that had already pushed spruce trees to the limits of their resilience; the trees were unable to protect themselves from insect pests at that time, leading to widespread tree mortality (CCSP 2009c).

In the future, facing changes in precipitation, temperature, and sea level, it might not be possible for ecosystems to meet historic benchmarks. Therefore, managers of ecosystem resources will likely have to modify their goals to accommodate these changes. For example, it could be necessary to foster the growth of more resilient components of ecosystems, such as those with only a few strong connections between them, which would build a "fire-break" into the systems and help to protect them from collapse (CCSP 2009c).

4.5.5 Marine, Coastal Systems, and Low-lying Areas

This section addresses climate-related impacts to marine and coastal ecosystems and low-lying areas. Coastal zones, commonly included as part of the marine *intertidal* and *neritic* zones, are unique environments where land and water meet. Though there is no single definition for coastal zones, all coastal zones include an area of land with a portion covered by saltwater. Burke *et al.* (2001) defines coastal zones as the "intertidal and subtidal areas on and above the continental shelf (to a depth of about 200m (650 feet)) – areas routinely inundated by saltwater – and immediately adjacent lands." Marine zones are also varied, often categorized according to both water depth and distance from land. In general, most geographic categorizations make clear delineations among shallow zones near the coast, open ocean areas, and the deepest areas of the sea; however, there is no one universal definition applicable to establishing the different subboundaries of marine zones. Alternatively, marine zones can also be defined by the ecosystems they support; NOAA has identified 64 Large Marine Ecosystems that each represent vast marine areas with distinct physical characteristics and where plant and animal populations are inextricably linked in the food chain (NOAA 2009a).

This section introduces the marine and coastal environments and discusses the observed and projected impacts of climate change. These environments are particularly vulnerable to warming water temperatures, sea-level rise, melting of freshwater ice, storm events, and water acidification (*see* Section 4.7.2. for discussion of water acidification).

4.5.5.1 Affected Environment

The world's coastal length is estimated to be 1,015,756 miles, with North America having the longest coastal length of all continents (Pruett and Cimino 2000 in Burke *et al.* 2001). Canada has the longest coastal length of any country in the world and the United States has the second longest, at 265,523 km (164,988 miles) and 133,312 km (82,836 miles), respectively (Pruett and Cimino 2000 in Burke *et al.* 2001). Important ecosystems found in coastal zones can include estuaries, coral reefs, coastal lagoons, mangroves, seagrass meadows, upwelling areas, salt marshes, beaches, bays, deltas, kelp forests, and barrier islands. A variety of terminology exists for describing coastal zone ecosystems. Table 4.5.5-1 lists some of the more commonly described ecosystems found in coastal zones.

Table 4.5.5-1

Common Coastal Ecosystem

Coastal Ecosystem	Description
Coastal Wetlands	The broadest definition of wetlands occurring along coastal zones. They include a number of natural communities that share the unique combination of aquatic, semi-aquatic, and terrestrial habitats that results from periodic flooding by tidal waters, rainfall, or runoff.
Sandy Shorelines	Sandy areas along coastlines where high-energy wave actions deposit and move around sand and sediment.
Barrier Islands	Long narrow islands running parallel to the mainland that provide protection to the coast.
Tidal Wetlands	A type of coastal wetland that is affected by both tides and freshwater runoff.
Estuaries	Bodies of water and their surrounding coastal habitats typically found where rivers meet the ocean.
Mangroves	Coastal wetlands found in tropical and subtropical regions typically characterized by shrubs and trees with an affinity to saline tidal waters.
Tidal Salt Marshes	A type of coastal wetland frequently or continually inundated with water, characterized by soft-stemmed vegetation adapted to saturated soil conditions. a/
Coral Reefs	A large underwater calcium carbonate formation that includes a diverse collection of biological communities.
Coastal Deltas	Typically a triangular deposit of silt and sand deposited at the mouth of a river along a coast.
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Coral Reefs	A large underwater calcium carbonate formation that includes a diverse collection of biological communities.
Coastal Deltas	Typically a triangular deposit of silt and sand deposited at the mouth of a river along a coast.

a/ EPA (2006)

Coastal zones are areas of substantial biological productivity that provide food, shelter, spawning grounds, and nurseries for fish, shellfish, birds, and other wildlife. The interaction between aquatic and terrestrial components of coastal ecosystems creates a unique environment that is critical to the life cycles of many plant and animal species. In the United States, 85 percent of commercially harvested fish depend on estuaries and coastal waters at some stage in their life cycle (Summers *et al.* 2005), while as much as 95 percent of the world's marine fish harvest is caught or reared in coastal waters (Sherman 1993 in Burke *et al.* 2001). Most historical information available on coastal ecosystems focuses on data related to fisheries (*see* Section 4.5.6, Food, Fiber, and Forests, for a detailed discussion on fisheries). As more research is conducted on other increasingly important coastal ecosystems, new data and information are becoming available. For example, coral reefs alone, while representing only 0.2 percent of the total area of oceans (Bryant *et al.* 1998), harbor more than 25 percent of all known marine fish (Tibbetts 2004). In addition, the species in some coral reefs can reach densities of 1,000 per square meter (Tibbetts 2004). In the United States, coastal ecosystems provide the Country's essential nesting, feeding, and breeding habitat for 85% of the waterfowl and other migratory birds (Summers *et al.* 2005). Coastal zones have also been found to support a much higher percentage of the world's threatened and endangered species.

Because a disproportionate percentage of the world's population lives in coastal zones, the activities of humans have created environmental pressures that threaten the very resources that make the coastal zones desirable (Summers *et al.* 2005). The impact of these activities varies from place to place and depends on the types and sensitivity of coastal ecosystems involved. A wide range of pressures has been identified as causing adverse changes in coastal ecosystems, but the leading causes of coastal ecosystem degradation include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species (UNESCO and WWAP 2006). In addition, climate change might compound these pressures (UNESCO and WWAP 2006).

There are numerous ways to define marine zones. Table 4.5.5-2 illustrates some commonly used zones (note that many of zones are similar in definition or overlap with other zones). Zonal characteristics include their proximity to land and their depth. Water zones close to land tend to be shallower, warmer, and have greater exposure to sunlight compared to deeper waters; thus, these different zones support very distinct ecosystems. Note the intertidal and neritic zones can also be defined as coastal zones.

Table 4.5.5-2

Common Marine Ecosystem Zones a/

	Marine Ecosystem	Description
Shallow, near land	Intertidal or Littoral	The area where ocean meets land. Tidal variations mean some intertidal parts are submerged in water for only part of the day. The length of time an area is submerged can influence the ecosystem it supports. For this reason, intertidal zones can be further stratified vertically.
	Neritic	The shallow ocean area over the continental shelf. Sometimes differentiated from the intertidal zone by the fact that it is continuously submerged. Sometimes included as part of the intertidal zone.
	Coral reefs, estuaries, mangroves, and other coastal ecosystems often grouped under intertidal or neritic zones, but sometimes are defined separately.	
Upper open ocean	Oceanic or Pelagic	Upper part of open ocean. Colder water, but still receives sunlight. Supports plankton and the fish and other organisms that feed upon them.
Deep open ocean	Benthic	Lower part of open ocean, but excludes the deepest parts. Cold water, with little sunlight. Supports seaweed, bacteria, sea stars, and other bottom dwellers.
	Abyssal	Very cold and nutrient poor. Ecosystem consists mainly of bottom dwellers that feed on organic matter that drifts down from upper parts of ocean.
	Hydrothermal Vents	Found in abyssal zones. Support chemosynthetic bacteria that live on minerals emitted by the vents.
	Profundal	Deep zone below the point light can penetrate. Could include the other deep ocean zones above.

a/ Different categorizations might further stratify these zones, group some zones together, apply different names, or define them somewhat differently.

Marine ecosystems play critical roles in global ecology. Marine ecosystems support almost half of all known species on Earth, and contribute 5 percent of the protein in the human diet (NOAA 2009b). Plankton and seaweed growing in shallower waters are the primary resource for many marine and coastal food chains/webs. Marine zones also play an important role in climate change through absorption of CO_2. Plankton absorb CO_2 as they grow, and ultimately will sequester some of that carbon when they die and fall to the ocean bottom. Additionally, ocean water itself absorbs some of the CO_2 in the atmosphere, increasing water acidity and contributing to reduced concentrations of dissolved oxygen, both of which can harm marine ecosystems (*see* Section 4.7.2 for more information on ocean acidification) (EPA 2009b).

4.5.5.2 Environmental Consequences

4.5.5.2.1 Observed Trends and Impacts of Climate Change

Many marine and coastal ecosystems around the globe have been substantially degraded, and many have been lost altogether. Quantifying the changes in coastal ecosystems is difficult because historical data describing the previous extent of these ecosystems are very limited. More and higher-quality data characterizing the world's marine and coastal zones are needed (Burke *et al.* 2001).

Ecosystem Conditions

A warming climate is already affecting the ocean. Increasing water temperatures have caused a rapid poleward shift in fish and plankton populations in the North Atlantic (EPA 2009b). As ice melts and precipitation increases at varying degrees around the globe, freshwater enters the ocean system, decreasing salinity and increasing the temperatures. Boyer *et al*. (2005) found that salinity levels of the oceans have changed when comparing 5 year periods from 1955-1959 and 1994-1998 (investigating the ocean surface vertically down to a depth of 3 km), and found that some areas are experiencing freshening while others are experiencing increases in salinity; in some parts, it is reasoned that the increase in salinity is due to increased evaporation. This study concludes that some parts of the Atlantic and Pacific Oceans are decreasing in salinity, while other parts are increasing; in most areas of the Indian Ocean, the upper layers are increasing in salinity, while the subsurface layers are freshening. Hegerl *et al.* (2006 in Fischlin *et al.* 2007) found that observed changes in salinity are consistent with simulations of warming and an increase of the hydrologic cycle. Less saline waters can inhibit the vertical mixing of ocean waters interfering with the distribution of nutrients, although the ultimate impact of this phenomenon remains unclear (Denman *et al.* 2007).

Ocean ecosystems are being pressured by overfishing, pollution, and other human-induced stressors. The United Nations estimates that 75 percent of the world's fish stocks are fully exploited, overexploited, or depleted (FAO 2004 in Easterling *et al.* 2007) (*see* Section 4.5.6). Even where fish populations are stable, fishing alters marine ecosystems by reducing the age, size, geographic diversity, and biodiversity of the populations. Brander (2007) finds that this decrease in diversity leaves the ecosystems more vulnerable to environmental stressors such as climate change.

Recent studies using relatively new data collection methods link changes in temperature to the productivity in the world's oceans. Based on a decade of data from National Aeronautics and Space Administration satellite ocean-color sensors launched in 1997, Behrenfeld *et al.* (2006) in Doney (2006) show that trends in chlorophyll productivity closely follow changes in temperature, and that in general, phytoplankton biomass and growth decline as surface waters warm. In addition, excess amounts of decaying plankton and elevated dissolved CO_2 concentrations can cause and expand hypoxic (low-oxygen) zones, or oceanic dead zones, which could physiologically stress marine animals (Brewer and Peltzer 2009 in Kundzewicz *et al.* 2007). Additionally, as the oceans absorb CO_2, they become more acidic, threatening coral reef ecosystems (EPA 2009b) (*see* Section 4.7.2. for more information on ocean acidification). A recent study found that one-third of the 704 zooxanthellate reef-building coral species assessed are at increased risk of extinction (Carpenter *et al.* 2008). This number has risen dramatically in recent decades due to bleaching and diseases driven by elevated sea-surface temperatures.

The conditions of coastal ecosystems vary from place to place and depend on many factors. Attempts have been made to assess the global extent and distribution of aquatic habitats, but estimates vary considerably depending on the type and source of data (UNESCO and WWAP 2006). While inventories of coastal zones exist, no high-quality data sets or indicators are available at the global level that track changes in condition over time (UNESCO and WWAP 2006). Despite the lack of high-quality data, it is safe to assume that coastal zones with substantial human populations are vulnerable to a range of human activities that can increase pressure and cause adverse changes to coastal ecosystems. As mentioned above, typical coastal ecosystem degradation would include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species. The effects of sea-level rise from climate change could compound these potential impacts.

EPA considers the current overall coastal condition of the United States to be fair (Summers *et al.* 2005). EPA evaluated six geographic coastal regions (Great Lakes Coastal Area, Northeast Coastal Area, Southeast Coastal Area, Gulf Coast Coastal Area, West Coastal Area, and Alaska, Hawaii, and Island Territories) using five ecological health indicators (water quality, sediment quality, benthic, coastal habitat, and fish tissue contaminants) to assess estuarine coastal conditions as good, fair, or poor. Of the five indicators, only the coastal habitat index received an overall poor rating. The benthic and sediment quality indices rated fair to poor, while the water quality and fish tissue contaminants indices received fair ratings. Of the six coastal regions, the Southeast Coastal Area ranked highest, with all indicators rating fair to good. The region with the worst coastal condition was the Northeast Coastal Area, with four of the five indicators rating poor or fair to poor. In terms of human and aquatic life use, 21 percent of the assessed coastal resources of the Country are considered unimpaired (good condition), whereas 35 percent are impaired (poor condition) and 44 percent threatened (fair condition).

Burke *et al.* (2001) found the following trends affecting the conditions of marine and coastal ecosystems:

- Many coastal habitats are disappearing at a fast pace, with extensive losses in the past 50 years.
- Although some industrial countries have improved coastal water quality, chemical pollutant discharges are increasing overall as agriculture intensifies and new synthetic compounds are developed.
- Pollution-filtering capacities are lost as coastal ecosystems are lost.
- Nutrient inputs to coastal waters appear to be increasing because of population increase and agricultural intensification.
- The frequency of harmful algal blooms resulting in mass mortality of marine organisms has increased substantially over the past few decades.
- More than 25 different coral reef diseases have been recorded since 1970, and reports of coral bleaching have increased measurably in recent years.
- The capacity of coastal ecosystems to produce fish for human harvest has been highly degraded by overfishing, destructive trawling techniques, and loss of coastal nursery areas.
- An increased number of invasive species is being reported throughout the world's coastal ecosystems.
- Increased occurrences of hypoxia (shortage of oxygen in water) have been reported.
- Many commercial fish species and other marine wildlife have become threatened.

- Large-scale marine oil spills have been declining, but oil discharges from land-based sources are believed to be increasing.
- The number of protected marine and coastal areas has increased, indicating greater awareness of the need to protect these environments.
- Global marine fish production has increased six-fold since 1950.
- Notable ecosystem changes have occurred over the last half-century in some fishery areas, such as the North Atlantic and Northeast Pacific.

Sea-level Rise

There is strong evidence that temperature increases caused a rise in global sea level during the 20th Century (Parry *et al.* 2007). Because each coastal area has its own unique geographic and environmental characteristics, consequences from adaptations to climate change are expected to differ for each community. Areas of critical sensitivity on the global scale include Tokyo, Shanghai, London, Thailand, India, and Vietnam (Nicholls *et al.* 2007a in National Science and Technology Council 2008). These areas share the characteristics of coastal location, low elevation, large population, and stressed resources. Because of their proximity to the water's edge and the high level of infrastructure typical of many coastal communities, these urban centers are sensitive to changes in sea-level rise (National Science and Technology Council 2008).

Recent data suggest that the rise in global sea level has had an effect on some U.S. coastal zones. Sea-level rise is non-uniform around the world. In some regions, rates of rise have been as much as several times the global mean, while other regions have experienced falling sea level. This might be the result of variations in thermal expansion and exchanges of water between oceans and other reservoirs, ocean and atmospheric circulation, and geologic processes (EPA 2009b). Satellite measurements provide unambiguous evidence of regional variability of sea-level change from 1993 to 2003, with the largest sea-level rise occurring in the western Pacific and eastern Indian Oceans (EPA 2009b).

Tide gauges have measured the average rate of sea-level rise to be 1.8 millimeters (0.07 inch) +/– 0.5 millimeter (0.019 inch) per year from 1961 to 2003 and 1.7 millimeters (0.07 inch) +/– 0.5 millimeter (0.02 inch) per year over the past century (EPA 2009b). These changes are attributed to thermal expansion associated with rising global temperature, thawing of permafrost, and loss of sea ice (EPA 2009b). The global ocean temperature averaged from the surface to a depth of approximately 700 meters (2,300 feet) has increased by 0.10 °C (0.18 °F) over the period of 1961 to 2003, contributing to an average increase in sea level of 0.4 millimeter (0.02 inch) +/– 0.1 millimeter (0.004 inch) per year (EPA 2009b). This contribution increased from 1993 to 2003, with a rate of sea-level rise of 1.6 millimeters (0.06 inch) +/– 0.5 millimeter (0.02 inch) per year (EPA 2009b). Melting of mountain glaciers, ice caps, and land ice have also contributed to the measured sea-level rise. From 1961 to 2003, the melting of land ice has contributed approximately 0.7 millimeter (0.03 inch) +/– 0.5 millimeter (0.02 inch) per year to sea-level rise, with an accelerated rate of 1.2 millimeter (0.05 inch) +/– 0.4 millimeter (0.02 inch) per year between 1993 and 2003 (EPA 2009b). Recent global sea-level data from satellite altimetry show an accelerated rate of sea-level rise of 2.4 millimeters (0.094 inch) per year evident from 1993 to 2003 (Domingues *et al.* 2008 in Epstein *et al.* 2005), and a rate of 3.36 millimeters (0.13 inch) +/– 0.4 millimeter (0.02 inch) from 1993 to 2007 (Beckley *et al.* 2007 in Chao *et al.* 2008), although it is uncertain whether this more recent rate increase is part of a long-term trend or decadal variability (EPA 2009b).

Sea-level data show a rise of 0.8 to 1.2 inches per decade since 1958 along most of the Atlantic and Gulf Coasts in the United States (EPA 2009b), with the Gulf Coast experiencing a rise of a few inches per decade (primarily due to land subsidence) and parts of the Alaskan coasts experiencing decreases in relative sea level (due to land rising) of a few inches per decade (National Science and Technology Council 2008 and EPA 2009b). Approximately one-sixth of U.S. land that is close to sea level is in the mid-Atlantic region; consequently, much of the reporting on effects focuses on that region (National Science and Technology Council 2008). Over the past century, the highest rate of sea-level rise has been observed in the mid-Atlantic region, in part resulting from subsidence of the land surface (Gutierrez *et al.* 2007). For example, Virginia has observed sea-level rise at 4.4 millimeters (0.17 inch) per year compared to 1.8 millimeters (0.07 inch) per year in Maine (Zervas 2001 in Gutierrez *et al.* 2007). New Jersey, with 60 percent of its population living along the 127 miles of coastline, has experienced coastline subsidence and beach erosion, threatening communities and coastal wetlands (Union of Concerned Scientists 2007 in Kundzewicz *et al.* 2007, Aucott and Caldarelli 2006, Jacob *et al.* 2000). Sea level on the California coast rose by almost 18 centimeters (7.1 inches) over the last century (EPA 2009b).

Enhanced storm surge is an associated stressor directly related to sea-level rise. In one example, Frumhoff *et al.* (2007) discusses the impacts of surging waters during a coastal storm in December 1992, when strong winds and rising water levels disrupted the New York City public transit system and required the evacuation of communities in New Jersey and Long Island. Sea-level rise in the Chesapeake Bay has accelerated erosion rates, resulting in wetland destruction (National Science and Technology Council 2008). According to the Maryland Geological Survey, Tropical Storm Isabel resulted in the loss of an estimated 20 acres or more of land on the western shore of Chesapeake Bay, causing significant damages to shoreline structures (Maryland Department of Planning 2004).

Coastal wetland loss is occurring where ecosystems are squeezed between natural and artificial landward boundaries and rising sea levels (EPA 2009b). Rise in sea level could be contributing to coastal erosion across the eastern United States (Zhang *et al.* 2004 in Rosenzweig *et al.* 2007). In Mississippi and Texas, more than half of the shorelines have eroded at average rates of 2.6 meters (8.5 feet) to 3.1 meters (10.2 feet) per year since the 1970s, while 90 percent of the Louisiana shoreline has eroded at a rate of 12.0 meters (39.4 feet) per year (EPA 2009b). Areas in Louisiana are experiencing barrier island erosion, resulting in an increased height of waves (Nicholls *et al.* 2007a in National Science and Technology Council 2008). Furthermore, regional sea-level rise has contributed to increased storm-surge impacts along the North American eastern coast (National Science and Technology Council 2008). Particularly because subsidence is occurring in parts of this area, areas such as the Louisiana and Gulf coasts are considered at high risk from erosion and storm surges, and any area along the coast with low elevation, large populations, and stressed resources could be expected to be at risk from any future sea-level rise. Saltwater intrusion is a projected threat to estuarine and mangrove ecosystems. The decline of bald cypress forests in Louisiana and cabbage palm forests in Florida has already been linked with saltwater intrusion. (EPA 2009b) Low-lying areas of the United States Pacific coast are also at increasing risk of flooding as sea level rises.

4.5.5.2.2 Projected Impacts of Climate Change for the United States

Impacts to marine and coastal ecosystems are expected to continue due to climate and non-climate stressors, particularly where coastal populations increase and demand more coastal space and resources. As of 2003, 153 million people (53 percent of the total population) lived in coastal counties of the United States, an increase of 33 million people since 1980. The U.S. coastal population was projected to rise to 160 million by 2008. It is also estimated that an additional 25 million people will live in the coastal United States in the next 25 years (EPA 2009b). This change in population is expected to compound the anticipated adverse effects of climate change on coastal communities, placing heavier demand on already stressed ecosystems (EPA 2009b). Nicholls *et al.* (2007b) in (EPA 2009b) suggests that "The major non-climate impacts for the U.S. and other world regions include drainage of coastal wetlands, resource extraction, deforestation, introductions of invasive species, shoreline protection, and the discharge of sewage, fertilizers, and contaminants into coastal waters," and further notes "The cumulative effect of these non-climate, anthropogenic impacts increases the vulnerability of coastal systems to climate-related stressors."

Sea-level Rise

A range of adverse effects from climate change is expected in the United States, one of the most damaging of which is expected to be sea-level rise. Sea-level rise in the 21st Century is expected to exceed that of past years, with potential adverse consequences for coastal communities and the infrastructures they support. Recent studies have shown that global sea level does not rise uniformly and that the coastal United States is expected to experience significantly higher sea levels than the global average (Bamber *et al.* 2009b, Yin *et al.* 2009, both in Pew Center on Global Climate Change 2009). Some general effects associated with rising sea levels include:

- Loss of land area due to submergence and erosion of lands in the coastal zone;
- Changes to coastal environments;
- More flooding due to storm surges; and
- Salinization of estuaries and groundwater (National Science and Technology Council 2008).

For islands such as those in Hawaii and other U.S. territories in the Pacific, outcomes could include a reduction in island size and the abandonment of inundated areas (National Science and Technology Council 2008, EPA 2009b).

The effects of sea-level rise on some coastal communities could be devastating because of increased flooding and erosion. As much as 21 percent of the U.S. mid-Atlantic coastal wetlands are potentially at risk of inundation between 2000 and 2100 (EPA 2009b), and coastal wetlands already experiencing submergence are "virtually certain" to continue to shrink due to accelerated sea-level rise, among other climate- and non-climate-related factors (EPA 2009b). Additionally, the melting of the Greenland ice sheet could have an effect on ocean circulation and sea-level rise dynamics, which might exacerbate sea-level rise experienced on the northeast North American coast (Hu *et al.* 2009). Extensive erosion has already been documented across the East Coast, as have notable decreases in the coastal wetlands of Louisiana, the mid-Atlantic region, New England, and New York (Rosenzweig *et al.* 2007 in National Science and Technology Council 2008). Erosion is expected to be worse in sandy environments along the mid-Atlantic coast, Mississippi, and Texas (National Science and Technology Council 2008, Nicholls *et al.* 2007a in National Science and Technology Council 2008). Over the past fifty years, Alaska's western and northeastern coastline has experienced a doubling in the rate of erosion as high-wind events have occurred more frequently (GCRP 2009). Over this century, the Pacific storm track may move northward as projected sea surface temperatures increase and sea ice cover decreases accelerating coastal erosion (GCRP 2009). The IPCC notes that sandy shorelines are already retreating and that sea-level rise due to climate change is an underlying cause. Furthermore, areas in Louisiana are experiencing barrier-island erosion, resulting in increases in the height of waves that make it to shore (EPA 2009b). A large storm can affect the shoreline position for weeks to a decade or longer (Morton 1994, Zhang *et al.* 2004, List *et al.* 2006, Riggs and Ames 2003, all in Gutierrez *et al.* 2007). Tidal wetlands, estuarine beaches, marshes, and deltas are expected to be inundated with water in areas such as the Mississippi River, Louisiana Delta, and the Blackwater River marshes in Maryland (Titus *et al.* 2008 in National Science and Technology Council 2008). The "coastal squeeze" phenomenon, where wetlands are trapped between natural and human-made land boundaries, is causing wetland loss and habitat destruction (EPA 2009b). Freshwater resources are also at risk given the *likely* intrusion of saltwater into groundwater supplies, adversely affecting water quality and salinization rates (Kundzewicz *et al.* 2007b in National Science and Technology Council 2008).

The most devastating impacts related to increased mean sea level are associated with impacts of storm surge (EPA 2009b). The height of storm surges will increase if sea level rises, regardless of storm frequency and intensity increases; thus, a storm of similar behavior will cause greater damage with rising sea level (Fisher *et al.* 2000 in Easterling *et al.* 2007). One study suggests the 100-year flood might actually occur every 25 to 30 years (Najjar *et al.* 1999 in Easterling *et al.* 2007). By mid-century, Boston and Atlantic City could experience a 100-year flood event every 2 to 4 years and annually by the end of the century (Frumhoff *et al.* 2007).

Sections of the California coastal ecosystems are at risk due to sea-level rise. The historic rate of sea-level rise observed at San Francisco and San Diego during the past 100 years was 15 to 20 centimeters (5.9 to 7.9 inches). Parts of the California coast are at risk for flood damage, which could further jeopardize levees in the City of Santa Cruz (California Environmental Protection Agency 2009). Santa Cruz is 20 feet above sea level and has levees built to contain the 100-year flood. The ENSO events of 1982-1983 and 1997-1998 corresponded to high sea level episodes (Flick 1998 in Cayan *et al.* 2006). The most severe coastal impacts occur as a result of coinciding factors including (a) elevated storm surge during, (b) high astronomical tide with (c) higher sea levels due to monthly-to-annual sea-level fluctuations associated with ENSO events, and (d) higher mean sea levels (Cayan *et al*. 2008).

In the San Francisco Bay Area, by 2050, 180,000 acres of shoreline will be vulnerable to inundation with a 16-inch rise in sea level, which is the lower of two sea-level rise scenarios considered by the Bay Area Conservation and Development Commission. Additionally, a 16-inch rise in sea level would impact 90 to 95 percent of existing tidal marshes and tidal flats, 20 percent of which would be vulnerable to permanent submersion and erosion. (Heberger *et al.* 2009 in BCDC 2009)

Storm Events

The frequency and intensity of storms are expected to increase at the same time sea levels rise and sea surface temperatures increase (Nicholls *et al.* 2007a in National Science and Technology Council 2008).

One ecological effect of intense storms is the loss of coastal wetlands, which has been documented on many occasions. A prominent recent example is the loss of coastal lands as a result of Hurricane Katrina in 2005. In Louisiana alone, the loss of land during Hurricane Katrina was approximately 217 square miles. The Chandeleur Islands, which New Orleans relied on as a tropical storm buffer, lost 85 percent of their surface area (CCSP 2008b). Parts of New Orleans and surrounding areas are 1.5 to 3 meters (4.9 to 9.8 feet) below sea level. Using a mid-range estimate of sea-level rise of 480 millimeters (roughly 1.6 feet) and accounting for land subsidence, the region could be 2.5 to 4.0 meters (8.2 to 13.1 feet) or more below mean sea level by 2100. Further, in this scenario, a storm surge of 3 to 4 meters (9.8 to 13.1 feet) (an estimated storm surge from a Category 3 hurricane), without the effect of waves, could be 6 to 7 meters (19.7 to 23.0 feet) above areas that were heavily populated in 2004. (EPA 2009b)

Severe storms and sea-level rise have had detrimental effects on coastal ecosystems in areas with sandy beaches. Many species rely on the wellbeing of, and accessibility to, beaches. Examples include:

- Diamondback terrapins and horseshoe crabs rely on beach sands to bury their eggs. The eggs not only act to propagate the species, but some shorebirds, such as the piping plover, rely on these eggs as a food source (USFWS 1988 in CCSP 2009b).
- Horseshoe crabs rarely spawn unless sand is deep enough to nearly cover their bodies, about 10 centimeters (4 inches) (Weber 2001). Shoreline protection structures designed to slow beach loss can also block horseshoe crab access to beaches and can trap or strand spawning

crabs when wave energy is high (Doctor and Wazniak 2005). In this case, both the loss of beach and the adaptation strategy selected by the community can harm local species.

- A rare firefly, *Photuris bethaniensis*, is found only in areas between dunes on Delaware's barrier beaches. Its habitat is at risk due to beach stabilization and hardening of shorelines, which limits migration of dunes and the formation of the swales between dunes where the firefly is found (CCSP 2009b).

Because the distribution of marine fish and plankton is largely driven by climate-related factors, climate change is causing significant ecosystem alterations, including marine species shifts and effects on fisheries. The IPCC estimates that 20 to 30 percent of marine species studied would be in climate zones outside their current ranges with a temperature rise of 3.5 to 5.5 °F, and would likely be at risk of extinction (CCSP 2009a). Rising water temperatures and other climate-driven changes (*e.g.*, salinity, dissolved oxygen levels, ocean circulation) have been associated with the movement of plankton by 10° latitude toward the poles over a period of 4 decades in the North Atlantic (EPA 2009b). Tuna stocks in the Pacific are expected to shift eastward due to climate change, and marine ecosystems in Alaska are already experiencing significant alterations (CCSP 2009a). The Bering Sea produces the largest commercial fishery harvests in the United States and supports subsistence economies of the indigenous peoples of Alaska (ACIA 2005). Current observations indicate that continued climate-related changes in the north Bering Sea could result in major shifts in marine fish stocks, including commercially important species such as Pollock, upon which Alaskan Natives depend (Grebmeier *et al.* 2006).

4.5.5.2.3 Projected Global Impacts of Climate Change

Globally, coastal systems and low-lying areas are experiencing adverse effects related to climate change and sea-level rise, such as coastal inundation, erosion, ecosystem loss, coral bleaching and mortality at low latitudes, thawing of permafrost, and associated coastal retreat at high latitudes (*very high confidence*) (Nicholls *et al.* 2007c in Ebi *et al.* 2008). To further exacerbate the stressors, human settlement and encroachment on coastal systems and low-lying areas have been increasing, with an estimated 23 percent of the world's population living within about 60 to 65 miles of the coast and no more than about 330 feet above sea level (Small and Nicholls 2003 in National Science and Technology Council 2008).

Sea-level Rise

Although non-uniform around the world, global sea level is estimated to have risen by 1.7 millimeters (0.07 inch) +/– 0.5 millimeter (0.02 inch) per year over the past century, with the western Pacific Ocean and the eastern Indian Ocean experiencing the greatest rise (Nicholls *et al.* 2007c in Ebi *et al.* 2008). Sea-level rise, coupled with both projected sea surface temperatures increasing 1 ºC (1.8 ºF) to 3 °C (5.4 °F) and intensified cyclonic activity, could lead to larger waves and storm surges, which would impact coastal systems and low-lying areas across the globe (Nicholls *et al.* 2007c in Ebi *et al.* 2008). The loss or degradation of coastal ecosystems has a direct impact on societies that depend on coastal-related goods and services such as freshwater and fisheries and has the potential to impact hundreds of millions of people (Parry *et al.* 2007).

There is variability in the projected effects from climate change and sea-level rise on an international scale. For instance, if the global mean annual temperature increases above 1980 to 1999 levels, coastal systems and low-lying areas are anticipated to sustain increased damage due to floods and storms; an additional increase of 2 °C (3.6 °F) would lead to an increase of millions of people that could experience coastal flooding each year; an increase of 3 °C (5.4 °F) is estimated to cause a loss of 30 percent of the global coastal wetlands (*high confidence*; IPCC 2007d, Figure SPM.2). Coastal wetland ecosystems are at substantial risk from sea-level rise if they are sediment-starved or prevented from migrating inland. As sea water temperatures increase, it is *likely* that coral bleaching and mortality will rise unless corals demonstrate thermal adaptation (Nicholls *et al.* 2007c in Ebi *et al.* 2008). These adverse impacts are expected to increase in severity as the global mean annual temperature increases.

IPCC (2007d) and EPA (2009b) state that sea level *will likely* rise 0.18 to 0.59 meter (0.6 to 2.0 feet) by 2100 relative to 1980-1999 (these numbers represent the 5 to 95% range across all SRES scenarios). However, this estimate does not fully account for effects from loss of land-surface ice flowing into the ocean; it might also underestimate ice losses from the Greenland and Antarctic ice sheets (Pfeffer *et al.* 2008, Meier *et al.* 2007 in Kundzewicz *et al.* 2007, Rahmstorf 2007, Shepherd and Wingham 2007); and it does not account for adjustments to water volume due to changes in global precipitation (Wentz *et al.* 2007, Zhang *et al.* 2007). Recent studies that account for some of these effects indicate that sea-level rise might be even higher. For example, Pfeffer *et al.* (2008) estimates sea level could rise 0.8 to 2.0 meters (2.6 to 6.6 feet) by 2100 compared to present day, while Rahmstorf (2007) uses a semi-empirical approach to estimates a rise of 0.5 to 1.4 meters (1.6 to 4.6 feet) by 2100 compared to 1990 levels. None of these studies account for the potential complex changes in ocean circulation that could further influence sea-level rise.

Complete melting of the Greenland ice sheet could occur from a sustained summertime warming in the region of 5 °C (9 °F) (with a range of uncertainty from 2 °C to 7 °C [4 °F to 13 °F]) (CCSP 2009a), which would exacerbate coastal sea-level rise (Hu *et al.* 2009). This scenario raises concern regarding the viability of coastal communities, salt marshes, corals, and mangroves. A sea-level rise of about 36 centimeters (14 inches) from 2000 to 2080 is projected to reduce coastal wetlands by 33 percent, with the largest impact on the Atlantic and Gulf of Mexico coasts of the Americas, on the Mediterranean, on the Baltic, and on small-islands (Nicholls *et al.* 2007c in Ebi *et al.* 2008).

IPCC SRES estimated that the coastal population could grow from 1.2 billion people in 1990 to between 1.8 billion and 5.2 billion people by the 2080s, with this range dependent on coastal migration. Although the impact of sea-level rise on a specific region can be difficult to quantify given regional and local variations (Parry *et al.* 2007), the IPCC describes the following coastal regions as the most vulnerable to the impact of climate change: South Asia, Southeast Asia, East Asia, Africa, and small islands (Nicholls *et al.* 2007c in Ebi *et al.* 2008).

Many of the coastal cities that are most vulnerable to adverse impacts of climate change are at further risk due to human activities such as agriculture, aquaculture, silviculture, industrial uses, and residential uses that have degraded the natural protective qualities of the coastal systems (Nicholls *et al.* 2007c in Ebi *et al.* 2008). Examples of coastal countries at risk for shoreline retreat and flooding due to degradation associated with human activity include Thailand (Durongdej 2001, Saito 2001, both in National Science and Technology Council 2008); India (Mohanti 2000 in National Science and Technology Council 2008); Vietnam (Thanh *et al.* 2004 in National Science and Technology Council 2008); and the United States (Scavia *et al.* 2002 in National Science and Technology Council 2008), with emphasis on the seven Asian megadeltas that have a combined population of more than 200 million (Nicholls *et al.* 2007c in Ebi *et al.* 2008). Of particular concern are those highly populated coastal regions in countries with limited financial resources to protect or relocate its populations (Nicholls *et al.* 2007c in Ebi *et al.* 2008).

Small islands are particularly vulnerable to climate change and sea-level rise, especially those prone to subsidence (Parry *et al.* 2007). Beach erosion is projected to increase as sea level rises and sea water temperature increases. Arctic islands could experience increased erosion and volume loss as permafrost and ground ice warms in response to rising global temperatures (Mimura *et al.* 2007). Coastal stability in the Arctic is influenced by a combination of factors, including shoreline exposure, relative sea-level change, local geology, temperatures, ground ice, and sea ice (EPA 2009b). Rising temperatures reduce the thickness and spatial extent of sea ice creating more open water, this allows for winds to generate stronger waves thereby increasing shoreline erosion (EPA 2009b). This dynamic process is exacerbated by relative sea-level rise and thawing of permafrost (EPA 2009b).

Changes in Sea Ice and Ocean Warming

Annual average temperature in the Arctic has increased at twice the rate of the rest of the world, and additional warming of 4 to 7 °F is expected over the next century. The stronger warming is primarily a result of the positive feedback due to decreased surface albedo as sea ice is lost (EPA 2009b). Annual average Arctic sea ice extent decreased 2.7 +/– 0.6 percent per decade from 1978 to 2005. In 2007, sea ice extent was approximately 23 percent less than the previous all-time minimum observed in 2005. Average sea ice thickness in the central Arctic *very likely* has decreased up to approximately 3 feet from 1987 to 1997 (EPA 2009b). Recent results indicate that summer Arctic sea ice could be gone as early as 2037 (Wang and Overland 2009). Sea ice dynamics are nonlinear and many thermodynamic processes will affect potential threshold behavior (Eisenman and Wettlaufer 2009).

Ocean warming and sea-ice decline is leading to a change from arctic to subarctic conditions in the northern Bering Sea. This is having significant impacts on Arctic sea-ice ecosystems. Phytoplankton (algae) that form the base of the Arctic food web bloom on the underside of sea ice. The timing and distribution of plankton blooms are regulated by the ice edge in spring, and as the extent and location of the ice edge changes with warming sea surface temperatures, the timing of blooms change. This leads to more consumption at the surface by zooplankton and less organic material reaching the sea bed. As a result, there is a decline in benthic production of clams and other small mollusks and crustaceans, which are the food source for many bottom-feeding sea ducks and marine mammals, including walrus and gray whales. (Janetos *et al.* 2008)

As a result of these dynamics, the trend toward more subarctic ecosystem conditions in the northern Bering Sea is contributing to declines in Arctic marine mammal and diving seabird populations, and in commercial and subsistence fisheries (Grebmeier *et al.* 2006). In other ocean basins, there is evidence of changes in important prey species of zooplankton, with resulting food-web changes. For example, in the North Atlantic the distribution of warm-water copepods (aquatic crustaceans) has shifted north by 10° latitude as a result of a change in the North Atlantic Oscillation and climate (Beaugrand *et al.* 2002a). In the southwest Atlantic, the distribution of emperor and Adelie penguins, which depend on ice habitat, has shifted to the north and contracted (Forcada and Trathan 2009 in Easterling *et al.* 2007).

Positive impacts anticipated to be experienced in high latitudes include a longer tourist season and better navigability (Mimura *et al.* 2007).

4.5.6 Food, Fiber, and Forest Products

This section defines food, fiber, and forest product resources and the existing conditions and potential vulnerability of each to the impacts of climate change. The primary source of information in this section is the IPCC Fourth Assessment Report (Easterling *et al.* 2007), specifically, Chapter 5 for food, fiber, and forest products.

The food, fiber, and forest sector is a substantial source of livelihood and food for large numbers of the world's population and a major land cover type at a global level. Cropland, pasture, or natural forests account for approximately 70 percent of Earth's land cover. The United Nations Food and Agriculture Organization (FAO) estimates that approximately 450 million of the world's poorest people depend entirely on this sector for their livelihood (Easterling *et al.* 2007).

According to IPCC, this sector includes agriculture, forestry, and fisheries and the IPCC describes the climate-change impacts to these systems and their capacity to provide food and sustenance for human consumption. This sector also includes subsistence and smallholder agriculture, defined as rural producers who farm or fish primarily with family labor and for whom this activity provides the primary source of income (Easterling *et al.* 2007).

4.5.6.1 Affected Environment

An estimated 40 percent of Earth's land surface is used for cropland and pasture (Foley *et al.* 2005 in Easterling *et al.* 2007). The FAO estimates that natural forests cover another 30 percent of the land surface, and that 5 percent of that natural forest area generates 35 percent of global timber production (FAO 2000 in Easterling *et al.* 2007). Almost 70 percent of people in lower-income countries around the world live in rural areas where agriculture is the primary source of livelihood. Growth in agricultural incomes in developing countries fuels the demand for non-basic goods and services fundamental to human development. The FAO estimates that the livelihoods of roughly 450 million of the world's poorest people depend entirely on managed ecosystem services. Fish provide more than 2.6 billion people with at least 20 percent of their average per-capita animal protein intake, but 75 percent of global fisheries are fully exploited, overexploited, or depleted (FAO 2004 in Easterling *et al.* 2007).

4.5.6.1.1 Terrestrial Systems

The distribution of crop, pasture, and forest species between the polar and equatorial latitudes is a function of existing climatic and atmospheric conditions, and a function of photoperiod. Agricultural, pastoral, and forestry systems depend on total seasonal precipitation and its pattern of variability, and on wind and humidity. Crops exhibit threshold responses to their climatic environment, which affect their growth, development, and yield (Porter and Semenov 2005 in Easterling *et al.* 2007). Short-term natural extremes, such as storms and floods, interannual and decadal climate variations, and large-scale circulation changes, such as ENSO, all have important effects on crop, pasture, and forest production (Tubiello 2005 in Easterling *et al.* 2007).

For example, Europe experienced a particularly extreme climate event during the summer of 2003, with temperatures up to 6 °C (11 °F) above long-term means, and precipitation deficits up to 12 inches (Trenberth *et al.* 2007 in Easterling *et al.* 2007). Associated with this extreme climate event was a decline in corn yield of 36 percent in the Po River valley in Italy and 30 percent in France. In addition, French fruit harvests declined by 25 percent, winter wheat yields declined by 21 percent, and hay and other forage production declined by an average of 30 percent (Ciais *et al.* 2005 in Easterling *et al.* 2007). The impacts to the terrestrial biosphere (*e.g.*, increased tree death) could increase due to the lag effect of the heat wave in the years following an extreme event (Heimann and Reichstein 2008). African droughts between 1981 and 1999 caused livestock mortality from 20 percent to more than 60 percent in countries such as Botswana, Niger, Ethiopia, and Kenya (Easterling *et al.* 2007).

Total forest productivity might rise modestly, with considerable global variation, due to extended growing seasons and elevated CO_2 concentrations. Nitrogen deposition and warmer temperatures have likely increased forest growth in locations not water limited. For example, in regions that are historically limited by low temperatures and short growing seasons, forest growth seems to be slowly accelerating (less than 1 percent per decade). Conversely, growth is slowing in areas subject to drought. For example, in the southwestern United States, growth rates have decreased since 1895, correlating to drought caused by warming temperatures. Similarly, increased drought stress has lowered the growth of white spruce on Alaska's dry south-facing slopes (EPA 2009b).

Wildfires have been increasing in some areas, limiting forest productivity. The wildfire season in the western United States has increased by 78 days in the last 3 decades. Burn durations of large fires (more than 2,470 acres) has increased from 7.5 to 37.1 days due to an increase in spring and summer temperatures of 1.4 °F (EPA 2009b).

Overall, climate change might benefit crop and pasture yields in mid- to high-latitude regions, while decreasing yields in dry and low-latitude regions. Local extinctions of fish species are expected, particularly at the edges of habitat ranges (Easterling *et al.* 2007).

Agricultural and forest lands are experiencing multiple stresses that increase their vulnerability to climate-change impacts. Examples include soil erosion, salinization of irrigated areas, overgrazing, over-extraction of groundwater, loss of biodiversity, and erosion of the genetic resource base in agricultural, forest, and pasture areas. Overfishing, loss of biodiversity, and water pollution in aquatic areas are stresses that increase the vulnerability of fishery resources to climate-change impacts (Easterling *et al.* 2007).

The vulnerability of these resources depends on both the exposure to climate conditions and capacity to cope with changing conditions. Exposure to conditions highly depends on local geography and environment. Adaptive capacity is dynamic and depends on wealth, human capital, information and technology, material resources and infrastructure, and institutions and entitlements (Easterling *et al.* 2007).

Sub-Saharan Africa offers one example of a region that is highly vulnerable to food insecurity (Vogel 2005 in Easterling *et al.* 2007). Drought conditions, flooding, and pest outbreaks are some of the existing stressors on food security that could be influenced by future climate change. Options for addressing food insecurity in this region (and overall development initiatives related to agriculture, fisheries, and forestry) could be constrained by health status, lack of information, and ineffective institutional structures. These constraints could limit future adaptations to periods of heightened climate stress (Reid and Vogel 2006 in Easterling *et al.* 2007).

4.5.6.1.2 Aquatic Systems

Spatial adaptation of marine ecosystems to climate change is in some ways less geographically constrained than for terrestrial systems. The rates at which planktonic ecosystems have shifted their distribution have been very rapid over the past 3 decades, which can be regarded as natural adaptation to a changing physical environment (Beaugrand *et al.* 2002b in Easterling *et al.* 2007). Most fishing communities use stocks that fluctuate due to interannual and decadal climate variability, and consequently have developed considerable coping capacity (King 2005 in Easterling *et al.* 2007).

Research on the relationship between water temperature and the health of freshwater fishes indicates different impacts in summer and winter. Although temperature increases might cause seasonal increases in growth in winter, mortality risks to fish populations occur at the upper end of their thermal tolerance zone in summer.

World capture production of finfish and shellfish in 2004 was more than twice that of aquaculture, but since 1997, capture production decreased by 1 percent whereas aquaculture increased by 59 percent (Easterling *et al.* 2007). The increasingly important aquaculture sector allows for the application of similar types of management adaptations to climate change suggested for crop, livestock, and forestry sectors. This is not the case, however, for marine capture fisheries, which are shared resources subject to varying degrees of effective governance. Adaptation options for marine capture fisheries include altering catch size and effort. Three-quarters of world marine fish stocks are exploited at levels close to or above their productive capacity (Bruinsma 2003 in Easterling *et al.* 2007). Reductions in level of effort and harvest are required to sustain yields. Such a course of action might also benefit fish stocks that are sensitive to climate variability when their population age-structure and geographic substructure are reduced (Brander 2005 in Easterling *et al.* 2007).

4.5.6.2 Environmental Consequences

Earth's land surface is composed mostly of managed cropland and pasture (40 percent) and natural forests (30 percent) (Foley *et al.* 2005 in Easterling *et al.* 2007). These sectors provide important commodities that are produced in a variety of geographic and climatic regions (CCSP 2008c). Continued growth and productivity of the world's agriculture and forests is necessary to sustain human economic and social development.

The discussion below focuses on impacts to food and industrial crops, fisheries, agricultural pastures, commercial forestry, and subsistence farming (Easterling *et al.* 2007). The key drivers for climate impacts in this sector are higher temperatures, changed precipitation and transpiration dynamics, the effects of increased CO_2 concentrations on vegetative growth and yield, greater frequency in extreme weather events, and increased stressors to forests and agriculture in the form of pests and weeds (Easterling *et al.* 2007).

The world's food crops, forests, and fisheries have evolved to be in tune with the present climatic environment. The productivity of these systems ultimately relies on the interaction of various climate factors, including temperature, radiation, precipitation, wind speed, and water vapor pressure (Easterling *et al.* 2007). Threshold climatic conditions for crops and forests affect their growth and yield, and climatic conditions and their interaction influence the global distribution of agricultural and forest species (Porter and Semenov 2005 in Easterling *et al.* 2007). Extreme weather events, including droughts and intense rainfall episodes, can adversely impact crop yields due to the increases and decreases of water associated with these events (CCSP 2008c).

The sensitivity to climate change and exposure to various other stressors increases the vulnerability of the forest, food, and fiber systems (Easterling *et al.* 2007). Non-climate stressors such as soil erosion, overgrazing, loss of biodiversity, decreased availability of water resources, increased economic competition among regions, and the adaptive capacity of various species increase overall sensitivity to the climate and thus exacerbate the adverse effects of climate change (CCSP 2008c).

Climate change could also benefit agriculture and silviculture through the CO_2 fertilization effect. CO_2 is essential for plant growth; some research suggests that higher atmospheric concentrations lead to higher productivity of some food, fiber, and forest crops. Milder winters and longer growing seasons could also increase productivity in some regions.

Important examples that highlight the link between large-scale climate changes and the sensitivity of the food, fiber, and forest systems include the effects of ENSO, a relatively well-known phenomenon, on crop yield. In Australia, during ENSO years there is increased probability of a decline in farmers' incomes by as much as 75 percent below the median income compared to non-ENSO years (Tubiello 2005 in Easterling *et al.* 2007). Another example is the extreme heat wave that occurred in Europe in 2003, which lowered maize yield by 36 percent in Italy and 30 percent in France (Ciais *et al.* 2005 in Easterling *et al.* 2007). Uninsured losses for the entire European Union agriculture sector were estimated at 13 billion euros; 4 billion euros was lost in France alone (Sénat 2004 in Easterling *et al.* 2007).

In the United States, particularly in the north, the average increase in temperature is expected to lead to a longer growing season. However, temperature increases could also lead to increased sensitivity to climate change in the southeast and the corn belt (Carbone *et al.* 2003 in National Science and Technology Council 2008). The Great Plains region is not expected to experience increased sensitivity to climate change (Mearns *et al.* 2003 in National Science and Technology Council 2008).

The most recent comprehensive and peer-reviewed literature about global climate impacts on the food and forestry sectors is from the IPCC Fourth Assessment Report. The SAP 4.3 Report (CCSP 2008c) provides an additional source of information on the impacts of climate change on agriculture, land resources, and biodiversity in the United States. Most of the evidence cited in this section focuses on the results of the IPCC Fourth Assessment Report and SAP 4.3 (CCSP 2008c). Additionally, this section includes information from EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202 (a) of the Clean Air Act* (EPA 2009b). However, because new evidence is continuously emerging on the subject of climate-change impacts on the agriculture and forest systems, the discussion below also draws on results reported in more recent studies.

4.5.6.2.1 Projected Impacts of Climate Change for the United States

Forests

In the United States, the combination of human management and temperate climate has resulted in a productive and healthy forest system, as exemplified by the southern pine plantations (CCSP 2000). Forests are generally considered the most productive of the terrestrial ecosystems and provide important commodities like timber products. They are also key biodiversity sanctuaries and providers of ecosystem services. Forests cover roughly one third of the land in the United States. Net growth of these forests (growth minus removals minus decomposition) accounts for removing about 910.7 $MMTCO_2$ per year from the atmosphere, about 12.7 percent of gross national GHG emissions (EPA 2009a). Globally, forests account for the largest fraction of terrestrial ecosystem sequestered carbon, estimated to be roughly 1,640 petagrams (3,615 trillion pounds) of carbon (Sabine *et al.* 2004 in CCSP 2008). Climate change could directly affect the ability of forests to provide key services and commodities in several ways.

Overall, forest productivity could increase through the CO_2 fertilization effect, the warming of colder climates associated with increased CO_2 concentrations, and increased precipitation, especially in arid regions (EPA 2009b). Forest growth in North America will likely increase between 10 and 20 percent throughout the 21st Century, but with noticeable variation both temporally and regionally (EPA 2009b). The productivity gains will be temporally and regionally dependent. For example, the growth of high elevation forests in the Cascade Mountains in the Northwest United States is expected to increase in the short terms. However, over the long term, deficits in soil moisture will adversely impact tree growth and productivity (GCRP 2009).The expected productivity benefits from increased CO_2 concentrations can be counteracted by water shortages and drought, which in turn are affected by increased nitrogen deposition rates and ozone concentrations (Malmsheimer *et al.* 2008). Additionally, new studies indicate that the direct CO_2 fertilization effect on tree growth is less than previously believed (EPA 2009b).

One key impact of climate change is the extended risk and increased burn area of forest fires coupled with pathogenic stressors that damage fragile forest systems (EPA 2009b). It is projected that the forest fire season (summer) could be extended by 10 to 30 percent as a result of warmer temperatures (Parry *et al.* 2007). Certain forest types including the pinon pine-juniper forests in the Southwest region will be especially susceptible to forest fire risk because of current drought conditions in the region (GCRP 2009). In the western states, the anticipated warmer spring and summer temperatures are expected to reinforce longer fire seasons and increased frequency of large wildfires. In turn, the carbon pools within forests are expected to be affected by changes in forest composition and reduced tree densities (Westerling *et al.* 2006 in CCSP 2008).

More specifically, the Hadley and Canadian climate and ecological models project an increase in the fire season hazard by 10 percent in the 21st Century in the United States, with small regional decreases in the Great Plains and a 30-percent increase in Alaska and the Southeast (CCSP 2000). Highlighting the geographic differences even within a state, two climate models (the Geophysical Fluid Dynamics Laboratory model and the Parallel Climate Model) were run using "business as usual" (A2) and "transition to a low GHG emissions" (B1) IPCC SRES emissions scenarios. The results showed increases in fire risk in Northern California (15 to 90 percent), increasing with temperature, whereas, in Southern California, the change in fire risks ranged from a decrease of 29 percent to an increase of 28 percent. These results were largely driven by differences in precipitation between the different scenarios. In Southern California the drier conditions simulated in both the Geophysical Fluid Dynamics Laboratory model scenarios led to reduced fire risks in large parts of southern California, with fire risks increased in parts of the San Bernardino Mountains (Westerling and Bryant 2006a).

Historical evidence indicates that the warmer periods in the past millennium correlated with increased frequency in wildfires, particularly in western forests (CCSP 2008c). General circulation models project increased wildfire activity in the western states, particularly from 2010 through 2029 (Flannigan *et al.* 2000, Brown *et al.* 2004a, both in CCSP 2008). In 2060, models have projected forest fire severity increases of 10 to 30 percent in southeastern states and 10 to 20 percent in northeastern states (Flannigan *et al.* 2000 in CCSP 2008). Some models have projected even larger increases in wildfire activity, particularly in the southeastern region of the United States (Bachelet *et al.* 2001a in CCSP 2008). Potential losses to North American producers from increased disturbances (including wildfires, insects, and diseases) coupled with climate-change impacts have been estimated to range from $1 to $2 billion per year averaged throughout the 21st Century (Sohngen and Sedjo 2005 in Field *et al.* 2007).

Ancillary consequences of the projected increase in wildfire frequency across the United States include an increase in GHG emissions and criteria air pollutant emissions. Although the GHGs released through wildfires could eventually be sequestered by forest regrowth, this carbon release might not be fully recovered in the short term and thus might be an important source of CO_2 in the atmosphere (Kashian *et al.* 2006 in CCSP 2008). Particularly in forests in the western United States, "If wildfire trends continue, at least initially this biomass burning will result in carbon release, suggesting that the forests of the western United States could become a source of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature increase scenario" (Westerling *et al.* 2006b in CCSP 2008).

Invasive Species

The increasing occurrence of forest fires, which is likely to continue with projected warming temperatures, would impact ecosystem services, reduce the potential for carbon storage via forest management, and provide increased potential habitat for invasive species and insect outbreaks (Parry *et al.* 2007).

Because invasive species and pests are not constrained by the need for pollinators or seed spreaders, these species are more adaptable to the warming climate (Vila *et al.* 2007 in CCSP 2008). The northward movement of weed species, especially invasive weeds, is likely to be a result of higher projected temperatures and increased CO_2 concentration. This movement northward could further be accelerated, because some studies that have shown that the responsiveness of weeds to glyphosate, an important herbicide used in the United States, diminishes with increases in CO_2 concentration levels (Ziska *et al.* 1999 in CCSP 2008).

Disease and Pathogens

Warming temperatures might be allowing for the migration of diseases and pathogens (CCSP 2008c). More specifically, increases in temperature are influencing the development of insect lifecycles, reducing winter mortality rates (EPA 2009b) and "influence[ing] synchronization of mass attacks required to overcome tree defenses" (Ryan *et al.* 2008b in CCSP 2008). EPA (2009b) states that the impacts of climate change on North American commercial forestry are likely to be sensitive to changes in disturbances from insects and diseases.

Warming trends in the United States have already allowed for earlier spring insect activity and increased proliferation of certain species (CCSP 2008c). In the Great Plains region, red fire ant and rodent populations are projected to increase due to warming temperatures associated with climate change (GCRP 2009). These warming trends have also allowed for an increase in the survival rates of diseases and pathogens that affect crops and plant and animal species. Recent research has linked rising temperatures to increased outbreaks of the mountain pine beetle, the southern pine beetle, and the spruce beetle (EPA 2009b). Rising temperatures have also been correlated with the expansion of suitable range for the hemlock wooly adelgid and the gypsy moth (Ryan *et al.* 2008b in CCSP 2008). Not only are the boundaries of insects being shifted by climate change, but "tree physiology and tree defense mechanisms" are being altered (Kirilenko and Sedjo 2007). The damage to forests is expected to depend on seasonal warming – increases in winter and spring temperatures might increase losses to insects such as the southern pine beetle (Gan 2004 in Field *et al.* 2007).

The control of increased insect populations, especially in the projected warmer winters and in the southern regions, might require increased applications of insecticides. It is important to control these insect populations because of their ability to spread other pathogens, especially the flea beetle, which is known to be a conduit for the corn damaging bacterium Stewart's Wilt (CCSP 2008c).

Migration

Under future climate-warming scenarios, plant and animal species are expected to shift northward and to migrate to higher elevations, thus redistributing North American ecosystems (Parry *et al.* 2007). The projected increases in precipitation over dry regions might encourage forest growth and displace some grasslands (CCSP 2008c). Recent bioclimate modeling indicates that over the long term the diversity of tree species in the Northwest will increase while in the Southwest tree species richness will decrease. Plants and trees which are native to the Southeast region will likely shift northward into the Midwest region as temperatures rise (GSCRP 2009). However, the benefit of increased diversity of species in the North over the long term might lead to decreases in the short term because migration of new species northward might be slower than the disappearance of species who have not adapted to local conditions (EPA 2009b).

As an example of species migration as a result of climate change, the United States has experienced an incursion of perennial herbaceous species that limit the soil moisture available for other crops throughout the growing season (CCSP 2008c). The invasion of these non-native species could impact how these regions adapt to climate change and could lead to the potential for more frequent wildfires by increasing vegetation density (Fenn *et al.* 2003 and Wisdom *et al.* 2005 both in CCSP 2008). As another example, aspen trees in Colorado have been encroaching on the more cold-tolerant spruce-fir forests over the past century (EPA 2009b). Additionally, certain habitats like the mountain forests are losing ground due to lowland encroachment and high-altitude habitat loss as a result of warming (EPA 2009b). In the Southwest, grasslands are expected to expand and shift into some forest areas as a result of increasing temperatures and changing precipitation profiles in this region (GCRP 2009).

A marked change in forest composition and distribution has been noted in Alaska, as indicated by a northward migration of the subarctic boundary tree line by 6 miles, and the displacement of 2 percent of the Alaskan tundra in the past 50 years (EPA 2009b). Also, as evidenced by remote sensing analysis, the growing season is increasing in length by roughly 3 days per decade (CCSP 2008c). Arctic vegetation is expected to shift northward and cause forests to overtake tundra (EPA 2009b).

Crops and Agriculture

The agriculture sector in the United States is vulnerable to climate change due to the many factors that affect crops and agriculture, including the availability of water resources, the adaptive capacity of the agricultural sector, technological improvements in farming practices, economic competition, and existing climate and soil conditions (EPA 2009b).

In the early part of the 21st Century, moderate climate change could increase crop yields on agricultural land by 5 to 20 percent (Easterling *et al.* 2007). However, this increase would depend on crops that rely on already highly utilized water resources (Parry *et al.* 2007). Crops that are near the threshold of their productive temperature range (*i.e.*, crops that are "near the warm end of their suitable range"), such as wine grapes, apricots, alomonds, artichokes, figs, kiwis, olives and walnuts in California, are expected to decrease in yield or quality based on moderate climate-change scenarios (EPA 2009b and GCRP 2009). The probability of the loss of popular and recognizable plants such as saguaro cacti and Joshua trees will increase because temperature increases will increasingly affect the reproductive development of various crops, particularly in arid regions (CCSP 2008c).

Grain crops in the United States are likely to initially benefit from the increased temperature and CO_2 levels. However, as temperatures continue to rise, sensitivity of these grain crops could increase. This sensitivity is expected to an even greater extent for horticultural crops such as tomatoes and onions, compromising their productive yield (CCSP 2008c). Various studies have found differing thresholds for maize production in the United States, with one in particular showing a 17-percent reduction of maize yield per 1 °C (1.8 °F) increase in temperature (Lobell and Asner 2003 in CCSP 2008). Other crops, such as wheat, are regionally and temporally dependent. Studies show that wheat yield in the Great Plains "is estimated to decline 7 percent per 1 °C increase in air temperature between 18 and 21 °C [50 and 53 °F] and about 4 percent per 1 °C increase in air temperature above 21 °C" (Lobell and Field 2007 in CCSP 2008). Similarly, rice yields are projected to decline about 10 percent per 1 °C increase for temperature profiles that are above current summer mean air temperatures (CCSP 2008c).

Using an assumed 1.2 °C (2.2 °F) warming over the next 30 years, maize, wheat, sorghum, and dry bean yields are projected to each decrease by 4.0 to 9.4 percent in their major production areas of the United States. Soybean yield, on the other hand, is projected to increase 2.5 percent in the Midwest. However, crop yields in the South will likely decrease. (EPA 2009b)

In the Great Lakes region, fruit production might benefit from climate change, although there might be increased risk of winter thaws and spring frost (Bélanger *et al.* 2002, Winkler *et al.* 2002, both in Field *et al.* 2007). In New Jersey, higher summer temperatures are expected to depress the yields of a number of other economically important crops adapted to cooler conditions (*e.g.*, spinach, lettuce) by mid-century, while rising winter temperatures are expected to drive the continued northward expansion of agricultural pests and weeds (such as kudzu) (Frumhoff *et al.* 2007). Cranberries are especially susceptible because of their requirement to be subjected to long periods of cold winter temperatures for development (Frumhoff *et al.* 2007).

Climate changes could result in significant impacts to irrigation needs. Decreased rainfall, increased evaporation from higher temperatures, and longer growing seasons can all increase irrigation needs. Recent studies indicate that by 2030, changes in irrigation requirements could range from -1 to +451 percent for corn in the United States. Overall, irrigation requirements in the U.S. are projected to increase by 35 to 64 percent (EPA 2009b).

Agriculture could also be affected by the impact of climate change on pests and weeds. Warming trends have in some cases led to earlier spring activity and proliferation of some species. Warmer winters also might allow for higher survival rates of pathogens and parasites. Further, weeds might respond more favorably to elevated CO_2 levels than cash crops. However, further research is needed on this topic before conclusions can be drawn on the effects of elevated CO_2 levels on pests and weeds (EPA 2009b).

Extreme Weather Events

The negative impacts of increased frequency of extreme weather events on crop yield might temper the beneficial effects of increased CO_2 concentrations (CCSP 2008c). Extreme weather events, including droughts and intense rainfall episodes, might adversely impact crop yields due to the increases and decreases of water associated with these events (CCSP 2008c).

Multi-year droughts, which could have been a result of increased temperature conditions in lower-elevation forests in the southwestern region, have had a large impact on forest mortality rates (Breshears *et al.* 2005 in CCSP 2008). The mortality rate continued to increase even though growth at the forest tree line had been increasing previously (Swetnam and Betancourt 1998 in CCSP 2008). Forest productivity has decreased from climate change-induced warming in drought-prone regions (McKenzie *et al.* 2001 in CCSP 2008) and in subalpine regions (Monson *et al.* 2005, Sacks *et al.* 2007, both in CCSP 2008). Droughts are more prevalent in the western U.S. but the East could also be affected by drought and the associated reductions in water supply (EPA 2009b). In the Great Plains region, the projected increase in drought frequency and severity will stress the region's water resources that, in turn, supply water for the agriculture sector. The irrigated agricultural areas in the southern Great Plains will especially be vulnerable to these water resource impacts, particularly because the region is already experiencing unsustainable water use (GCRP 2009).

Intense rainfall events will also cause crop losses via soil compaction and increased susceptibility to root diseases. Intense rainfall also causes more runoff and leaching. In turn, this will delay spring planting for crops, which influences economic profits of the agriculture sector (EPA 2009b). Surface waters could be inundated by sediments, pathogens, and pesticides as increased runoff from crop fields and animal agriculture operations result from intense rainfall events (EPA 2009b).

Livestock

The livestock production infrastructure in the United States is likely to be influenced by the climate-change-induced distributional and productivity changes to plant species. Livestock production during the summer season would *very likely* be reduced due to higher temperatures, but livestock production during winter months could increase, again due to the projected increase in temperatures (CCSP 2008c).

The expected elevated CO_2 concentrations could diminish the quality of grass feed. An increase in the carbon-to-nitrogen ratio would decrease the nutritional value of feed. In turn, grazing livestock that feed on lower-quality grasses might be affected in terms of decreased weight and health (EPA 2009b). For example, an experiment conducted on shortgrass prairie found that increased CO_2 concentrations reduced the protein concentration, which in turn reduced the digestibility of forage by 14 percent in mid-summer (CCSP 2008c). Expected future average climate-change conditions could have less effect on livestock productivity and potential livestock loss than the effects of increased weather variability (*e.g.*, droughts and temperature extremes) (EPA 2009b).

Models of the impact of climate change on agriculture have projected decreases in livestock productivity in the United States simply due to projected temperature increases. In 2050, such a model projects an average decrease in swine, beef, and milk production of 0.9 to 1.2 percent, 0.7 to 2.0 percent, and 2.1 to 2.2 percent, respectively (Frank *et al.* 2001 in CCSP 2008). Higher temperatures directly affect animals' abilities to maintain homeostasis; consequently, livestock must engage in altered metabolic thermoregulatory processes (Mader *et al.* 1997, Davis *et al.* 2003c, both in CCSP 2008). The induced thermal stress on livestock often results in a reduction in physical activity and ultimately diminishes feed intake. Livestock production losses and associated economic losses might be attributed to increasing temperatures that are "beyond the ability of the animal to dissipate [and] result in reduced performance (*i.e.*, production and reproduction), health, and well-being" (Hahn *et al.* 1992, Mader 2003, both in National Science and Technology Council 2008). However, EPA (2009b) points out that decreases in livestock production from hotter summers will likely be partly offset by increased production from warmer winters (EPA 2009b).

The increased temperature expected as a result of climate change could allow for easier migration of animal pathogens and diseases, especially in the northward transition from the low to mid-latitudes, which would adversely affect livestock wellbeing in the United States (White *et al.* 2003, Anon 2006, van Wuijckhuise *et al.* 2006, all in CCSP 2008).

Fisheries

Freshwater fisheries are sensitive to changes in water temperature, and to changes in river flows and lake levels caused by changes in surface water (EPA 2009b). Although fisheries in cold freshwater regions are expected to be adversely affected, fisheries in warm freshwater regions could benefit from climate change (EPA 2009b). The effects of temperature increases have caused northward shifts of fisheries systems and this is expected to continue in the future (CCSP 2008c). According to IPCC, "many warm-water and cool-water species will shift their ranges northward or to higher altitudes" (Clark *et al.* 2001, Mohseni *et al.* 2003, both in Field *et al.* 2007). It has been observed that Pacific salmon species have been recently appearing in Arctic rivers (EPA 2009b). In the Southeastern region of the United States, a reduction in dissolved oxygen associated with warmer water temperatures could potentially lead to increased mortality rates for certain fish species (GCRP 2009).

An example of negative impacts that result from large-scale species migration is the recent migration of two protozoan parasites from the Gulf of Mexico northward into Delaware Bay. This parasitic incursion, possibly as a result of climate change, has led to a substantially increased mortality rate of oysters in the region (Hofmann *et al.* 2001 in CCSP 2008).

According to IPCC, the survival of brook trout in the United States is directly correlated to the availability of its preferred cold-water habitat. As temperatures increase, mortality rates also increase for certain species of trout (EPA 2009b). Other cold-water salmonid species are likely to be negatively affected by rising temperatures (EPA 2009b). It is *likely* that other coldwater species could disappear from all but the deeper lakes; cool-water species will be lost mainly from shallow lakes; and warm-water species will thrive, except in the far south, where temperatures in shallow lakes will exceed survival thresholds (EPA 2009b). Stocks of the river-spawning walleye will likely decline due to lower lake levels and climate-change impacts in Lake Erie (Jones *et al.* 2006 in Field *et al.* 2007).

Coastal fisheries are also expected to experience the negative impacts of climate change, including coral reef bleaching, due to increased ocean temperatures (EPA 2009b).

4.5.6.2.2 Projected Global Impacts of Climate Change

Although the preceding section highlights anticipated impacts of climate change in the United States, there are additional impacts that could affect forest and agriculture systems elsewhere in the world.

Crops

Globally, climate change will affect the agriculture and forest sectors. A recent Harvard report on Climate Change Futures states that a "changing climate will alter the hydrological regime, the timing of seasons, the arrival of pollinators and the prevalence, extent, and type of crop diseases and pests" (Epstein *et al.* 2005). Throughout the mid- to high-latitudinal regions, crop-specific productivity increases are projected for global mean temperature increases of 1 to 3 ºC (1.8 to 5.4 ºF). Beyond a 3-ºC increase in global mean temperature, crop productivity is expected to decrease in some regions (Easterling *et al.* 2007). Depending on crop type, experiments on the effects of increased CO_2 concentrations (namely, 550 ppm as opposed to existing levels of roughly 380 ppm) suggest that crop yields could increase by 0 to 25 percent (EPA 2009b). In the lower-latitude dry regions, cereal crop productivity is projected to decrease with temperature increases of 1 to 2 ºC (1.8 to 3.6 ºF), thereby exacerbating hunger issues for the population living in these regions (Parry *et al.* 2007).

In a modest warming climate scenario, adaptive practices such as using various cultivars and altering planting and harvesting times might maintain cereal crop yields and possibly allow for an increase in productivity in the high latitudinal and temperate regions (Easterling *et al.* 2007). The adaptive practice in regions with 1 to 2 ºC temperature increases corresponds to an avoidance of a 10- to 15-percent reduction in yield for cereal crops (Parry *et al.* 2007).

According to IPCC, the "projected changes in the frequency and severity of extreme climate events will have more serious consequences for food and forestry production, and food insecurity, than will changes in projected means of temperature and precipitation" (Easterling *et al.* 2007). The low latitudinal regions might experience an increase in the frequency of extreme weather events like floods and droughts, which could adversely affect crop production, especially in subsistence farming regions (Easterling *et al.* 2007). Extreme weather events "reduce crop yield and livestock productivity beyond the impacts due to changes in mean variables alone, creating the possibility for surprises" (Parry *et al.* 2007). The reduced adaptive capacity of small-scale farmers such as subsistence and artisanal fisherfolk could result in increased vulnerability to extreme weather events, sea-level rise, and the spread of human disease, which could negatively affect agricultural and fish yields (Parry *et al.* 2007). Existing climate-change models do not yet include recent findings on precipitation extremes that are expected to impact agricultural production in areas such as southern Asia, northern Europe, and eastern Australia. These areas are expected to experience an impact on agricultural productivity as a result of projected increased precipitation extremes such as floods and droughts (Christensen *et al.* 2007b in Easterling *et al.* 2007). Certain crops, such as wheat, are impacted by high precipitation events because wheat is "susceptible to insects and diseases (especially fungal diseases) under rainy conditions" (Rosenzweig and Hillel 1998 in Epstein *et al.* 2005). On the other hand, during droughts, certain fungi, such as *Aspergillus flavus*, are stimulated and will feed on drought-weakened crops (Epstein *et al.* 2005).

Decreases in crop and forest yields in moderate warming scenarios for the low latitudes will likely result in increased dependence on food imports in these typically the developing countries. As such, agricultural exports to lower latitude countries are likely to increase in the short term (Parry *et al.* 2007).

There could be a marginal increase in the population at risk of hunger due to climate change, but this would occur in the context of an overall decrease in the global population at risk of hunger as a result of anticipated economic development (Parry *et al.* 2007).

Forests

Globally, commercially grown forests for use in timber production are expected to increase modestly in the short term, depending on geographic region (Easterling *et al.* 2007). Large regional and local differences are anticipated, as is a shift in terms of production increase from the lower latitudes to the higher latitudes (Parry *et al.* 2007). This poleward shift of forests and vegetation is estimated at roughly 500 kilometers (about 310 miles) or more for the boreal zones for climate scenarios with CO_2 concentrations of double present levels (Kirilenko and Sedjo 2007). In terms of distributional production, net benefits will accrue to regions experiencing increased forest production, whereas regions with declining activity will likely face net losses (Kirilenko and Sedjo 2007).

Due to increases in CO_2 concentration, there is potential for a carbon fertilization effect on the growth of trees, with some experiments showing up to an 80-percent increase in wood production for orange trees (Kirilenko and Sedjo 2007). There is evidence to support elevated growth for young, immature forests in response to higher CO_2 concentration levels (Parry *et al.* 2007). However, free-air CO_2 enrichment experiments indicate that mature forests show no appreciable response to elevated CO_2 concentrations. However, young, immature forests show elevated growth in response to higher CO_2 concentrations (Parry *et al.* 2007). It should be noted that one study regarding forest free-air CO_2 enrichment of 100-year-old tree stands found little to no enhanced stem growth, but this lack of growth might be explained by the relative difficulty of controlling for constant CO_2 levels (Kirilenko and Sedjo 2007).

Many forest models have projected increases in forest production in certain geographic regions (with a few exceptions). For example, the Terrestrial Ecosystem Model and the Center for International Trade in Forest Products Global Trade Model have simulated a future harvest increase of 2 to 11 percent in western North America, a 10- to 12-percent increase in New Zealand, a 10- to 13-percent increase in South America, and a harvest decrease in Canada (Kirilenko and Sedjo 2007).

It is important to contrast these possible short-term benefits with the negative implications of a warming climate, because “continued warming favors more fungal and insect of forests, and more harsh weather will further weaken tree defenses against pests” (Epstein *et al.* 2005). For example, in Europe the spruce bark beetle will likely produce more broods more frequently than in the past due to the warmer climate (Schlyter *et al.* 2006 in Malmsheimer *et al.* 2008). The ability of forests to continue to function as providers of agriculture and energy and sequester carbon will be affected by climate change (Epstein *et al.* 2005). The extreme weather events causing drought and decreased soil moisture, in concert with increased damage from insect and pathogen outbreaks and wildfires, might result in large-scale deforestation, as evidenced by recent trends in the Amazon basin (Kirilenko and Sedjo 2007). Climate-vegetation models have indicated that at CO_2 concentration levels of roughly three times present levels, the Amazon rainforests will eventually be lost due to climate change (Cox *et al.* 2004 in Kirilenko and Sedjo 2007).

Fisheries

The aquaculture and fisheries sector is expected to experience negative impacts as a result of the regional changes in the distribution and proliferation of various marine species (Easterling *et al.* 2007). As the distribution of certain fish species continues to be regionally rearranged, there is the potential for notable extinctions in the fisheries system, especially in freshwater species, in temperature ranges at the margin (Parry *et al.* 2007). Recent evidence indicates that the Meridional Overturning Circulation, which supplies nutrients to the upper layers of the Pacific and Atlantic Oceans, is slowing and therefore adversely affecting regional production of primary food supply for fisheries systems (McPhaden and Zhang 2002, Curry and Mauritzen 2005, Gregg *et al.* 2003, Lehodey *et al.* 2003b, all in Easterling *et al.* 2007). In the North Sea, a shift in the distribution of warm-water species such as zooplankton has resulted in a shift of fish species from whiting to sprat (Beaugrand 2004 in CCSP 2008).

The largest economic impacts associated with the fisheries sector as a result of climate change are expected to occur in coastal regions of Asia and South America (Allison *et al.* 2005 in CCSP 2008). Specifically, regional climate change could most affect species such as tuna and Peruvian anchovy (Barber 2001, Lehodey *et al.* 2003a, both in CCSP 2008).

Earlier spring ice melts in the Arctic and diminishing sea ice are affecting the distribution and productivity of marine species, particularly the upper-level sea organisms. In turn, fish harvests in the Arctic region are expected to change in the warming future. Freshwater species in the Arctic region are expected to be most affected by increasing temperatures (Wrona *et al.* 2005 in Field *et al.* 2007).

4.5.7 Industries, Settlements, and Society

This section defines industries, settlements, and society resources and describes the existing conditions and potential vulnerability of each to climate-change impacts. In addition, this section briefly describes the potential vulnerability of cultural resources, including archaeological resources and buildings of historic significance, to climate-change impacts. The primary source for the information in this section is the IPCC Fourth Assessment Report (Wilbanks *et al.* 2007), specifically, Chapter 7 for industry, settlement, and society.

The industries, settlements, and society sector encompasses resources and activities that describe how people produce and consume goods and services, deliver and receive public services, and live and relate to each other in society.

As defined by IPCC, this sector includes:

- Industry – manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (Wilbanks *et al.* 2007);
- Services – trade, retail, and commercial services, tourism, risk financing/insurance (IPCC 2007a);
- Utilities/infrastructure – systems designed to meet relatively general human needs, often through largely or entirely public utility-type institutions (Wilbanks *et al.* 2007);
- Human settlement – urbanization, urban design, planning, rural settlements (Wilbanks *et al.* 2007); and
- Social issues – demography, migration, employment, livelihood, and culture (Wilbanks *et al.* 2007).

4.5.7.1 Affected Environment

The industry, settlements, and society sector covers a very broad range of human institutions and systems, including the industrial and services sectors, large and small urban areas and rural communities, transportation systems, energy production, and financial, cultural, and social institutions.

A principal objective of human societies is to reduce their sensitivity to weather and climate. Recent experience with storms such as Hurricane Katrina reveals the limits to human control over climate-related impacts on industries, settlements, and society. Systems that are sensitive to climate change include air and water quality, linkage systems (transportation and transmission networks), building structures, resource supplies, social networks, and economic systems (Wilbanks *et al.* 2007).

This sector normally experiences and is generally resilient to variability in environmental conditions. Industries, settlements, and human society, however, can be vulnerable to extreme or persistent changes. Vulnerability increases when changes are unexpected or if resources or other factors inhibit the ability of this sector to respond to changes (EPA 2009b).

Together, industry and economic services account for more than 95 percent of gross domestic product in highly developed economies and between 50 and 80 percent of gross domestic product in less-developed economies (World Bank 2006 in Wilbanks *et al.* 2007). Industrial activities are vulnerable to temperature and precipitation changes. For example, in Canada, weather-related road accidents translate into annual losses of at least $1 billion Canadian annually, and more than a quarter of air travel delays in the United States are weather related (Andrey and Mills 2003 in Wilbanks *et al.* 2007). Buildings, linking systems, and other infrastructure are often in areas vulnerable to extreme weather events (flooding, drought, high winds). Trapp *et al.* (2007) found a net increase in the number of days in which severe thunderstorm environmental conditions could occur during the late 21^{st} Century using global and high-resolution regional climate models. The analysis suggests a future increase in these conditions of 100 percent or more in Atlanta, Georgia, and New York, New York. Such extreme events that can threaten linkage infrastructures such as bridges, roads, pipelines, or transportation networks could cause industry to experience substantial economic losses (Wilbanks *et al.* 2007). In one example of non-storm-related impacts of climate change to infrastructure, in Russia there have been documented structural failures due to unusual levels of permafrost thaw from warming trends (EPA 2009b).

Institutional infrastructure is generally considered to be less vulnerable to weather and climate variation, as it embodies less fixed investment and is more readily adapted within the time scale of climate change. In some cases, experience with climatic variability can enhance the resilience of institutional infrastructure by triggering adaptive responses (Wilbanks *et al.* 2007).

Vulnerability to climate-change impacts is determined by local geography and social context, rather than by large-scale or aggregate factors (Wilbanks *et al.* 2007). A trend toward urbanization can also increase the vulnerability of an area when that urbanization concentrates people in areas at risk for negative climate-change impacts. Sections 4.5.7.1.1 through 4.5.7.1.3 briefly describe risk factors associated with local geography, social context, and urbanization.

4.5.7.1.1 Geography

Extreme weather events are more likely to pose risks to industry, settlements, and society than gradual climate change (Wilbanks *et al.* 2007). Resources and activities in areas with higher susceptibility to extreme weather events (high temperatures, high winds, and flooding) are more vulnerable to the impacts of climate change. The most vulnerable areas are likely to be Alaska, coastal and river basins susceptible to flooding, arid areas, and areas where the economic bases are climate sensitive (EPA 2009b). Extreme weather events can damage transportation routes and other infrastructure, damage property, dislocate settlement patterns, and disrupt economic activity (EPA 2009b). Gradual climate change can change patterns of consumption, decrease or increase the availability of inputs for production, and affect public-health needs. Such impacts are experienced locally, but can be linked to impacts on national and global systems (Wilbanks *et al.* 2007).

Archaeological resources and buildings of historic significance are fixed in location and are therefore vulnerable to the effects of extreme weather events and gradual changes associated with local geography. Extreme weather events can expose archaeological resources and damage structures. Over time, gradual changes to weather patterns can also erode protective cover around archaeological resources and increase the rate of deterioration of historic buildings. Vulnerability of these resources to climate-change impacts is tied to the susceptibility of location and local geography to extreme and gradual changes to weather.

4.5.7.1.2 Social Context

Worldwide, many of the places where people live are under pressure from a combination of growth, social inequity, jurisdictional fragmentation, fiscal shortfalls, and aging infrastructure. These stresses can include scarcity of water, poor sanitation, inadequate governance structures, unmet resource requirements, economic inequities, and political instability. While these types of stresses vary greatly across localities, they can combine with climate-change impacts to result in substantial additional stress at local, national, and global levels (Wilbanks *et al.* 2007).

The social impacts associated with climate change will be mainly determined by how the changes interact with economic, social, and institutional processes to minimize or magnify the stresses. From an environmental justice perspective, the most vulnerable populations include the poor, the very old and very young, the disabled, and other populations that have limited resources and ability to adapt to changes (EPA 2009b). Environmental justice issues are made apparent as warmer temperatures in urban summers have more direct impact on those living and working without air conditioning (EPA 2009b). Section 4.6 addresses environmental justice.

4.5.7.1.3 Urbanization

It is estimated that one third of the world's urban population (almost 1 billion people) lives in overcrowded and unserviced slums, and 43 percent of the urban population is in developing countries. More generally, human settlements are often situated in risk-prone regions such as steep slopes, ravines, and coastal areas. These risk-prone settlements are expected to experience an increase in population, urbanized area, and economic activity. The population in the near-coastal zone (*i.e.*, within 330 feet elevation and 60 to 65 miles distance from the coast) has been estimated to be between 600 million and 1.2 billion, or 10 to 23 percent of the world's population (Adger *et al.* 2005a, McGranahan *et al.* 2006, both in Wilbanks *et al.* 2007). Migration from rural to urban areas is a common response to calamities such as floods and famines (Wilbanks *et al.* 2007).

4.5.7.2 Environmental Consequences

Key climate-change impacts on this set of human systems are likely to vary widely and depend on a range of location-specific characteristics and circumstances. Moreover, potential climate-change impacts on this sector could be particularly challenging to determine because effects tend to be indirect rather than direct. For example, changes in temperature, a direct effect of climate change, affect air pollution concentrations in urban areas, thereby affecting human health and health care systems. These are all indirect effects (Wilbanks *et al.* 2007). The significance of climate-change impacts on human systems will largely be determined through its interaction with other processes, driving forces, and stresses (CCSP 2008d). This type of multi-stress perspective indicates that changes in climate extremes are very often of more concern than changes in climate averages (EPA 2009b).

The human institutions and systems that comprise the industry, settlements, and society sector tend to be quite resilient to fluctuations in environmental conditions that are within the range of normal occurrence. However, when environmental changes are more extreme or persistent, these systems can exhibit a range of vulnerabilities "especially if the changes are not foreseen and/or if capacities for adaptation are limited" (Wilbanks *et al.* 2007). For this reason industry, settlements, and society in developing countries are expected to be more vulnerable to direct and indirect climate-change impacts than they are in industrialized countries (Wilbanks *et al.* 2007).

Climate change is expected to affect industry, settlements, and society via a range of physical effects, including the frequency and intensity of tropical cyclones and storms, extreme rainfall and floods, heat and cold waves, drought, temperature extremes, precipitation, and sea-level rise. Following the approach in Wilbanks *et al.* (2007), the categories of human systems addressed in this section include industry, services, utilities and infrastructure, settlements, and social issues. The following paragraphs describe each category and potential climate impacts on each category. Subsequent sections describe in more detail key systems within these categories that are expected to experience impacts associated with climate change.

Industry – This category includes manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (Wilbanks *et al.* 2007). These activities can be vulnerable to climate change when (a) facilities are in climate-sensitive areas such as coasts and floodplains, (b) the sector depends on climate-sensitive inputs such as food processing, or (c) the sector has long-lived capital assets (Ruth *et al.* 2004 in Wilbanks *et al.* 2007). For the energy sector, in addition to possible infrastructure damage or destruction from the effects of climate change (*e.g.*, as could happen due to extreme weather events) effects could include climate-driven changes in demands for energy. For example, demand for heating could decline in winter months while demand for cooling could rise in summer months (CCSP 2008d).

Services – This category includes trade, retail and commercial services, tourism, and risk financing or insurance (Wilbanks *et al.* 2007). Possible climate-change impacts on trade include impacts on transportation from extreme weather events like snow and ice storms that could impede the ability to transport goods, or impacts on comparative advantage of a region or country due to temperature shifts that affect production. Climate-change impacts on transportation could also affect retail and commercial services. Retail and commercial services could also be affected by climatic conditions that affect prices of raw materials and by potential damage to infrastructure, such as facilities in climate-sensitive areas like coastal regions. Extreme events such as hurricanes can also affect tourism infrastructure. Tourism services could also be affected by climate-change impacts through temperature shifts and changes that affect the natural landscape of tourist destinations. Potential indirect effects of climate change on tourism include changes in availability of water and energy prices. Regarding the insurance sector, climate-change impacts could lead to increasing risk, which could trigger higher premiums and more conservative coverage. A reduction in availability of or ability to afford insurance could in turn lead to impacts on local and regional economies.

Utilities and infrastructure – This category includes systems that are "designed to meet relatively general human needs, often through largely or entirely public utility-type institutions" (Wilbanks *et al.* 2007). This includes physical infrastructure such as water, transportation, energy, and communications systems, and institutional infrastructure such as shelters, public health-care systems, and police, fire, and emergency services. "These infrastructures are vulnerable to climate change in different ways and to different degrees depending on their state of development, their resilience, and their adaptability" (Wilbanks *et al.* 2007). In general, institutional infrastructure tends to be less vulnerable to climate change than physical infrastructure because it typically involves less investment in fixed assets and is more flexible over timeframes that are relevant to climate change. There are numerous points where impacts on different infrastructures interact and the failure of one system can put pressure on others. At the same time, however, "this means that measures to protect one sector can also help to safeguard the others" (Wilbanks *et al.* 2007).

Human settlement – Climate change interacts with other stresses in its impact on human settlements (Wilbanks *et al.* 2007). Potential impacts on human settlements could be experienced through several pathways. Sea-level rise threatens populations in coastal areas by accelerating the inundation of coastal wetlands, threatening vital infrastructure and water supplies, augmenting summertime energy demand, and affecting public health (Wilbanks *et al.* 2007). Changes in precipitation patterns could alter the availability of potable water, while changes in temperature could affect air quality and contribute to an increase in incidents of heat stress and respiratory illnesses (Wilbanks *et al.* 2007). In urban areas, the Urban Heat Island effect (Wilbanks *et al.* 2007), which relates to the "degree to which built and paved areas are associated with higher temperatures than surrounding rural areas" (National Science and Technology Council 2008), might affect the manner in which climate change affects these areas. For example, imbalances in the urban metabolism could aggravate climate-change impacts such as the role of the Urban Heat Index in the formation of smog in cities (CCSP 2008d).

Social Issues – Within human settlements, society could also experience a variety of effects associated with climate change. For example, communities could experience increasing stress on management and budget requirements for public services if demands on public health care and disaster risk reduction grow (CCSP 2008d). There could be a loss of cultural and traditional groups of people, *e.g.* "indigenous societies in polar regions" (Wilbanks *et al.* 2007). Societal concerns that might be affected by the impacts of climate change include socioeconomic issues relating to developed versus developing areas and rich versus poor. As poorer populations tend to have weaker infrastructure and economies tied to climate-sensitive resources, their vulnerability to climate-change impacts is expected to be higher and their capacity to cope or adapt are expected to be lower than wealthier populations (EPA 2009b).

4.5.7.2.1 Projected Impacts of Climate Change for the United States

The research literature on climate-change impacts on U.S. industry, settlements, and society is relatively sparse. "At the current state of knowledge, vulnerabilities to possible impacts are easier to project than actual impacts because they estimate risks or opportunities associated with possible consequences rather than estimating the consequences themselves" (CCSP 2008d). In general, "climate change effects on human settlements in the United States are expected to occur as a result of interaction with other processes" (National Science and Technology Council 2008). These effects include those on health, water resources, physical infrastructure (notably transportation systems), energy systems, human settlements, and economic opportunities.

Impacts on human health and human health care systems are expected to arise because of temperature-related stress. Increases in cases of respiratory illness associated with high concentrations of ground-level ozone; water-, food-, and vector-borne diseases; and allergies related to higher concentrations of plant species are expected.

Effects on water are expected to include reductions in snowpack, river flows, and groundwater levels, saline intrusion in rivers and groundwater, an increase in water demand due to increasing temperatures, and impacts on sanitation, transportation, food and energy, and communication infrastructures from severe weather events.

The U.S. coastline, deltas, and coastal cities such as the Mississippi Delta and surrounding cities, are vulnerable to sea-level rise. "Rapid development, including an additional 25 million people in the coastal United States over the next 25 years will further reduce the resilience of coastal areas to rising sea levels and increase the economic resources and infrastructure vulnerable to impacts" (Field *et al.* 2007b in National Science and Technology Council 2008).

Effects on other key human systems are discussed in greater detail below. Because this section deals with such a broad set of human systems, the potential impacts of climate change and potential adaptations available to key human systems are discussed together. Given the enormous range of human systems that could be affected by climate change, the discussion here is focused on a few key systems for which impacts can best be characterized or supported by sufficient information.

Impacts on Transportation Infrastructure

Climate affects the design, construction, operation, safety, reliability, and maintenance of transportation infrastructure, services, and systems (EPA 2009b). The potential for climate change raises critical questions about how changes in temperature, precipitation, storm events, sea-level rise, and other climate variables could affect the system of roads, airports, rail, public transit, pipelines, ports, waterways, and other elements of the nation's and the world's complex transportation systems.

Climate changes anticipated during the next 50 to 100 years include higher temperatures, changes in precipitation patterns, increased storm frequency and intensity, and rising sea levels globally, resulting from the warming of Earth's oceans and decline in polar ice sheets. These changes could affect the transportation system in a wide variety of ways. The following paragraphs summarize those of greatest relevance for the United States.

- *Increases in very hot days and heat waves.* It is very likely that heat extremes and heat waves will continue to become more frequent, more intense, and last longer in most regions during the 21st Century. This could increase the cost of transportation construction, operations, and maintenance.
- *Increases in Arctic temperatures.* Arctic warming is virtually certain because temperature increases are expected to be greatest over land and at most high northern latitudes. As much as 90 percent of the upper layer of permafrost could thaw under more pessimistic emissions scenarios.
- *Rising sea levels.* It is virtually certain that sea levels will continue to rise in the 21st Century as a result of thermal expansion and loss of mass from ice sheets. This could make much of the existing transportation infrastructure in coastal areas prone to frequent, severe, and/or permanent inundation.
- *Increases in intense precipitation events.* It is very likely that intense precipitation events will continue to become more frequent in widespread areas of the United States. Transportation networks, safety, and reliability could be disrupted by visibility problems for drivers, and by flooding, which could result in substantial damage to the transportation system.
- *Increases in hurricane intensity.* Increased tropical storm intensities, with larger peak wind speeds and more intense precipitation, are likely. This could result in increased travel disruption, impacts on the safety and reliability of transportation services and facilities, and increased costs for construction, maintenance, and repair (Transportation Research Board 2008).

Numerous studies have examined ways of mitigating the transportation sector's contribution to global warming from GHG emissions. However, far less attention has been paid to the potential impacts of climate change on U.S. transportation systems and on how transportation professionals can best adapt to climate changes that are already occurring, and will continue to occur into the foreseeable future even if drastic mitigation measures were taken today. Because GHGs have long life spans, they continue to impact global climate change for decades (Transportation Research Board 2008).

Scientific evidence reports that climate change is already occurring, and that it will trigger new, extreme weather events and could lead to surprises, such as more rapid than expected rises in sea levels or temperature changes. Every mode of transportation will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers (Transportation Research Board 2008).

Consideration of climate-change-related factors in transportation planning and investment decisions should lead to a more resilient, reliable, and cost-effective transportation system in the coming decades. When decisionmakers better understand the risks associated with climate change, they can make better decisions about potential adaptation strategies and the tradeoffs involved in planning, designing, constructing, operating, and maintaining transportation systems (Transportation Research Board 2008).

Projected climate changes have profound implications for transportation in the United States (Transportation Research Board 2008). Climate change is likely to increase costs for construction and maintenance of transportation infrastructure; impact safety through reduced visibility during storms and destruction of elements of the transportation system during extreme weather events; disrupt transportation networks with flooding and visibility problems; inundate substantial portions of the transportation system in low-lying coastal areas; increase the length and frequency of disruptions in transportation service; cause substantial damage and incur costly repairs to transportation infrastructure; and impact the overall safety and reliability of the Nation's transportation system (Transportation Research Board 2008).

Transportation systems across the United States are projected to experience both positive and negative impacts from climate change over the next century; the degree of impacts will be determined, in part, by the geographic region (Transportation Research Board 2008). Coastal communities are especially vulnerable to impacts associated with sea-level rise, increased frequency or intensity of storms, and damage to the transportation system due to storm surges and flooding. The literature indicates that the intensity of major storms could increase by 10 percent or more, which could result in more frequent Category 3 (or higher) storms along the Gulf Coast and the Atlantic Coast (Transportation Research Board 2008). Warming temperatures might require changes in the kinds of materials used for construction of transportation facilities, and in the operation and maintenance of transportation facilities and services. Higher temperatures could require the development and use of more heat-tolerant materials (Transportation Research Board 2008). Restrictions on work rules could increase the time and costs for labor for construction and maintenance of transportation facilities. Rail lines could be affected by higher temperatures and more frequent rail buckling, which would affect service reliability, safety, and overall system costs and performance. Costs could increase for ports, maintenance facilities, and transportation terminals if higher temperatures require an increase in refrigeration and cooling (Transportation Research Board 2008); and higher temperatures could affect aircraft performance and the runway lengths required for safe operation (Transportation Research Board 2008). In addition, due to the potential global nature of the changes in severe weather, climate change could profoundly affect the operational aspects of aviation and overall air traffic and air space management (CCSP 2008b). On the positive side, higher temperatures might open up northern transportation routes for longer periods and allow more direct routing for marine transportation (Transportation Research Board 2008). In addition, warmer or less snowy winters could be beneficial by reducing delays, improving ground and air transportation reliability, and decreasing the need for winter road maintenance (EPA 2009b).

Changes in precipitation patterns could increase short-term flooding, resulting in decreased safety, disruptions in transportation services, and costly damage to transportation infrastructure. Hotter climates could exhibit reduced soil moisture and average runoff, which might require changes in the management and maintenance of publicly owned rights-of-way. The potential increase in heavy rainfall might exceed the capacity of existing drainage systems, resulting in more frequent flooding and associated disruptions in transportation system reliability and service, increased costs for maintenance of existing facilities, and increased costs for construction of new facilities (Transportation Research Board 2008).

Relative sea-level rise might inundate existing transportation infrastructure and substantially increase the cost of providing new transportation facilities and services. Some portions of the transportation infrastructure in coastal areas, or in areas prone to flooding, might have to be protected with dikes or levees – increasing the cost for construction and maintenance, and the potential for more serious flooding incidents associated with the failure of such dikes and levees (Transportation Research Board 2008).

Increased storm frequency and intensity might lead to more disruption to greater transportation services, and damage to transportation infrastructure in coastal and inland areas. Model results for the study of the Gulf Coast conservatively estimated a 22- to 24-foot potential surge for major hurricanes (Transportation Research Board 2008). During Hurricane Katrina (a Category 3 storm at landfall) surges exceeded these heights in some locations (Transportation Research Board 2008). While the specific location and strength of storm surges are difficult to project due to the variation of the scale and trajectory of individual tropical storms, substantial portions of the coastal infrastructure across the United States are vulnerable to increased damage resulting from the impacts of climate change (Transportation Research Board 2008). The central Gulf Coast is particularly vulnerable because of the frequency of hurricanes, its loss of natural protection (*e.g.*, barrier islands and wetlands), and that much of its land is sinking in relation to mean sea level (EPA 2009b).

Disruptions in transportation-system availability could result in substantial economic impacts associated with increased costs to construct or repair transportation infrastructure, and costs associated with disruptions in transportation for goods and services. Increasing fuel costs and delays in transportation service result in increased transport costs, which are then passed on to consumers. A substantial disruption in transportation (*e.g.,* destruction of a major transportation facility by hurricane, flood, or other extreme weather event) could affect the regional economy in many different ways. Communities are likely to require long periods of time to recover from these events, and some communities could be permanently affected (Transportation Research Board 2008).

The analysis to date raises clear cause for concern regarding the vulnerability of transportation infrastructure and services in coastal areas, and across the United States. Addressing the risks associated with a changing climate in the planning and design of transportation facilities and services can help public agencies and private investors to minimize disruptions to the smooth and safe provision of transportation services; and can protect the substantial investments made in the Nation's transportation infrastructure now and in the future (Transportation Research Board 2008).

According to the CCSP *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure Report* (Transportation Research Board 2008), four key factors are critical to understanding how climate change might affect transportation:

- *Exposure.* What is the magnitude of stress associated with a climate factor (sea-level rise, temperature change, severe storms, and precipitation) and the probability that this stress will affect a transportation segment or facility?
- *Vulnerability.* Based on the structural strength and integrity of the infrastructure, what is the potential for damage and disruption in transportation services from this exposure?

- *Resilience.* What is the capacity of a system to absorb disturbances and retain transportation performance?
- *Adaptation.* What response(s) can be taken to increase resilience at both the facility (*e.g.*, a specific bridge) and system levels?

New approaches to address climate-change factors in transportation planning and decisionmaking could include:

- *Extending planning timeframes.* To address the long time frame over which climate changes and environmental processes occur, planning time frames might need to be extended beyond the typical 20- to 30-year planning horizon. The fact that transportation infrastructure can last for many decades (or even more than 100 years) argues for planning for much longer time frames to examine the potential impacts of climate change and other elements of the natural environment on the location, construction techniques, and costs for transportation infrastructure investments that are expected to last for many decades (Transportation Research Board 2008).

- *Conducting risk assessment analysis for transportation investments.* Transportation investments face many uncertainties, including the potential impacts of climate change on construction, operations, and maintenance. Planners and decisionmakers can use iterative risk management analysis to evaluate potential risks of all types, and to identify potential ways to minimize the risks and increase the resiliency of transportation infrastructure. Transportation structures and facilities can be hardened, raised, or even relocated if needed. Where it is critical to safety, reliability, and mobility, redundant systems might be necessary for the most critical elements of the transportation system (Transportation Research Board 2008).

Impacts on Energy Systems

Although the energy sector has been seen as a driver of climate change, the energy sector is also subject to the effects of climate change (Wilbanks *et al.* 2007, EPA 2009b). All major energy sources are subject to a variety of climate change effects, including temperature, wind, humidity, precipitation, and extreme weather events (Bhatt *et al.* 2007; EPA 2009b). The most direct climate-change impacts for fossil fuel and nuclear power plants, for example, are related to power-plant cooling and water availability (Bhatt *et al.* 2007). Each kilowatt of electricity generated by thermoelectric generation requires about 25 gallons of water. Power plants rank only slightly behind irrigation in freshwater withdrawals in the United States (USGS 2004 in Bhatt *et al.* 2007). In addition, about 10 percent of all U.S. coal shipments were delivered by barge in 2003; consequently, low river flows can create shortfalls in coal supplies at power plants (Bhatt *et al.* 2007).

CCSP identified potential effects of climate change on energy production and use in the United States, which are stated in terms of likelihood (Wilbanks *et al.* 2007). Principal impacts and their likelihood are as follows:

- Climate change will reduce total energy demand for space heating; effects will differ by region (*virtually certain*).
- Climate change will increase total energy demand for space cooling; effects will differ by region (*virtually certain*).

- Net effects on energy use will differ by region. Overall impacts will be affected by patterns of interregional migration – which are likely to be in the direction of net cooling load regions – and investments in new building stock (*virtually certain*).
- Temperature increases will increase peak demands for electricity (*very likely*).
- Changes in the distribution of water availability will affect power plants; in areas with decreased water availability, competition for water supplies between energy and other sectors will increase (*virtually certain*).
- Temperature increases will reduce overall efficiency of thermoelectric power generation (*virtually certain*).
- In some regions, energy resource production and delivery systems will be vulnerable to the effects of sea-level rise and extreme weather events, especially the Gulf Coast and the East Coast (*virtually certain*).
- Hydropower production will be directly and substantially affected by climate change, especially in the West and Northwest (*very likely*).
- Climate change concerns will affect perceptions and practices related to risk management behavior in investment by energy institutions (*very likely*).
- Climate change concerns are almost certain to affect public and private sector energy technology research and development investments and energy resource and technology choices by energy institutions, along with associated emissions (*virtually certain*).

CCSP concluded that there is very little literature on adaptation of the energy sector to effects of climate change, and its following discussion is therefore largely speculative (Wilbanks *et al.* 2007). Both energy users and providers are accustomed to changing conditions that affect their decisions. The energy sector is among the most resilient of all economic sectors in terms of responding to changes within the range of historical experience (Wilbanks *et al.* 2007). Adaptations to the effects of climate change on energy use could focus on increased demands and rising costs for space cooling; likely responses include investing in more efficient cooling equipment and building envelopes. Increased demands for both peak and average electricity demands could lead to contingency planning for load leveling, more efficient and expanded generation capacity, expanded interties, and increased storage capacity (Wilbanks *et al.* 2007).

In terms of energy production and supply, the most likely near-term adaptation is expected to be an increase in perceptions of uncertainty and risk in long-term strategic planning and investment, with investors seeking to reduce risks through such approaches as diversifying supply sources and technologies, and risk-sharing arrangements (Wilbanks *et al.* 2007).

Impacts on Human Settlements

The impacts of climate change on human settlements are expected to be substantial in a number of ways. "Settlements are important because they are where most of the [U.S.] population lives, often in concentrations that imply vulnerabilities to location-specific events and processes" (Wilbanks *et al.* 2007). Among the general effects of climate change are increased stress on human settlements due to higher summer temperatures and decreased stress associated with warmer winter temperatures. Changes in precipitation and water availability, rising sea levels in coastal regions, and greater risks from extreme weather events such as storms, flooding, and droughts are also expected to affect human settlements to various degrees (EPA 2009b). At the same time, stresses due to extreme cold weather events, such as blizzards and ice storms, are expected to decrease (Wilbanks *et al*. 2007). In addition to climate change itself, climate-change mitigation measures could affect human settlements. For example, policies related to energy sources and uses, environmental emissions, and land use could have direct and short-term effects on settlements in regions where the economies are closely related to the production and consumption of large quantities of fossil fuels (CCSP 2008d).

Predicting climate-change impacts on U.S. settlements is difficult because climate change is not forecast on a scale that is appropriate for local decisionmaking, and because climate is not the only change that settlements are confronting. A key example is the continuing population shift, particularly among persons who have reached retirement, toward the Sun Belt and coastal areas. This means an ever larger elderly population could be at risk, especially from extreme weather events such as tropical storms, and some types of vector-borne diseases and heat-related illnesses (CCSP 2008d).

Anticipated human impacts include:

- Increased water demands associated with warming accompanied by changes in precipitation that alters access to water (Gleick 2000, Kirshen 2002, Ruth *et al.* 2007, all in CCSP 2008d).
- Damages or disruptions to services associated with urban infrastructure such as sanitation systems, electricity transmission networks, communication systems, and the like could occur as a result of storms, floods, and fires (CCSP 2008d).
- Sea-level rise could jeopardize many of the 673 coastal counties and threaten population centers (Neumann *et al.* 2000, Kirshen *et al.* 2004, both in CCSP 2008d).
- Vulnerable populations such as the poor, elderly, those in ill health, the disabled, persons living alone, and individuals with limited rights (*e.g.*, recent migrants) are expected to be at greater risk from climate change (CCSP 2008d).

The vulnerability of human settlements and infrastructure in coastal areas to natural disasters such as hurricanes and tropical storms was demonstrated through the damages Hurricanes Katrina and Rita caused along the U.S. Gulf Coast.

There is considerable potential for adaptation through technological and institutional development, in addition to behavioral changes, in particular where such developments meet other sustainable development needs (CCSP 2008d). There are various possible adaptation strategies for human settlements including assuring effective governance; increasing the resilience of physical and linkage infrastructures; changing settlement locations over time; changing settlement form; reducing heat-island effects; reducing emissions and industry effluents; improving waste handling; providing financial mechanisms for increasing resiliency; targeting assistance programs for especially impacted segments of the population; and adopting sustainable community development practices (Wilbanks *et al.* 2005 in Wilbanks *et al.* 2007). The choice of strategies and policies for adaptation depend on their relationships with other social and ecological processes and level of economic development (O'Brien and Leichenko 2000 in Wilbanks *et al.* 2007).

Impacts on Economic Opportunities and Risks

Communities or regions that depend on climate-sensitive resources or goods or whose comparative advantage could be affected are expected to be particularly vulnerable to climate change. The insurance sector is an example of an industry that could be highly vulnerable to climate impacts. Overall risk exposure of insurers' has grown considerably (*e.g.*, the National Flood Insurance Program's exposure increased four-fold since 1980 to nearly $1 trillion in 2005 and the Federal Crop Insurance Corporation's exposure grew up to $44 billion) (U.S. GAO 2007). In the United States, of the $19 trillion in insured commercial and residential properties, 41 percent are in coastal communities (EPA 2009b). In Florida, this portion is 79 percent; in New York 63 percent; and in Connecticut 61 percent (EPA 2009b). To the extent that climate change increases costs for insurers or increases the difficulty of forecasting risks, the insurance sector might “withdraw (or make much more expensive) private insurance coverage from areas vulnerable to climate change impacts” (National Science and Technology Council 2008).

Trade, retail, and commercial services, and tourism are other economic areas that are expected to be affected by climate-change impacts, largely as a result of impacts on the transportation and energy sectors. For example, impacts on transportation will affect distribution and receipt of goods for retail services. A decline in water levels could jeopardize this mode of transporting manufacturing. Future low-flow conditions in some areas could affect the ability of ships to navigate waterways and use some ports (EPA 2009b).

Tourism could be affected by “changes in the landscape of areas of tourist interest” and by changes in the availability of resources and energy costs (Wilbanks *et al.* 2007). In the United States, climate-change impacts could affect winter recreation and tourism in the Northeast. Warmer winters would “shorten the average ski and snowboard seasons, increase snow making requirements, and drive up operating costs,” possibly “prompting further closures and consolidation of ski areas northward toward the Canadian border” (Frumhoff *et al.* 2007).

Historical and Cultural Resources

A variety of cultural and historical resources are at risk from climate change. Alaska is the region expected to be most affected by climate change, largely because of location (warming is more pronounced closer to the poles) and way of life (settlement and economic activities based around Arctic conditions) (CCSP 2008d). Indigenous communities in Alaska are facing major economic and cultural impacts because they depend for subsistence on various climate-sensitive animals such as polar bears, walruses, seals, and caribou (National Science and Technology Council 2008). “Changes in species’ ranges and availability, access to these species, a perceived reduction in weather predictability, and travel safety in changing ice and weather conditions present serious challenges to human health and food security, and possibly even the survival of some cultures” (EPA 2009b).

Impacts on National Security

This section draws heavily from national security reports, as peer-reviewed studies are unavailable. These reports represent a collection of security assessments based on congressional testimonies, and assessments from military advisory boards and councils on foreign relations. The following reports were consulted: the Center for Naval Analyses (CNA) Corporation report, “National Security and the Threat of Climate Change” (The CNA Corporation 2007), which was researched and written under the direction of 11 retired senior military officers; the Center for Strategic and International Studies and the Center for a New American Security’s report, “The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change” (Campbell *et al*. 2007); the Council on Foreign Affairs’ special report, “Climate Change and National Security: An Agenda for Action” (Busby 2007); the Pew Center on Climate Change report, “National Security Implications of Global Climate Change” (Pew Center on Global Climate Change 2009); the paper for the European Council, “Climate Change and International Security” (ECEC 2008); and the Department of Defense’s “Quadrennial Defense Review Report” (DOD 2010).

Climate change has profound implications for America’s national security both domestically and abroad. Sea-level rise, storm surges, extreme weather events, and changes in temperature and precipitation patterns all pose serious threats to global stability. Regions in Asia, Africa, and the Middle East with marginal living standards will be particularly vulnerable as economic and environmental conditions worsen (NIC 2008; The CNA Corporation 2007). Further, climate change acts as a threat multiplier[21] for instability in volatile regions of the world (Campbell *et al*. 2007; DOD 2010); NIC 2008; The CNA Corporation 2007).

Areas of conflict driven by climate change that might impact U.S. and international security include the following:

- increased conflict over resources, stemming from changes in agricultural production and freshwater availability (Brown and Crawford 2009; The CNA Corporation 2007; ECEC 2008; Pew Center on Global Climate Change 2009);
- risk of economic damage to coastal cities and critical infrastructure from sea-level rise and an increase in natural disasters (The CNA Corporation 2007; Pew Center on Global Climate Change 2009; Busby 2007);
- loss of territory and border disputes resulting from sea-level rise;
- environmentally-induced migration from loss of coastal land, desertification, and a decreased availability of resources due to climate change (Pew Center on Global Climate Change 2009; ECEC 2008);
- potential for tension and instability over energy supplies (The CNA Corporation 2007; ECEC 2008);
- increasing pressure on international governance, stemming from the potential resentment of those impacted by climate change towards those considered responsible for climate change (ECEC 2008).

These areas of conflict could add political and social tension, as well as an economic burden, to the United States and other stable countries, for example, if such countries were to accept large immigrant and refugee populations (The CNA Corporation 2007; DOD 2010; ECEC 2008; Busby 2007). In addition, the U.S. military could become overextended as it responds to extreme weather events and natural disasters, as along with current or future national security threats (The CNA Corporation 2007; Pew Center on Global Climate Change 2009; DOD 2010; Busby 2007). As a result of the risks described above, the National Intelligence Council has expressed increasing concern regarding the geopolitical and national security consequences of climate change (NIC 2008).

4.5.7.2.2 Projected Global Impacts of Climate Change

As the discussion above suggests, the three major ways in which industry, settlements, and society are vulnerable to climate change are through impacts on economics, infrastructure, and health. The magnitude of impacts on industry, settlements, and society largely depends on location and the level of development of the area or region. The following discussion highlights anticipated impacts on key human systems at the global level.

Global Energy Sector Impacts

Regarding energy production and use, expected global impacts will likely be similar to those described above for the United States. When the climate warms, less heating will be needed for industrial, commercial, and residential buildings, with changes varying by region and by season (Wilbanks *et al.* 2007). Electricity is used in areas around the world for cooling; coal, oil, gas, biomass, and electricity provide energy for heating. Regions with substantial requirements for both cooling and

[21] "Threat multiplier" refers to an action that further intensifies the instability of a system that poses a security concern.

heating could see net increases in electricity demands while demands for other energy sources decline (Hadley *et al.* 2006 in Wilbanks *et al.* 2007).

According to one study, by 2100 the benefits (reduced heating) will be about 0.75 percent of gross domestic product, and impacts (increased cooling) will be approximately 0.45 percent (Tol 2002a, 2002b, both in Wilbanks *et al.* 2007). These percentages could be affected by migration from heating-intensive regions to cooling-intensive regions (Wilbanks *et al.* 2007).

Climate change could also affect global energy production and distribution if extreme weather events become more frequent or intense (EPA 2009b); and in regions that depend on water supplies for hydropower or thermoelectric generation if there are substantial changes in rainfall/snowfall locations and seasonality. Reduced stream flows are expected to jeopardize hydropower production in some areas, but higher precipitation rates resulting in greater or more sustained stream flows could be beneficial (Casola *et al.* 2005, Viosin *et al.* 2006, both in Wilbanks *et al.* 2007). More frequent or intense extreme weather events could threaten coastal energy infrastructures, including electricity transmission and distribution facilities (Bull *et al.* 2007).

Warming temperatures resulting in melting of permafrost threaten petroleum production facilities and pipelines, electrical transmission towers, and nuclear power plants in the Arctic region (EPA 2009b). As with Alaska's North Slope facilities, structural failures in transportation and industrial infrastructure are becoming more common in northern Russia due to melting permafrost (EPA 2009b).

Global Transportation Sector Impacts

The IPCC concludes, with *very high confidence*, that data since 1970 have demonstrated anthropogenic temperature rises have visibly altered ecosystems (Parry *et al.* 2007). Other stressors on the built environment and the ability of cities and countries to adapt to a changing climate make it difficult to discern the exact impacts of climate change on transportation systems around the world. Additional factors, such as projected population growth, are expected to exacerbate the effects of climate change. Development typically occurs in coastal regions, especially in the newly developing third-world countries. These areas are particularly vulnerable to the impacts of projected increases in extreme weather events such as hurricanes, cyclones, unusually heavy precipitation, and flooding. In addition, these developing countries are less able to adapt to expected changes due to their limited resources and other pressing needs (Wilbanks *et al.* 2007).

Transportation-system vulnerabilities in more-developed countries often focus on physical assets and infrastructures and their economic value and replacement costs, along with linkages to global markets. Vulnerabilities in less-developed countries often focus on human populations and institutions that are likely to have very different transportation needs and resources (Wilbanks *et al.* 2007). A warmer, drier climate could exacerbate many of the problems of developing countries, including drought and decreases in food production in areas of Africa and Asia (Wilbanks *et al.* 2007).

At a national scale, industrialized countries such as Norway can cope with most kinds of gradual climate change, but localized differences can show considerable variability in stresses and capacities to adapt (Kates and Wilbanks 2003 in National Science and Technology Council 2008, O'Brien *et al.* 2004, Kirshen *et al.* 2006).

Impacts on the U.S. transportation systems described above apply in other countries as well. Based on information developed by the Transportation Research Board (2008) the potential impacts of climate change on transportation fall into the two major categories, as follows:

- Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days, intense precipitation events, intense hurricanes, drought, and rising sea levels, coupled with storm surges and land subsidence. The impacts will vary by mode of transportation and region, but they will be widespread and costly in both human and economic terms and will require substantial changes in the planning, design, construction, operation, and maintenance of transportation systems.
- Potentially, the greatest impact of climate change on global transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of rising sea levels coupled with storm surges, and exacerbated in some locations by land subsidence (National Science and Technology Council 2008).

Given the global nature of the impacts of climate change and the world economy, coordination within and among nations will become increasingly important (Wilbanks *et al.* 2007). Strong and complex global linkages and interactions occur throughout the world today and are likely to increase in the future. Climate-change effects cascade through interlinked systems for international trade, migration, and communication patterns, producing a variety of direct and indirect effects. Some of these impacts might be anticipated. However, many might not, especially if the globalized economy becomes less resilient and more interdependent (Wilbanks *et al.* 2007).

The impacts of an extreme weather event in one location (*e.g.*, Hurricane Katrina in Louisiana) causes ripple effects throughout the transportation system in the United States and in areas around the world linked to the United States through the ports in the affected area (Transportation Research Board 2008).

There are now incidences in Europe, North America, and Japan of new transportation infrastructure being designed and constructed with potential climate change in mind. For example, designing bridges and other infrastructure at higher elevations in anticipation of sea-level rise over the life span of these transportation-system elements (Wilbanks *et al.* 2007).

Global Human Settlements Impacts

Human settlements are vulnerable to the effects of climate change in three major ways: (1) through economic sectors affected by changes in input resource productivity or market demands for goods and services, (2) through impacts on certain physical infrastructure, and (3) through impacts of weather and extreme events on the health of populations. The degree of vulnerability tends to be a function of the location (coastal and riverine areas are most at risk), economy (economies most dependent on weather-related sectors are at highest risk), and size (larger settlements are at greater aggregate risk, but they likely have greater resources to prevent the impacts of climate change and respond to events that result from climate changes, such as hurricanes, floods, or other extreme weather events) (EPA 2009b).

Shifts in precipitation patterns might affect already stressed environments. For example, mean precipitation in all four seasons has tended to decrease in all main arid and semi-arid regions of the world (northern Chile and northeast Brazil, West Africa, and Ethiopia, drier parts of southern Africa, and western China) (Folland *et al.* 2001 in Wilbanks *et al.* 2007). Increasing temperature could aggravate ozone pollution in many cities, which could affect quickly growing urban areas that are experiencing more air pollution problems, especially those in developing countries (Wilbanks *et al.* 2007). Additionally, sea-level rise will threaten the habitability of island nations in the Caribbean and Pacific, where 50 percent of populations live within 0.9 mile of the shoreline (EPA 2009b).

Extreme weather events affect settlements and society in developing countries just as they do developed countries – through damage and destruction of infrastructure and loss of human life – although perhaps in slightly different ways. For example, in some urban areas of developing countries, informal settlements develop. These informal settlements are especially vulnerable because they tend to be built on hazardous sites and be susceptible to floods, landslides, and other climate-related disasters (Cross 2001, UN-Habitat 2003, both in Wilbanks *et al.* 2007). Another example is how "[i]n developing countries, a common cause of death associated with extreme weather events in urban areas is electrocution by fallen power cables" (Few *et al.* 2004 in Wilbanks *et al.* 2007).

Generally, low-income and other vulnerable populations would experience the same impacts from climate change as populations in comparable geographic areas described in this section and Sections 4.5.6, Food, Fiber, and Forest Products, and 4.5.8, Human Health. However, as with environmental justice populations in the United States, vulnerable populations would likely experience climate-change impacts differentially. The magnitude of climate-change impacts on residents of poorer countries would be expected to be greater (EPA 2009b). For example, IPCC notes that the continent of Africa's "major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change" (Wilbanks *et al.* 2007).

As discussed in this section, the danger to human health from climate change will affect developing countries differentially. The IPCC states that "Adverse health impacts will be greatest in low-income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers, and coastal populations" (Wilbanks *et al.* 2007). Section 4.5.8 describes in detail the potential health effects from climate change on developing countries, which include:

- Increases in malnutrition, and related health impacts, in developing regions of the world due to declining crop yields;
- Potential increases in water-related diseases, such as diarrhea-causing pathogens, due to higher temperatures;
- Potential for continuation of upward trends in certain vector-borne diseases, such as malaria in Africa, which have been attributed to temperature increases; and
- Increases in temperature leading to increased ozone and air pollution levels in large cities with vulnerable populations.

Section 4.5.6 and this section describe the effects of climate change on developing countries that would differ or be substantially more severe than similar effects experienced by developed nations. Because the developing world tends to depend more on small-scale farming and subsistence economic activities, individuals in these areas would be disproportionately affected by climate-change impacts on agricultural and subsistence resources. In particular, these impacts could include:

- Decreases in precipitation in developing parts of the world, such as southern Africa and northern South America, leading to decreases in agricultural production and increased food insecurity;
- Substantial potential for impacts on small-scale subsistence farmers resulting from increases in extreme weather events projected under global climate change, reducing agricultural production in some areas of the globe;

- Changes in the range of fish and animals and species extinctions, affecting populations in developing nations that depend economically on these resources;
- Declines in tourism, especially to coastal and tropical areas heavily affected by sea-level rise, with severe economic consequences for smaller, developing nations; and
- Sea-level rise and severe weather-related events affecting the long-term habitability of atolls (low coral reef-formed islands) (Barnet and Adger 2003).

Global Impacts on Economic Opportunities and Risks

Impacts vary by region and locality and cannot be generalized for all nations. Although impacts are expected to vary, a factor that developed countries have in common is that their access to material and financial resources provides them opportunities to adapt to the effects of a changing climate. In contrast, poorer countries are expected to be less able to adapt to climate change because they lack both the physical and financial resources needed to bolster their resilience to the same extent possible in wealthier countries (EPA 2009b).

In developing countries "industry includes a greater proportion of enterprises that are small-scale, traditional, and informally organized…Impacts of climate change on these businesses are likely to depend on…location in vulnerable areas, dependence on inputs sensitive to climate, and access to resources to support adaptive actions" (Wilbanks *et al.* 2007). One specific industry that could become more vulnerable to direct and indirect impacts of climate change is tourism. Impacts on this industry can be "especially significant for smaller, tourist-oriented countries often in the developing world" (Wilbanks *et al.* 2007). It seems "likely that tourism based on natural environments will see the most substantial changes due to climate change…Tropical island nations and low-lying coastal areas may be especially vulnerable as they may be affected by sea-level rise, changes in storm tracks and intensities, changes in perceived climate-related risks, and changes in transport costs…" (Wilbanks *et al.* 2007). The implications are most notable for areas in which tourism is a relatively large share of the local or regional economy, and those for which adaptation would represent a relatively substantial need and a relatively substantial cost (Wilbanks *et al.* 2007). Trade is another industry that could be affected by extreme weather events that temporarily close ports or transportation routes and damage infrastructure critical to trade, both domestic and international. There could be "linkages between climate change scenarios and international trade scenarios, such as a number of regional and sub-regional free trade agreements" (Wilbanks *et al.* 2007). However, research on this topic is lacking.

4.5.8 Human Health

4.5.8.1 Affected Environment

Climate change has contributed to human mortality and morbidity (*very high* confidence; IPCC 2007b) with further projected increases (EPA 2009b). Climate change could increase the risk of flooding; increase incidence of heat waves; change the severity, duration, and location of extreme weather; increase surface temperature; and alter precipitation intensity and frequency. These events can affect human health either directly through temperature and weather or indirectly though changes in water, air, food quality, vector ecology, ecosystems, agriculture, industry, and settlements. Climate change can also affect health through social and economic disruption. Malnutrition, death, and disease brought on by climate change are projected to affect millions of people (Confalonieri *et al*. 2007).

4.5.8.2 Environmental Consequences

4.5.8.2.1 Observed Health Impacts and Vulnerabilities Associated with Climate Change

Heat Waves

A heat wave is a period of abnormally high temperatures that can be accompanied by unusual humidity. This weather phenomenon is not formally specified by a time period or temperature reading. Conventionally, a heat wave lasts several days to several weeks, though a 1-day event can qualify as a heat wave. The temperature to qualify as a heat wave depends on what is considered unusually hot for that region, because increases in mortality can occur below temperatures considered extremely hot (Ebi *et al.* 2008). IPCC has found the number of hot days, hot nights, and heat waves to have increased (Confalonieri *et al.* 2007). Global warming has increased the intensity of heat waves (Houghton *et al.* 2001 in Epstein *et al.* 2005), due in part to disproportionate warming at night (Easterling *et al.*1997 in Epstein *et al.* 2005). Heat waves can trigger poor air quality and forest fires, leading to further increases in human mortality and morbidity (Bates. 2005, Goodman *et al.* 2004, Keatinge and Donaldson 2001, O'Neill *et al.* 2005, Ren *et al.* 2006, all in Ebi *et al.* 2008).

The impact of a heat wave on the affected population depends on the population's health and economic status. Globally, those most sensitive to heat waves include the rural population, the elderly, outdoor workers, the very young, city dwellers, those with less education, those who are socially isolated, medicated, or mentally ill, and those without available air conditioning (Chaudhury *et al.* 2000 in Confalonieri *et al.* 2007; Diaz *et al.* 2002, Klinenberg 2002, McGeehin and Mirabelli 2001, Semenza *et al.* 1996, Whitman *et al.* 1997, Basu *et al.* 2005, Gouveia *et al.* 2003, Greenberg *et al.* 1983, O'Neill *et al.* 2003, Schwartz 2005, Jones *et al.* 1982, Kovats *et al.* 2004, Schwartz *et al*. 2004, Semenza *et al.* 1999, Watkins *et al.* 2001, all in Ebi 2008; EPA 2009b). People in developed areas also can be impacted substantially by heat waves. Existing electricity grids in the United States would be severely stressed by a major heat wave, leading to brownouts and blackouts and further contributing to increased heat-related illnesses (Epstein *et al.* 2005). In addition, increased electricity demand during heat waves and summer months can compound health issues because air pollutant levels from electrical generating units increase (IPCC, 2007b). Populations identified to be vulnerable to heat waves in the United States include those with diabetes, mobility constraints, and cognitive constraints (Schwartz 2005 in Ebi *et al.* 2008; EPA 2006 in Ebi *et al.* 2008).

The urban heat island effect could increase temperatures experienced in cities by 2 to 10 ºF compared to neighboring rural and suburban areas (EPA 2009c in Ebi *et al.* 2008). This increase in temperature occurs, in part, as the city pavement and buildings absorb a greater amount of incoming solar radiation compared to vegetation and trees; in addition, heat is also emitted from buildings and transportation (EPA 2009c, Pinho and Orgaz 2000, Vose *et al.* 2004, Xu and Chen 2004, all in Ebi *et al.* 2008). However, it has been demonstrated that during a heat wave, not all urban areas experience greater heat-related mortality than the surrounding rural and suburban areas (Sheridan and Dolney, 2003 in Ebi *et al.* 2008). In addition, a sociological analysis of a 1995 Chicago heat wave found populations were at higher risk in neighborhoods without public gathering places and active street life (Klinenberg 2002 in Ebi *et al.* 2008). Population growth over the next 50 years is projected to occur primarily in cities, thereby increasing the number of people exposed to heat waves (EPA 2009b).

Cold Waves

Human mortality and morbidity can also be caused by cold waves. Cold waves affect human health through death, hypothermia, frostbite, damage to organs such as kidneys, pancreas, and liver, with the greatest risk to infants and the elderly (NOAA 2001). Cold waves can cause further complications of heavy snow, ice, coastal flooding, and stranded motorists. As with a heat wave, the classification of a cold wave varies by region, with no formal definition for the minimum temperature reached, the rate of temperature fall, or the duration of the event. Populations in temperate countries that do not traditionally experience cold waves tend to be more sensitive (Honda *et al.* 1998 in Confalonieri *et al.* 2007); however, populations in cold environments are considered vulnerable if electricity or heating systems fail (EPA 2009b). The human-health reaction of a population to a cold wave can vary depending on income, (Healy 2003 in Ebi *et al.* 2008), age, topography, climate (Curriero *et al.* 2002, Hajat 2006, both in Confalonieri *et al.* 2007), race (Fallico *et al.* 2005 in Ebi *et al.* 2008), sex (Wilkinson *et al.* 2004 in Ebi *et al.* 2008), health (Wilkinson *et al.* 2004 in Ebi *et al.* 2008), dress (Donaldson *et al.* 2001 in Ebi *et al.* 2008), and access to fuel (Healy 2003 in Ebi *et al.* 2008). Cold days, cold nights, and frost days have become less common (IPCC 2007b), with the winter season projected to continue to decrease in duration and intensity (IPCC 2007e in Ebi *et al.* 2008). This could lead to a decrease in cold-related health impacts, notwithstanding external factors, such as influenza outbreaks (Ebi *et al.* 2008, EPA 2009b). It has not been determined if the reduced mortality associated with cold waves will be more or less than the increased heat-related mortality projected to occur in response to climate change (CCSP 2008d, EPA 2009b).

Extreme Weather Events

Climate change is anticipated to affect the number, severity, and duration of extreme weather events (Fowler and Hennessey 1995 in Sussman *et al.* 2008). Extreme weather events include floods, tropical and extra-tropical cyclones, tornadoes, windstorms, and drought. Extreme weather can further trigger additional extreme events such as wildfires, negatively affecting infrastructure, including sanitation, human mortality and morbidity, and mental health (Confalonieri *et al.* 2007). The loss of shelter, large-scale population displacement, damage to community sanitation and health care, and reduction in food availability can extend the level of mortality and morbidity beyond the actual event (Curriero *et al.* 2001b in Sussman *et al.* 2008). Factors that influence population vulnerability to extreme weather include location, population density, land use, age, income, education, health, health-care response, and disaster preparedness (Blaikie *et al.* 1994, Menne 2000, Olmos 2001, Adger *et al.* 2005b, Few and Matthies 2006, all in Confalonieri *et al.* 2007; EPA 2009b).

Adverse weather conditions create safety hazards and delays in the Nation's transportation systems, especially on its highways. The Federal Highway Administration estimates that about 28 percent of highway crashes occur during adverse weather, resulting in about 19 percent of highway fatalities (AMS, 2004), while the Federal Motor Carrier Safety Administration found that the factor "environmental conditions" was the critical reason[22] for 3 percent of large truck crashes (FMCSA, 2007). Extreme weather events that increase adverse weather conditions on the Nation's highways could affect highway safety.

Floods occur with the greatest frequency compared to other extreme weather events (EM-DAT 2006 in Confalonieri *et al.* 2007). The intensity of a flood depends on rainfall, surface runoff, evaporation, wind, sea level, and local topography (Confalonieri *et al.* 2007). Health impacts related to flood events include deaths and injuries sustained during a flood event; increased transmission and prevalence of infectious diseases; toxic contamination of supplies and food; and post-traumatic stress disorders (EPA 2009b). Additional health impact stressors such as geographic displacement and damage

[22] The Federal Motor Carrier Safety Administration conducted the Large Truck Crash Causation Study sample of 963 crashes involving 1,123 large trucks and 959 motor vehicles that were not large trucks between 2001 and 2003. The Study defines the Critical Reason as the immediate reason for the critical event (*i.e.*, the failure leading to the critical event). The critical reason is assigned to the vehicle coded with the critical event in the crash. It can be coded as a driver error, vehicle failure, or environmental condition (roadway or weather). Other causal coding includes a Critical Event and Associated Factors.

to possessions and property can occur after the initial event, leading to continued disruption and anxiety regarding the recurrence of the event (Tapsell *et al.* 2002 in Ebi *et al.* 2008). Coastal storms can cause drowning by the associated storm surge particularly in regions of high-density populations living in low-lying coastal sections, as evidenced in the U.S. Gulf Coast during 2005 Hurricane Katrina (EPA 2009b).

Drought is an abnormal period of dry weather that has led to substantial decrease in water availability for a given location (Huschke 1959). The health impacts associated with a drought include mortality, malnutrition, infectious diseases, and respiratory diseases (Menne and Bertollini 2000 in Confalonieri *et al.* 2007). Aggravating this situation, malnutrition increases the susceptibility of contracting an infectious disease (Confalonieri *et al.* 2007) and drought-related population displacement can reduce access to adequate and safe water, food, and shelter, leading to increased malnutrition and infectious diseases. Further health impacts can spiral, such as a change in the transmission of mosquito-borne diseases during and after the drought event (Confalonieri *et al.* 2007). Impacts on agricultural productivity affect health through risk of under- and malnutrition (Epstein *et al.* 2005), and increased dust storm activity and frequency of forest fires. Drought conditions weaken trees' defenses against pests and can result in increased threats to human health from forest fires (Mattson and Haack 1987, Boyer 1995, Holsten *et al.* 2000, all in Epstein *et al.* 2005). Health impacts associated with drought tend to be more prevalent in drier climates with poor populations and where there is human-induced water scarcity. Therefore, the most severe drought-related health impacts are likely to be in developing countries rather than in the United States (EPA 2009b).

Air Quality

Climate change can affect air quality through altering local weather patterns and/or pollution concentrations. Ground-level ozone, PM, and airborne allergens contribute to poor air quality, leading to respiratory ailments and premature mortality. Increasing exposure to these pollutants would have substantial negative health impacts (Confalonieri *et al.* 2007).

Ground-level ozone contributes to urban smog, and occurs both naturally and as a secondary pollutant formed through photochemical reactions of NO_x and VOCs.[23] These reactions are accelerated with increasing sunlight and temperatures. Ozone concentrations tend to peak around 3pm through 6pm depending and in the warmer season. EPA (2009b) states that ozone generally increases with higher temperatures. Studies have already found increasing levels of ground-level ozone in most regions (Wu and Chan 2001, Chen *et al.* 2004, both in Confalonieri *et al.* 2007). A recent study found increases in CO2 concentrations contribute to increased water vapor and temperatures and separately increase ozone more with higher ozone (Jacobson 2008). These lead to an increase in U.S. annual air pollution deaths by about 1,000 (350-1,800) where about 40% of the additional death may be due to ozone (the remaining 60% to particles). The study further extrapolates the findings to a global scale estimating 21,600 (7,500-39,000) excess CO2-caused annual pollution deaths

Ozone exposure is associated with respiratory ailments such as pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis, chest pain and other respiratory diseases (Mudway and Kelly 2000, Gryparis *et al.* 2004, Bell *et al.* 2005, 2006, Ito *et al.* 2005, Levy *et al.* 2005, all in Confalonieri *et al.* 2007). Asthmatics are considered a sensitive population (Ebi *et al.* 2008). Long-term exposure to elevated amounts of ozone has been shown to affect lung efficiency (Ebi *et al.* 2008).

PM comprises solid and liquid particles suspended in the atmosphere varying in both chemical composition and origin. Concentrations of PM are affected by emission rates and local weather

[23] NO_x is emitted, in part, through the burning of fossil fuels. VOCs are emitted from varying sources, including burning of fossil fuels, transpiration, evaporation from stored fuels, solvents and other chemicals.

conditions such as atmospheric stability, wind, and topography. Some particulates display seasonal variability directly linked to seasonal weather patterns (Alvarez *et al.* 2000, Kassomenos *et al.* 2001, Hazenkamp-von Arx *et al.* 2003, Nagendra and Khare 2003, Eiguren-Fernandez *et al.* 2004, all in Confalonieri *et al.* 2007). In Mexico City and Los Angeles, local weather conditions can create a stagnant air mass, restricting dispersion of pollution. Seasonal weather patterns can further enhance the chemical reactions of emissions, thereby increasing secondary PM (Rappengluck *et al.* 2000, Kossmann and Sturman 2004, both in Confalonieri *et al.* 2007; EPA 2009b).

Breathing PM can cause respiratory ailments, heart attack, and arrhythmias (Dockery *et al.* 1993, Samet *et al.* 2000, Pope *et al.* 1995, 2002, 2004, Pope and Dockery 2006, Dominici *et al.* 2006, Laden *et al.* 2006, all in Ebi *et al.* 2008). Populations at greatest risk could include children, the elderly, and those with heart and lung disease, diabetes (Ebi *et al.* 2008), and high blood pressure (Künzli *et al.* 2005 in Ebi *et al.* 2008). Chronic exposure to PM could decrease lifespan by 1 to 3 years (Pope 2000 in American Lung Association 2008). Increasing PM concentrations are expected to have a measurable adverse impact on human health (Confalonieri *et al.* 2007).

Forest fires contribute to poor air quality conditions. During the fifth largest U.S. wildfire, in 1999, medical visits at the Hoopa Valley National Indian Reservation increased by 52 percent, with symptoms affecting lower respiratory tract and preexisting cardiopulmonary conditions (Mott *et al.* 2002). Human-health ailments associated with forest fires include burns, smoke inhalation, mortality, eye illnesses, and respiratory illnesses (Confalonieri *et al.* 2007, Ebi *et al.* 2008). One study found there is an increase in the number of patients requesting emergency services for smoke and ash inhalation when there are large fires (EPA 2009b). Certain regions are anticipated to experience an increase in frequency and intensity of fire events with projected changes in temperature and precipitation. Pollutants from forest fires can affect air quality for thousands of miles (EPA 2009b). Pollution from forest fires along with other pollutants, such as carbon monoxide, ozone, desert dust, mould spores and pesticides, can be transported thousands of kilometers on time scales of 4 to 6 days and affecting populations far from the sources (Gangoiti *et al.* 2001, Stohl *et al.* 2001, Buchanan *et al.* 2002, Chan *et al.* 2002, Martin *et al.* 2002, Ryall *et al.* 2002, Ansmann *et al.* 2003, He *et al.* 2003, Helmis *et al.* 2003, Moore *et al.* 2003, Shinn *et al.* 2003, Unsworth *et al.* 2003, Kato *et al.* 2004, Liang *et al.* 2004, Tu *et al.* 2004, all in Confalonieri *et al.* 2007).

Water-borne and Food-borne Diseases

Substantial morbidity and childhood mortality has been linked to water- and food-borne diseases. Climate change is projected to alter temperature and the hydrologic cycle through changes in precipitation, evaporation, transpiration, and water storage. These changes, in turn, potentially affect water-borne and food-borne diseases, such as salmonellosis, campylobacter, leptospirosis, and pathogenic species of vibrio. They also have a direct impact on surface-water availability and water quality. It has been estimated that more than 1 billion people in 2002 did not have access to adequate clean water (McMichael *et al.* 2003 in Epstein *et al.* 2005). Increased temperatures, greater evaporation, and heavy-rain events have been associated with adverse impacts on drinking water through increased waterborne diseases, algal blooms, and toxins (Chorus and Bartram 1999, Levin *et al.* 2002, Johnson and Murphy 2004, all in Epstein *et al.* 2005). A seasonal signature has been associated with waterborne disease outbreaks (EPA 2009b). In the United States, 68 percent of all waterborne diseases between 1948 and 1994 were observed after heavy rainfall events (Curriero *et al.* 2001a in Epstein *et al.* 2005).

Climate change could further impact a pathogen by directly affecting its life cycle (Ebi *et al.* 2008). The global increase in the frequency, intensity, and duration of red tides could be linked to local impacts already associated with climate change (Harvell *et al.* 1999 in Epstein *et al.* 2005); toxins associated with red tide directly affect the nervous system (Epstein *et al.* 2005).

Many people do not report or seek medical attention for their ailments of water-borne or food-borne diseases; hence, the number of actual cases with these diseases is greater than clinical records demonstrate (Mead *et al.* 1999 in Ebi *et al.* 2008). Many of the gastrointestinal diseases associated with water-borne and food-borne diseases can be self-limiting; however, vulnerable populations include young children, those with a compromised immune system, and the elderly.

Vector-borne Diseases

Infections can be spread by the bite of an infected arthropod (termed vector-borne) such as mosquitoes, ticks, sandflies, and blackflies, or through non-human vertebrates such as rodents, canids, and other mammals. Such diseases include typhus, malaria, yellow fever, dengue fever, West Nile virus, Western Equine encephalitis, Eastern Equine encephalitis, Bluetongue virus, and Lyme disease. Increased insect density has been correlated with milder seasonal variability (Confalonieri *et al.* 2007) and tick distributions tend to expand with higher minimum temperatures (Ebi *et al.* 2008). In the United States, the greatest transmissions of West Nile virus occurred during the 2002 through 2004 summers associated with above average temperatures (EPA 2009b). In general, climate and weather are important constraints on the range of transmission for vector-borne diseases. For example, temperature and flooding are key constraints on the range of mosquitoes, which serve as a primary vector for malaria and other diseases (Epstein *et al.* 2005). Changes in seasonal duration and increases in weather variability reduce or eliminate these constraints (Epstein *et al.* 2005). In southern Mozambique, the number of malaria cases increased four to five times over long-term averages in the days and weeks following a severe flooding event in 2000 (Epstein *et al.* 2005). Temperature and the availability of water can both play key roles in regulating population size. For the deer tick, the disease vector for Lyme disease, off-host survival is strongly affected by these two variables; therefore, climate is the primary factor determining size and distribution of deer tick populations (Needham and Teel 1991, Bertrand and Wilson 1996, both in Epstein *et al.* 2005). Changes in land-use practices or to the habitat and behavior of wildlife hosts of the insect can also impact latitudinal or altitudinal shifts in the disease-carrying species (Confalonieri *et al.* 2007).

4.5.8.2.2 Projected Health Impacts of Climate Change on the United States

Human health is projected to be adversely affected by rising temperatures, increasing ground-level ozone concentrations, changes in extreme weather events, and increasing food- and water-borne pathogens. The impact of the varying health-related event is dependent on location. The United States is anticipated to sustain fewer cases of illness and death associated with climate change compared with the developing world (CCSP 2008d). The existing health infrastructure Federal Government disaster planning and emergency response systems are key assets to enable the United States to meet changing health-effect demands associated with climate change. These health impacts will vary in scope across the United States.

In the United States, there were 20,000 heat and solar-related deaths from 1936 to 1975, with the heat wave of 1980 accounting for more than 1,250 of these deaths (NOAA 2005 in Kundzewicz *et al.* 2007). There could be a rise in heat-related morbidity and mortality in the coming decades (CCSP 2008d) due, in part, to an aging population. By 2010, 13 percent of the population of the United States is projected to be over the age of 65 (Day 1996 in Ebi *et al.* 2008), and this proportion will grow dramatically as Baby Boomers age (EPA 2009b). Additionally, most population growth will occur in the cities, where temperatures tend to be higher due to the urban heat island effect (EPA 2009b). This shift toward an older, and more urban population, could increase heat-related health risks.

Studies have shown a decline in heat-related mortality over the past decades, possibly due to increased air conditioning usage and improved health care (Davis *et al.* 2002, Davis *et al.* 2003a, Davis *et* *al.* 2003b, Carson *et al.* 2006, all in Ebi *et al.* 2008). Heat waves are anticipated to increase in severity, frequency and duration, particularly in the Midwest and Northeast (CCSP 2008d). In U.S. regions where severe heat waves already occur, these events are projected (*high confidence*) to intensify in magnitude and duration. Tor example, in 2080 through 2099, Chicago could experience a 25-percent increase in the annual frequency of heat waves under the business-as-usual (A1B) emissions scenario (EPA 2009b).

The northern latitudes of the United States are likely to experience the greatest increases in average temperature and concentrations of many of the airborne pollutants (CCSP 2008d). A regional climate simulation projected air quality to worsen in Texas but to improve in the Midwest in 2045 to 2055 compared to 1995 to 2005 (Leung and Gustafson 2005 in Ebi *et al.* 2008). In urban areas, ground-level ozone concentrations are anticipated to increase in response to higher temperatures and increases in water vapor concentration (CCSP 2008d, Jacobson 2008). Climate change could further cause stagnant air masses that increase pollution concentrations of ground-level ozone and PM in populated areas. For example, one study projected an increase in upper Midwest stagnant air between 2000 and 2052 (Mickley *et al.* 2004 in Ebi *et al.* 2008). An alternative study found an increase in evaporative losses from nitrate particles reduces PM levels (Aw and Kleeman 2003 in Ebi *et al.* 2008). A recent study concluded that continuous local outdoor CO_2 emissions can increase the respective CO_2 concentration for that area, thereby increasing ozone levels (Jacobson 2008).

The spring pollen season has recently been shown to begin earlier than usual in the Northern Hemisphere (D'Amato *et al.* 2002, Weber 2002, Beggs 2004, all in Confalonieri *et al.* 2007). There is further evidence suggesting a lengthening of the pollen season for some plant species (Confalonieri *et al.* 2007). A recent study determined that the density of air-borne pollen for some species has increased, however, it is not understood what the allergenic content of this additional pollen is (Huynen and Menne 2003, Beggs and Bambrick 2005, both in Confalonieri *et al.* 2007). Additionally, climate change could alter the pollen concentration of a given plant species as the species reacts to increased concentrations of CO_2. Current findings demonstrate that ragweed pollen production and the length of the ragweed pollen season increase with rising CO_2 concentrations and temperatures (Wan *et al.* 2002, Wayne *et al.* 2002, Singer *et al.* 2005, Ziska *et al.* 2005, Rogers *et al.* 2006a, all in Confalonieri *et al.* 2007). Invasive plant species with high allergenic content, such as ragweed and poison ivy, have been found to be spreading in particular locations around the world, increasing potential health risks (Rybnicek and Jaeger 2001, Huynen and Menne 2003, Taramarcaz *et al.* 2005, Cecchi *et al.* 2006, all in Confalonieri *et al.* 2007). For example, a field study determined urban locations could experience an increase in ragweed pollen compared to rural locations due to the projected temperature and CO_2 concentrations in these locations (Field *et al.* 2007d in EPA 2009). Scientific findings are not conclusive about how climate change might impact allergenic illnesses in the United States, particularly in relation to other factors such as changes in land use, air pollution, and adaptation practices (EPA 2009b).

Extreme weather events are likely to be altered by climate change, though there is uncertainty projecting the frequency and severity of events. Some regions in the United States might experience drought conditions due to the reduction in rainfall, while other sections of the Country are likely to experience increased frequency of heavy rainfall events, leading to potential flood risk (GCRP 2009). It is considered *very likely* (greater than 90 percent certainty) that over the course of this century there will be an increase in the frequency of extreme precipitation (IPCC 2007a). The Southeast, Intermountain West, and West are likely to experience an increase in frequency, severity, and duration of forest fires (CCSP 2008d, Brown *et al.* 2004b, Fried *et al.* 2004, all in Ebi *et al.* 2008). Impacts to respective vulnerable populations could change in the future as shifts occur in population, suburban development, and community preparedness. It is very likely that a large portion of the projected growth of the United States population will occur in areas considered to be at risk for future extreme weather events (Ebi *et al.* 2008). Hence, even if the rate of health impacts decreased, the growth in population in risk areas would still cause an increase in the total number of people affected. Intense tropical cyclone activity is "*likely*" to intensify, increasing the risk of death, injuries, diseases, and mental health disorders (EPA 2009b).

Pathogen transmission depends on many climate-related factors such as temperature, precipitation, humidity, water salinity, extreme weather events, and ecological shifts, and could display seasonal shifts (Ebi *et al.* 2008). Few studies have projected the health impact of vector-borne diseases. Vector-borne illnesses are likely to shift or expand northward and to higher elevations with the possible introduction of new vector-borne diseases (CCSP 2008d), while decreasing the range of tick-borne encephalitis in low latitudes and elevation (Randolph and Rogers 2000 in Ebi *et al.* 2008). For example, the northern range limit of Lyme disease could shift north by as much as 200 kilometers (about 124 miles) by 2020 and 1,000 kilometers (about 621 miles) by 2080 (Field *et al*. 2007a; EPA 2009b). Malaria in the United States is unlikely to be affected by climate change variables given public intervention and vector control (EPA 2009b).

Food- and water-borne pathogens might spread with a warmer climate. Increases in temperature, precipitation, and extreme events could spread these pathogens, depending on their survival, persistence, habitat range, and transmission under changing climate and environmental conditions. While the quality of the U.S. water supply is well maintained by the Safe Drinking Water Act and the Clean Water Act, individuals can still be exposed to these pathogens through other means (*e.g.*, swimming) (EPA 2009b).

Climate change is anticipated to increase ozone-related diseases (Sussman *et al.* 2008). However, it is important to note that the concentration of ground-level ozone for a particular location varies as a function of temperature, wind, solar radiation, atmospheric moisture, atmospheric mixing, and cloud cover. The impact climate change has on some of these variables could have a positive effect on ozone concentrations, while simultaneously the impact of climate change on other variables could have a negative effect on ozone concentrations (EPA 2009b). Therefore, when estimating the impact climate change will have on ground-level ozone, it is necessary to account for *all* of these factors, and not just temperature (EPA 2009b). That said, climate change is projected to increase surface layer ozone concentrations in urban and polluted rural environments (EPA 2009b).

Climate change could also have opposing effects on PM. On the one hand, increased precipitation and humidity in some areas could lower PM concentrations. On the other hand, increased forest fires could increase PM concentrations. Preliminary modeling indicates an overall small decrease in PM concentrations due to climate change; however, there are significant regional variations. In the United States, the Midwest and Northeast, for example, could experience noteworthy increases in PM concentrations (EPA 2009b).

Overall, populations within certain regions of the United States regions could experience climate change-induced health impacts from a number of pathways simultaneously. For instance, populations in coastal communities could experience an extreme weather event, such as a tropical cyclone and flooding, adding to health burdens associated with sea-level rise or coastal erosion.

4.5.8.2.3 Projected Global Health Impacts of Climate Change

Globally, climate change is anticipated to contribute to both adverse and beneficial health impacts. Projected adverse health impacts include malnutrition leading to disease susceptibility (*high confidence*); increased heat-wave-, flood-, storm- and fire-induced mortality (*high confidence*); decrease in cold-related deaths (*high confidence*); increased diarrheal disease burden (*medium confidence*); increased levels of ground-level ozone (*high confidence*); and altered geographic distribution of some infectious disease vectors (*high confidence*) (Confalonieri *et al.* 2007). A decrease in cold-related mortality and some pollutant-related mortality, increased crop yields in certain areas, and restriction of certain diseases in certain areas (if temperatures or precipitation rise above the critical threshold for vector or parasite survival) are examples of projected beneficial health impacts (Confalonieri *et al.* 2007). The adverse impacts, however, greatly outweigh the beneficial impacts, particularly after mid-century (Confalonieri *et al.* 2007).

Regionally, the impact on human health will vary. Some Asian countries could experience increasing malnutrition by 2030, with crop yields decreasing later in the century, rendering the population in the region particularly vulnerable to malnutrition-associated diseases and disorders (Confalonieri *et al.* 2007). Certain coastal areas will experience flooding by 2030, impacting human mortality (Confalonieri *et al.* 2007). By 2080, Lyme disease is projected to have moved northward into Canada, due to a two- to four-fold increase in tick abundance (Confalonieri *et al.* 2007). By 2085, climate change is projected to increase the population at risk to dengue fever to a total of 3.5 billion people (Confalonieri *et al.* 2007).

Heat waves have been experienced globally; thousands of deaths incurred in India over the 18 heat waves recorded between 1980 and 1998 (De and Mukhopadhyay 1998, Mohanty and Panda 2003, De *et al.* 2004, all in Confalonieri *et al.* 2007). In August 2003, approximately 35,000 deaths were linked to a heat wave in Europe, with France alone incurring more than 14,800 deaths (Hemon and Jougla 2004, Martinez-Navarro *et al.* 2004, Michelozzi *et al.* 2004, Vandentorren *et al.* 2004, Conti *et al.* 2005, Grize *et al.* 2005, Johnson *et al.* 2005b, all in Confalonieri *et al.* 2007). About 60 percent of the heat-wave-related deaths in France were people at or over 75 years of age (Hemon and Jougla 2004 in Confalonieri *et al.* 2007). Overall, studies have linked high temperatures to about 0.5 to 2 percent of annual mortality in the elderly European population (Pattenden *et al.* 2003, Hajat *et al.* 2006, both in Confalonieri *et al.* 2007).

In 2003, floods in China affected 130 million people (EM-DAT 2006 in Confalonieri *et al.*2007). In 1999, storms with floods and landslides in Venezuela killed 30,000 people (Confalonieri *et al.* 2007).

The World Health Organization (WHO) estimates that a high proportion of those in dry regions (approximately 2 billion) experience malnutrition, infant mortality, and water-related diseases (WHO 2005 in Confalonieri *et al.* 2007). Children in low-income countries are particularly vulnerable to loss of life due to diarrhea. The transmission of the enteric pathogen appears to increase during the rainy season for children in sub-Saharan Africa (Nchito *et al.* 1998, Kang *et al.* 2001, both in Confalonieri *et al.* 2007). In Peru, higher temperatures have been linked to periods of increased diarrhea incidence experienced by adults and children (Checkley *et al.* 2000, Speelmon *et al.* 2000, Checkley *et al.* 2004, Lama *et al.* 2004, all in Confalonieri *et al.* 2007).

Cholera outbreaks associated with floods can occur in areas of poor sanitation. A study of sea-surface temperatures in the Bay of Bengal demonstrated a bimodal seasonal pattern that translated to increased plankton activity and leading to increases in cholera in nearby Bangladesh (Colwell 1996, Bouma and Pascual 2001, both in Confalonieri *et al.* 2007).

Dengue is considered the most important vector-borne viral disease (Confalonieri *et al.* 2007). There is a strong correlation between climate-based factors such as temperature, rainfall, and cloud cover with the observed disease distribution in Colombia, Haiti, Honduras, Indonesia, Thailand and Vietnam (Hopp and Foley 2003 in Confalonieri *et al.* 2007). About one-third of the world's population lives in areas with climate conditions favorable for dengue (Hales *et al.* 2002, Rogers *et al.* 2006b, both in Confalonieri *et al.* 2007).

Malaria is a vector-borne disease spread by mosquitoes. Depending on location, malaria outbreaks could be influenced by rainfall amounts and sea-surface temperatures in southern Asia, Botswana, and South America (Kovats *et al.* 2003, Thompson *et al.* 2005, DaSilva *et al.* 2004, all in

Confalonieri *et al.* 2007). A recent study of malaria in East Africa found that the measurable warming trend the area has experienced since the 1970s can be correlated with the potential of disease transmission. (Pascual *et al.* 2006 in Confalonieri *et al.* 2007). However, southern Africa was not shown to exhibit the same trend (Craig *et al.* 2004 in Confalonieri *et al.* 2007). External factors are also influencing the number of cases of the disease in Africa, such as drug-resistant malaria, and parasite and HIV infections. Studies did not provide clear evidence that malaria in South America or the continental regions of the Russian Federation have been affected by climate change (Benitez *et al.* 2004, Semenov *et al.* 2002, both in Confalonieri *et al.* 2007). In general, however, higher temperatures and more frequent extreme weather occurrences (such as floods and droughts) are projected to have a stronger influence on the wider spread of malaria with increasing climate change (McMichael *et al.* 1996 in Epstein *et al.* 2005).

Temperature has been shown to affect food- and water-borne diseases (EPA 2009b). Several studies have found increases in salmonellosis cases (food poisoning) within 1 to 6 weeks of the high-temperature peaks (controlled by season). This could be due in part to the processing of food products and the population varying its eating habits during warmer months (Fleury *et al.* 2006b, Naumova *et al.* 2006, Kovats *et al.* 2004a, D'Souza *et al.* 2004a, all in Ebi *et al.* 2008). High temperatures have been shown to increase common types of food poisoning (D'Souza *et al.* 2004b, Kovats *et al.* 2004b, Fleury *et al.* 2006a, all in Confalonieri *et al.* 2007). Increasing global temperatures could contribute to a rise in salmonellosis cases (Ebi *et al.* 2008). There is further concern that projected increasing temperatures from climate change will also increase leptospirosis cases, a disease that is resurging in the United States.

The effects of climate change on air quality are expected to adversely impact people suffering from asthma and other respiratory ailments. Increases in temperature, humidity, the prevalence and frequency of wildfires, and other factors are expected to result in more smog, dust, and particulates that exacerbate asthma. Widespread respiratory distress throughout many regions of the world is a possible result of climate change. Existing asthma treatment and management plans might be overwhelmed, leading to major increases in asthma-related morbidity and mortality (Epstein *et al.* 2005).

Warm climates are more apt to support the growth of the pathogenic species of *Vibrio*, leading to shell-fish related death and morbidity that might affect the United States, Japan and Southeast Asia (Janda *et al.* 1988, Lipp *et al.* 2002, both in Ebi *et al.* 2008, 2-10; Wittmann and Flick 1995, Tuyet *et al.* 2002, both in Confalonieri *et al.* 2007). If temperatures increase, the geographic range and concentration of the *Vibrio* species could expand. For example, as the waters of the northern Atlantic have warmed, the concentration of *Vibrio* species has increased (Thompson *et al.* 2004 in Ebi *et al.* 2008). Future ocean warming might also lead to the proliferation of harmful algal blooms, releasing toxins that contaminate shellfish and lead to food-borne diseases (Confalonieri *et al.* 2007).

In 2000, WHO estimated that climate change has caused the loss of more than 150,000 lives (Campbell-Lendrum *et al.* 2003, Ezzati *et al.* 2004, McMichael 2004, all in Confalonieri *et al.* 2007). The projected risks in 2030 described by WHO study vary by health outcome and region; most of the increase in disease is due to diarrhea and malnutrition. More cases of malaria are projected in countries situated at the edge of the existing distribution. The projected health impact associated with malaria is mixed, with some regions demonstrating increased burden and others exhibiting decreased burden.

4.5.9 Tipping Points and Abrupt Climate Change

This section starts by providing an overview of tipping points and abrupt climate change, then discusses specific climate systems that could be affected, and concludes with a summary.

4.5.9.1 Overview

The phrase "tipping point" is most typically used in the context of climate change and its consequences to describe situations in which the climate system (the atmosphere, oceans, land, cryosphere,[24] and biosphere) reaches a point at which there is a disproportionately large or singular response in a climate-affected system as a result of only a moderate additional change in the inputs to that system (such as an increase in the CO_2 concentration). Exceeding one or more tipping points, which "occurs when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause" (NRC 2002b in EPA 2009), could result in abrupt changes in the climate or any part of the climate system. These changes would likely produce impacts at a rate and intensity far greater than the slower, steady changes currently being observed (and in some cases, planned for) in the climate system (EPA 2009b).

The phrase tipping point is also used outside the climate-modeling community. In addition to climate scientists, many others – including biologists, marine chemists, engineers, and policymakers – are concerned about tipping points because it is not just the climate that can change abruptly. The same type of non-linear responses exists in the physical, environmental, and societal systems that climate affects. For example, ocean acidity resulting from an elevated atmospheric concentration of CO_2 might reach a point at which there would be a dramatic decline in coral ecosystems. [25] Consideration of possible tipping points could therefore encompass sharp changes in climate-affected resources and not be restricted to climatic parameters and processes.

Using the broad definition of the term tipping point to include both climate change and its consequences, the scale of spatial responses can range from global (*e.g.*, a "supergreenhouse" atmosphere with higher temperatures worldwide), to continental or subcontinental changes (such as dramatically altering the Asian monsoon), to regional (*e.g.*, drying in the southwestern United States, leading to drought and increases in the frequency of fires), to local (such as loss of the Sierra Nevada snowpack). The definition of tipping point used by Lenton *et al.* (2008) (discussed below) specifically applies only to subcontinental or larger features, whereas public policy is concerned with a wider range of scales, as the IPCC analysis (discussed below) suggests.

The temporal scales considered are also important. On crossing a tipping point, the evolution of the climate-affected system is no longer controlled by the time scale of the climate forcing (such as the heat absorption by GHGs), but rather is determined by its internal dynamics, which can either be much faster than the forcing, or substantially slower. The much faster case – abrupt climate change – might be said to occur when the:

- Rate of change is sharply greater than (or a different sign than) what has prevailed over previous decades;
- State of the system exceeds the range of variations experienced in the past; or
- Rate has accelerated to a pace that exceeds the resources and ability of nations to respond to it.

Climate changes could occur in many ways as tipping points are reached. These mechanisms range from the appearance or unusual strengthening of positive feedbacks – self-reinforcing cycles – and

[24] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.
[25] For example, climate-related thresholds for ecosystems are discussed in CCSP SAP 4.2.

reversible-phase transitions in climate-affected systems to irreversible-phase transitions – where a threshold has been crossed that could lead to either abrupt or unexpected changes in the rate or direction of change in climate-affected systems. Although climate models incorporate many positive (and negative, or dampening) feedback mechanisms, the magnitude of these effects and the threshold at which the feedback-related tipping points are reached are only roughly known, especially regarding global impacts. In addition, models of climate and climate-affected systems do not contain all feedback processes. As subsequently shown in this section, substantial progress has been made in understanding the qualitative processes associated with tipping points, although there are limits to the quantitative understanding of many of these systems.

In recent years, the concept of a tipping point (or a set of tipping points) and abrupt change (or abrupt changes) in Earth's climate system has been attracting increased attention among climate scientists and policymakers. For example, information on *Abrupt Climate Change and High Impact Events* was recently presented in the *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009b). The information that follows provides a brief survey of tipping points and abrupt climate change, drawing on perspectives from key analyses of the issue and other relevant research – IPCC, CCSP, Lenton *et al.* (2008), and paleoclimate[26] evidence – and uses much of the same available literature as used in EPA (2009b) and recent peer-reviewed research.

In its Fourth Assessment Report, the IPCC addresses the issue of tipping points in the discussion of "major or abrupt climate changes" (Meehl *et al.* 2007) and highlights three large systems: the meridional overturning circulation (MOC) system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet. The IPCC states that there is uncertainty in the understanding of these systems but concludes that these systems are *unlikely* to reach their tipping points within the 21st Century (Meehl *et al.* 2007). The IPCC also mentions additional systems that might have tipping points (as noted below), but does not include estimates for them.

The IPCC WGII report provides insight on the uncertainties surrounding tipping points, their systemic and impact thresholds, and the value judgments required to select a critical level of warming (Carter *et al.* 2007). The presence of these thresholds can also present their own physical and ecological limits and informational and cognitive barriers to adaptation (Adger *et al.* 2007). In the case of this EIS, uncertainty prevents NHTSA from being able to quantify the impacts of the alternatives under consideration on specific tipping-point thresholds.

In the IPCC WGII report, certain thresholds are assumed and then used with analyses of emissions scenarios and stabilization targets to assess how certain impacts might be avoided (Schneider *et al.* 2007). For example, several authors hypothesize that a large-scale climatic event or other impacts (for example, widespread coral-reef bleaching; deglaciation of West Antarctica) would be likely if atmospheric CO_2 concentrations stabilize at levels exceeding 450 ppm, although the location of the tipping points and thresholds is uncertain (O'Neill and Oppenheimer 2002, Lowe *et al.* 2006, and Corfee-Morlot and Höhne 2003, all in Schneider *et al.* 2007).

The CCSP reaches similar conclusions in its report *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008). The CCSP report summarizes scientific studies suggesting that there are several "triggers" of abrupt climate change and that "anthropogenic forcing *could* increase the risk of abrupt climate change;" however, "future abrupt

[26] Paleoclimatology is the study of climate change through the physical evidence left on Earth of historical global climate change (prior to the widespread availability of records to temperature, precipitation, and other data). *See generally* http://www.giss.nasa.gov/research/paleo/.

changes cannot be predicted with confidence" because of the insufficiencies of current climate models, which reflect the limits of current understanding.[27] However, the CCSP report does reiterate the conclusions of the Committee on Abrupt Climate Change (NRC 2002a) that anthropogenic forcing could increase the risk of abrupt climate change and that (1) "greenhouse warming and other human alterations of the Earth system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events;" (2) "abrupt changes of the past are not fully explained yet, and climate models typically underestimate the size, speed, and extent of those changes;" and (3) "future abrupt changes cannot be predicted with confidence, and climate surprises are to be expected" (EPA 2009b).

The CCSP report (National Science and Technology Council 2008) considers the susceptibility of the same three systems to abrupt change as IPCC highlighted – the Atlantic MOC (AMOC) system that drives Atlantic Ocean circulation, the collapse of the West Antarctic ice sheet, and the loss of the Greenland ice sheet. The report also suggests that there are thresholds in non-climate systems influenced by CO_2 emissions, such as ocean acidification, where there could be a threshold beyond which existing coral reef ecosystems cannot survive (National Science and Technology Council 2008). The CCSP report concludes that these impacts, including climate-related thresholds, could occur in groups as thresholds are crossed, but, due to the uncertainty, more research is needed to quantify the impacts of crossing particular thresholds and to determine when these thresholds would be reached (National Science and Technology Council 2008).

The IPCC WGI report (Meehl *et al.* 2007) describes various climate and climate-affected systems that might undergo abrupt change, contribute to "climate surprises," or experience irreversible impacts, as follows: AMOC and other ocean circulation changes, Arctic sea ice, glaciers, and ice caps, Greenland and West Antarctic ice sheets, vegetation cover, and atmospheric and ocean-atmosphere regimes.

In the Fourth Assessment Report, IPCC also reiterated five "reasons for concerns" categorizing impacts of a similar type to provide a set of metrics reflecting severity of risk.[28] These reasons for concern include the risks of large-scale discontinuities (also referred to as singularities or tipping points).[29] Recently, Smith *et al*. (2008), the authors of the reasons for concern, describe revised sensitivities to increases in global mean temperature for the reasons for concern, and present a more thorough understanding of the concept of vulnerability based on expert judgment about findings in the literature assessed in the Fourth Assessment Report and additional research published since. In the case of the likelihood of large-scale discontinuities, including partial or complete deglaciation of the Greenland ice sheet or the West Antarctic ice sheet and substantial reduction or collapse of the AMOC, the authors acknowledge that "no single metric could adequately describe the diversity of impacts and associated risk for any one [reason for concern], let alone aggregate across all of them into a single "dangerous" global temperature threshold." However, based on "growing evidence that even modest increases in [global mean temperature] could commit the climate system to the risk of very large impacts on multiple-century time scales,"[30] the risks of large-scale discontinuities were expertly judged to begin being a source of substantial risk around 1 °C (around 2 °F). Smith *et al*. (2008) projected 2.5 °C (4.5 °F) – the midpoint of the warming range cited for partial deglaciation – to be the "possible trigger for commitment to large-scale global impacts over multiple-century time scales."

[27] *See* CCSP 2008d.
[28] The "reasons for concern" were originally introduced and discussed in the IPCC Third Assessment Report.
[29] The IPCC Third Assessment Report assessed the risks of abrupt and/or irreversible changes under the rubic of large-scale singularities or discontinuities, and this usage is retained in the Smith *et al*. (2008) paper. The other reasons for concern are (1) risks to unique and threatened systems, (2) risks of extreme weather events, (3) distribution of impacts (and vulnerabilities), and (4) net aggregate impacts.
[30] The term "commit' is used as in IPCC Fourth Assessment Report WGII and is derived from the possibility of crossing thresholds or irreversible change, but ones for which the actual impact could be substantially delayed.

Building on the IPCC and early CCSP research, at a workshop entitled "Tipping Points in the Earth System" experts identified several climate systems that have tipping points, and tested and refined a questionnaire subsequently distributed electronically to 193 international scientists. Fifty-two scientists (among them 16 workshop participants and 22 contributors to the IPCC Fourth Assessment Report) returned a completed questionnaire. Lenton *et al*. (2008) published the findings from this expert elicitation identifying nine systems facing separate tipping points due to increased CO_2 and temperature levels that met four scientifically based criteria to be considered "policy-relevant potential future tipping elements in the climate system" (Lenton *et al.* 2008). Additional systems were identified, but insufficient information precluded these systems from meeting the definition of policy relevant. The systems at risk that the researchers identified are: Arctic sea ice, Greenland ice sheet, West Antarctic ice sheet, Atlantic thermohaline circulation (a component of the AMOC), El-Niño-Southern Oscillation, Indian summer monsoon, Sahara/Sahel and West African monsoon, Amazon rainforest, and boreal forest.

The CCSP report SAP 3.4, *Abrupt Climate Change*[31] (CCSP 2008e), provides additional information on the topic of abrupt climate change, focusing on rapid change in glaciers, ice sheets, and hence sea level; widespread and sustained changes to the hydrologic cycle; abrupt change in the AMOC; and rapid release to the atmosphere of methane trapped in permafrost and on continental margins.

The report updates "the state and strength of existing knowledge, both from the paleoclimate and historical records, and from model predictions for future change" and "reflects the significant progress in understanding abrupt climate change that has been made since" the report by the Committee on Abrupt Climate Change (NRC 2002a) and the IPCC WGI report (Meehl *et al.* 2007).

4.5.9.2 Affected Climate Systems

The list of affected climate systems covered by the key analyses and peer-reviewed research identified above includes:

- Rapid changes in glaciers and ice sheets (including paleoclimate evidence on sea-level rise from previous ice-sheet melt);
- Hydrologic variability and change;
- Potential for abrupt change in the AMOC and Atlantic Thermohaline Circulation (a component of the AMOC);
- Potential for abrupt changes in atmospheric methane;
- El-Niño-Southern Oscillation;
- Indian summer monsoon;
- Sahara/Sahel and West African monsoon;
- Amazon rainforest; and
- Boreal forest.

Each system is described below.

Rapid Changes in Glaciers and Ice Sheets. Based on an assessment of the published scientific literature, Clark *et al.* (2008) found that "observations demonstrate that it is extremely likely that the GIS

[31] SAP 3.4 defines abrupt climate change as a "large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades, and causes substantial disruptions in human and natural systems." (CCSP 2008e)

[Greenland ice sheet] is losing mass and that this has very likely been accelerating since the mid-1990s" (EPA 2009b). Another recent CCSP report, SAP 1.2, *Past Climate Variability and Change in the Arctic and High Latitudes* (CCSP 2009a), finds a threshold for ice-sheet removal from sustained summertime warming in relation to pre-industrial temperatures of 5 °C (9 °F) (with a range of uncertainty from 2 to 7 °C [4 to 13 °F]) comparable to the range of required sustained warming of 1.9 to 4.6 °C (3.4 to 8.3 °F) suggested by Meehl *et al.* (2007) for the complete melting of the Greenland ice sheet, albeit over many hundreds of years (*see* EPA 2009b).

The surface of Arctic sea ice has a higher albedo (reflectivity) than the darker ocean surface. As sea ice melts from higher air and ocean temperatures, more of the ocean is exposed, which allows more radiation to be absorbed, amplifying the sea-ice melt. In summer, Arctic sea-ice loss could lead to the ice cap melting beyond a certain size/thickness, making it unstable and leading to an ice-free Arctic. Recent record ice losses and modeling studies have led some researchers to suggest that the summer Arctic will be ice-free within a decade or less, that there is a critical threshold for summer Arctic sea-ice loss, and that this threshold has already been crossed (Borenstein and Joling 2008 in Lenton *et al*. 2008).

The USGS estimates that a complete disintegration of the neighboring, predominantly land-based Greenland ice sheet would raise sea level by 6.55 meters (21.5 feet; Williams and Hall 1993 in USGS 2000). However, a recent paper by Pfeffer *et al*. (2008) studying *Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise* and taking dynamic land ice loss into account, postulates projections in sea-level rise of between 0.8 and 2.0 meters (2.6 and 6.6 feet), compared to the 0.18 to 0.59 meters (0.6 to 1.9 feet) projected in the IPCC Fourth Assessment Report. Pfeffer *et al*. (2008) conclude that "increases in excess of 2 meters [6.6 feet] are physically untenable" by 2100. Rahmstorf (2007) projects that sea-level rise in 2100 could be 0.5 to 1.4 meters (1.6 to 4.6 feet) above the 1990 level. The dynamic land ice-loss processes credited with accelerated ice loss include enhanced surface melt-water production penetrating to the glacier base lubricating motion; and buttressing ice-shelf removal, ice-front retreat, and glacier un-grounding that reduce resistance to glacier flow.

The Greenland ice sheet is also susceptible to positive feedbacks. Melting at the glacial margins lowers the edge of the ice sheet to elevations that are warmer and where more melting will occur. The IPCC estimated the Greenland ice sheet threshold for negative surface mass at 1.9 to 4.6 °C (3.4 to 8.3 °F) above pre-industrial temperature, well within the predicted temperature range for this century. Dynamic ice-melting processes, regional temperatures, warming surrounding oceans, and recent observations indicating that both Greenland and Antarctica are now losing mass have led researchers to conclude that the timescale for Greenland ice sheet collapse is conceivably on a scale of hundreds rather than thousands of years (Lenton *et al*. 2008).

The USGS (2005) estimates the collapse of the West Antarctic ice sheet would raise sea level by approximately 6 meters (approximately 20 feet) although the most recent reassessment by Bamber *et al*. (2009a) obtains a value of 3.3 meters (10.8 feet). The processes of surface melt and glacier un-grounding from melting at the base from a warmer ocean are implicated in the potential destabilization of the West Antarctic ice sheet (EPA 2009b). However, ice-sheet models do not include all the small-scale dynamical processes involving the glacier base and the ocean at the edge of the ice sheet (EPA 2009b, Meehl *et al*. 2007) and dynamic ice loss was not represented in the models used by the IPCC to project sea-level rise (EPA 2009b). Therefore, while these models suggest that Antarctica will gain in mass due to increased snowfall, Clark *et al.* (2008) indicate that substantial ice losses from West Antarctica and the Antarctic Peninsula are very likely occurring, so that Antarctica is losing ice mass on balance despite ice thickening over some higher-elevation regions (EPA 2009b). Lemke *et al*. (2007a) have presented satellite and *in situ* observations of dynamic ice-sheet reactions behind disintegrating ice shelves, and found no significant continent-wide trends in snow accumulation over the past several decades (EPA 2009b).

Because the present generation of models does not capture all these processes, Clark *et al.* (2008) state that "it is unclear whether [glacier accelerations of flow and thinning are] a short-term natural adjustment or a response to recent climate change," however, "accelerations are enabled by warming, so these adjustments will very likely become more frequent in a warmer climate."

Because the West Antarctic ice sheet is grounded below sea level, positive feedbacks could result from the loss of buttressing sea-ice shelves and the ingress of warmer ocean water. While centuries or millennia could pass before a collapse, the thresholds for ocean and surface atmospheric warming temperature are likely to be crossed this century (Lenton *et al*. 2008). A recent study of ice-core records suggests strong links between past West Antarctic climate, and potentially its ice sheet, to large-scale changes in global climate, particularly major El Niño events (Schneider and Steig 2008 in Lenton *et al*. 2008).

The paleoclimate record cited by IPCC, CCSP, and others gives an indication of sea-level rise from previous ice-sheet melt, and the corresponding temperature for these periods. For example, geological evidence showing the presence of elevated beaches suggests that global sea level was 4 to 6 meters (13 to 20 feet) higher during the most recent interglacial period about 125,000 years ago (Jansen *et al.* 2007). Paleoclimatic reconstructions suggest that global average temperature then was about 1 °C (1.8 °F) warmer than during the present interglacial period (Hansen *et al.* 2007). Corings from the ice sheets to determine their ages, supplemented by simulations of ice-sheet extent, suggest that large-scale retreat of the southern half of the Greenland ice sheet and other Arctic ice fields likely contributed roughly 2 to 4 meters (6.6 to 13.1 feet) of sea-level rise during the last interglacial period, with most of any remainder likely coming from the Antarctic ice sheet (Jansen *et al.* 2007). Schneider *et al.* (2007) assess similar paleoclimatic evidence for a sea-level rise of 4 to 6 meters (13.1 to 19.7 feet) during the last interglacial period, with polar temperatures 3 to 5 °C (5.4 to 9.0 °F) warmer than at present (and global mean temperature not notably warmer than at present) (EPA 2009b). Schneider *et al*. (2007) go on to conclude with medium confidence that partial melting of the Greenland ice sheet (and possibly the West Antarctic ice sheet) would occur over a timescale of centuries to millennia for a global average temperature increase of 1 to 4 °C (1.8 to 7.2 °F) in relation to 1990 to 2000 temperatures, causing the same rise in sea level (EPA 2009b).

Paleoclimatic reconstructions also indicate occurrences of abrupt changes in the terrestrial, ice, and oceanic climatic records. For example, ice-core records suggest that temperatures atop the Greenland ice sheet warmed by up to 8 to 16 °C (14.4 to 28.8 °F) within a few decades (EPA 2009b) during Dansgaard-Oeschger events,[32] which were likely caused by the North Atlantic Ocean being covered by catastrophic outflows of glacial meltwater from the North American ice sheet that was present during glacial times (Jansen *et al.* 2007). A more recent study (Steffensen *et al.* 2008) provides more detail, indicating that there was a sharp warming over 1 to 3 years (that is, "abrupt climate change happens in [a] few years"), followed by a more gradual warming over 50 years.

For the future, Hansen *et al.* (2007) and Hansen *et al.* (2008) suggest that climate feedback processes not included in most climate models (e.g., slower surface albedo and ice-sheet feedbacks) have the potential to cause large and rapid shifts in climate and in factors like glacial melt and sea-level rise that are closely dependent on the climate.

[32] Dansgaard-Oeschger events are very rapid climate changes – up to 7.0 °C (12.6 °F) in some 50 years – during the Quaternary geologic period, and especially during the most recent glacial cycle. (*A Dictionary of Geography*. Oxford University Press, 1992, 1997, 2004.) Sedimentary evidence suggests that they were driven, at least on some occasions, by the rapid draining of melt-water lakes when ice dams burst.

In a study utilizing model simulations and paleoclimatic data,[33] Hansen *et al.* (2007) conclude that "…a CO_2 level exceeding about 450 ppm is 'dangerous,'" where "dangerous" is defined by the authors to be global warming of more than 1 ºC (1.8 ºF) above the level in 2000, potentially leading to highly disruptive effects. Although this 450-ppm estimate has limitations and uncertainties, Hansen's more recent publications have suggested a target atmospheric CO_2 concentration of 350 ppm (Hansen *et al.* 2008) – lower than the CO_2-equivalent concentration, including the offsetting effects of aerosols, is today.

The range of views linking past and future sea-level rise is clearly broad, with uncertainty attributable to each view.

Hydrologic Variability and Change. Clark *et al*. (2008) state that "there is no clear evidence to date of human-induced global climate change on North American precipitation amounts," however, "further analysis [since the IPPC Fourth Assessment Report] of climate models scenarios of future hydrological change over North America and the global subtropics indicate that subtropical aridity is likely to intensify and persist due to future greenhouse gas warming." The projected drying would extend into the southwest United States and potentially increase the likelihood of future severe and persistent drought in the region, and while model results indicate that this drying might have already begun, it cannot be definitively distinguished from the natural variability of hydro-climate for the region (EPA 2009b).

A recent paper by Solomon *et al*. (2009) also demonstrates the potential for substantial – and irreversible – decreases in dry-season rainfall in a number of already-dry areas (including the southwest United States), and while these impacts are not expressly related to a specific tipping point or an associated abrupt climate change, the magnitude and irreversibility of these impacts makes them policy relevant. The paper shows that the climate change resulting from an increase in atmospheric CO_2 levels from near present-day values – 385 ppm – to a peak of 450 to 600 ppm over the coming century is largely irreversible. Solomon *et al*. (2009) used a suite of AOGCM projections to characterize precipitation changes. More than 80 to 90 percent of the models project increased drying of respective dry seasons for the regions of southern Europe, northern Africa, southern Africa, southwestern United States, eastern South America, and western Australia; and long-term irreversible warming and mean rainfall changes. For example, changes in dry-season precipitation in southwestern North America would be about 10 percent for 2 °C (3.6 °F) of global mean warming, comparable to the American "dust bowl," with average rainfall decreases of around 10 percent over about 10 to 20 years.

Potential for Abrupt Change in the Atlantic Meridional Overturning Circulation. The AMOC is the northward flow of warm, salty water in the upper layers of the Atlantic Ocean coupled to the southward flow of colder water in the deep layers, and transports oceanic heat from low to high latitudes. Clark *et al*. (2008) state, "it is very likely that the strength of the AMOC will decrease over the course of the 21st Century in response to increasing greenhouse gases, with a best estimate decrease of 25–30 percent." They go on to say that the AMOC is very unlikely to undergo an abrupt transition to a weakened state during the course of the 21st Century, and is unlikely to collapse during this period, although they do not entirely exclude the possibility (EPA 2009b).

[33] The authors compare the corresponding GHG concentrations and associated temperature increases to paleoclimatology research to demonstrate that abrupt changes have occurred in Earth's past, resulting from a similar range in increased temperature as those being projected, and to argue the existence of a CO_2 concentration equivalent level (in atmospheric GHG concentration) at which the probability of abrupt, irreversible changes in climate-affected systems might occur.

The term thermohaline circulation (THC) refers to the physical driving mechanism of ocean circulation, resulting from fluxes of heat and fresh water across the sea surface, subsequent interior mixing of heat and salt, and geothermal heat sources. The MOC, discussed in the IPCC and CCSP reports, is the observed response in an ocean basin to this type of ocean circulation coupled with wind-driven currents. The Lenton *et al.* (2008) paper refers to risk to the Atlantic THC instead of the AMOC because they are discussing the influence of climate change on the underlying cooling or freshwater forcing of the Atlantic Ocean circulation, even though this in turn dramatically affects the AMOC.

If enough fresh water enters the North Atlantic (such as from melting sea ice or the Greenland ice sheet), the density-driven sinking of North Atlantic waters might be reduced or even stopped, as apparently occurred during the last glacial cycle (Stocker and Wright 1991 in Lenton *et al.* 2008). This would likely reduce the northward flow of thermal energy in the Gulf Stream and result in less heat transport to the North Atlantic. At the same time, reduced formation of very cold water would likely slow the global ocean THC, leading to impacts on global climate and ocean currents. The IPCC review of the results of model simulations suggests that an abrupt transition of the Atlantic Ocean's component of the global THC is *very unlikely* this century. However, more recent modeling that includes increased freshwater inputs suggests there could be initial changes this century, with larger and more intense reductions in the overturning circulation persisting for many centuries (Mikolajewicz *et al.* 2007 in Lenton *et al*. 2008).

Potential for Abrupt Changes in Atmospheric Methane. A "catastrophic" release of CH_4 to the atmosphere from clathrate hydrates[34] in the sea bed and permafrost, and from northern high-latitude and tropical wetlands, has been identified as a potential cause of abrupt climate change (EPA 2009b). Clark *et al*. (2008) state that the size of the hydrate reservoir is uncertain (perhaps by up to a factor of 10), making judgments about risk difficult to assess (EPA 2009b). This uncertainty is borne out by a recent study by Tanocai *et al*. (2009) estimating soil organic carbon pools in the northern circumpolar permafrost regions. The study reports new estimates – including deeper layers and pools not previously accounted for – about double those reported in previous analyses for the first meter of soil.

Clark *et al.* (2008) conclude that despite suggestions in the literature of a possible dramatic abrupt release of CH_4 to the atmosphere, modeling and isotopic fingerprinting of ice-core CH_4 do not support such a release over the last 100,000 years or in the near future, and "the risk of catastrophic release of methane to the atmosphere in the next century appears very unlikely" (EPA 2009b). However, Clark *et al.* (2008) also state "it is very likely that climate change will accelerate the pace of persistent emissions from both hydrate sources and wetlands. Current models suggest wetland emissions could double in the next century. However, because these models do not realistically represent all of the processes thought to be relevant to future northern high-latitudes CH_4 emissions, much larger (or smaller) increases cannot be discounted. Acceleration of persistent release from hydrate reservoirs is likely, but its magnitude is difficult to estimate" (EPA 2009b).

[34] Clathrate hydrates are "inclusion compounds" in which a hydrogen-bonded water framework – the host lattice – traps "guest" molecules (typically gases) within ice cages. Naturally occurring gas hydrate on Earth is primarily methane hydrate and forms under high pressure–low temperature conditions in the presence of sufficient methane. These conditions are most often found in relatively shallow marine sediments on continental margins, but also in some high-latitude terrestrial sediments (permafrost). Although the amount of methane stored as hydrate in geological reservoirs is not well quantified, it is very likely that very large amounts are sequestered in comparison to the present total atmospheric methane burden (Brook *et al*. 2008).

El-Niño-Southern Oscillation (ENSO).[35] The changes that might lead to increasingly persistent (and frequent) El Niño (or La Niña) conditions are particularly uncertain. Increases in ocean heat content could have an effect on ENSO conditions, but predictive and paleoclimate modeling studies do not agree on the magnitude, frequency, and direction of these effects. However, ENSO has substantial and large-scale effects on the global climate system (Lenton *et al*. 2008).[36]

Indian Summer Monsoon. The Indian summer monsoon is the result of land-to-ocean pressure gradients and advection of moisture from ocean to land. By warming the land more than the ocean, climate change generally strengthens the monsoon. However, reductions in the amount of solar radiation that is absorbed by the land surface, due to some types of land-use change, generally weaken it. An albedo greater than roughly 50 percent is necessary to simulate the collapse of the Indian summer monsoon in a simple model (Zickfield *et al.* 2005 in Lenton *et al*. 2008). IPCC projections do not project passing a threshold this century, although paleoclimatic reconstructions do indicate that the monsoon has changed substantially in the past (Lenton *et al*. 2008).

West African Monsoon. Sahara/Sahel rainfall depends on the West African monsoon circulation, which is affected by sea-surface temperature. By warming the land more than the ocean and therefore causing greater upward movement of the air, GHG forcing is expected to draw more moist oceanic air inland and thereby increase rainfall in the region, which as simulated by some models. Other models, however, project a less productive monsoon. The reasons for this inconsistency are not clear (Lenton *et al*. 2008).

Amazon Rainforest. The recycling of precipitation in the Amazon rainforest implies that deforestation, reductions in precipitation, a longer dry season, and increased summer temperature could contribute to forest dieback. These conditions are thought to be linked to a more persistent El Niño and an increase of global average temperature by 3 to 4 °C (5.4 to 7.2 °F). Important additional stressors also present include forest fires and human activity (such as land clearing). A critical threshold might exist in canopy cover, which could be reached through changes in land use or regional precipitation, ENSO variability, and global forcing (Lenton *et al*. 2008).

Boreal Forest. The dieback of boreal forest could result from a combination of increased heat stress and water stress, leading to decreased reproduction rates, increased disease vulnerability, and subsequent fire. Although highly uncertain, studies suggest a global warming of 3 °C (5.4 °F) could be the threshold for loss of the boreal forest (Lenton *et al*. 2008).

4.5.9.3 Summary

The IPCC, CCSP, and Lenton *et al.* (2008) conclude that the loss of the Greenland ice sheet, the collapse of the West Antarctic ice sheet, and the disruption of the Atlantic THC systems are not expected to cross their estimated tipping elements in this century (though actions this century could create enough momentum in the climate system to cross the threshold in future centuries[37]). Lenton *et al.* (2008) determined that several other systems (loss of Arctic sea ice, Indian summer monsoon disruption,

[35] ENSO describes the full range of the Southern Oscillation (see-saw of atmospheric mass or pressure between the Pacific and Indo-Australian regions) that includes both sea-surface temperature increases and decreases compared to the long-term average. El Niño is the oceanic component – used on its own to describe the warming of sea-surface temperatures in the central and eastern equatorial pacific – and the Southern Oscillation is the atmospheric component.
[36] ENSO influences patterns of tropical sea surface temperature, and has been implicated in historical episodes of extreme drought, including the "mega-droughts" (900 to 1600 A.D.).
[37] *See* Lenton *et al.* (2008).

Sahara/Sahel and West African monsoon changes, drying of the Amazon rainforest, and warming of the boreal forest) could reach a tipping threshold within the century, however.

A factor that might accelerate climate change at rates faster than those currently observed is the possible shift of soil and vegetation-carbon feedbacks, causing the soil and vegetation to become carbon sources rather than carbon sinks. At present, soil and vegetation act as sinks, absorbing carbon from the atmosphere as plant material and storing carbon in the soil when the plants die. However, by mid-century (about the time the IPCC projects the global average temperature reaches 2.0 ºC [3.6 ºF] above pre-industrial levels), increasing temperatures and precipitation could cause increased rates of transpiration, resulting in soil and vegetation becoming a potential source of carbon emissions (Cox *et al.* 2000 in Meehl *et al.* 2007). Warming could also thaw frozen Arctic soils (permafrost), causing the wet soils to emit more CH_4, a GHG. This suggestion is supported by the findings of the most recent CCSP reports, with Clark *et al*. (2008) suggesting that it is very likely that climate change will accelerate the pace of persistent emissions from hydrate sources and wetlands (EPA 2009b). In fact, there is evidence that permafrost is already melting (Walter *et al*. 2007).

Across all of the climate systems for which tipping points have been hypothesized or observed from the paleoclimatological record, uncertainties exist, especially for timing estimates, and the uncertainties are at least partly responsible for the broad spectrum of views regarding tipping points. Exactly where these tipping points exist, and the levels at which they occur, are still a matter in need of further scientific investigation before precise quantitative conclusions can be made.

Where information in this EIS analysis is incomplete or unavailable, as here due to current climate modeling limitations, NHTSA has relied on the CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). CEQ regulations state, in part, that when an agency is evaluating "reasonably foreseeable significant adverse impacts on the human environment and …information relevant to…[the] impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known, the agency shall include within the [EIS]:

(1) a statement that such information is incomplete or unavailable;

(2) a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

(3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

(4) the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason."

40 CFR § 1502.22 (b).

This EIS addresses the requirements of 40 CFR § 1502.22 appropriately. The above survey of the current state of climate science tipping points provides a "summary of existing credible scientific evidence which is relevant to evaluating the…adverse impacts of the CAFE standards." In *Colorado Environmental Coalition v. Dombeck,* the Tenth Circuit found that the ultimate goal of the agency is to ensure that the EIS's "form, content, and preparation foster both informed decision making and informed public participation" (185 F.3d 1162, 1172 [10th Cir. 1999] [quoting *Oregon Envtl. Council v. Kunzman*, 817 F.2d 484, 492 (9th Cir. 1987)]). The Tenth Circuit held that 40 CFR § 1502.22 could not be read as imposing a "data gathering requirement under circumstances where no such data exists." *Id.*

In this case, this EIS acknowledges that information on tipping points or abrupt climate change is incomplete, and the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks, beyond emission levels serving as a reasonable proxy for the risks and impacts of climate change, including tipping point risks. This action alone, even as analyzed for the most stringent alternative, is very unlikely to produce sufficient CO_2 emissions reductions to avert emission levels corresponding to abrupt and severe climate change. Under EPCA, as amended by EISA, NHTSA has the authority to set fuel economy standards for U.S. passenger cars and light trucks, which account for roughly 3.3 percent of global annual CO_2 emissions. Even if NHTSA could set standards that reduced emissions from this sector to zero, tipping-point thresholds (whether they occur at 550 ppm or any other level of that general order of magnitude) would not likely be avoided without other significant global actions.

To the degree that the action in this rulemaking reduces the rate of CO_2 emissions, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. Moreover, while NHTSA's action alone does not produce sufficient CO_2 emissions reductions, it is one of several other federal programs, which, in conjunction with NHTSA CAFE standards, could make substantial contributions in averting levels of abrupt and severe climate change. These conclusions are not meant to be read as expressing NHTSA views that tipping points in climate-related systems are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action.*" 42 U.S.C. § 4332(2)(C)(i) (emphasis added). The discussion above fulfills NHTSA's NEPA obligations regarding this issue.

4.6 ENVIRONMENTAL JUSTICE

4.6.1 Affected Environment

Executive Order (EO) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, directs federal agencies to "promote nondiscrimination in federal programs substantially affecting human health and the environment, and provide minority and low income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment." EO 12898 also directs agencies to identify and consider disproportionately high and adverse human health or environmental effects of their actions on minority and low-income communities, and provide opportunities for community input in the NEPA process, including input on potential effects and mitigation measures. CEQ, the entity responsible for compliance with EO 12898, has provided agencies with general guidance on how to meet the requirements of the EO as it relates to NEPA in *Environmental Justice Guidance Under the National Environmental Policy Act* (CEQ 1997). This guidance document also defines the terms "minority" and "low-income community" in the context of environmental justice analysis. Members of a minority are defined as: American Indians or Alaskan Natives, Asian or Pacific Islanders, Blacks, and Hispanics. Low-income communities are defined as those below the poverty thresholds from the U.S. Census Bureau. The term "environmental justice populations" refers to the group comprised of minorities and low-income communities as defined.

In compliance with EO 12898, NHTSA provides in this EIS a qualitative analysis of the cumulative effects of the proposed action in regard to air pollutant discharges and climate change on these populations.[38]

As described in Section 3.5.10, research studies have shown that minority and low-income populations often disproportionately reside near high-risk polluting facilities, such as oil refineries, and "mobile" sources of air toxins and pollutants, as in the case of populations residing near highways. Environmental justice populations also tend to be concentrated in areas with a higher risk of climate-related impacts. CCSP notes that this geographic placement might put these communities at higher risk, "from climate variability and climate-related extreme events such as heat waves, hurricanes, and tropical and riverine flooding" (CCSP 2008).

4.6.2 Environmental Consequences

4.6.2.1 Air Quality

NHTSA predicts that upstream emissions from oil refining would decrease, which could cause a local improvement in air quality for residents near oil refineries. This improvement could represent a small positive impact on environmental justice populations living or working near these facilities.

Emissions of all but one of the criteria air pollutants analyzed and all but one of the MSATs analyzed would decrease overall with adoption of any of the action alternatives and the foreseeable fuel economy improvements (*see* Section 4.3). However, increases in VMT due to the rebound effect are still projected to cause increases in emissions of some criteria and toxic air pollutants in some air quality

[38] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ (1984) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

nonattainment areas. These emissions would be distributed throughout the roadway network. The large size of each nonattainment area and the minor emissions increases in affected nonattainment and other areas make it unlikely that there would be disproportionate effects to environmental justice populations.

4.6.2.2 Effects of Climate Change in the United States

Environmental justice populations in the United States, as defined by EO 12898, would experience the same general impacts as a result of global climate change felt by the U.S. population as a whole and described in Sections 4.5.6, Food, Fiber, and Forest Products; 4.5.7, Industries, Settlements, and Society; and 4.5.8, Human Health. However, the CCSP notes that the general climate change impacts to the U.S. population might be differentially experienced by environmental justice populations, explaining that “[e]conomic disadvantage, lower human capital, limited access to social and political resources, and residential choices are social and economic reasons that contribute to observed differences in disaster vulnerability by race/ethnicity and economic status” (CCSP 2008). These impacts are similar to those that would be experienced globally, although the severity of impacts experienced by developing countries would likely be disproportionately larger than those experienced in developed nations, such as the United States.

Within the United States, some environmental justice populations are likely to be affected. Citing GCRP (2009), EPA (2009) adds, “climate-related changes will add further stress to an existing host of social problems that cities experience, including neighborhood degradation, traffic congestion, crime, unemployment, poverty, and inequities in health and well-being. Climate change impacts on cities are further compounded by aging infrastructure, buildings, and populations, as well as air pollution and population growth”.

The remainder of this section discusses, qualitatively, the most substantial areas of potential disproportionate impacts for these populations in the United States.

4.6.2.2.1 Human Health

Low-income and minority communities exposed to the direct effects of extremes in climatic conditions might also experience synergistic effects with preexisting health risk factors, such as limited availability of preventative medical care and inadequate nutrition (CCSP 2008).

As described in Section 4.5.7, increases in heat-related morbidity and mortality as a result of higher overall and extreme temperatures is likely to disproportionately affect minority and low-income populations, partially as a result of limited access to air conditioning and a result of high energy costs (CCSP 2008, EPA 2009, O’Neill *et al.* 2005). Urban areas, which often have relatively large environmental justice populations, would likely experience the most substantial temperature increase due to the urban “heat island” effect and could be particularly vulnerable to this type of health impact (CCSP 2008, Knowlton *et al.* 2007).

The IPCC notes that many human diseases are sensitive to weather. Increasing temperatures could lead to expanded ranges for a number of diseases (CCSP 2008). As described in Section 4.5.8, the number and severity of outbreaks for vector-borne illnesses, such as the West Nile Virus, could become more frequent and severe. Because the vectors of these diseases (such as mosquitoes) are more likely to come into contact with environmental justice populations, there could be disproportionate impacts. For example, an outbreak of the mosquito-borne dengue fever in Texas primarily affected low-income Mexican immigrants living in lower-quality housing without air conditioning, leading a team researching the outbreak to conclude that the low prevalence of dengue in the United States is primarily due to economic, rather than climatic, factors (Reiter *et al.* 2003).

4.6.2.2.2 Land Use

In the United States, two primary types of geographical environmental justice communities are likely to be affected by global climate change: urban areas, because of their relatively high concentrations of low-income and minority residents, and indigenous communities. Environmental justice communities in urban areas, because of previously mentioned heat exposure and health issues, are likely to experience climate change impacts more acutely. Additionally, environmental justice populations in coastal urban areas (vulnerable to increases in flooding as a result of projected sea-level rise, larger storm surges, and human settlement in floodplains) are less likely to have the means to quickly evacuate in the event of a natural disaster (CCSP 2008, GCRP 2009). CCSP, as an example, notes that flooding in Louisiana following the 2005 Hurricane Katrina primarily killed poor and elderly residents having no means to flee (GCRP 2009). In Alaska, more than 100 Native American villages on the coast and in low-lying areas along rivers are subject to increased flooding and erosion due to climate change (GCRP 2009). These indigenous communities could face major impacts on their subsistence economies from climate change. These impacts would result from their partial reliance on arctic animals, such as seals and caribou, for food and the potential destruction of transportation infrastructure due to ground thaw.

As of 2003, about half of the U.S. population lived in the country’s 673 coastal counties (EPA 2009). In coastal and floodplain areas prone to flooding because of larger storm surges and generally more extreme weather, increases in flood insurance premiums could disproportionately affect environmental justice populations unable to absorb the additional cost. Lack of sufficient insurance coverage might render these populations more financially vulnerable to severe weather events.

Potential food insecurity as a result of global climate change, particularly among low-income populations in the United States and abroad, is an often mentioned concern (Wilbanks *et al.* 2007, CCSP 2008). Climate change is likely to affect agriculture by changing the growing season, limiting rainfall, and water availability, or increasing the prevalence of agricultural pests (*see* Section 4.5.6 for more information). In the United States, the most vulnerable segment of the population to food insecurity is likely to be low-income children (Cook and Frank 2008 in CCSP 2008).

4.7 NON-CLIMATE CUMULATIVE IMPACTS OF CARBON DIOXIDE

4.7.1 Affected Environment

In addition to its role as a GHG in the atmosphere, CO_2 is exchanged from the atmosphere to water, plants, and soil. CO_2 dissolves easily in water and more easily in salt water, such as oceans. In water, CO_2 combines with water molecules to form carbonic acid. The amount of CO_2 dissolved in the upper ocean is related to its concentration in the air. As the atmospheric concentration continues to increase, this process takes up about 30% of each year's emissions (Canadell *et al.* 2007). This reduces the increase in the atmospheric concentration of CO_2, but also increases the acidity of the ocean. Although ocean uptake is slowly decreasing, the increasing CO_2 concentration will have a global effect on the oceans. It is estimated that by 2100, ocean pH could drop 0.3 to 0.5 units in relation to pre-industrial levels (Caldeira and Wickett 2005).

Terrestrial plants remove CO_2 from the atmosphere through photosynthesis and use the carbon for plant growth. This uptake by plants can influence annual fluctuations of CO_2 on the order of 3 percent from growing season to non-growing season (Schneider and Londer 1984 in Perry 1994). Increased levels of CO_2 essentially act as a fertilizer, influencing normal annual terrestrial plant growth. Over recent decades, terrestrial uptake has amounted to about 30% of each year's emissions (Canadell *et al.* 2007).

In addition, CO_2 concentrations affect soil microorganisms. Only recently have the relationships between above-ground and below-ground components of ecosystems been considered significant; there is increasing awareness that feedbacks between the above-ground and below-ground components play a fundamental role in controlling ecosystem processes. For example, plants provide most of the organic carbon required for below-ground decomposition. Plants also provide the resources for root-associated microorganisms (Wardle *et al.* 2004). The "decomposer subsystem in turn breaks down dead plant material and indirectly regulates plant growth and community composition by determining the supply of available root nutrients" (Wardle *et al.* 2004).

Specific plant species, depending on the quantity and quality of resources provided to below-ground components, might have greater impacts on soil biota and the processes regulated by those biota than do other plants. Variation in the quality of forest litter produced by co-existing species of trees, for example, "explains the patchy distribution of soil organisms and process rates that result from 'single tree' effects" (Wardle *et al.* 2004). The composition of plant communities has a consistent and substantial impact on the composition of root-associated microbes; however, the effects of plant community composition on decomposer systems are apparently context-dependent. In one study, manipulating the composition of plant communities in five sites in Europe produced distinctive effects on decomposer microbes, while root-related soil microbes experienced no clear effect (Wardle *et al.* 2004).

The amount of carbon stored in soils of temperate and boreal forests is about four times greater than the carbon that is stored by vegetation and is "33 percent higher than total carbon storage in tropical forests" (Heath *et al.* 2005). Terrestrial communities contain as much carbon as the atmosphere. Forest soils are also the longest lived carbon pools in terrestrial ecosystems (King *et al.* 2004). Several experiments involving increases of atmospheric CO_2 resulted in increased carbon mass in trees, but a reduction of carbon sequestration in soils. This is associated with increasing soil microorganism respiration (Heath *et al.* 2005); respiration is associated with "root herbivory, predation, consumption of root exudates, and the decomposition of root and leaf litter" (King *et al.* 2004).

NHTSA provides in this EIS a qualitative analysis of the cumulative effects of the proposed action regarding to non-climate cumulative impacts of CO_2.[39]

4.7.2 Environmental Consequences

4.7.2.1 Ocean Acidification

Ocean acidification occurs when CO_2 dissolves in seawater, initiating a series of well-known chemical reactions that increases the concentration of hydrogen ions and makes seawater less basic (and therefore more acidic), measured as a decline in pH (Bindoff *et al*. 2007, Denham *et al*. 2007). An important consequence of this change in ocean chemistry is that the excess hydrogen ions bind with carbonate ions, making the carbonate ions unavailable to marine organisms for forming the calcium carbonate minerals (mostly aragonite or calcite) that make up their shells, skeletons, and other hard parts. Once formed, aragonite and calcite will dissolve back into the surrounding seawater, unless the water contains a sufficiently high concentration of carbonate ions (recent reviews by Doney 2009, Doney *et al*. 2009, EPA 2009, Fabry *et al*. 2008, Fischlin *et al.* 2007, Guinotte and Fabry 2008, Royal Society 2005).

For many millennia before present, there was little change in ocean pH. Even during the warm Cretaceous period, about a 100 million years ago, when atmospheric CO_2 concentrations were between three and ten times higher than at present, it is considered unlikely that there was any significant decrease in ocean pH. This is because the rate at which atmospheric CO_2 changed in the past was much slower than at present, and during slow natural changes, the carbon system in the oceans has time to reach a steady state with sediments. If the ocean starts to become more acidic, some carbonate will be dissolved from sediments, buffering the chemistry of the seawater so that pH changes are lessened (Royal Society 2005).

However, as anthropogenic emissions have increased there has been an accumulation of CO_2 in the atmosphere and a net flux of CO_2 from the atmosphere to the oceans. As a result, the pH and carbonate ion concentrations of the world's oceans have declined and are now lower than at any time in the past 420,000 years (Hoegh-Guldberg *et al*. 2007). It is estimated that the pH of today's oceans has declined in relation to the pre-industrial period by 0.1 pH units (on a log scale), representing a 30-percent increase in ocean acidity (Caldeira and Wickett 2003; EPA 2009). Regionally, high latitude ocean water has experienced greater reduction in pH due to low buffer capacity, compared to low latitude ocean water (EPA 2009). Scientists predict that as early as 2050, ocean pH could be lower than at any time during the past 20 million years (Feely et al., 2004). This rate of change is at least a hundred times greater than during the past hundreds of millennia (Royal Society 2005). By 2100, depending on the emissions scenario modeled, the average ocean pH could decline by 0.3 to 0.5 pH units in relation to pre-industrial levels (Fischlin et al. 2007; EPA 2009). Atmospheric CO_2 would need to be stabilized under 500 parts per million (ppm) for the decline in locally measured ocean pH to remain below the 0.2 pH unit limit established by EPA in 1976 for the protection of marine life (Caldeira *et al*. 2007).

At present, ocean surface waters are super-saturated with respect to the two prevalent calcium carbonate forms – aragonite and calcite (Bindoff *et al*. 2007) – but the saturation horizon (the depth above which supersaturation occurs and within which, for example, all near surface reef systems were located in pre-industrial times) is becoming shallower (Feely *et al*. 2004). As the oceans absorb increasing amounts

[39] *See* U.S.C § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ (1984) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

of CO_2, the greatest pH decline in relation to the global average will occur in polar and subpolar regions. CO_2 dissolves more readily in cold water, which is naturally low in carbonate ion concentration and more acidic than surface waters (Meehl *et al*. 2007). Under the IPCC IS92a "business as usual" scenario (Pepper *et al*. 1992), the multi-model projection of 788 ppm of atmospheric CO_2 by 2100 indicates that as early as 2050, Southern Ocean surface waters would begin to become undersaturated with respect to aragonite; by 2100 all of the Southern Ocean south of 60 degrees south and portions of the Subarctic North Pacific could become undersaturated (Orr *et al*. 2005; EPA 2009). Simulation of the IPCC IS92a scenario predicted wintertime aragonite undersaturation in the Southern Ocean between 2030 and 2038 (McNeil and Matear 2008). Simulation of the SRES A2 scenario (IPCC 2000) predicts aragonite undersaturation in Arctic surface waters once the CO_2 concentration increases above 450 ppm (Steinacher *et al*. 2009). Under this scenario, the ocean volume that is saturated with respect to aragonite, and therefore contains much of the ocean's biodiversity, could decrease from about 42 percent today to 25 percent by 2100, resulting in a significant loss of marine life (Steinacher *et al*. 2009).

Recent observations indicate that ocean acidification is increasing in some areas faster than expected. Hydrographic surveys have found that this occurs when, for example, wind-induced upwelling of seawater that is undersaturated with respect to aragonite spreads out over the continental shelf; evidence of this is reported from western North America during unusual weather conditions, decades earlier than model predictions for average weather conditions (Feely *et a*l. 2008). Measurements of ocean pH off the coast of Washington State over a period of 8 years, for example, found that acidity in the region has increased more than 10 times faster than other areas (Wootton *et al*. 2008).

4.7.2.1.1 Effects of Ocean Acidification on Marine Calcifiers

Laboratory and observational studies make clear that, with few exceptions, the reduction in calcium carbonate resulting from ocean acidification reduces the calcification rates of marine organisms, a finding that holds over a wide range of taxa (reviewed by Doney 2009, Doney *et al*. 2009, EPA 2009, Fabry *et al*. 2008, Guinotte and Fabry 2008, Fischlin *et al*. 2007, Royal Society 2005). Table 1 in Fabry *et al*. (2008) and Table 2 in Guinotte and Fabry (2008) provide citations for the available literature. Here we provide representative results, ranging from the individual to ecosystem level, for a variety of marine taxa.

Warmwater Corals. Studies indicate that a doubling of the CO_2 concentration from pre-industrial levels to 560 ppm will result in a 20- to 60-percent decrease in the calcification rates of tropical reef-building corals, with the percent decrease depending on the species (Kleypas *et al*. 1999, Guinotte and Fabry 2008, Hoegh-Guldberg 2007). Langdon *et al*. (2000) and Leclerq *et al*. (2000) showed that saturation state was the primary factor determining calcification rates of coral reef ecosystems grown in a large mesocosm (*i.e.*, an outdoor cage). Fine and Tchernov (2007) showed that two species of coral experienced complete dissolution of their shells in highly acidified water but were able to regrow their shells when returned to water of normal pH. Under the SRES A2 scenario, ocean waters with an aragonite saturation level considered suitable for coral growth are projected to disappear in the second half of this century; water considered optimal for coral growth, which covered about 16 percent of the ocean surface in pre-industrial times, could be gone within the next few years (Guinotte *et al*. 2006).

As a result of the combined effects of increased CO_2 and "bleaching" events resulting from elevated sea surface temperatures, tropical and subtropical corals could become rare by 2050 (Hoegh-Guldberg 2007). Bleaching occurs when corals eject their symbiotic algae when the temperature of surface waters increase above a threshold near 30 °C. Increases in sea surface temperatures have contributed to major bleaching events of subtropical and tropical coral reefs (EPA 2009). These bleaching events increase the risk of disease among surviving coral (EPA 2009). For example, in Virgin Islands National Park, fifty percent of the corals have died from bleaching or subsequent disease outbreaks (EPA 2009). The IPCC concluded that it is "very likely" that a projected future increase in sea surface temperature of 1 to 3 degrees °C will result in more frequent bleaching events and widespread coral mortality, unless there is long-term thermal adaptation by corals and their algal symbionts (Nicholls *et al*. 2007; EPA 2009). A group of 39 coral experts from around the world estimated that one-third of reef-building corals face elevated risk of extinction. A group of 39 coral experts from around the world estimated that one-third of reef-building corals face elevated extinction risk from climate change and local anthropogenic stressors (Carpenter *et al*. 2008). The vulnerability of these corals to thermal stress will also be dependent on the existence of additional adverse factors stressing the corals such as overfishing, pollution, invasive species, and available nutrients (EPA 2009).

Coldwater Corals. As the saturation horizon becomes shallower, saturated waters are becoming limited to the warm surface layers of the world's oceans. As a result, under the IPCC "business as usual" scenario, it is projected that by 2100, only 30 percent of coldwater corals will remain in saturated waters (Guinotte *et al*. 2006).

Marine Algae. Crustose coralline algae are critical for coral reefs because they cement together carbonate fragments. Under high CO_2 conditions in an outdoor mesocosm experiment, the recruitment rate and percentage cover of crustose coralline algae decreased by 78 percent and 92 percent, respectively, whereas that of non-calcifying algae increased by only 52 percent (Kuffner *et al*. 2008). While some marine phytoplankton grow well over a wide range of pH, others have growth rates that vary greatly over a narrow 0.5 to 1.0 pH unit change (Hinga 2002). Eutrophication and ocean acidification might interact to increase the frequency of blooms of those species that tolerate extreme pH (Hinga 2002). Coccolithophores, planktonic microalgae that are the main calcifiers in the ocean, show a mix of responses. In one study, coccolithophores show reduced calcification when grown at 750 ppm CO_2 (Riebesell *et al.* 2000), while in another study they showed no change (Langer *et al*., 2006).

Molluscs. Gazeau *et al*. (2007) found that calcification in a mussel species and Pacific oyster declined by 25 percent and 10 percent, respectively, when grown in seawater at 740 ppm CO_2, which is the concentration expected by 2100 under the IPCC IS92a scenario. Pteropods, small marine snails, show shell dissolution in seawater undersaturated with respect to aragonite (Feely *et al*. 2004, Orr *et al*. 2005). When live pteropods were collected in the Subarctic Pacific and exposed to a level of aragonite undersaturation similar to that projected for the Southern Ocean by 2100 under the IPCC IS92a emissions scenario, shell dissolution occurred within 48 hours (Orr *et al*. 2005). Declines in pteropods are a particular concern in high-latitude oceans, where they are a critical food source for marine animals ranging from krill (small shrimp-like organisms) to whales, and including highly valued fish such as salmon. Therefore, their loss could have significant effects on high-latitude food webs (Guinotte and Fabry 2008).

Echinoderms. Sea urchins show reduced early development (Kurihara and Shirayama 2004) and shell growth (Shirayama and Thornton 2005) in seawater with elevated CO_2 concentrations.

Field observations are limited but consistent with the results of laboratory and mesocosm studies, as follows:

- Shifts in community composition were observed in a mussel-dominated rocky intertidal community experiencing rapid declines in pH. Years of low pH were accompanied by declines in calcerous species (*e.g.*, mussels, stalked barnacles) and increases in non-calcerous species (*e.g.*, acorn barnacles, algae) (Wootton *et al*. 2008).
- Near-subsurface areas with natural, volcanic venting of CO_2, stony corals are absent and the abundance of calcifying sea urchins, coralline algae, and gastropods is greatly reduced (Hall-Spencer *et al*. 2008).

- Moy *et al*. (2009) provided direct evidence that ocean acidification is affecting shell formation, finding that the shells of foraminifera in the Southern Ocean are lighter than shells of the same species in core samples from ocean sediments that predate the industrial revolution. Modern shells were found to be 30 to 35 percent lighter than older shells of the same size.
- De'ath *et al*. (2009) examined growth patterns of 328 massive coral colonies from the Great Barrier Reef of Australia and found that their rates of calcification have declined by almost 15 percent since 1990, to values lower than any seen for the past 400 years. The investigators believe that the main causes of this continuing decline are increasing sea surface temperatures and ocean acidification.

4.7.2.1.2 Changes in the Effectiveness of the Ocean Sink

In addition to its role in calcium carbonate formation, carbonate ion concentration also controls the uptake of CO_2. As CO_2 increases in surface waters and carbonate concentration declines, the effectiveness of the ocean as a "sink" for CO_2 will decrease (Bindoff *et al*. 2007, Denham *et al*. 2007, Sabine *et al*. 2004). In addition, ocean warming decreases the solubility of CO_2 in seawater (Binhoff *et al*. 2007, Denham *et al*. 2007). Observations and modeling studies indicate that the sinks in the North Atlantic (Lefèvre *et al*. 2004, Schuster and Watson 2009) and Southern Ocean (LeQuéré *et al*. 2007, Lovenduski *et al*. 2008) have declined in recent decades, consistent with expectations. From 2000 to 2006, it is estimated that the oceans absorbed about 25 percent of anthropogenic CO_2 emissions, representing a decline in the ocean sink from earlier decades (Canadell *et al*. 2007).

4.7.2.1.3 IPCC Conclusions about Ocean Acidification

The IPCC conclusions about ocean acidification are as follows (EPA 2009, Denman *et al*. 2007):

- The biological production of corals, and calcifying phytoplankton and zooplankton within the water column, could be inhibited or slowed down as a result of ocean acidification.
- Cold-water corals are likely to show large reductions in geographic range this century.
- The dissolution of calcium carbonate at the ocean floor will be enhanced, making it difficult for benthic calcifiers to develop protective structures.
- Acidification can influence the marine food web at higher trophic levels.

4.7.2.2 Plant Growth and Soil Microorganisms

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2 concentrations in the atmosphere could increase the productivity of terrestrial systems. CO_2 can have a stimulatory or fertilization effect on plant growth (EPA 2009). Plants use CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report states that "[o]n physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising CO_2, referred to as 'CO_2 fertilization'" (Denman *et al.* 2007). IPCC projects with *medium* confidence that forest growth in North America will likely increase 10 to 20 percent, due to both CO_2 fertilization and longer growing seasons, over this century (EPA 2009, Field *et al*. 2007).

Under bench-scale and field-scale experimental conditions, several investigators have found that higher CO_2 concentrations have a fertilizing effect on plant growth (*e.g.*, Long *et al.* 2006, Schimel *et al.* 2000). Through free air CO_2 Enrichment experiments, at an ambient atmospheric concentration of 550 ppm CO_2, unstressed C3 crops (*e.g.*, wheat, soybeans, and rice) yielded 10 to 25 percent more than under current CO_2 conditions, while C4 crops (*e.g.*, maize) yielded up to 10 percent more (EPA 2009). In addition, IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing net primary productivity (NPP) increases of 23 to 25 percent (Norby *et al.* 2005), but much smaller increases for grain crops (Ainsworth and Long 2005). Overall, about two-thirds of the experiments show positive response to increased CO_2 (Ainsworth and Long 2005; Luo *et al.* 2004). Since saturation of CO_2 stimulation due to nutrient or other limitations is common (Dukes *et al.* 2005; Köerner *et al.* 2005), the magnitude, and effect of the CO_2 fertilization is not yet clear.

Forest productivity gains that might result through the CO_2 fertilization effect can be reduced by other changing factors, but the magnitude of this effect remains uncertain over the long term (EPA 2009). Easterling *et al*. (2007) discussed studies suggesting that the CO_2 fertilization effect might be lower than assumed previously, with the initial increases in growth potentially limited by competition, disturbance (*e.g.*, storm damage, forest fires, and insect infestation), air pollutants (primarily tropospheric ozone), nutrient limitations, ecological processes, and other factors (EPA 2009).

The CO_2 fertilization effect could mitigate some of the increase in atmospheric CO_2 concentrations by resulting in more storage of carbon in biota. It should also be noted that while CO_2 fertilization can result in a greater mass of available vegetation, it can also increase the carbon-to-nitrogen ratio in plants. In one study, such fertilization of forage grasses for livestock increased their abundance, but reduced their nutritional value, affecting livestock "weight and performance" (EPA 2009). Additionally, there is evidence that *long-term* exposure to elevated ambient CO_2 levels, such as areas near volcano outgassing, will result in a die-off of some plants. Although, under typical atmospheric CO_2 concentrations, soil gas is 0.2 to 0.4 percent CO_2, while in areas of observed die-off, CO_2 concentration comprised as much as 20 to 95 percent of soil gas (EPA 2009). Any CO_2 concentration above 5 percent is likely to adversely impact vegetation, and if concentrations reach 20 percent, CO_2 is observed to have a phytotoxic effect (EPA 2009).

The current annual exchange in CO_2 between the atmosphere and terrestrial ecosystems is estimated at nine to 10 times greater than annual emissions produced as a result of burning fossil fuels. Even a small shift in the magnitude of this exchange could have a measurable impact on atmospheric CO_2 concentration (Heath *et al.* 2005). The above-ground/below-ground processes and components in terrestrial ecosystems typically sequester carbon. Studies are now confirming that variations in atmospheric CO_2 have impacts not only on the above-ground plant components, but also on the below-ground microbial components of these systems.

In one study, an increase in CO_2 *directly* resulted in increased soil microbial respiration. However, after 4 to 5 years of increased exposure to CO_2, "the degree of stimulation declined" to only a 10 to 20 percent increase in respiration over the base rate (King *et al.* 2004). Additionally, the degree of stimulation was linked to variability in seasonal and interannual weather (King *et al.* 2004). Ryan *et al*. (2008) suggest that for forest ecosystems, several unresolved questions prevent a definitive assessment of the effect of elevated CO_2 on components of the carbon cycle other than carbon sequestration, mostly in wood (EPA 2009).

The increase in microbe respiration could, therefore, diminish the carbon sequestration role of terrestrial ecosystems. Because of the number of factors involved in determining soil respiration and carbon sequestration, the threshold for substantial changes in these activities varies spatially and temporally (King *et al.* 2004).

As with the climatic effects of CO_2, the changes in non-climatic impacts associated with the alternatives is difficult to assess quantitatively. In the possible climate scenarios presented by IPCC, atmospheric CO_2 concentrations increase from current levels of approximately 380 ppm to as much as 800 ppm in 2100 (Kleypas *et al.* 2006). Whether the distinction in concentrations is substantial across alternatives is not clear because the damage functions and potential existence of thresholds for CO_2 concentration are not known. However, what is clear is that a reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce the ocean acidification effect and the CO_2 fertilization effect.

Chapter 5 Mitigation

Council on Environmental Quality (CEQ) regulations for implementing the procedural requirements of the National Environmental Policy Act (NEPA) require that the discussion of alternatives in an Environmental Impact Statement (EIS) "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives." 40 CFR § 1502.14(f). In particular, an EIS should discuss the "[m]eans to mitigate adverse environmental impacts." 40 CFR § 1502.16(h). As defined in the CEQ regulations, mitigation includes:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

40 CFR § 1508.20.

Under NEPA, an EIS should contain "a reasonably complete discussion of possible mitigation measures."[1] Essentially, "[t]he mitigation must 'be discussed in sufficient detail to ensure that environmental consequences have been fairly evaluated.'"[2] Under NEPA, an agency does not have to formulate and adopt a complete mitigation plan,[3] but should analyze possible measures that could be adopted. An agency should state in its Record of Decision whether all practicable means to avoid or reduce environmental harm have been adopted in the selected alternative. 40 CFR § 1505.2(c). Generally, an agency does not propose mitigation measures for an action resulting in beneficial effects.

5.1 OVERVIEW OF IMPACTS

The National Highway Traffic Safety Administration's (NHTSA's) proposed action is to implement Corporate Average Fuel Economy (CAFE) standards for model years (MYs) 2012-2016, as required by the Energy Independence and Security Act of 2007 (EISA). The cumulative impacts analysis (*see* Chapter 4) considers the implementation of CAFE standards for MYs 2012-2016 and for MYs 2017-2030.[4] Under Alternative 1, No Action, there would be no action under the National Program, and thus NHTSA would take no action to implement the MYs 2012-2016 CAFE standards. The No Action Alternative (Alternative 1) assumes that average fuel economy levels in the absence of CAFE standards beyond 2011 would equal the manufacturer's required level of average fuel economy for MY 2011. Compared to the No Action Alternative, each of the eight action alternatives (Alternatives 2 through 9)

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[1] *Northern Alaska Environmental Center v. Kempthorne*, 457 F.3d 969, 979 (9th Cir. 2006) (citing *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 352 (1989)).

[2] *Id.* (citing *City of Carmel-By-The-Sea v. U.S. Dept. of Transp.*, 123 F.3d 1142, 1154 (9th Cir. 1997)).

[3] *Id*. (citing *Robertson*, 490 U.S. at 352 (noting that NEPA does not contain a substantive requirement that a complete mitigation plan be actually formulated and adopted)). *See* also *Valley Community Preservation Com'n v. Mineta*, 231 F. Supp. 2d 23, 41 (D.D.C. 2002) (noting that NEPA does not require that a complete mitigation plan be formulated and incorporated into an EIS).

[4] Although NHTSA will set CAFE standards for MYs 2017 and beyond in a future rulemaking, this NEPA analysis makes assumptions about the MYs 2017-2030 standards based on the MYs 2012-2016 standards, the EISA requirements, and the Annual Energy Outlook 2009 assumptions regarding projected vehicle fuel economy increases.

would result in a decrease in energy consumption, carbon dioxide (CO_2) emissions, and associated climate-change effects.

As analyzed in this EIS, emissions from criteria air pollutants and mobile source air toxics (MSATs) are generally anticipated to decline. According to the analyses described in Sections 3.3 and 4.3, some emissions would increase under some alternatives and for some analysis years, while most would demonstrate declines compared to the No Action Alternative (Alternative 1). Health effects are estimated to be reduced, and monetized health benefits would occur under all action alternatives.

Nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$), sulfur oxides (SO_x), volatile organic compounds (VOCs), benzene, and diesel particulate matter (DPM), exhibit decreases in emissions under all action alternatives for all analysis years, compared to the No Action Alternative (Alternative 1). Therefore, any negative health impacts associated with these emissions are similarly expected to be reduced, and mitigation is not necessary.

According to the NHTSA analysis, emissions of carbon monoxide (CO), acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde could increase under certain alternatives and analysis years, which requires further examination regarding the need for mitigation. The potential for harm depends on the selection of the final standards, the magnitude of the increases, and other factors. In all cases except for acrolein and formaldehyde, the increases are less than 1 percent; approximately 0.9 percent or less for acetaldehyde; and 0.7 percent or less for 1,3-butadiene, compared to emissions under the No Action Alternative (Alternative 1). Under the Preferred Alternative (Alternative 4) the increases in emissions in 2030 compared to the No Action Alternative would be 3,062 tons (0.5 percent) for CO, 50 tons (0.6 percent) for acetaldehyde, 6 tons (1.5 percent) for acrolein, 25 tons (0.7 percent) for 1,3-butadiene, and 33 tons (0.4 percent) for formaldehyde.

5.2 MITIGATION MEASURES

As noted above, NEPA does not obligate an agency to adopt a mitigation plan. Rather, NEPA requires an agency to discuss possible measures that could be adopted.[5] In accordance with NEPA and CEQ regulations, the following is a discussion of possible measures that could mitigate the effects of NHTSA's action. These include current and future actions that NHTSA or other federal agencies could take. Any of these actions would mitigate the environmental impacts associated with some of the action alternatives and provide even greater environmental benefits.

It should be noted that even if CO emissions show some level of increase, the associated harm might not increase concomitantly. After a long downward trend, there have been fewer than three violations of the CO standards per year since 2002, owing to the success of regulations governing fuel composition and vehicle emissions (EPA 2009c). Also, vehicle manufacturers can choose which technologies to employ to reach the new CAFE standards. Some of their technology choices result in higher or lower impacts for these emissions. Nevertheless, there is the potential that some air pollutant emissions will increase in some years for some alternatives.

Beyond these considerations, at the national level there could also be increases in criteria and toxic air pollutant emissions in some nonattainment areas as a result of implementation of the CAFE

[5] *Id*. (citing *Robertson,* 490 U.S. at 352 (noting that NEPA does not contain a substantive requirement that a complete mitigation plan be actually formulated and adopted)). *See* also *Valley Community Preservation Com'n v. Mineta*, 231 F. Supp. 2d 23, 41 (D.D.C. 2002) (noting that NEPA does not require that a complete mitigation plan be formulated and incorporated into an EIS).

standards under the action alternatives. These increases would represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act (CAA) standards.

In regard to air quality, federal transportation funds administered by the Federal Highway Administration (FHWA) could be available to assist in funding projects to reduce increases in emissions. FHWA provides funding to states and localities specifically to improve air quality under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program. The FHWA and the Federal Transit Administration (FTA) also provide funding to states and localities under other programs that have multiple objectives including air quality improvement. Specifically, the Surface Transportation Program provides flexible funding that may be used by states for projects on any federal-aid highway (DOE 2009a). As state and local agencies recognize the need to reduce emissions of CO, acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde (or other emissions eligible under the CMAQ Program, including the criteria pollutants and MSATs analyzed in this EIS), they have the ability to apply CMAQ funding to reduce impacts in most areas. Further, the U.S. Environmental Protection Agency (EPA) has the authority to continue to improve vehicle emissions standards under CAA, which could result in future reductions as EPA promulgates new regulations.

Each of the proposed alternatives would reduce energy consumption and greenhouse gas (GHG) emissions compared to the No Action Alternative (Alternative 1), resulting in a net beneficial effect. Regardless of these reductions, passenger cars and light trucks are a major contributor to energy consumption and GHG emissions in the United States. Although an agency typically does not propose mitigation measures for an action resulting in a net beneficial effect, NHTSA would like to highlight several other federal programs, which in conjunction with NHTSA CAFE standards, can make significant contributions in further reducing energy consumption and GHG emissions.

The programs discussed below are ongoing and at various stages of completing their goals. All these programs present the potential for future developments and advances that could further increase the net beneficial effect of the environmental impacts identified in this EIS.

Regarding energy consumption, EPA administers Renewable Fuel Standards (RFS) under Section 211(o) of the CAA. EPA is required to determine the standard applicable to refiners, importers, and certain blenders of gasoline annually. The renewable fuel standard for 2009 is 10.21 percent.[6] The current proposed standard would increase the volume of renewable fuel required to be blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022 (EPA 2009a). EPA estimates that the greater volumes of biofuel mandated by proposed standards would reduce GHG emissions from transportation by a total of 6.8 billion tons CO_2 equivalent when measured over a 100-year timeframe and discounted at 2 percent. This is equivalent to approximately 160 million tons CO_2 equivalent per year. *See* Section 4.4.3.3 for further details.

In addition, the U.S. Department of Transportation (DOT), in coordination with EPA and the U.S. Department of Housing and Urban Development, announced six livability principles around which the agencies will coordinate agency policies. One of the principles is focused on increasing transportation options, which aims to decrease energy consumption, improve air quality, and reduce GHG emissions (EPA 2009b). Known as the Federal Sustainable Communities Partnership, this agency coordination establishes the basis upon which DOT, with assistance from EPA and the Department of Housing and Urban Development, can embark on future projects and direct existing programs toward further achievements in the areas of energy consumption, air quality, and climate change. Specifically, DOT has a Secretarial goal to lower the number of vehicle miles traveled (VMT). In support of this goal, Secretary

[6] Environmental Protection Agency, *Federal Register Environmental Documents: Renewable Fuel Standard for 2009*, http://www.epa.gov/fedrgstr/EPA-AIR/2008/November/Day-21/a27613.htm (last visited on Jul. 28, 2009).

LaHood testified before the Senate Committee on Environment and Public Works detailing a departmental policy of cooperation and community planning, aimed at developing livable communities and improving multi-modal transportation, which is anticipated to result in decreasing VMT (LaHood 2009). Similarly, the Smart Growth movement presents great potential for mitigating environmental effects caused by fuel consumption for transportation. EPA provides information and support for Smart Growth, further encouraging its growth (EPA 2010).

DOT and other federal agencies are currently working to implement Executive Order (EO) 13514 issued by President Obama.[7] This Executive Order on Federal Sustainability sets measurable environmental performance goals for federal agencies and focuses on making improvements in their environmental, energy, and economic performance. EO 13514 required each federal agency to submit a 2020 GHG emissions reduction target from its estimated 2008 baseline to CEQ and to the Office of Management and Budget (OMB) by January 4, 2010. On January 28, 2010, President Obama announced that the federal government will reduce its GHG emissions by 28 percent by 2020.[8] This federal target is the aggregate of 35 federal agency self-reported targets. As the single largest energy consumer in the U.S. economy, the White House estimates that achieving the federal agency GHG emissions reduction target will reduce federal energy use by the equivalent of 646 trillion BTUs, equal to 205 million barrels of oil, and taking 17 million cars off the road for one year.

DOT is also one of more than a dozen agency members of the U.S. Climate Change Technology Program, which the Department of Energy (DOE) leads, that is aimed at the development and adoption of technologies designed to reduce the U.S. carbon footprint (DOE 2009b). Additionally, DOE administers programs that provide mitigating effects, such as the Section 1605b Voluntary Reporting of Greenhouse Gases. Section 1605b reporting provides a forum for recording strategies and reductions in GHGs and is a voluntary program that facilitates information sharing (DOE 2009b). Such programs can provide a source of information and strategy for future programs.

DOT's high speed rail initiative will provide a travel alternative that will reduce U.S. GHG emissions. The overall strategy involves two parts: improving existing rail lines to make current train service faster and identifying potential corridors for the creation of high-speed rail. In furtherance of these goals, on January 28, 2010, President Obama announced DOT's American Recovery and Reinvestment Act High-Speed and Inter-city Passenger Rail grants.[9] With 31 states and the District of Columbia receiving awards, these grants are jump-starting high-speed rail development in the United States.

The FTA is actively supporting the DOT Livability Initiative and the Federal Sustainable Communities Partnership with its programs to expand mass transit, another travel alternative that will reduce U.S. GHG emissions (FTA 2010a). The FTA works with public transportation providers and other key stakeholders to implement strategies that reduce GHG emissions from the transportation sector. FTA's grants, technical assistance, research, and policy leadership all play a role in the agency's efforts to address climate change (FTA 2010b). For example, FTA's grant programs support purchases of fuel efficient and alternative fuel transit vehicles.

Also within DOT, the FAA is a sponsor of the Commercial Aviation Fuels Initiative (CAAFI), which is a coalition of the U.S. commercial aviation community that acts as a focal point for engaging the

[7] Federal Leadership in Environmental, Energy, and Economic Performance, Exec. Order No. 13514, 74 FR 52117 (Oct. 8, 2009).

[8] *See* http://www.whitehouse.gov/the-press-office/president-obama-sets-greenhouse-gas-emissions-reduction-target-federal-operations (last accessed Feb. 3, 2010).

[9] *See* http://www.whitehouse.gov/blog/2010/01/28/president-obama-delivers-american-high-speed-rail (last accessed Feb. 3 2010).

emerging alternative fuels industry (FAA 2009). The CAAFI seeks to enhance energy security, and thereby reduce GHG emissions, in the transportation sector by promoting the development of alternative fuel options for use in aviation. Similarly, the Maritime Administration (MARAD) is exploring alternative fuels for ferries and other vessels via workshops with key stakeholders.

Regarding carbon emissions, DOE administers programs designed to give consumers and industries information required to make environmentally conscious decisions. Specifically, the DOE Clean Cities program develops government-industry partnerships designed to reduce petroleum consumption (DOE 2009a). The focus on urbanized areas overlaps with some of the nonattainment areas identified in Sections 3.3.2 and 4.3.2. Also, DOE administers the Vehicle Technologies Program, which creates public-private partnerships that enhance energy efficiency and productivity and bring clean technologies to the marketplace (DOE 2009c).

As NHTSA notes throughout the EIS, annual passenger car and light truck GHG emissions will continue to increase regardless of what level NHTSA sets CAFE standards. NHTSA's setting of CAFE standards will reduce the rate at which these emissions will increase. *See* Figure 2.6-1. NHTSA recognizes the importance of mitigating GHG emissions in this sector, and in the transportation sector more generally. Emissions mitigation in the transportation sector can only be discussed in the context of larger national emissions reductions policies and strategies. GHG emission reductions of the order of magnitude necessary to mitigate climate change will require concurrent efforts from many different international actors, from both the public and private sectors. For this reason, mitigation of global GHG emissions presents a unique set of challenges far beyond this rulemaking. That said, in the light duty vehicle sector, some policies that could be explored to contribute to this sector's GHG mitigation include expanding and improving mass transit, raising gas taxes or other driving-associated fees to deter VMT growth, and setting lower speed limits. When appropriate, increased motor fuel taxes or VMT fees could provide incentives to travelers to reduce trip lengths and shift to less carbon-intensive modes. A federal policy to reduce speed limits on national highways could reduce transportation GHG emissions because reducing highway traveling speeds generally increases vehicle fuel economy. For example, reducing speed from 70 to 55 miles per hour increases fuel economy for an average vehicle by over 6 miles per gallon. However, achieving these benefits would require strong enforcement.

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Chapter 8 Distribution List

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) (40 Code of Federal Regulations 1501.19) specify requirements for circulating an Environmental Impact Statement (EIS). In accordance with those requirements, NHTSA is mailing this EIS to the agencies, officials, and other interested persons listed in this chapter.

8.1 FEDERAL AGENCIES

- Advisory Council on Historic Preservation
- Council on Environmental Quality
- Council on Environmental Quality, NEPA Oversight
- Delaware River Basin Commission
- Denali Commission
- Federal Energy Regulatory Commission, Division of Gas - Environmental and Engineering
- Federal Energy Regulatory Commission, Division of Hydropower, Environment and Engineering
- Federal Energy Regulatory Commission, Office of Energy Projects
- International Boundary and Water Commission
- International Boundary and Water Commission, Environmental Management Division
- Marine Mammal Commission
- National Capital Planning Commission, Office of Urban Design and Plan Review
- National Science Foundation, Office of the General Counsel
- Office of Science and Technology Policy, National Science and Technology Council, Executive Office of the President
- Presidio Trust, NEPA Compliance Division
- Susquehanna River Basin Commission
- Tennessee Valley Authority, NEPA Policy
- U.S. Agency for International Development, Bureau for Economic growth, Agriculture, and Trade
- U.S. Department of Agriculture, Agricultural Research Service

- U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Environmental Services
- U.S. Department of Agriculture, Cooperative State Research, Education and Extension Service
- U.S. Department of Agriculture, Farm Service Agency
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Department of Agriculture, Rural Business-Cooperative Service
- U.S. Department of Agriculture, Rural Housing Services, Technical Support Branch
- U.S. Department of Agriculture, Rural Utilities Service, Engineering and Environmental Staff
- U.S. Department of Agriculture, U.S. Forest Service
- U.S. Department of Commerce, Economic Development Administration, Legislative and Intergovernmental Affairs
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Planning and Integration Office
- U.S. Department of Defense, Army Corps of Engineers, Office of Environmental Policy
- U.S. Department of Defense, Office of Deputy Undersecretary of Defense of Installations and Environment, Environmental Security
- U.S. Department of Energy, Office of Climate Change Policy (PI-63)
- U.S. Department of Energy, Office of NEPA Policy and Compliance (EH-42)
- U.S. Department of Energy, Western Energy and Waste Management Unit
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Building and Facilities Office
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Environmental Health, Agency for Toxic Substances and Disease Registry, Environmental Public Health Readiness Branch
- U.S. Department of Health and Human Services, Food and Drug Administration, Center for Food Safety and Applied Nutrition

- U.S. Department of Health and Human Services, Food and Drug Administration, Office of Commissioner
- U.S. Department of Health and Human Services, Health Resources and Services Administration
- U.S. Department of Health and Human Services, Indian Health Service, Division of Sanitation Facilities Construction
- U.S. Department of Health and Human Services, National Institutes of Health, Division of Environmental Protection, ORF, Environmental Quality Branch
- U.S. Department of Health and Human Services, Office of the Secretary, Office for Facilities Management and Policy, Division of Real Property
- U.S. Department of Homeland Security, Federal Emergency Management Agency
- U.S. Department of Homeland Security, Office of Safety and Environment
- U.S. Department of Homeland Security, U.S. Coast Guard, Environmental Management Division (G-SEC-3)
- U.S. Department of Housing and Urban Development, Office of Environment and Energy
- U.S. Department of Justice, Environment and Natural Resources Division
- U.S. Department of Labor, Mine Safety and Health Administration, Office of Standards, Regulations, and Variances
- U.S. Department of Labor, Occupational Safety and Health Administration, Office of the Assistant Secretary
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs
- U.S. Department of the Interior
- U.S. Department of the Interior, Bureau of Indian Affairs
- U.S. Department of the Interior, Bureau of Land Management, Renewable Resources Planning Division, Planning and Science Policy
- U.S. Department of the Interior, Bureau of Reclamation
- U.S. Department of the Interior, Main Interior
- U.S. Department of the Interior, Minerals Management Service, Environmental Assessment Branch
- U.S. Department of the Interior, National Park Service, Cultural Resources GIS Facility
- U.S. Department of the Interior, National Park Service, Environmental Quality Division

- U.S. Department of the Interior, Office of Environmental Policy and Compliance
- U.S. Department of the Interior, Office of Environmental Policy and Compliance, Natural Resources Management Team, Transportation Projects
- U.S. Department of the Interior, Office of Surface Mining
- U.S. Department of the Interior, U.S. Fish and Wildlife Service
- U.S. Department of the Interior, U.S. Geological Survey, Office of Environmental Affairs Program
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs
- U.S. Department of Transportation
- U.S. Department of Transportation, Federal Aviation Administration
- U.S. Department of Transportation, Federal Aviation Administration, Office of Environment & Energy (AEE-400)
- U.S. Department of Transportation, Federal Highway Administration
- U.S. Department of Transportation, Federal Highway Administration, Office of NEPA Facilitation
- U.S. Department of Transportation, Federal Maritime Administration
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration
- U.S. Department of Transportation, Federal Railroad Administration
- U.S. Department of Transportation, Federal Railroad Administration, Office of Railroad Development
- U.S. Department of Transportation, Federal Transit Administration
- U.S. Department of Transportation, Maritime Administration, Office of Environmental Activities
- U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy
- U.S. Department of Transportation, Office of the Secretary
- U.S. Department of Transportation, Pipeline & Hazardous Materials Safety Administration
- U.S. Department of Transportation, Research and Innovative Technology Administration
- U.S. Department of Transportation, Research and Innovative Technology Administration, Volpe Center, Environmental Engineering Division

- U.S. Department of Transportation, Saint Lawrence Seaway Development Corporation
- U.S. Department of Transportation, Surface Transportation Board, Section of Environmental Analysis
- U.S. Environmental Protection Agency
- U.S. Environmental Protection Agency, NEPA Compliance Division
- U.S. Environmental Protection Agency, Office of Federal Activities, EIS Filing Section
- U.S. Environmental Protection Agency, Office of Transportation and Air Quality
- U.S. Institute for Environmental Conflict Resolution, ECR Policy and Leadership
- U.S. Nuclear Regulatory Commission
- Valles Caldera Trust

8.2 STATE AND LOCAL GOVERNMENT ORGANIZATIONS

- American Samoa Department of Public Safety
- Assistant Corporation Counsel of the City of New York, Environmental Law Division
- California Attorney General's Office
- Connecticut Office of the Attorney General
- Corporation Counsel of the City of New York
- Georgia Environmental Protection Division
- Massachusetts Attorney General's Office
- Missouri Department of Natural Resources
- Montana Department of Environmental Quality
- New Mexico Department of Attorney General
- New Mexico Environment Department
- New York State Department of Transportation
- Oregon Department of Attorney General
- Pennsylvania Department of Environmental Protection
- Tennessee Department of Transportation
- Vermont Attorney General, Environmental Division

- Washington State Department of Ecology

8.3 ELECTED OFFICIALS

- The Honorable Bob Riley, Governor of Alabama
- The Honorable Sean Parnell, Governor of Alaska
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa
- The Honorable Janice Brewer, Governor of Arizona
- The Honorable Mike Beebe, Governor of Arkansas
- The Honorable Arnold Schwarzenegger, Governor of California
- The Honorable Bill Ritter, Governor of Colorado
- The Honorable M. Jodi Rell, Governor of Connecticut
- The Honorable Jack Markell, Governor of Delaware
- The Honorable Adrian Fenty, Mayor of the District of Columbia
- The Honorable Charlie Crist, Governor of Florida
- The Honorable Sonny Perdue, Governor of Georgia
- The Honorable Felix P. Camacho, Governor of Guam
- The Honorable Linda Lingle, Governor of Hawaii
- The Honorable C.L. “Butch” Otter, Governor of Idaho
- The Honorable Pat Quinn, Governor of Illinois
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Chet Culver, Governor of Iowa
- The Honorable Mark Parkinson, Governor of Kansas
- The Honorable Steven Beshear, Governor of Kentucky
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable John E. Baldacci, Governor of Maine
- The Honorable Martin O’Malley, Governor of Maryland
- The Honorable Deval Patrick, Governor of Massachusetts

- The Honorable Jennifer M. Granholm, Governor of Michigan
- The Honorable Tim Pawlenty, Governor of Minnesota
- The Honorable Haley Barbour, Governor of Mississippi
- The Honorable Jay Nixon, Governor of Missouri
- The Honorable Brian D. Schweitzer, Governor of Montana
- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable Jim Gibbons, Governor of Nevada
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable Chris Christie, Governor of New Jersey
- The Honorable Bill Richardson, Governor of New Mexico
- The Honorable David A. Paterson, Governor of New York
- The Honorable Bev Perdue, Governor of North Carolina
- The Honorable John Hoeven, Governor of North Dakota
- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable Ted Strickland, Governor of Ohio
- The Honorable Brad Henry, Governor of Oklahoma
- The Honorable Ted Kulongoski, Governor of Oregon
- The Honorable Edward G. Rendell, Governor of Pennsylvania
- The Honorable Luis Fortuño, Governor of Puerto Rico
- The Honorable Donald L. Carcieri, Governor of Rhode Island
- The Honorable Mark Sanford, Governor of South Carolina
- The Honorable Mike Rounds, Governor of South Dakota
- The Honorable Phil Bredesen, Governor of Tennessee
- The Honorable Rick Perry, Governor of Texas
- The Honorable Gary Herbert, Governor of Utah
- The Honorable Jim Douglas, Governor of Vermont

- The Honorable Bob McDonnell, Governor of Virginia
- The Honorable John P. deJongh, Jr., Governor of the United States Virgin Islands
- The Honorable Chris Gregoire, Governor of Washington
- The Honorable Joe Manchin, III, Governor of West Virginia
- The Honorable Jim Doyle, Governor of Wisconsin
- The Honorable Dave Freudenthal, Governor of Wyoming

8.4 NATIVE AMERICAN TRIBES

- Cedarville Rancheria
- Leisnoi Village aka Woody Island Tribal Council
- Mille Lacs Band of Ojibwe
- Native Village of Point Hope
- Natives of Larsen Bay
- Table Mountain Rancheria

8.5 STAKEHOLDERS

- Alliance of Automobile Manufacturers
- American Association of Blacks in Energy
- American Council for an Energy Efficient Economy
- American International Automobile Dealers Association
- American Jewish Committee
- American Jewish Committee, Washington Chapter, Office of Government and International Affairs
- BG Automotive Group, Ltd.
- BMW (US) Holding Corp.
- BMW of North America, LLC
- California Air Pollution Control Officers Association
- Cambridge Consumers’ Council
- Cambridge Consumers’ Council, Massachusetts Consumers Council

- Center for Biological Diversity
- Chrysler LLC
- Conservation Law Foundation
- Conservation Law Foundation, Vermont Advocacy Center
- Consumer Action
- Consumer Federation of America
- Consumers for Auto Reliability and Safety
- Consumers Union
- Douglas Long
- Environment America
- Environmental Council of the States
- Environmental Defense Fund
- Evangelical Lutheran Church in America
- Ford Motor Company
- Ford Motor Company, Environmental and Safety Engineering
- Fred T. Teal, Jr.
- Friends Committee on National Legislation
- Fuji Heavy Industries USA/Subaru
- General Motors Corporation
- General Motors, Public Policy Center
- Gibson, Dunn & Crutcher LLP
- Insurance Institute for Highway Safety
- James L. Adcock
- Jean Public
- Jewish Community Relations Council of Greater Washington
- Kirkland & Ellis LLP

- Maryknoll Office of Global Concerns
- Michael Gordon
- Missionary Society of St. Columban
- Missionary Society of St. Columban, Columban Justice Peace and Integrity of Creation Office
- National Automobile Dealers Association
- National Council of Churches USA
- National Tribal Environmental Council
- Natural Resources Canada
- Natural Resources Defense Council
- Natural Resources Defense Council, Vehicles Campaign
- Nissan North America, Inc.
- Northeast States for Coordinated Air Use Management
- Presbyterian Church (USA)
- Public Citizen
- Ray Koonuk, Jr.
- Sierra Club
- Sierra Club Global Warming and Energy Program
- Sierra Club Legislative Office
- Stratacomm on behalf of Aluminum Association Auto & Light Truck Group
- The Consumer Alliance
- The Episcopal Church
- The Mountaineers – Conservation Executive Committee
- The United Methodist Church General Board of Church and Society
- U.S. PIRG
- U.S. PIRG, Illinois PIRG
- U.S. PIRG, MASSPIRG

- Union for Reform Judaism
- Union of Concerned Scientists
- Union of Concerned Scientists, Washington Office
- United Church of Christ
- University of Colorado School of Law
- Volkswagen Group of America
- Volkswagen of America, Industry-Government Relations
- Western Governors’ Association
- Western Regional Air Partnership

Chapter 9 Index

Chapter 10 Responses to Public Comments

The National Highway Traffic Safety Administration (NHTSA) submitted to the U.S. Environmental Protection Agency (EPA) a draft Environmental Impact Statement (DEIS) to disclose and analyze the potential environmental impacts of the new Corporate Average Fuel Economy (CAFE) standards for Model Years (MYs) 2012-2016 and reasonable alternative standards in the context of NHTSA's CAFE Program pursuant to National Environmental Policy Act (NEPA) implementing regulations issued by Council of Environmental Quality (CEQ), U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations. On September 25, 2009, NHTSA published in the *Federal Register* (*FR*) a Notice of Availability of its DEIS. NHTSA's Notice of Availability also made public the date and location of a public hearing, and invited the public to participate at the hearing on October 30, 2009, in Washington, DC. The Notice of Availability of the DEIS triggered a 45-day public comment period. In accordance with CEQ NEPA implementing regulations, the public was invited to submit comments on the DEIS until November 9, 2009. NHTSA mailed approximately 300 copies of the DEIS to interested parties, including federal, state, and local officials and agencies; elected officials, environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 8 of the DEIS.

On Monday, September 28, 2009, EPA and NHTSA published in the *Federal Register* (*FR)* the Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Proposed Rule. The publication of the proposed rule opened a 60-day comment period and the public was invited to comment submit comments on or before November 27, 2009 by posting to either the EPA or NHTSA docket (EPA-HQ-OAR-2009-0472 or NHTSA-2009-0059). Comments submitted to the EPA docket were considered as comments submitted to the NHTSA docket and are under consideration for the final rule. A combined total of 11,356 public submissions were received on the NHTSA and EPA dockets. NHTSA and EPA also held three public hearings to receive comments on the rulemaking. NHTSA reviewed all of the rulemaking comments during preparation of this final Environmental Impact Statement (FEIS). Comments that were considered substantive to the EIS are summarized in Section 1.5.3. Comments received on the rulemaking will be responded to in the final rule.

NHTSA received 11 written comments from interested stakeholders on the DEIS. In addition, during the public comment hearing in Washington, DC, three people provided oral statements. In this chapter of the FEIS, NHTSA has quoted substantive excerpts from these comments and responded to the comments received, as required by NEPA (40 CFR § 1503.4).

NHTSA considered and evaluated all written and oral comments received during the public comment period in the preparation of this FEIS. NHTSA changed the EIS, in part, to respond to comments on the DEIS. NHTSA also changed the EIS as a result of updated information that became available after issuance of the DEIS.

NHTSA appreciates the comments provided during development of the EIS. The transcript from the public hearing and written comments submitted to NHTSA are part of the administrative record and are available on the Federal Docket, which can be found on the Web at http://www.regulations.gov, Reference Docket No.: NHTSA-2009-0059. Written comments and the public hearing transcript can also be viewed in their entirety in Appendix G of this FEIS. Sections 10.1 through 10.6 provide comments on the DEIS and NHTSA's responses to those comments. Table 10-1 lists the topics addressed in this chapter. Table 10-2 is an index of the comments from individuals, federal and state agencies, and private industry and the location in this chapter of NHTSA's responses to those comments.

Table 10-1

Outline of Issues Raised in Public Comments on the DEIS

10.1	**PURPOSE AND NEED**
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10.2.2	Standards-setting
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Table 10-2

Index of Comments from Individuals, Federal and State Agencies, and Private Industry

Commenter	Document ID Number a/	Location of Comment Excerpts and NHTSA's Responses
Federal Agencies		
Centers for Disease Control and Prevention	0042	10.3.4.1
Environmental Protection Agency, Susan Bromm	0052.1	10.2.3.4.1
USDA Agricultural Research Service, Facilities Division	0043	Non-substantive
State Agencies		
Tennessee Department of Transportation, Gerald Nicely	0046	10.1.5, 10.2.1, 10.2.2.1, 10.2.4.6, 10.3.4.1, 10.6.5
Missouri Department of Natural Resources, Dru Buntin	0051.1	10.2.1, 10.2.3.4.1, 10.3.2.1, 10.3.2.2
New York Department of Transportation, Stanley Gee	0098	10.2.2, 10.2.3.4, 10.2.3.4.7, 10.2.4.3, 10.2.4.6, 10.5
Industry		
Environmental Consultants of Michigan	0050.1	10.1.5, 10.2.4.3, 10.6.4
Organizations		
Center for Biological Diversity, Public Citizen, and the Sierra Club, Brian Nowicki	0053.1	10.1.3, 10.2.1, 10.2.2.1, 10.2.4.2, 10.2.4.3, 10.2.4.5, 10.2.4.6, 10.3.3, 10.4.1, 10.4.2
Sierra Club, Ann Mensikoff	TRANS01	10.1.5, 10.2.4.2, 10.2.4.6, 10.4.1
Public Citizen, Lena Pons	TRANS02	10.1.4, 10.2.4.2, 10.2.4.6, 10.4.1
Consumer Federation of America, Mark Cooper	TRANS03	10.2.2, 10.2.3.4.1, 10.2.3.4.3, 10.2.3.4.5, 10.2.3.4.6, 10.2.4.4, 10.2.4.6
Individuals		
Gail Gilbert	0019	10.2.1, 10.3.1
Douglas Long	0045	10.1.1, 10.2.1
James Adcock	0049	10.1.2, 10.1.3, 10.2.1, 10.2.2, 10.2.2.1, 10.2.3.1, 10.2.3.2, 10.2.3.3, 10.2.3.4, 10.2.3.4.2, 10.2.3.4.3, 10.2.3.4.4, 10.2.3.4.5, 10.2.4.1, 10.3.4.1, 10.3.4.2, 10.3.5, 10.6.1, 10.6.2, 10.6.3, 10.6.5

a/ Documents may be found at http://www.regulations.gov, Reference Docket No.: NHTSA-2009-0059.

10.1 PURPOSE AND NEED

10.1.1 Purpose and Need Statement

Comments

Docket Number: 0045
Organization: Individual
Commenter: Douglas Long

The American people need energy independence, more fuel efficient vehicles and cleaner air to breathe. To do that, President Barack Obama has introduced a plan to reduce vehicle fuel emissions and increase fuel mileage for vehicles in the model year 2012 to 2016. As an American citizen, tax payer and registered voter I want to establish that I support this plan by saying that we have to find alternative ways to conserve petroleum usage, either by improving fuel mileage from fossil fuel burning vehicles or by using energy sources such as electric or hydrogen alternatives, or by combining both technologies in future vehicles we will drive to achieve this goal.

We need to allow our country to achieve the increased benefits of a single, nationwide program to reduce light duty vehicle Green House Gas (GHG) emissions and reduce the country's dependence on fossil fuels by improving fuel economy . . . .

Oil prices have increased dramatically over the past several years, causing financial stress globally. In 2008, the United States really felt the punch of high fuel costs. In some areas, the price of a gallon of gasoline rose to over $4.00 per gallon. . . . When gasoline prices go up, it causes a ripple effect through the transportation industry, food industry, retail sales, and the car manufacturing industry as examples. …After experiencing such high costs of fuel and feeling the economic effects, it's time the American public support our government’s stance in developing policies that will assist in decreasing air pollution and increasing fuel economy at the same time.

Docket Number: 0044.1
Organization: Anonymous
Commenter: Anonymous

How will car dealers guarantee to consumers that cars will last and run when they themselves are not sure because this mile per gallon regulation has been pushed ahead by Obama. I see that these fuel standards are to help the issue of global warming. Global warming is only natural on earth, and will happen regardless of cars having an increase in car mileage. The President placing these new regulations on auto makers is not his job to do in my opinion. Why is the government just now proposing these new guidelines? The government has known about global warming for a long time-- why get in a hurry now? Having more fuel efficient cars will preserve more oil, but really how much oil is out there for us to use? While there are many theories out there about global warming and how much oil is available it is all a matter of opinion.

This regulation has many positive aspects, but it should not have been pushed ahead by the government. Oil running out or global warming getting worse is not going to be rescued by moving up these regulations four years. The President should not have control over the miles per gallon on a vehicle and cause auto makers more money that will ultimately trickle down to consumers.

* * * * *

The new standards regarding miles per gallon on vehicles are a great benefit to society to help increase better fuel mileage, greenhouse emissions, and save consumers money. There are a lot more negatives to this new regulation than positives. As the prices of gas continue to raise it will help people still be able to afford the cars or trucks they want and have better gas mileage at the same time. People currently buy trucks although the gas mileage is not good and gas is very expensive, so these new standards may increase sales slightly. These new regulations will cost auto makers money, and this cost will then be placed on the consumer. The money consumers will save on gas may be eaten up with the increase in car prices because they have to be fuel efficient. Many fuel efficient cars are not American cars right now, so people currently have the option to buy fuel efficient without the government forcing each car dealer to have a more fuel efficient car. Some car dealers are just catching up on other regulations, so now having this regulation moved up four years will only require research and development teams to work harder and longer to make sure they meet the deadline.

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

NHTSA ought to reduce the period of years covered by this regulation to a minimum in order to be able to respond to assumed forthcoming cap and trade treaties and legislation. For this reason we ask that the regulations be set for the minimum allowed number of years, not the maximum.

Response

Energy conservation is a core consideration of the agency in setting fuel economy standards. In proposing standards for MYs 2012-2016, NHTSA is acting pursuant to the Energy Policy and Conservation Act (EPCA), 49 U.S.C. § 32901 et seq., as amended by the Energy Independence and Security Act of 2007 (EISA), which requires the agency to set "maximum feasible" fuel economy standards for passenger cars and light trucks, taking into account four factors – technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the Nation to conserve energy. Id. at § 32902(f). NHTSA has carefully balanced these considerations and believes that the proposed action represents the maximum feasible fuel economy standards.

NHTSA recognizes that the proposed action alone will not avert climate change. A suite of many GHG emission reduction policies in numerous countries—across numerous sectors of their economies—would need to be implemented to mitigate climate change substantially. Nonetheless, EPCA does not limit NHTSA's duty under the National Environmental Policy Act (NEPA) to consider the environmental impacts of its rule. This FEIS reflects NHTSA's careful consideration of the environmental impacts of its proposed action and a reasonable range of alternatives.

In response to the comment regarding the timeframe of the proposed action, we note that in enacting EISA, Congress granted NHTSA the discretion to set CAFE standards anywhere from 1 model year to 5 model years at a time. See 49 U.S.C. § 32902(b)(3)(B). We believe setting standards five years at a time has benefits. By doing so, NHTSA promotes regulatory stability and provides significantly more lead time, which enables manufacturers to achieve and NHTSA to set more ambitious CAFE standards. If NHTSA waited until just 18 months before a model year to set standards for that model year, rather than setting standards for multiple years, the agency would have little ability to require the manufacturers to make more than relatively modest improvements to the products they would already have established for that year. Changing plans and making substantial improvements requires lead time. Due to the nature of automobile production, manufacturers generally set production and supply contracts years in advance. While modest changes can be made in 18 months, substantial changes would be impracticable in such a *short time. Because NHTSA believes that the best approach is to set CAFE standards for 5 model years, NHTSA has proposed standards for MYs 2012-2016.*

10.1.2 Public Review and Comment

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We wish to express up front great disappointment and frustration that the NAS 2009 update was not made available in time for the comment period of the DEIS. We believe this is inappropriate, given that Congress specifically called for NAS input to enlighten these controversial issues. . . . Further the DEIS and the reviews of the DEIS do not incorporate the Congressionally called for 2009 revision of the NAS document. We believe the clock should be stopped until the NAS 2009 report has been delivered and NHTSA and the DEIS reviewers have had a chance to respond.

* * * * *

While NAS 2002 valued reducing the risk of GHG highly, NHTSA and EPA list GHG as by far a weaker reason to increase CAFE. EPA and NHTSA need to explain why they are ignoring NAS in these matters.

* * * * *

Given NHTSA's great reliance on IPCC we suggest that NHTSA needs to formally invite IPCC to comment on NHTSA's chosen levels of CAFE stringency.

Response

In accordance with EPCA, as amended by EISA, NHTSA must go forward with setting fuel economy standards as directed by Congress. Because of the requirement to set standards for MY 2012 by the end of March 2010, the agency cannot wait for the National Academy of Sciences (NAS) report. See 49 U.S.C. § 32902(a) (requiring the agency to set CAFE standards for any model year at least 18 months in advance of the start of that model year). For both the joint Notice of Proposed Rulemaking (NPRM) and for the alternatives described in this FEIS, NHTSA has a considerable body of information, including the comments it received on the NPRM.

However, as explained in the joint NPRM, NHTSA plans to continue to work with the National Academy of Sciences to update the list of fuel-saving technologies and their associated costs and effectiveness numbers on a 5-year interval. To ensure that the combined passenger car and light truck fleets meet the statutorily mandated floor of 35 mpg in 2020, NHTSA will continue to assess whether the industry is on track during the 5 years covered by this rulemaking.

With regard to IPCC, NHTSA has provided multiple opportunities for interested parties to be heard. See DEIS Section 1.5; FEIS Section 1.5. On April 1, 2009, NHTSA informed the public through notice in the Federal Register regarding its plans to prepare an EIS. The April Notice initiated scoping[1] by requesting public input on the scope of the environmental analysis to be conducted. See 74 Federal Register (FR) 14857. On September 25, 2009, EPA published a Notice of Availability of the DEIS, which reflected our

[1] Scoping, as defined under NEPA, is an early and open process for determining the scope of issues to be addressed in an EIS and for identifying the significant issues related to a proposed action. See 40 CFR § 1501.7.

review and consideration of public scoping comments and the studies suggested by the commenters. See 74 FR 48951. Also on September 25, 2009, NHTSA published its own Notice of Availability of a Draft Environmental Impact Statement (DEIS) for New Corporate Average Fuel Economy Standards and Notice of Public Hearing. See 74 FR 48894. NHTSA's notice instructed the public where they could find the DEIS, invited comment on the DEIS, and announced details concerning how interested members of the public could participate in an October 30, 2009 public hearing on the DEIS.

On September 28, 2009, NHTSA and EPA published a joint NPRM, with NHTSA proposing CAFE standards, and EPA proposing GHG standards for MYs 2012-2016 light-duty vehicles. See 74 FR 49454. The NPRM informed the public that an EIS process was underway, and sought comments on the proposed rule. After issuing the DEIS, NHTSA provided a 45-day public-comment period, which closed on November 9, 2009. On October 30, 2009, before the close of the comment period, NHTSA held a public hearing on the DEIS in Washington, DC, during which interested parties were invited to testify.

Like the rest of the public, the Intergovernmental Panel on Climate Change (IPCC) was alerted to NHTSA's development of an EIS and was free to comment at any of the stages noted above.

10.1.3 Agency Consultation

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

NHTSA must complete an Endangered Species Act Section 7 Consultation to ensure that its action will not jeopardize or adversely modify the critical habitat of any species listed as "threatened" or "endangered."

The DEIS is non-committal with regard to its responsibilities under the federal Endangered Species Act to consult with U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries Service to ensure that this action will not jeopardize or adversely modify the critical habitat of any species listed as "threatened" or "endangered." "NHTSA is also currently exploring its obligations under Section 7 of the Endangered Species Act with U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries Service." DEIS at 1-11.

Section 4.5 of the DEIS includes a long discussion of the likely impacts of climate change on plant and animal species, including species protected under the federal Endangered Species Act. "Global average temperature increases in excess of 1.5 to 2.5 °C (2.7 to 4.5 °F) are statistically likely to threaten 20 to 30 percent of plant and animal species with extinction by 2100 (EPA 2009b, GCRP et al. 2009)." DEIS at 4-110. In addition, Section 3.4 includes a discussion of the effects on climate change that are likely to result from the rule.

Congress enacted the Endangered Species Act ("ESA") to conserve endangered and threatened species and the ecosystems upon which they depend. 16 U.S.C. § 1531(b). The Supreme Court's review of the ESA's "language, history, and structure" convinced the Court "beyond a doubt" that "Congress intended endangered species to be afforded the highest of priorities." Tennessee Valley Authority v. Hill, 437 U.S. 153, 174 (1978). . . . Once a species is listed under the ESA, Section 7 requires all federal agencies to "insure" that their actions neither "jeopardize the continued existence" of any listed species nor "result in the destruction or adverse modification" of its "critical habitat." 16 U.S.C. § 1536(a)(2). In addition, the "take" of listed species is generally prohibited. Id. at § 1538(a); 50 C.F.R. § 17.31(a). "Take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(19). The Services may, however, permit "incidental" take on a case-by-case basis if it finds, among other things, that such take will be minimized and mitigated and that such take will not "appreciably reduce the likelihood of survival and recovery of the species." Id. at § 1539(a).

Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to include "all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. Examples include, but are not limited to: (a) actions intended to conserve listed species or their habitat; (b) the promulgation of regulations; (c) the granting of licenses, contracts, leases, easements, rights-of-way, permits, or grants-in-aid; or (d) actions directly or indirectly causing modifications to the land, water, or air." 50 C.F.R. § 402.02. This regulatory definition of "action" clearly encompasses NHTSA's rulemaking, since the emissions from the regulated automobiles unquestionably will cause "modification to the land, water, or air." The U.S. Fish and Wildlife Service's and National Marine Fisheries Service's Consultation Handbook, Procedures for Conducting Consultation and Conference Activities under Section 7 of the Endangered Species Act (March 1998) explains the above terms and definitions. There can also be no question that the enormous volume of direct, indirect, and cumulative emissions from the regulated vehicles "may affect" listed species, and therefore the NHTSA must consult.

NHTSA's rulemaking will impact species listed as threatened and endangered in several ways, yet NHTSA has failed to initiate the required Section 7 consultations with [U.S. Fish and Wildlife Service and NOAA Fisheries] on its impact. NHSTA must initiate and complete the required Section 7 consultations on the rulemaking, or it may be held liable for take of listed species from the impacts of its action, including increased greenhouse gas emissions and other emissions such as NOx. On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species throughout is range due to global warming. Endangered and Threatened Wildlife and Plants, Determination of Threatened Status for the Polar Bear (Ursus maritimus) Throughout its Range, 73 Fed. Reg. 28212-28303 (May 15, 2008). NHTSA must consult on the impact of its rulemaking, and its proposal to set fuel economy standards far below what is technologically achievable, on the polar bear.

On May 9, 2006, the National Marine Fisheries Service listed the staghorn and elkhorn corals as threatened due in part to increasing ocean temperature and ocean acidification due to anthropogenic greenhouse emissions. 71 Fed. Reg. 26852. NHTSA must consult on the impact of its rulemaking on these coral species. NHTSA must also consult on the impact of its rulemaking on the polar bear's and the corals' critical habitat, once such habitat is designated.

Global warming was cited by the U.S. Fish and Wildlife Service in its critical habitat rulemakings for the Quino Checkerspot and Bay Checkerspot butterflies. See 73 Fed. Reg. 3328-3373 and 72 Fed. Reg. 48178-48218. NHTSA must consult on the impact of its rulemaking on these species and their critical habitat.

NHTSA must not limit its consultation, however, to species like the polar bear, corals, and checkerspot butterflies for which anthropogenic greenhouse emissions were cited as a reason for listing or as an impact in the listing or critical habitat rules. The Center has identified 143 listed species for which a recovery plan has been adopted that specifically identifies climate change or a projected impact of climate change as a direct or indirect threat to the species, as a critical impact to be mitigated, as a critical issue to be monitored, and/or as a component of the recovery criteria. See Exhibit A. This is clear evidence that the NHTSA's rulemaking "may affect" these species. The NHTSA must consult on the impact of its action on all listed species which may be affected.

The direct, indirect, and cumulative impacts of setting fuel economy standards for all cars and light trucks nationally are extraordinarily significant, and therefore a large number of species may be implicated. Where, as here, NHTSA's rulemaking is national in scope, NHTSA should conduct a nationally focused consultation. . . . If anything, a nationally focused consultation will provide the opportunity to most efficiently analyze the impact of the rulemaking on species and groups of species.

The rulemaking will impact listed species in ways beyond global warming and ocean acidification. For example, vehicles are a primary source of excess nitrogen in the environment. Excess nitrogen contributes to major environmental problems including reduced water quality, eutrophication of estuaries, nitrate-induced toxic effects on freshwater biota, changes in plant community composition, disruptions in nutrient cycling, and increased emissions from soil of nitrogenous greenhouse gases. Nitrogen deposition therefore impacts species listed under the Endangered Species Act in a number of ways. [Citation omitted].

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

DEIS does not adequately describe impact of CAFE decisions on West Coast species extinction risks, including the Polar Bear, Pacific Northwest Salmon, Mtn Pika, Eastern Pacific Northwest Native Pine Species, etc . . . .

DEIS fails to explain how NHTSA and EPA avoid responsibility to ESA by monetizing SCC - and then ignoring the value of species extinction in that estimate of SCC! We believe SCC needs to include a valuation of species extinction and explanation of how the agencies reconcile these particular choices with ESA.

Response

Under Section 7(a)(2) of the Endangered Species Act (ESA) federal agencies must ensure that actions they authorize, fund, or carry out are "not likely to jeopardize" federally listed threatened or endangered species or result in the destruction or adverse modification of the designated critical habitat of these species. 16 U.S.C. § 1536(a)(2). If a federal agency determines that an agency action may affect a listed species or designated critical habitat, it must initiate consultation with the appropriate Service – the U.S. Fish and Wildlife Service (FWS) of the Department of the Interior and/ or National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries Service) of the Department of Commerce, depending on the species involved—in order to ensure that the action is not likely to jeopardize the species or destroy or adversely modify designated critical habitat. See 50 CFR § 402.14. Under this standard, the federal agency taking action evaluates the possible effects of its action and determines whether to initiate consultation. See 51 FR 19926, 19949 (Jun. 3, 1986).

NHTSA has reviewed applicable ESA regulations, case law, guidance, and rulings in assessing the potential for impacts to threatened and endangered species from the proposed CAFE standards. NHTSA believes that the agency's action of setting CAFE standards, which will result in nationwide fuel savings and, consequently, emissions reductions from what would otherwise occur in the absence of the agency's CAFE standards, does not require consultation with NOAA Fisheries Service or the FWS under section 7(a)(2) of the ESA. For additional discussion of the agency's rationale, see Section 3.5.2.1.4 of the FEIS. Accordingly, NHTSA has concluded its review of this action under Section 7 of the ESA.

10.1.4 Document Structure and Readability

Comments

Docket Number: TRANS02
Organization: Public Citizen
Commenter: Lena Pons

The agency has not produced a document that adequately informs the public. The DEIS is a long, complex document that assumes a great deal of familiarity with fuel economy standards, transportation energy policy, and climate change policy. For a layperson, the document is inaccessible and daunting. However, the agency is charged with producing a document that is written in plain language and written so that decision-makers and the public can readily understand it. The complexity of the rulemaking, the process by which the agency sets the standards, the coordination of multiple agencies in developing the standards and the global nature of impacts considered in the document ensure that even the best effort to present the impacts of the range of alternatives would not be considered plain language by many.

In order to meaningfully talk about the range of alternatives, some familiarity of the reader with the subject matter must be assumed. And we do not suggest that the agency make no mention of technical elements in its analysis in presenting environmental impacts. However, presenting the impacts in a context that is relatable and relevant to the reader would significantly improve the usefulness of the document, guiding decision-making and informing the public.

Response

NHTSA has worked to make this EIS reader-friendly. As the commenter recognized, however, the extreme complexity of the subject matter warrants significant technical discussion. In response to this comment, NHTSA has revised the Summary to focus on communicating the importance of the impacts of the agency's action in a non-technical, and average-reader-friendly way. This summary contains (1) a general discussion of the greenhouse effect and climate change, (2) a summary of impacts expected with climate change, (3) a brief discussion of the direct, indirect, and cumulative effects of alternatives on GHG emissions as well as atmospheric CO_2 *concentration, global mean surface temperature, sea-level rise, and precipitation, (4) graphical depictions of impacts of the agency action on U.S. light-duty vehicle fleet emissions, and (5) additional context to help decisionmakers and the public understand the differences among the alternatives and how this action fits into larger U.S. GHG reduction goals. NHTSA has formatted the Summary to make use of layout and fonts that are easier to read.*

For ease of access, in addition to the Summary included with the complete EIS, NHTSA will also publish the Summary on its website as a stand-alone document. We believe readers will find this new summary helpful in their understanding of the FEIS.

10.1.5 Joint Rulemaking and the National Program

Comments

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

EPA and NHTSA jointly proposed this rule establishing a national program that would improve fuel economy and reduce greenhouse gas emissions. The proposed rule contains two separate sets of standards applying to passenger cars, light-duty trucks and medium-duty passenger vehicles, covering model years 2012 through 2016. TDOT applauds this harmonized approach that will align the CAFE standards and EPA's greenhouse gas regulations. It makes sense to develop these regulations in a coordinated fashion, and this alignment of regulations affecting automobiles should provide significant benefits. TDOT hopes the two agencies will continue to work together to improve the efficiency, safety and environmental performance of motor vehicles sold in the United States.

* * * * *

Creating a strong national program will meet the president's commitment, provide U.S. consumers with clean vehicle choices, and allow the struggling auto industry to emerge as the model for a clean energy economy. The proposed rule to strengthen the CAFE standards is a strong step forward for fuel economy, and one of the centerpieces of a sound national energy policy.

Docket Number: 0050.1
Organization: Environmental Consultants of Michigan
Commenter:

In setting up separate rules for tailpipe greenhouse gases and fuel economy these two federal agencies establish unique sets of flexibilities, credit schemes, penalties, and administrative compliance requirements. Inevitably one of these standards will be more stringent compared to the other for individual manufacturers. Situations will arise wherein a corporation or individual will fail both sets of requirements for a single offense. This is unprecedented, unnecessary, overly bureaucratic, redundant and a violation of both common law and the Fifth Amendment to the U. S. Constitution which prohibits the government from prosecuting more than one time for a single offense and from imposing more than one punishment for a single offense. [Citations omitted].

Nowhere is this multiple punishment for a single offense more evident than in the case of a manufacturer electing to pay a statutorily permitted fine in lieu of changing their business strategy to meet a CAFE standard. BMW, Daimler, Porsche, Tata and VW among other companies routinely pay CAFE fines. Under the proposal, after paying the normal CAFE fine, these companies would be subject to a separate action wherein EPA voids ab initio the certificate of conformity necessary to sell a motor vehicle. Not only does this proposal impose more than one punishment for a single offense, but this administrative action renders the statute permitting the paying of CAFE fines in lieu of meeting the standard meaningless as no company would risk the administrative penalties imposed for selling a vehicle without a certificate of conformity. [Citations omitted].

Depending on the compliance strategy adopted by a manufacturer, one of these two standards will be more stringent. For example, the Alternative Motor Fuel Act encourages automobile manufacturers to produce flexible fueled vehicles that can operate on more than one fuel. CAFE laws provide an incentive to produce these vehicles. Under the proposed rule, the EPA standard would impose barriers to the production of these vehicles negating the counting of these vehicles for compliance with the GHG standard. On the flip side, the EPA proposal selects other technologies to incentivize, including "advanced technology" credits wherein the qualifying vehicles are given a multiplier of 1.2 to 2.0 for each vehicle produced, air conditioning credits and credits for qualifying "off-cycle" technologies. These credits do not apply to CAFE compliance.

EPA argues that the Supreme Court required the Agency to determine if greenhouse emissions contribute to health and welfare concerns and if so to take appropriate action. The Agency on April 17, 2009 signed The Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act. After making this finding, EPA has arbitrarily and capriciously jumped to the conclusion that the only recourse is to regulate tailpipe GHG emissions in duplication of the NHTSA regulation of vehicle fuel economy required under EISA. [Citations omitted].

Arbitrarily jumping to the conclusion that tailpipe standards are necessary is a misreading of the decision handed down by the Supreme Court and a complete abdication of any objective policy review.

* * * * *

Thus there will continue to be a single National Program with no need for separate state standards with or without a duplicative national tailpipe greenhouse gas standard.

Docket Number: TRANS01
Organization: Sierra Club
Commenter: Ann Mensikoff

As Congress continues to debate climate legislation, NHTSA along with EPA are taking perhaps what is the most significant step this administration can take to curb global warning and saving oil.

Response

NHTSA must issue a CAFE standard under EPCA, as amended by EISA. For each future model year, EPCA requires that NHTSA establish standards at "the maximum feasible average fuel economy level that it decides the manufacturers can achieve in that model year," based on the agency's consideration of four statutory factors: technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the Nation to conserve energy. See 49 U.S.C. §§ 32902(a), 32902(f).

In addition, section 202(a)(1) of the Clean Air Act states that "the Administrator shall by regulation prescribe (and from time to time revise) . . . standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles . . . which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." 42 U.S.C. § 7521(a). If EPA makes the appropriate endangerment and cause or contribute findings, then section 202(a) authorizes EPA to issue standards applicable to emissions of those pollutants. In Massachusetts v. EPA, the Supreme Court directed the EPA to determine whether or not emissions from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. 549 U.S. 497, 532-35 (2007). The Court explained that EPA's mandate to protect public health and welfare is wholly independent from NHTSA's mandate to promote energy efficiency, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency. Massachusetts v. EPA, 549 U.S. at 532.

On December 15, 2009, EPA finalized its finding that CO_2 (one of six atmospheric GHGs) endangers the public health and welfare, and is therefore a CAA pollutant for purposes of vehicle GHG emissions. See 74 FR 66496; see also the EPA Endangerment Finding and Technical Support Document for a detailed discussion of these findings. Because EPA has issued both what is known as an "endangerment finding" and a "cause and contribute finding," it must now set emissions standards under Title II of the CAA, as described above.

NHTSA does not agree with the commenter's view that the National Program could lead to "multiple punishment for a single offense" in violation of the Fifth Amendment. A single act can violate different *statutes, and if so, may be appropriately penalized. Violations of EPCA and the CAA are proven differently, and so would constitute separately punishable offenses.*

Because both NHTSA and EPA have statutory obligations to regulate the related standards of vehicle fuel economy and CO_2 and other vehicle GHG emissions, President Obama announced the National Fuel Efficiency Policy on May 19, 2009.[2] *In the announcement of this national policy, the President directed that the two agencies establish consistent, harmonized, and streamlined requirements that would improve fuel economy and reduce GHG emissions for all new passenger cars and light trucks sold in the United States. The agencies have reasonably done so in this joint rulemaking, based on their respective statutory authorities.*

Finally, the statement that the proposed treatment of FFV credits under the joint proposal impermissibly eliminates the incentive in EISA to produce FFVs is incorrect. In fact, the proposal states that because FFV credits are part of manufacturers' compliance strategy in the initial years of the National Program, EPA will accept the FFV credits under EISA for purposes of the CAA program through and including MY 2015 vehicles in order to provide these manufacturers sufficient lead time. See 74 FR at 49531. Thereafter, these vehicles would be evaluated based on their actual performance, in keeping with the overall requirement of CAA section 202(a) to require achievable reductions of air pollutants emitted by motor vehicles at reasonable cost. The requirement is independent of the EPCA/EISA treatment of FFVs, and therefore EPA is not bound to follow that scheme. See Massachusetts v. EPA, 549 U.S. at 532 (EPA obligation to protect the public health and welfare are "wholly independent of DOT's mandate to promote energy efficiency").

[2] President Obama Announces National Fuel Efficiency Policy, The White House, May 19, 2009. Available at: http://www.whitehouse.gov/the_press_office/President-Obama-Announces-National-Fuel-Efficiency-Policy/ (last accessed Dec. 28, 2009). Remarks by the President on National Fuel Efficiency Standards, The White House, May 19, 2009. Available at: http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-on-national-fuel-efficiency-standards/ (last accessed Dec. 28, 2009).

10.2 THE PROPOSED ACTION AND ALTERNATIVES

10.2.1 Proposed Action

Comments

Docket Number: 0019
Organization: Individual
Commenter: Gail Gilbert

These standards are a big step forward and I urge you to keep them strong to ensure that we reap their full benefit.

Docket Number: 0045
Organization: Individual
Commenter: Douglas Long

This proposal would establish regulations that would protect the American people by enforcing car manufacturers to produce even cleaner and more fuel efficient vehicles than ever before. Reducing GHGs would serve to protect the environment in which all humans and animals live. Increasing fuel mileage would allow the U.S. dollar to go further by Americans not having to spend it at the gas stations so often. These two positive attributes of this proposal only leave me with a belief that I have to support. Cleaner more fuel efficient vehicles are something the American people need.

* * * * *

The proposal is intended to enhance vehicle fuel economy, while protecting motor vehicle safety and being mindful of the risk of harm to the overall United States economy. Let it be known, I support this proposal.

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

I would like to begin by commending the National Highway Traffic Safety Administration (NHTSA) for developing rules that meet Congress' 2007 mandate for tighter CAFE standards, and to apply those standards in 2016 well in advance of the 2020 Congressional mandate.

Docket Number: 0051.1
Organization: Missouri Department of Natural Resources
Commenter: Dru Buntin

Overall, the Department supports the proposal by the National Highway Traffic Safety Administration (NHTSA) and Environmental Protection Agency (EPA) to implement a more stringent CAFE standard than the no additional action alternative to reducing emissions from mobile sources.

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

Setting fuel economy standards for all cars and light trucks nationally is one of the single most important actions that the government can take to reduce greenhouse emissions. NHTSA should correct the flaws [we have] identified . . . in the EPCA and NEPA analyses, and promptly propose and then finalize new fuel economy levels which actually achieve the "maximum feasible" level.

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

In general we believe EPA and NHTSA are offering way too many loopholes, credits, and footprint "gaming" opportunities to make for an effective regulation actually reducing fuel consumption.

* * * * *

We suggest that NHTSA needs to compare how the US is lagging behind on fuel economy compared to the rest of the world in order to determine whether or not US fuel economy forms a "gating function" for the success or failure of US diplomatic climate change negotiations and whether a greater show of "good faith" on the part of the US isn't necessary in order for other nations to take or negotiations on climate change seriously.

* * * * *

We believe that NHTSA should set higher MPG CAFE targets leading to lower environmental damage.

Response

Individual commenters noted that the standards were "a big step forward," that they would ensure the production of "cleaner and more fuel efficient vehicles than ever before," and that they significantly speed up the timetable set by Congress in EISA requiring the U.S. fleet to reach a combined average CAFE standard of 35 mpg in MY 2020, although some thought the agency should set higher CAFE standards.

One commenter suggested that, while a national standard for fuel economy was of great importance to the reduction of GHG emissions, NHTSA should finalize fuel economy levels which achieve the "maximum feasible" level. NHTSA believes that the preferred alternative achieves the maximum feasible average fuel economy level as required by EPCA, 49 U.S.C. § 32902(a), considering the four statutory factors (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the Nation to conserve energy).

Finally, we note that NHTSA's action is to set maximum feasible CAFE standards for vehicles for sale in the United States, based on the four factors noted above, not to establish a "gating function" for other efforts.

10.2.2 Standards-setting

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

The assumptions for fuel stringency set for 2012 have already been met by Mfg by 2010, indicating 2 years loss without reason.

* * * * *

Do the proposed standards "increase ratably"? No: the standards DO NOT increase ratably if the required level of fuel economy for 2012 has already been accomplished by Mfgs by 2010, leading to two years where the Mfgs do not have to do anything, or alternatively that they can use to "get ahead in the game" which in turn will lead to greater effective stringency in the 2016 timeframe.

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

First, we must balance the goals of the underlying statutes: technical feasibility, economic practicability -- which actually appear in both statutes almost identically -- the need to conserve energy -- which appears in NHTSA's governing statute -- and the need to reduce the environmental harm of gasoline consumption, which is obviously the purpose of the Clean Air Act being implemented. Reconciling those four goals we believe is achieved by setting the standard at the halfway point between the maximum economic benefit and the maximum practicable environmental benefit. We call this the 50/50 approach in the 2008 proceeding. We think that's the way you resolve the statutes.

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

Since the proposed standards assume a 10% rebound effect on future vehicle miles traveled, and the DEIS assumes that VMT is projected to increase significantly over the next 10-50 years, it is imperative that fuel economy standards be set at a level that is as stringent as the broadly defined "four factors" allow. Thus, the proposed CAFE standards should not simply rely on current market trends. It is appropriate for the standards to decrease oil dependence to the greatest extent possible with technology-forcing standards.

* * * * *

The proposal appears to place a greater emphasis on economic practicality than it places on the other statutory factors that NHTSA is required to consider in setting the CAFE standards.

Response

The agency does not agree with the comment that manufacturers will already meet the MY 2012 CAFE standards by 2010. With attribute-based standards, which are required by EPCA as amended by EISA, each manufacturer has its own fuel economy requirement in each model year based on the mix of vehicles it produces and where those vehicles fall along the footprint target curves. A manufacturer need not meet *the target for every single vehicle it produces, but may distribute its compliance burden among the vehicles it produces through averaging. Thus, a manufacturer may produce vehicles that are above their individual target fuel economy values at that point on the footprint curve, while also producing other vehicles that are below their target values, as long as the manufacturer's fleet averages out to the harmonic average required of that manufacturer based on its vehicle mix. While NHTSA agrees, therefore, that there are individual vehicles that may exceed the overall proposed MY 2012 passenger car fleet-wide average of 33.4 miles per gallon in MY 2010, the fleet as a whole is unlikely to exceed that level in MY 2012, based on Volpe model simulation and analysis.*

EISA requires ratable increases in CAFE standards starting in MY 2011, which the agency interprets to mean, in combination with the requirement to set the standards for each model year at the level determined to be the maximum feasible level that manufacturers can achieve for that model year, that the annual increases should not be disproportionately large or small in relation to each other. See Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 74 FR 49454, 49463, 49635 (Sep. 28, 2009). The proposed standards substantially meet this condition. In any case, we estimate that achieved CAFE levels for both passenger cars and light trucks (and thus their combined average fuel economy levels) will increase each year from 2012-2016, at least for the industry as a whole if not for each manufacturer individually.

Consumer Federation of America suggests a "50/50 approach in the 2008 proceeding," where the agencies would set the standard "at the halfway point between the maximum economic benefit and the maximum practicable environmental benefit" by taking into account four factors: technical feasibility, economic practicability, the need to conserve energy, and the need to reduce the environmental harm of gasoline consumption. The agencies have worked closely to ensure that their respective programs work in a coordinated fashion and provide regulatory compatibility that allows auto manufacturers to build a single national light-duty fleet that complies with both the GHG and the EPCA-based CAFE standards. NHTSA's action falls under the mandate of EPCA, rather than the Clean Air Act, and the agency's action must be guided by the requirements and factors contained in our statute.

EPCA requires the Secretary of Transportation to establish average fuel economy standards for each model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." 49 U.S.C. § 32902(a). When setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). NHTSA has carefully balanced the statutory factors and believes that the stringency levels of the Preferred Alternative (Alternative 4) most reasonably reflect these requirements. For further explanation of NHTSA's balancing of the statutory factors, see section IV.F of the NPRM. That said, the fundamental purpose of this EIS is to evaluate the environmental impacts of the alternatives to inform the decisionmaker, so that these impacts can be taken into account.

10.2.2.1 Technological Feasibility

Comments

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

The standards can be met through the use of available technologies, such as improvements in energy efficiency, transmissions and tires as well as in air conditioning systems. Some critics believe that technologies exist to meet even tighter standards, and argue that NHTSA should have proposed tighter standards that would have forced new advances in technology. As they are, these standards are still likely to promote more widespread use of advanced fuel-saving technologies like hybrid vehicles and clean diesel engines. In addition, with the certainty of a national policy in place, the standards should spur more technological innovations, which may ultimately reduce the costs of meeting the standards.

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

In addition, the upper range of alternatives presented in the DEIS fails to accurately describe a technologically feasible level. The highest stringency alternative analyzed in the DEIS would result in average fuel economy of 37.1 mpg in 2016. It is clear that this cannot, by any stretch of the imagination, be equated with what is "technologically feasible." First, cars on the road in the U.S. today already achieve approximately the same or better gas mileage than what NHTSA has defined as the combined fleet "technology exhaustion" for model year 2016. These include the Toyota Prius (48/45; city/highway) and the Honda Civic Hybrid (40/45; city/highway). Many more vehicles already surpass the upper range of alternatives in the DEIS (30.0 mpg) for the combined fleet in MY 2012: smartcar (33/41; city/highway); Toyota Yaris (29/36); Toyota Corolla (28/37); Nissan Altima Hybrid (35/33); Toyota Camry Hybrid (33/34); Hyundai Accent (27/32); Kia Rio (27/32); Mazda Tribute Hybrid 2WD (34/30); and Honda Fit (28/34). Second, the upper range of alternatives results in standards significantly lower than those currently in use in many other countries. Europe and Japan had average fuel economy standards of approximately 42 mpg in 2008—over 15 mpg higher than U.S. standards. Both Europe and Japan are predicted to continue increasing their fuel standards; even their high standards are not the technology maximum. The fact that other countries have achieved higher fuel standards indicates that there are eminently feasible technology options available today that have not been included in the DEIS. [Citations omitted].

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We disagree with the decisions by NHTSA and EPA to in practice exclude Strong Hybrid, PHEV, and EV technology during this time frame. Prius Strong Hybrid technology is now about 15 years old, and has been adopted by many Mfgs. EV Tesla is selling commercially. PHEV Volt and EV Leaf have been firmly announced by major manufacturers. To assume that these technologies will not exist in the marketplace even by 2016 flies in the face of the evidence. NHTSA assumes PHEV range of 20 MPG where the one announced PHEV has a range of 40 MPG. By choosing an artificially low range NHTSA artificially deflates the MPG possible via PHEV technology.

Response

EPCA requires that NHTSA establish standards at "the maximum feasible average fuel economy level that it decides the manufacturers can achieve in that model year," 49 U.S.C. § 32902(a), based on the agency's consideration of four statutory factors: technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy, id. at § 32902(f). EPCA does not define these terms or specify the weight to give each factor in balancing them. As defined by the agency, technological feasibility refers to whether a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established. 74 FR at 49461.

The commenters suggest that NHTSA's alternatives do not reflect technological feasibility because certain individual vehicle models currently on the road surpass the average fuel economy standards of each of the alternatives. CAFE standards are not measured by the performance of a single vehicle in a manufacturer's fleet. Rather, they are measured as the production-weighted average of the manufacturer's fleet-wide fuel economy. As explained in the NPRM, CAFE standards for each manufacturer are a function of their product mix.

Technological feasibility is but one factor the agency must consider. In setting CAFE standards, NHTSA must also consider the additional statutory factors. One of the other four statutory factors is "economic practicability." As set forth in the NPRM, "economic practicability" does not permit the CAFE standards to cause substantial economic hardship for automakers. See 74 FR at 49461.

As the commenter notes, some manufacturers have already incorporated more advanced diesel and hybrid technologies. However, NHTSA believes that requiring increased technology penetration beyond what the agency has already modeled would exceed maximum feasibility, for reasons set forth in the PRIA. Making substantial product changes requires lead time. Thus, the fact that some manufacturers are using a technology now does not mean it can be added fleetwide in the lead time necessary. NHTSA believes that it is not practicable for all manufacturers to incorporate these technologies across their entire fleets by MY 2016.

The commenters also suggest that NHTSA's alternatives do not properly reflect "technological feasibility" because other countries currently have higher fuel economy standards in place than those considered in the DEIS for the model years covered by this rulemaking. We disagree. Setting aside regulatory differences between these nations, this argument ignores the fact that the United States does not have the same fleet profile – including the distribution of various vehicle footprints – as other countries, and that average fuel economy is strongly dependent on fleet profile. EPCA requires NHTSA to set maximum feasible CAFE standards for passenger cars and light trucks produced for sale in the United States, not to set standards that require manufacturers to replicate the fleet profiles of other countries. NHTSA's determination of the technological feasibility and economic practicability tests must be applied within the context of the fleet of vehicles to be regulated – the projected U.S. fleet.

10.2.3 Volpe Model

10.2.3.1 General

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

While NHTSA has improved its "openness" to meaningful public review of its actions . . . . We find numerous cases where documentation referred to in the case documents is NOT at the location specified. We have contacted NHTSA and EPA for help in locating these "missing" supporting documents and we DID NOT receive credible assistance in locating these "missing" documents.

* * * * *

We continue to have problems in practice with the "openness" of the Volpe Model . . .

NHTSA states that Volpe has been open to review, including input and output files. This is false. We asked via FOIA 1/22/09 for the input and output parameters to Volpe and our request was denied by NHTSA . . . . The denied files corresponded to about 150,000 numerical values without which it was impossible to repeat Volpe results. Denial based on the fact that some of these 150,000 values were "proprietary."

* * * * *

The economic lifetime of PCs is 2 to 3 years. Thus Volpe targeting "PC 2003" is expecting a PC that is 2 to 3 generations old as its target machine. Volpe should be updated to compile correctly on contemporary PCs, versions of Excel and development environments.

Response

The Volpe model is a tool NHTSA uses to apply technologies and assess costs and benefits given a range of input assumptions, including vehicle market forecast information, technology costs and effectiveness, and economic externalities. NHTSA selects the input assumptions based on the available information at the time of the rulemaking. NHTSA provides interested parties and the public with relevant data and information used to develop inputs to the Volpe model and the rationale for selecting those inputs. FEIS Section 3.1.4 (detailing Volpe model inputs); NPRM, 74 FR 49454, 49646-49684 (Sep. 28, 2009). The NPRM contains detailed instructions on obtaining Volpe model software and documentation on NHTSA's website (available at http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/The%20Volpe%20Model/volpe_documentation_draft.pdf). See e.g., 74 FR 49454, 49637, n. 432.

NHTSA staff is aware of no attempts by Mr. Adcock to contact the agency for assistance locating supporting material related to the MYs 2012-2016 CAFE rulemaking. The Freedom of Information Act (FOIA) request Mr. Adcock references relates to the earlier MY 2011 CAFE rulemaking. In that FOIA request, Mr. Adcock requested files associated with NHTSA's MY 2011 CAFE rulemaking and the MYs 2011-2015 CAFE FEIS and, except for confidential business information, NHTSA provided Mr. Adcock with the requested files. The agency is prohibited by federal law from disclosing confidential business information; making this information publicly available would cause competitive harm to manufacturers. See 5 U.S.C. § 552(b)(4); 18 U.S.C. § 1905; 49 U.S.C. § 30167(a); 49 CFR Part 512; Critical Mass Energy Project v. Nuclear Regulatory Comm'n, 975 F.2d 871 (D.C. Cir. 1992).

NHTSA has increased transparency. The MY 2011 CAFE Final Rule, which was issued in March of 2009, was based significantly on confidential product planning information submitted by manufacturers to the agency. Notwithstanding this restriction, in its publicly available documents for the MY 2011 Final Rule, NHTSA provided aggregated information (compiled from individual manufacturer submissions) regarding its forecasts of the future vehicle market. In the MYs 2012-2016 rulemaking, the agency's vehicle market forecast does not contain confidential business information as previous baseline market forecasts did. See 74 FR 49454, 49484-49490, 49646-49654. Instead, the vehicle fleet currently used as an input to Volpe, like that used as an input to similar analysis by the EPA, is based on 2008 vehicle certification data as supplied by EPA. Therefore, as explained in the DEIS and joint NPRM, any interested party may obtain all files necessary to replicate the agency's analysis from NHTSA's website for the MYs 2012-2016 rulemaking. See DEIS Section 2.2.1; 74 FR 49454, 49637, n. 432. This change was made in response to comments on the previous rulemaking to enhance public transparency of the agency's modeling analysis.

The Volpe model and accompanying inputs used to conduct analysis documented in the DEIS for MYs 2012-2016 was made available on the NHTSA website within days of the DEIS release. The material *posted on the website included the model executable and model source code, as well as model documentation, model input and output files (excluding confidential business information) from analysis documented in the DEIS, and model log files documenting every model setting applied as actually operated by Volpe Center staff. Since the agency has used the Volpe model for CAFE rulemakings, both NHTSA and Volpe Center staff have made efforts to support individuals and groups inquiring of the agency regarding difficulties working with the Volpe model, and will continue to do so upon request.*

Users should encounter no difficulties installing and running the model, as the model documentation provides specific minimum hardware requirements and also indicates operating environment requirements, both of which have remained materially unchanged for more than a year. Also, Volpe Center staff members routinely install and run the model successfully on new laptops, desktops, and servers as part of normal equipment refreshes and interagency support activities. We believe, therefore, that if the minimum hardware and operating environment requirements are met, installing and running the model should be straightforward and successful. The model documentation notes that some of the development and operating environment used by the Volpe model (e.g., the software environment rather than the hardware on which that software environment operates), particularly the version of Microsoft Excel used by the model, is Microsoft Office 2003. The current model documentation states that "the software makes use of encryption algorithms available in Excel 2003" and that these "algorithms are not available in older versions of Excel." See Corporate Average Fuel Economy Compliance and Effects Modeling System Documentation, p.38.

We recognize that some users may have more recent versions of Microsoft Office. However, as in the case of other large organizations, software licensing decisions, including the version of Microsoft Office, is centralized in the Office of the Chief Information Officer. Nonetheless, the Volpe Model is proven on both Microsoft Office version 2003 and the newer 2007 version.

10.2.3.2 Vehicle Market Forecast

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We find that the Volpe Model ("Volpe") does not do a reasonably good job of predicting the future when it fails to predict the emergence of PHEVs and EVs -- and Mfgs are announcing product plans for such. The fact that Volpe under-predicts these available fuel efficiencies indicates that NHTSA assumptions underlying the design of Volpe are false. . . . The Volpe projections are inconsistent with the rate that hybrids are actually being introduced into the market. If Volpe cannot correctly predict "in the future" that which is already happening TODAY then Volpe cannot be relied upon. Volpe failure to predict technology we know is happening prior to 2012: PHEVs and EVs which implies there is something fundamentally wrong with NHTSA's understanding and modeling of the reality of the market.

* * * * *

We do not think it is rational to include in the design of the regulations vehicles from Mfgs who choose not to meet CAFE Stds. . . . Rather, stringency should be based solely on those who show reasonable intent to meet the standards, and the resulting penalties to those who choose "not to play the game" should be allowed to fall where they lie.

* * * * *

135 Car models and 104 truck models corresponds to 80 percent of total vehicle sales. Rather than putting equal weight on all vehicle models NHTSA should concentrate on the approx 250 models that actually sell in any appreciable quantity . . . . It does not make sense to base regulations on designs that in practice Mfgs do not sell, and citizens do not buy.

* * * * *

We disagree with the decisions by NHTSA and EPA to in practice exclude Strong Hybrid, PHEV, and EV technology during this time frame. Prius Strong Hybrid technology is now about 15 years old, and has been adopted by many Mfgs. EV Tesla is selling commercially. PHEV Volt and EV Leaf have been firmly announced by major manufacturers. To assume that these technologies will not exist in the marketplace even by 2016 flies in the face of the evidence.

* * * * *

If Strong HEVs thus represent the rational choice of consumers, then agency CAFE requiring LESS than Strong HEVs do not represent rational regulatory choices.

Response

The vehicle fleet currently used as an input to the Volpe model, like that used as an input to similar analysis by the Environmental Protection Agency (EPA), is based on 2008 vehicle certification data as supplied by EPA. The use of 2008 certification data is a change in this rulemaking from the confidential business information used as an input to the Volpe model for the MY 2011 Final Rule. This change was made in response to comments on the previous rulemaking to enhance transparency in the agency's modeling analysis.

For this rulemaking, the baseline vehicle fleet developed by EPA in consultation with NHTSA is comprised of MY 2008 data. MY 2008 was used for the baseline vehicle fleet because it is the most recent model year for which full data are publicly available. Vehicle manufacturers have 90 days after their last vehicle is produced for a model year to submit CAFE data to EPA. For most manufacturers, this is 90 days after the end of the calendar year. For example, in calendar year 2008, MY 2009 vehicles were tested and certified by the EPA. These MY 2009 vehicles were then sold in the latter part (often Fall) of 2008 until the following Fall of 2009. In early 2010 (calendar year), manufacturers will submit their total sales of MY 2009 vehicles. After these sales figures are submitted, the sales are combined with the previously measured and reported fuel economies for individual models of vehicles with particular drive trains to calculate the sales-weighted average fleet fuel economy. The analysis for this present rulemaking was conducted in the 2009 calendar year. At that time the full sales figures for MY 2009 vehicles were not yet submitted. Even though the fuel economies (and some other specifications) of the MY 2009 vehicles were known because they were tested earlier, the exact sales were not yet known for each company. Therefore, because MY 2008 data were the most complete and transparent dataset available, the agencies chose to use that data as the baseline.

As the commenter noted, using the MY 2008 certification data can result in the agencies' analyses counting vehicles that are no longer in production and excluding vehicles that will be in production during the timeframe of this rulemaking. The MY 2008 baseline dataset will only include vehicles that were in production during that model year and, conversely, not include vehicles introduced to the marketplace in subsequent model years. As the commenter stated, this means vehicles such as recently announced pure electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) along with other manufacturer-announced forward models, are not included in the dataset as these vehicles are not in production and, therefore, have not been certified by EPA. Having the MY 2008 baseline exclude these *vehicles doesn't prevent advanced technologies from being considered in the reference fleet or the final rule. The reference fleet is the MY 2008 baseline modeled to meet 2011 CAFE. The Volpe model (and EPA's OMEGA model) adds technology to vehicles to have the vehicle fleet meet current or future standards. If advanced technologies are necessary for a manufacturer to meet the standard, the model will simulate having that technology on a vehicle. This allows the agencies to determine the cost of the rule for each manufacturer based on the most cost effective fleet. Manufacturers' introduction of technology for reasons other than meeting the standard (such as marketing, image, or to gain experience) is not considered since these actions would not be properly attributable to the rule. Also, the agencies include certain modeling constraints on the addition of various technologies (including strong hybrids) based on the need for sufficient lead time (and other technical reasons) to introduce these technologies throughout the fleet.*

Manufacturer announcements regarding forward models pose difficulty for use as model inputs. Manufacturers tend to limit production projections in these releases in order to protect product planning information and to better manage press coverage. In any event, commenters have not shown that the market for and sales of electric vehicles would be sufficiently large during the period covered by this rulemaking to change the analysis. There are substantial questions—including driving range, limited utility, cost and infrastructure—associated with these vehicles.

NHTSA has evaluated the use of public manufacturer forward model press information to update the vehicle fleet inputs to the agency's modeling analysis. The challenges in this approach are evidenced by the continuous stream of manufacturer press releases throughout a defined rulemaking period. Consistency in the vehicle inputs is necessary throughout the rulemaking process. Maintaining vehicle fleet consistency across both NHTSA and EPA lends to the harmonized approach for this rulemaking. With this in mind, continual modification to the vehicle fleet based on release of non-specific information on future models and, most likely not finalized, product press releases would lead to potential inconsistencies in not only the model analysis throughout the rulemaking period but also to a loss of synchronization across both agencies.

More information on and explanation of the reasons for the baseline fleet used in the agency's modeling analysis as part of this rulemaking are located in the Draft Joint Technical Support Document. Docket No. NHTSA-2009-0059-0029. See also 74 FR 49454, 49484-49490, 49646-49654; DEIS Section 2.2.1.2008

The commenter suggested excluding from the agency's analysis vehicles produced by manufacturers that historically choose to pay fines instead of meeting CAFE targets. However, excluding all of these manufacturers of vehicles manufactured for sale in the US market from the analysis could compromise NHTSA's statutory obligation to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). Manufacturers that have historically chosen to pay fines are a real part of the fleet and NHTSA properly considers the capabilities of the existing vehicle fleet in determining what levels of stringency would be the maximum feasible for the industry as a whole. In the analysis, manufacturers that traditionally pay fines are still subject to the increased standards.

Some commenters may misunderstand the agency's use of the Volpe model. The Volpe model is not used to set the stringency of the standards. The model is a tool that allows the agency to estimate what it would take to comply with, as well as the costs and benefits of, CAFE standards at various stringencies. One of the inputs required by the model is a forecast of the future vehicle market for each manufacturer, from which NHTSA projects a set of technologies each manufacturer could apply in attempting to comply with the various levels of potential CAFE standards to be examined. The model then estimates the costs associated with the additional technology utilization, as well as accompanying changes in travel demand, *fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors. Although NHTSA uses the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model does not determine the CAFE standards NHTSA will promulgate as final regulations. See Section 2.2.1 of this EIS. NHTSA considers the results of the analyses conducted using the Volpe model and external analyses, including assessments of greenhouse gases and air pollution emissions, and technologies that may be available in the long term. NHTSA also considers whether the standards could expedite the introduction of new technologies into the market, and the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information, the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues, such as safety, and promulgates the maximum feasible standards based on its judgment.*

10.2.3.3 Technology Assumptions

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

ROLL can reasonably be accommodated in any model year by bolting on more efficient rubber compounds, and thus should be assumed for all models all model years.

We believe AERO can be applied to all vehicles.

Re Intelligent Cooling of LT: Since these vehicles actually tow or carry loads less than 1 percent of the time (based on this reviewers' traffic surveys in the Seattle Area) electrified cooling WOULD actually be effective in trucks 99 percent of the time.

Response

The application rate of low rolling resistance tires is constrained by two factors: (1) the development efforts required for each tire specification a manufacturer affixes to a vehicle it sells, and (2) the vehicle type offered by the manufacturer. As discussed below, given these constraints, NHTSA does not believe that low rolling resistance tires can feasibly be applied fleet-wide in MY 2012.

A manufacturer typically offers more than one specification of tire per vehicle it sells to balance supplier capacity, geographic needs and consumer interests. For each tire specification offered, manufacturers must commit substantial resources in terms of materials, facilities and engineering efforts to meet vehicle handling, ride, and comfort requirements and to accommodate Anti-lock Braking Systems and Electronic Stability Control systems. This effort and expenditure is typically associated with re-design and refresh cycles to balance necessary costs, facilities, development time and engineering resources—it is not a simple matter for a manufacturer to apply low rolling resistance tires to a vehicle. In light of NHTSA's statutory requirement to take into account technical feasibility and economic practicability in setting CAFE standards, NHTSA continues to apply this technology at the redesign or refresh milestones.

NHTSA does not apply this technology to vehicles in the Large Truck class due to the increased traction and handling requirements for off-road and braking performance at payload and towing limits. Likewise, this technology is not applied to vehicles in the performance car categories due to increased traction requirements for braking and handling, which cannot be met with low rolling resistance designs. Low *rolling resistance tires can sometimes sacrifice traction for increased fuel efficiency. Manufacturers have confirmed that they do not equip these vehicles with low rolling resistance tires.*

For the most part, aerodynamic improvements can most practicably and feasibly be applied at the vehicle redesign milestone event, with some minor modification possible at the vehicle refresh milestone. In most cases, improvements to vehicle aerodynamics require modification of the vehicle's body stampings and other stylistic external vehicle components. These changes involve extensive and non-adaptable manufacturing tooling revisions for implementation. Manufacturing tooling for a vehicle program is primarily developed, purchased and amortized for the planned vehicle lifecycle by both vehicle manufacturers and suppliers. In addition, underbody trays, reduced grill openings and other aerodynamic improvement techniques result in system-wide effects to airflow and heat management properties requiring component and engineering development efforts to ensure proper vehicle operation and serviceability.

In recognition of these constraints, the Volpe model incorporates vehicle redesign and refresh mechanisms in an attempt to accurately reflect how aerodynamic improvements can be applied throughout the rulemaking period to the vehicle fleet used as an input to the Volpe model analysis. NHTSA believes the redesign and refresh milestones for the vehicle fleet are set appropriately for this technology during this rulemaking period. The agency also expects that further aerodynamic improvements will not be applicable to performance cars, considering the extent to which the aerodynamic characteristics of such vehicles have already been optimized to balance fuel consumption and high-speed handling.

In assessing the application of Intelligent Cooling to vehicle classifications, NHTSA consulted with a globally recognized engineering services firm. NHTSA concluded that Intelligent Cooling should not be applied to Large Trucks and SUVs based on the manufacturer development principle that vehicles are developed and tested to perform at their designed limits.

In the Large Truck and SUV segment, manufacturers develop vehicle capabilities such as towing and hauling. As NHTSA noted in the MY 2011 CAFE Final Rule, Large Vehicles with towing capacity present a challenge for intelligent cooling systems, as these vehicles have higher cooling fan loads in comparison to passenger cars. See 74 FR 14196, 14297. To ensure the Large Truck and SUV towing and hauling capabilities the consumer is purchasing, manufacturers need to make them fully available throughout the vehicle lifecycle regardless of actual customer usage. For these reasons, NHTSA is continuing to exclude Intelligent Cooling application from the Large Truck vehicle segment in the agency's analysis.

10.2.3.4 Economic Assumptions

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

5-year cutoff on payback period on the assumption that consumers only value a vehicle's MPG technology on the first five years - is not a rational assumption because consumers well know how hard it is to unload gas guzzlers . . . . Choosing this irrational 5-year cutoff assumption in turn represents a large reduction in "duration" effectively causing a much higher depreciation rate than the claim 3 percent societal discount rate.

Assuming a 5-year horizon for the consumer's valuation of MPG improvements is the same as assuming vehicle purchasers assume that they will sell their vehicles in 5 years and be able to receive no premeium on that sale for high MPG. But, on the contrary consumers are well aware and it has been well reported that higher MPG vehicles hold their resale value better than lower MPG vehicles—and that low MPG SUVs and trucks are hard to unload at all!

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

The proposal does not appear to give due consideration to the economic benefits of improved fuel economy at the consumer level. It is not reasonable to assume that the only effect of fuel-costs savings will be a rebound effect. The only economic benefit that appears to be considered in the impact analysis is a $0.17/gallon benefit from reducing oil imports. Unfortunately, this anticipated benefit is difficult to comprehend since the DEIS indicates that fuel consumption will increase significantly in the future whether or not the proposed CAFE standards are implemented.

Response

The CAFE model applies a "payback period," specified as an input to the model, for the purpose of choosing from among available technology applications (where each technology application involves the application of a specific technology to one or more specific vehicle models). In making such choices, the model assigns each option an "effective cost," calculated by considering (1) the hardware cost that would be incurred, (2) the amount by which civil penalties would be reduced, and (3) the amount by which the manufacturer estimates vehicle price can be raised based on the projected reduction in fuel consumption. In calculating the third of these components, the model applies the input value of the "payback period," specifying the number of years manufacturers estimate that first purchasers "count" in making their purchasing decisions, to the extent supportable by increased fuel prices.

For the current rule, NHTSA has applied a payback period of five years. While less than the average full useful life of a vehicle, this is considerably longer than the three year period some manufacturers have cited. NHTSA does not assume that consumers would necessarily sell their vehicles after five years (the average loan period). Rather, NHTSA uses the five-year estimate to simulate the period of time manufacturers assume that potential vehicle buyers typically value fuel economy improvements in making their purchasing decisions.

In contrast, when estimating the actual value of fuel savings to both individual buyers and to society as a whole, NHTSA assumes that fuel savings are valued over the full expected lifetimes of vehicles. In effect, this assumes that the initial purchaser and any subsequent purchasers save fuel over the lifetime of the vehicle. In analysis conducted outside the CAFE model, the agency further assumes that, on average across each manufacturer's fleet, the resale value of a more fuel-efficient model increases by 35 percent of the increase in its original purchase price that was attributable to its higher fuel economy, irrespective of whether manufacturers believe they can correspondingly increase prices charged to first purchasers. Thus, the agency assumes that purchasing a new vehicle with higher fuel economy does increase its resale by a significant fraction of the increase in its original purchase price.

Contrary to the commenter's assumption, NHTSA considers the primary benefit to consumers from increased fuel economy to be the value of the fuel saved by owners over the expected lifetimes of their vehicles. NHTSA includes as additional consumer benefits from higher fuel economy the value of increased driving range and reduction in the frequency of refueling, as well as the value of added mobility afforded by additional driving due to the fuel economy rebound effect. The value of fuel savings *accounts for by far the largest share of total consumer benefits. In addition to consumer benefits, NHTSA includes the value of various other benefits that will result from requiring passenger cars and light trucks to achieve higher fuel economy, but that will be realized by the economy as a whole rather than by vehicle buyers. These include reductions in environmental and energy security externalities that result from producing, distributing, and consuming a lower volume of fuel.*

10.2.3.4.1 Rebound Effect

Comments

Docket Number: 0051.1
Organization: Missouri Department of Natural Resources
Commenter: Dru Buntin

The DEIS attributes the majority of the reductions in pollution emissions to the actual production, transport, and refining operations for fuel. These findings are based on the emissions reductions, assuming a decrease in number of barrels of crude oil required to be processed into fuel, compared to the no action alternative. It is assumed by the report that the majority, if not all, emissions reductions attributable to cars and trucks getting better mileage per gallon will be balanced by more miles traveled in a process referred to as the "rebound effect". This study used an across the board value of 10% rebound effect in all studies. The theory behind the rebound effect is that vehicles with higher fuel mileage will be driven more than the older vehicles they replaced, thus increasing their vehicle miles traveled (VMT). This increase in VMT is theorized to increase the emissions from actual driving to nearly the same level as the no action alternative.

Although it is reasonable to assume that some people will drive more if their vehicles get better gas mileage, there is no evidence presented in the report showing that the average consumer automatically increases the amount they drive when they get more miles per gallon. Nor does the report fully explain why 10% is assumed to be the estimated increase. In addition, the report's assumption that this effect will result in no overall emissions reductions from the actual driving of vehicles appears to be extremely conservative in the estimation of emissions reductions resulting from higher CAFE standards.

Docket Number: 0052.1
Organization: United States Environmental Protection Agency[3]
Commenter: Susan Bromm

We do have one area of clarification regarding the “rebound effect” which we suggest for inclusion in the Final EIS. While Appendix C recommends a rebound effect of 10 to 20 percent, and other sections of the DEIS recommend using an effect of 5 to 15 percent, a rebound effect of 10 percent was utilized in the analysis. EPA recommends that the FEIS include a paragraph providing a clarifying synopsis of the methodology and values of the rebound effect used in the analysis.

[3] *Under Section 309 of the Clean Air Act, EPA is required to review and publicly comment on the environmental impacts of major federal actions including actions which are the subject of EISs. If EPA determines that the action is environmentally unsatisfactory, it is required by Section 309 to refer the matter to CEQ. This is done by the Office of Federal Activities.*

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

It must properly value fuel savings, we think, by removing the rebound effect from the consumer private welfare analysis and setting it at a lower level for the societal analysis.

Response

Missouri DNR suggests that incorporating the rebound effect into NHTSA's analysis increases the vehicle-miles traveled sufficiently to offset the effect of reductions in emissions that would be expected to result from higher fuel economy. However, the estimates of emissions per vehicle-mile used in NHTSA's analysis, which were derived from EPA's MOBILE6.2 and MOVES motor vehicle emission models, do not vary significantly in response to changes in fuel economy.

Thus the only effect of higher fuel economy on emissions of criteria air pollutants, non-CO_2 GHGs, and airborne toxics incorporated into NHTSA's analysis is the increase in vehicle emissions that results from added driving as a consequence of the rebound effect. This rebound-effect driving occurs in response to increases in fuel economy from its level under the No Action Alternative, and results in estimated emissions of criteria air pollutants, non-CO_2 GHGs, and airborne toxics from increased vehicle use under each action alternative.

The net effect of each action alternative on combined emissions from fuel production and vehicle use is thus the difference between (1) the reduction in emissions from fuel production that results from the decline in fuel use under that alternative, and (2) the increase in emissions that results from added driving due to the rebound effect from higher fuel economy. As the DEIS reported and described in detail, and as the FEIS also reports, component (1) of the net change in emissions typically outweighs component (2), so that this calculation results in net declines in emissions of most, but not all, criteria air pollutants, non-CO_2 GHGs, and airborne toxics.

The commenter also suggests that NHTSA has not cited evidence that vehicle use actually increases in response to increased fuel economy, and has not fully explained the basis for its rebound effect estimates. To derive an estimate of the rebound effect for use in assessing the fuel savings and other impacts of more stringent CAFE standards, NHTSA reviewed 22 studies of the effect of fuel economy on vehicle use. See PRIA Section VIII. As NHTSA's review indicated, 21 of these studies concluded that vehicle use increases in response to higher fuel economy. NHTSA then performed a detailed analysis of these studies' estimates of the extent to which it does so, by tabulating and analyzing variation among the 66 estimates of the long-run rebound effect reported in these studies. The 66 estimates range from as low as 7 percent to as high as 75 percent, with a mean value of 23 percent. Approximately two-thirds of all 66 estimates reviewed range from 10 to 30 percent, as do two-thirds of all published estimates, and two-thirds of authors' preferred estimates.

NHTSA also developed new estimates of the rebound effect using national data on passenger car and light truck travel over the period from 1950 through 2006. The agency estimated various econometric models of the relationship between vehicle miles-traveled and factors likely to influence it, including household income, fuel prices, vehicle fuel efficiency, road and highway capacity, the number of vehicles in use, vehicle prices, and other factors. The results of NHTSA's analysis are generally consistent with the findings from other recent research in two respects: (1) they show that the average long-run rebound effect ranged from 16 percent to 30 percent over the period from 1950 through 2007, and (2) they indicate that the magnitude of the rebound effect declined throughout this period. However, the agency estimates that the decline in the rebound effect over this period was considerably less rapid than reported *in other recent research, and that its magnitude in 2007 ranged from 8 percent to 14 percent, well above the estimates reported in some recent studies.*

Projected values of the rebound effect for the period from 2010 through 2030, which the agency developed using forecasts of personal income, fuel prices, and fuel efficiency from AEO 2009's Reference Case, range from 4 percent to 16 percent, depending on the specific model used to generate them. In light of these results, the agency believes that the apparent decline over time in the magnitude of the rebound effect justifies using a value for future analysis that is lower than historical estimates. Because the lifetimes of vehicles affected by the alternative CAFE standards considered in this rulemaking will extend from 2012 until nearly 2050, a value that is significantly lower than historical estimates appears to be appropriate. Thus NHTSA has elected to use a 10 percent rebound effect in its analysis of fuel savings and other benefits from higher CAFE standards for this NPRM.

In response to EPA's recommendation, NHTSA has added a paragraph to the FEIS explaining the agency's choice of a single estimate of the rebound effect and identifying the 10 percent figure as that estimate, as discussed above.

In response to the comment provided by Consumer Federation of America, NHTSA believes that it is important to incorporate the rebound effect in its consideration of potential consumer welfare impacts and the analysis of social benefits resulting from higher fuel economy. The rebound effect is important to recognize in the analysis of consumer welfare impacts because the resulting increase in vehicle travel provides additional benefits (i.e., additional opportunities to participate in activities outside the home) to purchasers of new vehicles beyond those resulting from lower fuel consumption. At the same time, it is important to incorporate the rebound effect into the analysis of social benefits from requiring higher fuel economy, because doing so recognizes the partial offset of fuel savings and resulting social benefits – including reductions in environmental and energy security externalities that result from lower fuel production, distribution, and consumption – that occurs as a consequence of increased rebound-effect driving.

10.2.3.4.2 Social Cost of Carbon

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

The US Government Agencies et al need to agree upon a SCC and a discount rate associated with the economics and morality of intergenerational costs. We suggest that consumers need to be polled on THEIR "economic valuation" of the possible premature deaths of their children or grandchildren due to global warming. . . . C02 reduction efforts in the US results in designs and technologies that Mfgs can and do apply worldwide, reducing C02 emissions and fuel prices worldwide. To assume zero correlation between US actions and results overseas is not rational. Measuring only US environmental damages caused by only US vehicle emissions does not form a rational measure of the damages because applying this measurement technique on a nation-by-nation basis worldwide would not form a total equal to the total world-wide damages caused by vehicles worldwide. . . . Instead EPA and NHTSA either need to calculate world-wide SCC of US Vehicle Emissions, or alternatively calculate US SCC based on global vehicle C02 emissions. . . . CAFE's effects on global warming cannot sensibly be analyzed in isolation, but rather only as part of a national and international program to reduce GHG emissions.

* * * * *

We do not believe NHTSA has reasonably resolved the issue of species extinction and ESA with the SCC assumption of $20/ton. On the contrary, finding ESA and the issue of species extinction inconvenient, NHTSA simply chooses to ignore these issues when setting SCC! We believe provisions of the ESA are most consistent with an intergenerational discount rate of 0 percent -- since ESA expects that species available to one generation ought to be available to future generations.

* * * * *

NHTSA asks for input on how to calculate SCC. We recommend the following procedure, by example. Use an Environmental Economics measure of the total value of a local environment (the total economic services provided by the local environment) divided by the total number of people in that local environment to form a "total value of the local environment per person" value. For example in the Puget Sound region Earth Economics estimates this value is about one million dollars per person. Then pick a reasonable estimate of the elapsed time until C02 levels corresponding to what scientists consider irreversible damage is reached, for example 50 years. Take the ratio of these two numbers to arrive at a linearized C02 environmental damage per year: $20,000 C02 damage per citizen per year. Divide this by the amount of C02 emissions per citizen: 12.6 tons per citizen in WA state or $1,587 SCC per ton C02 emitted. Average these calculations across all citizens of the US to find a US-wide average SCC based on Environmental Economics -- if identical to Puget Sound results in a SCC of $1,587 per ton.

* * * * *

DEIS does not describe how the EPA SCC of $40-$68/ton in 2011 suddenly became $20/ton in 2012, nor how the US with 24 percent of Global GDP somehow only receives 6 percent of global warming economic damage! . . . this appears to be a "pulling a rabbit out of a hat" value determined simply by take the ratio of US land mass to total World land mass = 6 percent. More than this needs to be done to derive a credible number. For example by comparison the US represents 24 percent of World GDP - implying that perhaps the US has 4X more to lose than the NHTSA 6 percent magic number.

* * * * *

The Tol meta analysis of SCC is not nearly a credible reference given that MANY of the SCC estimates used in the meta analysis come from Tol! A more reasoned meta analysis would only accept the most recent ONE estimate from each author - and NONE from the author of the meta analysis itself! Please completely discard the Tol meta analysis as a rational source of SCC estimates!

* * * * *

In general consumers with differing projections of the "true" future cost of SCC and fuel prices will make differing estimates of the utility of the purchase of a particular vehicle. Analysis that assumes one particular "US-wide" value of SCC or fuel costs will thus reach erroneous conclusions about vehicles Mfgs should be offering consumers . . . .

* * * * *

We believe CAFE needs to be responsive to SCC as set by future cap and trade regulation. It would be inappropriate, for example, if carbon is trading at $40 a ton but NHTSA has set an assumption of $20 a ton.

Response

Federal government agencies are working toward, but do not yet have, an agreed-upon estimate for the social cost of carbon (SCC) to support federal regulatory activities where reducing emissions of CO_2 is an important potential outcome. Nevertheless, NHTSA is obligated under EPCA to issue a CAFE rule regardless of whether there is a uniform federal government view on the SCC. For the analysis in the FEIS, the agency modeled a primary SCC value of $56, and conducted a sensitivity analysis using $10 (see Sections 2.2.4 footnote 9 and 2.4 of this FEIS). However, this is not necessarily the estimate of the SCC that the agency will ultimately select for valuing reductions in CO_2 emissions in the final rule. The FEIS uses a high SCC in the Volpe model so that the stringency of the CAFE standards for the MNB Alternative and the TCTB Alternative are higher than they would be for a lower valuation of SCC. This results in higher fuel savings and greater changes in environmental impacts for these alternatives than would result from using a lower SCC value in the model. The intent of this is to demonstrate the maximum differences in environmental impacts between the alternatives. The environmental impacts of the action alternatives other than the MNB Alternative and the TCTB Alternative are not significantly affected by the valuation of social cost of carbon in the model, as shown in Table 2.4-1.

With regard to the comment that CAFE should be responsive to SCC as set by future cap and trade regulations, NHTSA does not believe it is appropriate to speculate on a market clearing price of carbon in a nationwide trading system. In addition, the market price for CO_2 emission permits would reflect the number of such permits that have been made available and the costs of achieving further reductions in CO_2 emissions, rather than the economic benefits from doing so. Thus the permit price would not necessarily provide reliable guidance about the economic benefits from increasing fuel economy, or for establishing the stringency of CAFE standards.

10.2.3.4.3 Military Costs

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We ask that NHTSA become more honest in their analysis of the role of oil in US involvement in Middle East Wars. . . . If the US didn't import any oil then the Middle East would not be of Strategic Importance. We suggest then that military costs have to be apportioned according to percent of oil imports; it cannot be independent of oil consumption as assumed by NHTSA. . . . Assumed 0 percent military cost assignment to maintaining the security of Middle East oil supplies is not reasonable.

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We suggest military spending be modeled as linearly proportional to oil imports. Thus a portion of Middle East military activities should properly be apportioned to the cost of oil imports - we suggest that 50 percent of military costs in the Middle East.

We believe that the cost of Middle East War can be more appropriately assigned than NHTSA current 0 percent similar to the following: $920,000,000,000 Cost of Iraq and Afghanistan Wars the last eight years, or $ 115,000,000,000 a year. 6,736,961,000 Barrels of Refined Petroleum a year equals 208,845,791,000 gallons, or an apportionment of $0.55 war costs per gallon. If we assign 50 percent to the "strategic oil value" and the other 50 percent) to the terrorist aspects, then we find $0,275 a gallon of gasoline should be added for military costs. . . . When monosopy costs are passed on to nations that represent military and terrorist threats to the US, how can it be that NHTSA assumes such monetary transfers are "neutral" to US interests??? This is not rational.

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

On the national security front, we believe the agency must assign a significant national security value to the benefit of reducing oil consumption. You don't have to look far to find politicians telling us how important our national security reducing our dependence on imported oil is. The fact that the governing statute, the most recently enacted amendments to the governing statute, had the title the Energy Independence and Security Act, should have alerted NHTSA to the fact that Congress considers the military and strategic value of oil to be important. In the floor statement, the manager of the bill, Mr. Markey, went to great lengths pointing out all of the military types who had helped finally get this improvement in increase in the CAFE level enacted. There's a substantial public policy in academic literature that believes oil has a military value. NHTSA has to stop putting a zero on the military value of reduced oil consumption.

Response

One possible component of the external economic costs of importing oil into the United States includes government outlays for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world. In the NPRM, NHTSA tentatively concluded that:

> *"NHTSA's analysis does not include savings in budgetary outlays to support U.S. military activities among the benefits of higher fuel economy and the resulting fuel savings… This view concurs with that of the recent ORNL study of economic costs from U.S. oil imports, which concludes that savings in government outlays for these purposes are unlikely to result from reductions in consumption of petroleum products and oil imports on the scale of those resulting from higher CAFE standards." See 74 FR 49674.*

NHTSA disagrees with the two commenters who took issue with this tentative conclusion and recommended that NHTSA assign a value to the reduction in military spending or other costs related to energy security that are likely to result from lower U.S. petroleum imports. NHTSA believes that there is no specific and measurable relationship that can be derived from the current literature, among higher CAFE standards, U.S. petroleum imports, and energy security costs.

Although it is conceivable that by reducing fuel consumption and U.S. petroleum imports from the Persian Gulf region, higher CAFE standards might reduce military and political risks in the Persian Gulf, the agency does not believe there is convincing evidence that this would reduce U.S. military expenditures. No commenter has presented any convincing evidence that this would occur, nor do any of the references commenters included provide such evidence. There is no support for the commenter's suggestion that military spending be modeled as proportional to oil imports.

Although one recent economic analysis cited by commenters estimates the value of U.S. military spending attributable to securing oil imports from the Persian Gulf region, this study does not *estimate the extent to which U.S. military spending is likely to vary in response to changes in U.S. imports of Persian Gulf oil. Thus, the reported values are clearly intended as estimates of the total and average per-gallon costs of U.S. military activities in the Persian Gulf that might reasonably be related to petroleum consumption by U.S. motor vehicles, and not as estimates of the extent to which those costs might be reduced as a consequence of lower fuel consumption by U.S. motor vehicles.*

We also note that any reduction in U.S. military spending would require a specific decision of the Administration and act of Congress and would not necessarily result simply from lower U.S. oil imports.

10.2.3.4.4 Fuel Prices

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We believe it is not rational to estimate future fuel prices 2012-2016 lower than current at the pump fuel prices.

Response

We disagree that current pump prices can be used to derive a more accurate forecast than the most recent federal government forecast for future gasoline prices. Pump prices for gasoline have been volatile in the past several years. The agency calculated and analyzed mpg standards and environmental impacts associated with each alternative under both the "Reference Case" for key model inputs, which uses the U.S. Energy Information Administration's (EIA's) Reference Case fuel price forecast, a domestic social cost of carbon, and a 7-percent discount rate; and under a "High Scenario" set of input assumptions, which uses the EIA "High Case" for fuel price forecast, a global social cost of carbon, and a 3-percent discount rate. This FEIS also analyzes the impacts of various other combinations of economic assumptions inputs.

In the DEIS, NHTSA relied on the EIA Annual Energy Outlook 2009 (AEO 2009) forecasts for the estimate of fuel price during the period covered by the agency's action (EIA 2009). In the analyses reported in the FEIS, NHTSA utilizes the recently updated forecast of future fuel prices presented in the EIA Annual Energy Outlook 2010 Early Release. The agency notes that the forecast of retail fuel prices for 2012-2016 presented in AEO 2010 averages slightly under $3.00 per gallon (in today's dollars). Federal government agencies generally use the EIA projections in their assessment of energy-related policies. In the DEIS and NPRM, the agency selected the EIA Reference Case fuel price forecast in performing the analysis. AEO 2009 also included "High Price Cases" and "Low Price Cases," which reflected uncertainties regarding future levels of oil production and alternative strategic responses to market conditions by petroleum suppliers. The commenter has not provided adequate grounds for NHTSA to depart from its use of the EIA forecast.

10.2.3.4.5 Consumer Demand

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We believe NHTSA continues to misunderstand the oil shock 1973: It was high gas prices, NOT CAFE which lead consumers to downsize their choice of vehicles. Higher CAFE standards allow the consumer to be able to afford to buy a larger more safe vehicle than in the absence of CAFE. Consumer preference in vehicles HAS changed as indicated by Mfgs advertising MPG NOT HP in their TV ads. That offered MPG is not what consumers desire can be implied by the universal Mfg practice of touting HWY MPG

NOT "Combined" MPG in their TV ads. . . . Assuming one set of beliefs or valuation of MPG among US citizens is false.

* * * * *

We believe the fundamental lack of understanding is that 15 percent of consumers (according to the Yale study) STRONGLY want higher fuel efficiency vehicles as a primary attribute of vehicle choice and that two thirds of consumers think that SOMETHING needs to be done about global warming. . . .

Fixed assumptions of depreciation for all vehicles (1/3 residual value after 5 years) are belied by looking up any source of resale values: High Fuel Efficiency Vehicles maintain their value much better than NHTSA is assuming.

* * * * *

Price pass-through to consumers: the huge price premiums being charged in practice to purchasers of strong hybrids belies NHTSA assumptions that consumers are unwilling to pay for fuel efficiency.

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

Our surveys show that consumers were out ahead of the auto makers in wanting more fuel efficient cars. We did a survey in which we asked people, "How much mileage do you want to get in your next car?" And they said, "We want to get 30 miles per gallon." Only two percent of the models in the showrooms get 30 miles per gallon or more.

So as we go forward, we have to recognize that there was a massive market failure here, and the auto makers are at least as much to blame as the consumers were. Either way, there is a sound basis for doing the math, for calculating the benefits, and setting the standards at a high level.

* * * * *

We believe the analysis must recognize the higher resale value of more fuel efficient vehicles.

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The agencies must recognize the willingness of consumers to change their demand for vehicles. We've had a dramatic demonstration of that in the past five years.

Response

The agency recognizes that increased fuel efficiency may result in increased residual value (resale amount) at the end of an ownership period. The NPRM for MYs 2012-2016 discussed this concept with regard to resultant price impacts due to technology application. The agency notes, however, that fuel efficiency is but one factor relevant to the determination of vehicle residual values. Additional factors that affect residual value include records of safety and durability, vehicle brand, and vehicle type. A fleet-wide residual value was taken into account in this rulemaking with the premise that the fuel efficiency of all vehicles will increase over the timeframe of this rule and that residual values will increase proportionally. The attribute-based stringency levels in the proposed rule are intended to retain a degree *of consumer choice. At the same time, the agency recognizes that the year-over-year stringency increases may also result in increases to vehicle residual value.*

In response to the comment regarding consumer demand for high fuel efficiency vehicles, the agency agrees that consumers value increased fuel economy. Vehicles with increased fuel economy are less costly to run. Without knowing the context or details of the survey cited by the commenter, the agency cannot opine on its findings. However, as described, the survey does not appear to take into account factors other than fuel economy that impact consumer demand for vehicles, such as vehicle type (e.g., passenger cars for small families, mini-vans for large families, pickup trucks for load-carrying). The agency does not believe that all consumers would make identical trade-offs between increased fuel economy and all other vehicle attributes.

In mandating that NHTSA set CAFE standards, Congress specifically directed that the agency set standards based on vehicle attributes, thereby recognizing that manufacturers have a mix of products to meet varying consumer demand. Pursuant to statute, NHTSA cannot mandate a single fuel economy for all vehicles; rather CAFE standards represent a fleet-wide average.

10.2.3.4.6 Consumer Welfare

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

If you look at the economic analysis, the societal benefit, the total societal benefit is made up primarily of the consumer welfare benefit. It accounts for about two-thirds of the net present value. The agencies must adopt and affirm an analytic framework that recognizes fuel economy standards and enhances consumer welfare. The billions of dollars of consumer welfare gains estimated in the economic analysis are substantial and real. The final rule must not only assert that the empirical estimates are gains for consumers, it should also conclude that there is a theoretical justification for incorporating those consumer welfare gains.

In the proposed rule the agencies identify an argument which says that consumers buy the cars they want and the government can't possibly improve on that outcome. Now, there are some people who believe that. There is no support for that in the academic or empirical literature. The agency also recognizes the argument that consumers because of their behavioral patterns, their motivations, their perceptions, their calculations, may not have perfect information, perfect foresight, the ability to calculate the life cycle cost of the automobile. And they identify that as a possible basis for concluding that a standard might help consumers get better products, that if they were smart enough they would be able to figure out they really need it.

Ironically, there is no discussion of the frailties of the auto industry. Automakers are people, too. They have the same problems of motivation, perception, and calculation. They make mistakes. We actually own two of them in the United States because they made mistakes. And there's solid evidence that it was management mistakes that contributed to the demise of the industry.

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

Two arguments are often used in criticizing tighter CAFE standards. Some argue that the costs are too high, while others believe that they will make vehicles less safe. The standards will cost up to $1,300 per vehicle by 2016 but would save the average driver $3,000 in fuel costs over the life of the vehicle. Future increases in fuel prices will mean even greater savings at the pump. After a five-year vehicle loan is paid off, the additional fuel savings from a more efficient vehicle will continue to benefit vehicle owners.

Response

NHTSA considers the potential effects of this rulemaking on consumer welfare as one part of the agency's evaluation of the costs and benefits of its proposal. From the societal perspective, the economic benefits and costs of establishing higher CAFE standards include not only private benefits and costs, but also changes in the value of environmental and economic externalities that result from fuel consumption and vehicle use. These include the reduction in potential climate-related economic damages resulting from lower CO_2 *emissions, reduced damages to human health from lower emissions of criteria air pollutants, reductions in economic externalities associated with U.S. petroleum imports, and increases in traffic congestion, vehicle noise, and accidents caused by the increased driving that results from the fuel economy rebound effect.*

A complete analysis of the potential effects of this rulemaking on consumer welfare will be published along with the forthcoming joint NHTSA-EPA Final Rule. For additional discussion of NHTSA's consideration of consumer welfare, see section IV.G of the PRIA.

10.2.3.4.7 Discount Rate

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

It is not clear if the same discount rate that is applied to future benefits is applied to future costs in the proposal. For example, several tables (e.g. Tables IV.G.4-10 through IV.G.4-14) present various cost and benefit values. The titles of these tables imply that a discount rate is applied equally to costs and benefits. However, the NPRM defines the discount rate as follows: 'The Reference Case uses a discount rate of 3 percent to discount future benefits." Although the sensitivity analyses in the DEIS and NPRM indicate that the only economic factors of importance are industry compliance costs, the cost of fuel, and the magnitude of the rebound effect, the DEIS and NPRM should more clearly define how discount rates are applied to both costs and benefits. As noted in our comments to NHTSA dated September 8, 2008, discount rates should be applied to both benefits and costs.

Response

One of the most complex issues in estimating benefits associated with the mitigation of climate change involves selecting the appropriate discount rate. Discounting future benefits and costs is intended to account for the reduction in their value to society when they are deferred until some future date, rather than received immediately. The discount rate expresses the percent decline in the value of these benefits – as viewed from today's perspective – for each year they are deferred into the future. In evaluating the non-climate-related benefits of the proposed standards, NHTSA has employed discount rates of both 3 percent and 7 percent as guided by the Office of Management and Budget. See 74 FR 49454, 49506; PRIA § VIII. NHTSA agrees that the discount rate should be applied to all benefits and costs that occur in the future. The discount rate, as applied to technology costs, the cost of fuel, and the magnitude of the rebound effect is described below.

NHTSA treats technology costs as occurring in the present, which is the model year in which future vehicles will be produced and sold. Thus, technology costs are not discounted in the proposal.

Additionally, NHTSA defines future savings in fuel costs as benefits, thereby discounting them as the commenter recommends. Future costs resulting from increased rebound-effect driving (including increased costs of congestion, accidents, and noise) are treated as 'dis-benefits' (i.e., negative benefits which are subtracted from positive benefits such as fuel savings). These future costs are also discounted as the commenter recommends. For additional details on the application of discount rates in the proposal, NHTSA refers readers to Section VIII of the PRIA.

10.2.4 Alternatives

Note to Reader

Where there is a federal action requiring an EIS, NEPA requires an agency to develop "alternatives to the proposed action." 42 U.S.C. § 4332(2)(C)(iii). CEQ regulations state that consideration of alternatives is the "heart" of an EIS. 40 CFR § 1502.14. However, under CEQ regulations and applicable case law, NHTSA is not required to include every conceivable "alternative" in an EIS, nor necessarily other hypothetical "alternatives" submitted by commenters. Rather, an agency is to consider "reasonable" alternatives. The purpose of and need for the action determines the range of reasonable alternatives under NEPA. NHTSA believes its analysis of alternatives satisfies NEPA.

The CEQ regulations state that the alternatives "should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public." 40 CFR § 1502.14. CEQ guidance also instructs that "[w]hen there are potentially a very large number of alternatives, only a reasonable number of examples, covering the full spectrum of alternatives, must be analyzed and compared in the EIS." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (Mar. 23, 1981). The CEQ regulations for EISs further provide that the alternatives section must:

- *(a) Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.*
- *(b) Devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits.*
- *(c) Include reasonable alternatives not within the jurisdiction of the lead agency.*
- *(d) Include the alternative of no action.*
- *(e) Identify the agency's preferred alternative or alternatives, if one or more exists, in the draft statement and identify such alternative in the final statement unless another law prohibits the expression of such a preference.*
- *(f) Include appropriate mitigation measures not already included in the proposed action or alternatives.*

40 CFR § 1502.14.

Agencies are required to examine reasonable alternatives, and not those that are a "worst case scenario." Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 354-55 (1989). An agency is not required to consider alternatives "whose effect cannot be reasonably ascertained, and whose *implementation is deemed remote and speculative." Headwaters, Inc. v. Bureau of Land Mgmt., Medford Dist, 914 F.2d 1174, 1180 (9th Cir. 1990) (quoting Life of the Land v. Brinegar, 485 F.2d 460 (9th Cir. 1973), cert. denied, 416 U.S. 961 (1974)). An agency is also not required to consider alternatives that are "infeasible, ineffective, or inconsistent with the basic policy objectives" of the proposal. Id. (citing California v. Block, 690 F.2d 753, 767 (9th Cir. 1982)).*

CEQ guidance on this point is similar. "Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (Mar. 23, 1981) (emphasis added).

The "rule of reason" also guides the choice of alternatives and the extent to which the EIS must discuss each alternative. See, e.g., City of Carmel-by-the-Sea v. U.S. Dep't of Transp., 123 F.3d 1142, 1155 (9th Cir. 1997). See also American Rivers v. FERC, 201 F.3d 1186, 1200 (9th Cir. 2000) (same, quoting City of Carmel-by-the-Sea, 123 F.3d at 1155). Under the rule of reason, an agency "need not consider an infinite range of alternatives, only reasonable or feasible ones." Id. (citing 40 CFR § 1502.14(a)-(c), as set forth above). "[F]or alternatives which were eliminated from detailed study, [an EIS must] briefly discuss the reasons for their having been eliminated." American Rivers v. FERC, 201 F.3d at 1200 (citing 40 CFR § 1502.14(a)) (emphasis in original).

With this understanding, and as explained in the NPRM and the DEIS, EPCA requires the Secretary of Transportation to establish average fuel economy standards for each model year at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." When setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." NHTSA has always taken passenger safety into account in adopting CAFE standards. NHTSA has also considered environmental issues and other relevant societal issues, such as safety. "Congress did not prescribe a precise formula by which NHTSA should determine the maximally-feasible fuel economy standard, but instead gave it broad guidelines within which to exercise its discretion." Competitive Enterprise. Inst. v. NHTSA, 901 F.2d 107, 121 (D.C. Cir. 1990) (citing Public Citizen v. NHTSA, 848 F.2d 256, 265 (D.C. Cir. 1988)). See also Ctr. for Auto Safety v. NHTSA, 793 F.2d 1322, 1340 (D.C. Cir. 1986) (same). Thus, EPCA does not require the agency to establish fuel-economy standards at any chosen level, but instead confers on NHTSA broad discretion to balance these factors when setting an appropriate standard.

This FEIS informs decisionmakers and the public of the reasonable alternatives and the environmental impacts associated with each alternative. Consistent with EPCA's overall purpose – energy conservation – NHTSA sought to balance the EPCA statutory factors when articulating its Preferred Alternative in the DEIS. After careful consideration of all comments, NHTSA concludes that Alternative 4 remains the agency's Preferred Alternative. Alternative 4 represents the required fuel economy level that NHTSA has determined to be the "maximum feasible" under EPCA, based on balancing statutory and other relevant considerations.

With this understanding of the applicable standards for NEPA alternatives in the context of this rulemaking under EPCA, NHTSA turns now to the comments the agency received regarding specific alternatives. The comments fell into several subcategories, which are set forth below along with NHTSA's response.

10.2.4.1 Environmentally Preferred Alternative

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

The DEIS fails to identify the "environmentally preferred alternative."

Response

The agency's preferred alternative was identified in the DEIS, in accordance with NEPA requirements. However, different requirements apply to the alternative that is considered to be environmentally preferable. The CEQ Regulations require that the alternative that is considered to be environmentally preferable be identified in the Record of Decision (ROD) for the agency action, not in the DEIS or FEIS. See 40 CFR § 1505.2. In accordance with 40 CFR § 1505.2(b) NHTSA will identify and discuss the alternative that is considered to be environmentally preferable in the ROD, which will be issued a minimum of 30 days after release of the FEIS. See 40 CFR § 1506.10(b).

10.2.4.2 No Action Alternative

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The No Action alternative presumes no federal action to raise fuel economy, not even actions necessary to achieve the 35 mpg standards mandated in the EISA. NHTSA claims that this is a requirement from CEQ. However, NHTSA cannot presume away implementation of California's (Pavley) standards that apply to greenhouse gas emissions from motor vehicles sold in California, representing approximately 40% of the U.S. new vehicle market. In addition, California has been granted the federal Clean Air Act waiver to implement the greenhouse gas standards; California and 16 other states are expected to implement these standards. The No Action scenario should have accounted for this.

Docket Number: TRANS01
Organization: Sierra Club
Commenter: Ann Mensikoff

NHTSA's no action scenario fails to account for California's implementation of its standards . . . . 40 percent of the market covered by those standards, a no action scenario which may be required by CEQ and should assume no national governmental action, that CAFE will not be implemented, that an energy bill will not be implemented, that NHTSA would do nothing, it cannot ignore the action that the agency cannot control . And I think in that case it's a failure to account for California's implementation and 40 percent of the vehicle market being covered by those standards that would affect how the different scenarios measure up and compare to each other in the DEIS. And I think it skews the analysis and should be reconciled in the final DEIS.

Docket Number: TRANS02
Organization: Public Citizen
Commenter: Lena Pons

Again, NHTSA has sensibly identified the problem that you cannot regulate greenhouse gas emissions for motor vehicles by regulating fuel economy alone. But the agency does not consider actions outside the jurisdiction as required by NEPA. These actions that have not been considered include continued regulation of greenhouse gases by California and the states and policies to reduce vehicle miles traveled. It is reasonably foreseeable that California will continue to extend regulations for greenhouse gas emissions for motor vehicles and intend to do so beyond 2017. NHTSA makes no attempt to consider the impacts of these standards for a substantial share of the U.S. light duty vehicle market.

Docket Number: TRANS01
Organization: Sierra Club
Commenter: Ann Mensikoff

NHTSA cannot ignore again California's implementation of its standards in its no action scenario.

Response

NEPA provides that, where a federal action requires an EIS, an agency must develop "alternatives to the proposed action." 42 U.S.C. § 4332(2)(C)(iii). Pursuant to CEQ regulations, the alternatives must be compared against a "no action" alternative. 40 CFR § 1502.14. CEQ guidance instructs that where the agency's choice of no action "would result in predictable actions by others, this consequence of the 'no action' alternative should be included in the analysis." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations ("Forty Questions"), 46 FR 18026, 18027 (Mar. 23, 1981). For example, "if denial of a permission to build a railroad to a facility would lead to construction of a road and increased truck traffic, the EIS should analyze this consequence of the 'no action' alternative." Id.

NHTSA's No Action Alternative (Alternative 1) assumes no action would occur under the National Program. Under that alternative, neither NHTSA nor EPA would issue a rule regarding the CAFE standard or GHG emissions for MYs 2012-2016. The No Action Alternative assumes that average fuel economy levels in the absence of CAFE standards beyond MY 2011 would equal the higher of the agencies' collective market forecast or the manufacturer's required level of average fuel economy for MY 2011.

Several commenters suggested that NHTSA's No Action Alternative should account for implementation of motor vehicle GHG standards by California and other states, which would directly affect the fuel economy of new passenger cars and light trucks sold in those states. Pursuant to the Clean Air Act (CAA), 42 U.S.C. § 7401 et seq., federal emission standards set by EPA generally preempt state and local government emission standards for new motor vehicles. California, however, may be granted a waiver to set emission standards under certain circumstances. See 42 U.S.C. § 7543; CAA § 209. In addition, pursuant to section 177 of the CAA, any other state may adopt a plan for regulating vehicle emissions if its plan is identical to one for which California was granted a waiver. See 42 U.S.C. § 7507.

On June 30, 2009, EPA granted a waiver to California, allowing the State to set GHG standards for motor vehicles starting with MY 2009. 74 FR 32744 (Jul. 8, 2009).[4] California has adopted regulations implementing such standards,[5] and, in addition, 13 other states and the District of Columbia have adopted California's standards pursuant to section 177 of the CAA.[6]

If NHTSA were not to implement CAFE standards for MYs 2012-2016,[7] it is likely that California, as well as those jurisdictions that have adopted the California standards, would enforce California state motor vehicle GHG standards pursuant to section 177 of the CAA (42 U.S.C. § 7507).[8] Assuming that most or all of these state regulations would be effective for MY 2012 vehicles,[9] one conceivable result of states enforcing California motor vehicle GHG standards in the absence of new CAFE standards is that the average fuel economy of new passenger cars and light trucks produced and sold in the United States would rise. However, while action by California and other states is likely in the absence of action by NHTSA, numerous factors (further detailed below), make the actual impact of such action – and therefore the impact of such action on the baseline analyzed by NHTSA – especially uncertain. In particular, the range of potential actions by numerous state actors, taken together with the complex economic and political considerations that may influence the automobile market in the absence of new CAFE standards, injects uncertainty into the determination of a modified No Action Alternative.

A no action alternative must take into account predictable actions of others. Forty Questions, 46 FR at 18027. At the same time, however, CEQ guidance indicates that the purpose of including a no action alternative in the EIS is to provide "a benchmark, enabling decisionmakers to compare the magnitude of environmental effects of the action alternatives." Id. As one court noted regarding the no action

[4] EPA's decision granting the California Air Resources Board's (CARB's) request for a waiver noted that CARB could "fully implement and enforce its regulations . . . for 2009 model year families issued both before and after the date of today's waiver . . . ." 74 FR at 32778.

[5] See 13 Cal. Code Regs. 1961.1.

[6] New York (6 N.Y. Code, R. & Regs., 218-8.3); Massachusetts (310 Code of Mass. Regs. 7.40(2)(a)(6)); Maryland (Code of Md. Regs. § 26.11.34); Vermont (Vt. Air Poll. Ctrl. Regs., subch. XI, 5-1106(a)(5)); Maine (06 Code of Maine Rules § 127); Connecticut (Conn. Admin. Code § 22a-174-36b); Arizona (Ariz. Admin. Code 18-2-1802); New Jersey (N.J. Admin. Code § 7:27); New Mexico (N.M. Admin. Code § 20-2-88); Oregon (Or. Admin. Rules § 340-257); Pennsylvania (36 Pa.B. 7424); Rhode Island (R.I. Air Poll. Ctrl. Reg. 37.2.3); Washington (Wash. Admin. Code § 173-423-090(2)); and Washington, D.C. (D.C. Law 17-0151). In addition, several other states appear to have completed steps necessary for the adoption of standards, including Florida and Colorado.

[7] Although EISA's recent amendments to EPCA direct NHTSA to increase CAFE standards and do not permit the agency to take no action on fuel economy, CEQ regulations mandate analysis of a no action alternative. See 40 CFR § 1502.14(d). CEQ has explained that: "[T]he regulations require the analysis of the no action alternative even if the agency is under a court order or legislative command to act." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026 (1981) (emphasis added).

[8] In a May 18, 2009 letter to EPA Administrator Lisa P. Jackson and Secretary of Transportation Ray LaHood, Mary D. Nichols, Chairman of the California Air Resources Board, stated that California committed "to revise its standards on GHG emissions from new motor vehicles for MY 2012 through 2016, such that compliance with the GHG emissions standards adopted by EPA shall be deemed compliance with the California GHG emissions standards. . . ." California's commitment contemplated that a number of actions would occur, including that EPA would propose and adopt national GHG standards "substantially as described in the May, 2009 Joint Notice of Intent to conduct rulemaking."

[9] State regulations implementing the California standards appear to have varying enforcement dates. While California and a number of states' regulations become effective for MY 2012 vehicles, other states begin to enforce the standards in 2011 or 2012. See e.g., N.M. Admin. Code 20-2-88; Code of Md. Regs. § 26.11.34; Ariz. Admin. Code 18-2-1802.

alternative, "the [CEQ] intended that agencies compare the potential impacts of the proposed major federal action to the known impacts of maintaining the status quo." Custer County Action Assoc. v. Garvey*, 256 F.3d 1024, 1040 (10th Cir. 2001) (citing* Ass'n of Pub. Agency Customers v. Bonneville Power Admin.*, 126 F.3d 1158, 1188 (9th Cir. 1997), and 46* FR *18,026, 18,027 (1981)). As explained below, NHTSA believes the No Action Alternative as described in the DEIS effectively serves its purpose as a benchmarking and comparison tool for the decisionmaker.*

In the absence of federal action, it is unclear how manufacturers would react to the two sets of standards that applied in different states – the California standard in California and in other states adopting the California standard, and no CAFE standard in all other states.[10] *For example, in the absence of federal action, rather than marketing different vehicle fleets in states that adopted the California standard and those that did not, some manufacturers might opt to produce and sell vehicles that met a uniform California standard nationwide. Alternately, in the current economic climate, it is plausible that a number of manufacturers might simply shift the availability and sale of more fuel-efficient existing models to those states that had adopted the California standards, while selling vehicles with lower fuel economy elsewhere. Manufacturers' product decisions in this regard are likely to depend in part on the number of states that adopt California standards and the timeline over which they are adopted.*

Hypothetically, the No Action Alternative could be affected in the following ways. If manufacturers complied with the California standard by shifting distribution networks to sell only higher mpg vehicles in those states that adopted and were enforcing California GHG emissions standards and to sell lower mpg vehicles in states that were not enforcing California GHG emissions standards, the agency's No Action Alternative would not change at all, because with this seemingly least-cost compliance strategy, the average fuel economy of these manufacturers' fleets would not change. At the other extreme, if manufacturers modified their fleets to meet California standards on average, the No Action Alternative would result in the same emissions reductions as the agency's Preferred Alternative. A manufacturer might choose this latter course of action to maximize flexibility in the distribution of vehicles across the country while simultaneously ensuring that it met GHG emissions limits in the states that were enforcing California's GHG emission standards. Different manufacturers might choose different strategies or combinations of strategies.

NHTSA believes that the likely reaction across all vehicle manufacturers would fall somewhere in between these two boundaries but cannot ascertain with any reasonable confidence the combination of shifts in vehicle distribution patterns and application of fuel-economy-increasing technologies that would occur. Due to these uncertainties, determining an appropriate and reasonable way to adjust the agency's No Action Alternative is problematic at best.

The broad geographical impacts of this action, as well as the numerous potential actors involved, make it distinguishable from most actions requiring the issuance of an EIS. Indeed, cases in which the No Action Alternative has been examined with regard to actions by others have generally been limited to those in

[10] *If NHTSA failed to take action to set CAFE standards for a given model year, no CAFE standard would apply for that model year.*

which an agency's action will be confined to a specific, identifiable locale and the actions expected by others in the absence of a federal agency's action are relatively certain.[11]

Aside from the uncertainty in determining the baseline for a modified No Action Alternative, as a practical matter, the agency does not understand how such a modification would change the decisionmaker's task. One commenter suggests that consideration of the California standards would affect how the alternatives "measure up and compare to each other in the DEIS" and that failure to consider them "skews the analysis." We believe that the practicable effect of taking the California standards into account would be to decrease the measured difference in environmental impacts between the No Action Alternative and the other alternatives under consideration. While the effects of the action alternatives would be measured from a different reference point, the difference between the action alternatives would not change. Thus, the fact that states might act in the absence of Federal action does not change the calculus before the federal decisionmaker in setting CAFE standards.

In NHTSA's view, given the uncertainty of determining the effect of state GHG standards on overall emissions in the absence of federal action, a modified No Action Alternative is not required here under CEQ guidance and applicable law. Because the effects of the action alternatives would simply be measured from a different, if possibly higher, reference point, such a modified No Action Alternative would not aid the decisionmaker or the public in understanding the relative environmental impacts of the alternatives.

10.2.4.3 Suggestions for New Alternatives

Comments

Docket Number: 0050.1
Organization: Environmental Consultants of Michigan
Commenter:

Low Carbon Fuel Standards are an emerging greenhouse gas control strategy employed around the world. Using the most recent GHG lifecycle models published by the Department of Energy's Argonne National Lab. Converting 100% of the ENTIRE ON ROAD FLEET of motor vehicles (not just new motor vehicles) to achieve over 100 mpg would be insufficient to achieve an 80% reduction in sector GHGs. On the other hand, changing less than half of the fuel to a second generation Fischer-Tropsch (or Mobil Process) gasoline and/or diesel would achieve this substantial reduction without changing the on road fleet. Thus Low Carbon Fuel Standards are:

1. Inevitable
2. Necessary to achieve any meaningful reduction in GHG emissions
3. Not in conflict with common law, the Fifth Amendment or the decision in Massachusetts vs. EPA

Given the refinery industry investment in hydrocarbon based fuels, it is reasonable to assume that if a National Low Carbon Fuel Standard is implemented, the industry will find ways to produce renewable

[11] *See, e.g., Nashvillians Against I-440 v. Lewis, 524 F.Supp. 962, 988-89 (M.D. Tenn, 1981) (upholding agency's determination that "no action" alternative should include anticipated improvements to a city's surface streets in the absence of building the proposed highway); Ctr. for Biological Diversity v. Dep't of the Interior, 581 F.3d 1063 (9th Cir. 2009) (finding agency's definition of "no action" alternative arbitrary and capricious where the agency had detailed knowledge of the plans of a potential land owner with regard to specific land proposed to be exchanged); Young v. Gen. Serv. Admin., 99 F.Supp.2d 59 (D.D.C. 2000) (finding government's inclusion of foreseeable private development of a specific site in the "no action" alternative reasonable).*

diesel and gasoline. Royal Dutch Shell is currently partnering with German based Choren Industries to build a biomass to biodiesel plant. Choren believes Bio-to-Liquid fuels could meet 10 percent of Germany's transport fuel needs by 2015. Its 'Carbo-V' process turns wood and other biomass into 'SunDiesel', capturing the attention of major corporations such as Volkswagen, Renault, Ford and Daimler. Choren estimates that global biomass production exceeds oil consumption by five-fold. [Citations omitted].

Choren and other biofuel innovators, such as Canadian ethanol developer Iogen (also partnered with Shell), work with biomass -- organic leftovers such as sawdust -- which are as abundant as they are cheap. A Canadian study revealed that the biodiesel produced from just 10 percent of the country's agricultural wastes would satisfy 16.7 percent of its appetite for diesel.

The key to achieving sustainability target in the transportation sector (and most other sectors) is the switch to low carbon and carbon-free fuels that can be used in existing vehicles.

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The EPCA is a “technology-forcing” statute, whereby a challenging standard encourages technological innovation. As part of the statutory balancing, NHTSA must necessarily determine what is “technologically feasible.” While NHTSA has discretion to set standards somewhere below that level based on its consideration of the three other statutory factors, if it is reasonable to do so, NHTSA violates both EPCA and NEPA by failing to even consider or disclose what is truly “technologically feasible.” An essential component of the EIS must be disclosure of the maximum “technologically feasible” fuel economy level, along with the environmental impact of choosing this level of fuel economy as compared to NHTSA’s preferred alternative and a reasonable range of additional alternatives. The DEIS fails to provide both the basic starting point for this analysis and the proper analysis that must follow. [Citations omitted].

In the DEIS, NHTSA rejects calls for analysis of a technologically feasible level. “We consider the upper range of alternatives presented in this EIS to be technology forcing because at these higher average annual percentage increases some manufacturers run out of technologies before reaching the required CAFE standard and, therefore, these standards will be theoretically impossible to meet for some manufacturers. Since these higher average annual percentage increase regulatory alternatives force manufacturers to do something they would not otherwise be required to do, they are in that sense “technology forcing” as well.” DEIS at 2-22. That is, NHTSA appears to define “technology forcing” as any standard that is beyond the capacity of “some” manufacturers, utilizing the technologies currently in use in those product lines.

In their proposed joint rulemaking, NHTSA and EPA recognize that this approach is incorrect: “At the same time, the law does not preclude a CAFE standard that poses considerable challenges to any individual manufacturer. The Conference Report for EPCA, as enacted in 1975, makes clear, and the case law affirms, ‘a determination of maximum feasible average fuel economy should not be keyed to the single manufacturer which might have the most difficulty achieving a given level of average fuel economy.’ Instead, NHTSA is compelled ‘to weigh the benefits to the nation of a higher fuel economy standard against the difficulties of individual automobile manufacturers.’

Id. The law permits CAFE standards exceeding the projected capability of any particular manufacturer as long as the standard is economically practicable for the industry as a whole. Thus, while a particular CAFE standard may pose difficulties for one manufacturer, it may also present opportunities for another.

The CAFE program is not necessarily intended to maintain the competitive positioning of each particular company. Rather, it is intended to enhance fuel economy of the vehicle fleet on American roads, while protecting motor vehicle safety and being mindful of the risk of harm to the overall United States economy." Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Proposed Rule, 74 FR 49461 (Sept. 28, 2008).

Furthermore, NHTSA's position directly contradicts the "technology forcing" intention of the EPCA, which is meant to encourage technological innovation in the field, not just the wider adoption of existing technologies. As the court in Center for Auto Safety v. Thomas noted, "[t]he experience of a decade leaves little doubt that the congressional scheme in fact induced manufacturers to achieve major technological breakthroughs as they advanced towards the mandated goal." 847 F.2d 843, 870 (D.C. Cir. 1988) (overruled on other grounds); see also Green Mt. Chrysler Plymouth Dodge Jeep v. Crombie, 508 F. Supp. 2d 295, 358-359 (D. Vt. 2007) (discussing technology-forcing character of EPCA and the use of increased fuel efficiency to augment performance rather than mileage). As explained by the court in Kennecott Greens Creek Min. Co. v. Mine Safety and Health Admin., "when a statute is technology forcing, the agency can impose a standard which only the most technologically advanced plants in an industry have been able to achieve-even if only in some of their operations some of the time." 476 F.3d 946, 957 (D.C. Cir. 2007) (quoting United Steel Workers of America, AFL-CIO-CLC v. Marshall, 647 F.2d 1189, 1246 (D.C. Cir. 1980). With regard to a similarly technology-forcing statute, the Clean Air Act, legislative history indicates that the primary purpose of the Act was not "to be limited by what is or appears to be technologically or economically feasible," which may mean that "industries will be asked to do what seems impossible at the present time." 116 Cong. Rec. 32901-32902 (1970), Legislative History of the Clean Air Amendments of 1970 (Committee Print compiled for the Senate Committee on Public Works by the Library of Congress), Ser. No. 93-18, p. 227 (1974); see also Whitman v. American Trucking Associations, 531 U.S. 457, 491 (2001).

* * * * *

Due to the technology-forcing nature of the statutory scheme, NHTSA was required to include one or more technology-forcing alternatives in the DEIS. Such an alternative would include standards that may appear difficult to achieve today, but that would force innovation as industry strives to meet such a standard. Having failed to include such an alternative, NHTSA then failed to analyze the environmental impacts of a technology-forcing standard. This omission is particularly significant because such a technology forcing standard would have environmental benefits that not only amplify the ability of automakers to meet higher standards in later years, but that also create benefits throughout the economy through new investment, the creation of green jobs, and the potential for technological development in one field to spur innovation in another sector. NHTSA's failure to consider this important aspect of the analysis renders the DEIS inadequate.

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

NYSDOT recommends that NHTSA establish a more aggressive standard and achievement timetable for the new CAFE standards. In our comments to NHTSA on the DEIS for the MY 2011-2015 standards dated August 18, 2008, NYSDOT recommended that NHTSA establish a hybrid of alternatives that would be equivalent to the "Total Costs Equal Total Benefits (TCTB)" alternative for passenger vehicles and the "Technology Exhaustion" alternative for light duty trucks. Such a standard would result in a required fuel economy of 43.3 mpg for passenger vehicles and 34.7 miles per gallon for light duty trucks.

Response

One commenter suggests that NHTSA's analysis should have taken into account "low carbon fuel standards." The commenter states that changing a portion of the fuel to a second generation gasoline and/or diesel would achieve a greater reduction in GHG emissions.

Under EPCA, NHTSA prescribes average fuel economy standards. Thus NHTSA does not have the statutory authority to require the reductions in GHGs emitted by vehicles driven; nor does it have the statutory authority to regulate the content or type of vehicle fuel. As a practical matter, however, as NHTSA's fuel economy standards are made more stringent, emissions of CO_2 per mile driven decrease. EPA's formula for calculating fuel economy (mpg) is controlled by and directly related CO_2 emissions.

In response to the comment that NHTSA did not include a technology-forcing alternative, the agency expects that, other than the No Action Alternative, all of the analyzed alternatives will induce manufacturers to implement additional technologies. Further, for the higher average annual percentage increases considered in this EIS some manufacturers run out of available technologies before reaching the required CAFE standard and, therefore, these standards will be theoretically impossible to meet for some manufacturers. Since these higher average annual percentage increase regulatory alternatives would tend to force manufacturers to do something they could not do with available technologies, they are in that sense "technology forcing" as well. Also, for most fuel efficiency technologies that NHTSA took into account in its analysis, the agency applied phase-in constraints that made less limited assumptions than in previous rulemaking analyses, while continuing to recognize that most technologies must still be applied as part of a vehicle freshening or redesign.

Further, NHTSA notes that, under CEQ regulations and applicable case law, NHTSA is not required to include every conceivable alternative in an EIS, nor necessarily other hypothetical alternatives submitted by commenters. Rather, an agency is to consider "reasonable" alternatives. The purpose of and need for the rulemaking determines the range of reasonable alternatives under NEPA. We consider our range of alternatives to represent a reasonable range of possible agency actions. For a discussion of the alternatives, see Section 2.3 of the DEIS and this FEIS, Chapter III of the PRIA.

10.2.4.4 Adoption of More Aggressive Alternatives

Comments

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

The transitional nature of this proceeding has led the agencies to set the standard at the level agreed upon by federal and state authorities through negotiation. But the subsequent analysis shows that the chosen levels leave a large quantity of consumer, economic, national security and environmental gains unrealized. If the standards were set at the level of maximum economic or maximum practicable environmental benefits, we would observe the following additional gains:

Gasoline consumption would be lower than the proposed standard by 28 to 34 billion gallons, pushing the total savings to about 90 billion gallons.

The net present value of societal savings would be 20 to 25 billion higher, pushing it to a total of over 120 billion. The consumer pocketbook savings would be about 80 billion, 10 billion more than the proposed standards.

Perhaps the most interesting, the average cost of conserved energy under a more rigorous standard would be less than $1.30 a gallon. The marginal cost would be $1.80 per gallon. That is compared to a projected average cost of gasoline over the life of the vehicles of $3.00 per gallon.

The American consumer would benefit mightily if we captured the efficiency, the much lower cost efficiency, and stopped spending it on gasoline. So setting the standards to maximize economic benefit or maximum practicable environmental benefit is a win-win-win for consumers, the nation, and the environment. That is why EPA and NHTSA as they reconcile their statutes must not let the transition extend past the 2016 model year. Each year of delay in moving to the proper level of the standard results in severe loss to consumers and the nation.

Response

Congress has stated that when setting maximum feasible CAFE standards, NHTSA must consider and balance the four EPCA statutory factors (i.e., technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy). 49 U.S.C. § 32902(f). NHTSA has balanced those factors in a way that achieves substantial fuel economy gains – on average 4.3 percent per year over five years. NHTSA notes that electing to impose more aggressive standards would impose substantial additional costs on the industry at a time when the industry and economy are both facing difficult conditions, and could result in part in more penalties rather than achieving higher levels of fuel economy. Overly aggressive standards would not achieve the result intended by EPCA, i.e., meeting EPCA's overarching goal of energy conservation while also weighing economic practicability and technological feasibility.

We disagree that consumer gains will be unrealized under the National Program. Consumers will be able to purchase a range of vehicles. This will include small, fuel-efficient vehicles.

One commenter noted that setting standards at the maximum economic or maximum practicable environmental benefit would result in additional gains, and appeared to urge the agency to take this into account in future rulemakings. By statute, the determination of the appropriate standards is based, not on maximum economic or environmental benefit, but on a balancing of the four factors identified above. The agency is mindful that there are lead time and other restraints that manufacturers face that limit acceleration of technologies. NHTSA has carefully balanced the statutory factors and believes that the Preferred Alternative reasonably accommodates these competing interests. For a discussion on NHTSA's balancing of the factors, see Section IV.F of the NPRM.

In response to comments urging NHTSA and EPA to look beyond MY 2016, we note that while this proposal covers MYs 2012-2016, EPA and NHTSA anticipate seeking a strong, coordinated national program for light-duty vehicles in model years beyond 2016 in a future rulemaking.

10.2.4.5 Sensitivity Analysis

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The sensitivity analysis of economic inputs to the Volpe model fails to describe the limitations and inherent problems of the model's cost-benefit analysis.

The sensitivity analysis of economic inputs to the Volpe model indicated relative insensitivity to a number of controversial factors. “Table 2.4-1 shows that fuel consumption (and thus related emissions and other environmental impacts) are relatively sensitive to fuel price projections, and somewhat sensitive to the estimated rebound effect, but relatively insensitive to changes in model input values for the discount rate, SCC, and oil import externalities.” DEIS at 2-19.

It is disappointing that NHTSA continues to rely on the outdated methods and assumptions of the Volpe model, even if the role of the Volpe model was greatly reduced in the development of the current rule. The fact that the model is relatively sensitive to the rebound effect raises serious concerns about the use of the Volpe model when NHTSA has failed to adequately consider other agency actions, policies, and social changes that may affect vehicle miles traveled much more significantly than does the rebound effect. In addition, the insensitivity of the model to the social cost of carbon indicates that the Volpe model is an inappropriate tool in this context. The Volpe model, like the DEIS as a whole, fails to adequately incorporate and respond to the enormous real-world impacts and costs at stake as a result of the impacts of climate change.

Response

The commenter does not appear to understand the agency’s use of the Volpe model. Although NHTSA uses the Volpe model as a tool to inform its consideration of potential CAFE standards, the results it produces are dependent on inputs selected by NHTSA. In addition to identifying the input assumptions underlying its decisions, NHTSA provides the rationale and justification for selecting those inputs, and is guided by the statutory requirements of EPCA in the ultimate selection of a CAFE standard. The agency recognizes that many of these variables (e.g., fuel price) are subject to change based on differing economic circumstances, making the assessment process difficult..

Recognizing the uncertainty inherent in many of the underlying estimates in the model, NHTSA uses the Volpe model to conduct both a sensitivity analysis, by changing one factor at a time, and a probabilistic uncertainty analysis (a Monte Carlo analysis that allows simultaneous variation in the factors), to examine how key measures vary in response to changes in these factors. This type of analysis is used to estimate the uncertainty of the costs and benefits of a given set of CAFE standards. Specifically, NHTSA examines the sensitivity of fuel savings and other benefits from adopting higher CAFE standards to variation in four economic parameters (specifically, the price of gasoline, the magnitude of the fuel economy rebound effect, the value of reducing CO_2 emissions, and whether to include non-zero values for the reductions in monopsony payments to foreign petroleum suppliers and in outlays for maintaining the U.S. military presence in the Persian Gulf). In addition, the agency separately examines the sensitivity of total benefits to variation in the value of health benefits stemming from reducing emissions of criteria pollutants and reductions in fatalities resulting from improved vehicle safety. For additional information and preliminary results of NHTSA’s sensitivity analyses the agency refers readers to Section XII of the PRIA which addresses Net Benefits and Sensitivity Analyses. The sensitivity analysis results under consideration for the final rule are discussed in Section 2.4.

NHTSA disagrees with the commenter’s assessment that the methods and assumptions of the Volpe model are outdated. The agency believes that the inputs it has selected and the range of alternatives considered in the DEIS and this FEIS fully inform the decisionmaker and the public about the environmental impacts of the Preferred Alternative, including impacts related to climate change.

NHTSA further disagrees with the commenter’s assertion that the Volpe model is unduly insensitive to inputs specifying some economic estimates, including SCC. The manner in which the Volpe model applies these inputs to calculate economic benefits is the same as would apply outside the Volpe model. For example, applying the estimated SCC involves simply multiplying the SCC by the quantity of carbon *dioxide emissions avoided. Therefore, calculations performed outside the model should be similar in their relative sensitivity to changes in different economic inputs. The range of SCC values examined spanned $5–$56 per ton of carbon dioxide – a range equivalent to approximately $0.044–$0.498 per gallon of gasoline. By comparison, the range of gasoline prices examined spanned $2.04-$5.47 (by calendar year 2030), a range nearly eight times larger than the SCC range. It is only natural, therefore, that economic calculations – whether implemented using the Volpe model, some other tool, or hand calculations – would be far less sensitive to these SCC variations than to these fuel price variations.*

10.2.4.6 Comparison of Alternatives and Context of Analysis

Comments

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

Cut global warming emissions by 215 million metric tons in 2020, the equivalent of taking nearly 32 million of today's cars and light trucks off the road that year. These standards are the single biggest step the U.S. can take to reduce energy consumption and greenhouse gas emissions. The draft EIS is much too negative about the significance of these reductions.

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The DEIS artificially minimizes climate change impacts by analyzing them only as a proportion of global greenhouse gas emissions.

The DEIS itself points out that by analyzing the climate impacts of the rule solely as proportions of global greenhouse gas emissions, these obviously enormous impacts are artificially reduced to the point that quantitative analysis is made exceedingly difficult. “Although the alternatives have the potential to substantially decrease GHG emissions, alone they would not prevent climate change. The magnitude of the changes in climate effects that the alternatives would produce – 2 to 5 ppm of CO2, a few hundredths of a degree Celsius difference in temperature, a small percentage change in the rate of precipitation increase, and 1 or 2 millimeters of sea-level rise – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions could be important – very small percentages of huge numbers can still yield substantial results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives; rather, it provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.” DEIS at S-40.

However, there are significant quantifiable differences among alternatives. For the DEIS to be meaningful and useful in making a decision, the agency must place impacts in a context that provides a basis for comparison between them. Rather than being compared only to overall global concentrations, alternatives should be analyzed for their effect on emissions from motor vehicles in particular and the U.S. transportation sector in general. For example, NHTSA estimates in the DEIS that in 2100 the 2012-2016 standards would reduce global greenhouse gas emissions by 0.4 to 0.8 percent, but this reduction is more meaningful as a percent reduction in emissions from the U.S. light duty transportation sector. The U.S. transportation sector is the second largest contributor to this nation’s greenhouse gas emissions behind only the electricity sector. Understanding how the various alternatives begin to curb this key sector’s emissions is crucial to understanding what impact NHTSA's first-ever efforts (in its joint rulemaking with EPA) to affect the U.S. contribution to global warming can and should make.

NHTSA should also present alternatives analyzed for their effect on emissions from, and their capacity to contribute to, a cross-sectoral and national effort to reduce greenhouse gas emissions and avoid some of the most severe and imminent impacts of climate change. For example, NHTSA should consider the alternatives in terms of reducing greenhouse gas emissions to 1990 levels by 2020 – data that can be relatively reliably estimated, and that is highly relevant to decision makers and the public. The EPA's inventory of greenhouse gas sources and sinks provides an estimate for 1990 greenhouse gas emissions and 2020 projected greenhouse gas emissions, assuming recent trends remain. Assuming reductions from light duty transportation that are proportional to reductions that must be contributed by other sectors to reach this goal, reductions of 423 million metric tons of carbon dioxide from the light vehicle sector alone are needed in 2020. NHTSA has estimated emissions reductions annually ranging between 217 million metric tons of CO2 and 479 million metric tons of CO2, with Alternatives 1-5 falling short of the 423 million metric tons threshold and Alternatives 6-9 meeting or exceeding the threshold. In this context, there are dramatic differences among alternatives. Other important contexts for assessing the emissions and reductions proposed in the rule are President Obama's commitment at the G8 summit in July 2009, to curtail climate change at 2 degrees Celsius above the historic average, and the need to reduce atmospheric concentrations to 350 ppm

Docket Number: TRANS01
Organization: Sierra Club
Commenter: Ann Mensikoff

Cars and light trucks emit 20 percent of U.S. C02 pollution. And CAFE standards can only reduce the emissions from that sector of the economy from those vehicles and should be evaluated, therefore, in a narrower context. NHTSA, and now EPA, has the administrative capacity to make a significant reduction in U.S. C02 emissions. NHTSA continues to minimize the impact of the different options it has control over rather than assessing them in an appropriate context or giving them meaning within a reasonably understandable context. And it therefore diminishes the differences between the different scenarios, the difference between getting to 35 in 2015 as we had urged based on the economic analysis in the prior rule and getting to 35 in 2016 here, leaving the door open for greater standards beyond that.

And also there is a significant difference between those in terms of nearer term oil savings, nearer term consumer savings and environmental benefits that are not adequately presented through the analysis done in this DEIS.

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I would urge the agency to focus the DEIS on how CAFE standards affect emissions for vehicles, and perhaps within the context of transportation, confining that analysis to nearer term will show greater impact and greater variation on the options presented by the agencies in this document.

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If you go out to 2100 and 779 parts per billion of carbon in the atmosphere and then you're looking at small changes in rainfall and weather, that's beyond the tipping point. At that point you are sort of saying that what you have control over really makes no difference in climate change and really will make no difference and, therefore, maybe we should do nothing in this context, because it becomes meaningless that far out and I think meaningless to the public and I would assume meaningless to other folks who would look at this and say what is the impact of the different options that the agency considered. You've got to either narrow your focus or account for other foreseeable changes that will complement fuel economy and give it meaning within that longer term context. But in my view, 2100 takes you too far out.

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The DEIS should inform the agency of its options and not diminish the differences between them or trivialize their importance.

Docket Number: TRANS02
Organization: Public Citizen
Commenter: Lena Pons

The agency has not placed the impacts of the range of alternatives in a context that allows for meaningful comparison. The purpose of the Draft Environmental Impact Statement is to support an action based on a range of alternatives considered and the impacts of that range. The document fails to achieve this purpose because it has not placed the impacts of the range of alternatives in a context that allows for meaningful comparison among the alternatives. The EPA estimates that the United States contributes 18 percent of global greenhouse gas emissions and that motor vehicles contribute 24 percent of U.S. greenhouse gas emissions. Therefore, motor vehicles are responsible for about four percent of global greenhouse gas emissions. Consistent with EPA's assessment in its proposed endangerment finding on carbon dioxide, no single source or category of sources dominates global initiatives but some sources may be significant.

NHTSA estimates in the DEIS that in 2100 the 2012 through 2016 standards would reduce global greenhouse gas emissions by 0.4 to 0.8 percent. Considering that if all motor vehicle sources of greenhouse gas emissions were shut down the reduction would be just four percent of global emissions, the impacts of proposed standards is significant with respect to reductions in the light duty transportation sector.

For the DEIS to be meaningful and useful in making a decision, the agency must place impacts in a context that provides a basis for comparison between them. One example of such a context would be to consider the alternatives in terms of reducing greenhouse gas emissions to 1990 levels by 2020, something which can relatively reliably be estimated as relevant and foreseeable to decision-makers and the public.

The EPA's inventory of greenhouse gas emissions provides us with an estimate for 1993 greenhouse gas emissions and projected greenhouse gas emissions in 2020, assuming recent trends. Considering reductions proportional to the contribution from the light duty transportation sector, reductions of 423 million metric tons of carbon dioxide are needed in 2020. Based on the DEIS, we can break out the alternatives and their annual reductions in greenhouse gas emissions in the light duty transportation sector. And considered in this context, Alternatives 1 through 5 would fall short of the reductions needed as estimated by EPA, while Alternatives 6 through 9 would meet or exceed those needed reductions. Considered in this context, you can make a confident decision about what action is supported by the DEIS.

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The Draft EIS does not serve the function of informing decision-makers about relative impacts of a range of alternatives. The document does not place impacts in a meaningful context to compare the alternatives and it does not provide a basis for decision-makers and the public to make a reasoned decision about the relative impacts of the proposed alternatives. Climate change is a problem that goes beyond just the transportation sector. It is unreasonable for the DEIS to judge fuel economy standards solely on its impact to global greenhouse gas emissions.

Transportation emissions are particularly complicated because they're dependent on the efficiency of the vehicle, the carbon content of the fuel used to propel it, and the number of miles a vehicle is driven. There is no one policy that can solve the problem, but fuel economy standards are a critical policy.

Transportation emissions account for a third of greenhouse gas emissions in the United States, so actions to reduce these emissions has a significant impact. However, since the agency cannot resolve the difference between alternatives considered on a global scale for the period considered, it must place the alternatives in a context that allows for differentiation between the options.

It is also important to remember that although the impact of this single policy is not sufficient to combat climate change, it does have a significant and measurable impact.

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NHTSA should place the alternatives in a context that allows for comparison and is relevant to the reader. For example, NHTSA discusses annual carbon dioxide reductions in terms of emissions of coal-fired power plants, but does not discuss whether the impact of eliminating emissions from those power plants would be significant or greater than reductions from the transportation sector.

We suggest that making a similar comparison readily available through the same EPA calculator that NHTSA used that presenting the impacts as equivalent to removing a number of cars from the road would be a better context for understanding. The agency could also devote more prose to discussing the relevance of light duty transportation to greenhouse gas emissions in the United States and globally which would help put into perspective the role of these regulations in reducing greenhouse gas emissions from the light duty transportation sector.

We urge that NHTSA revise the Draft Environmental Impact Statement to make it more informative to decision-makers and the public. This is an opportunity to set an example for how such a document can be used to communicate the value of source and sector specific policies for reducing greenhouse gas emissions.

Docket Number: TRANS03
Organization: Consumer Federation of America
Commenter: Mark Cooper

It's quite clear that fuel economy improvements cannot solve the national security problem. They cannot solve the climate change problem. And because they cannot solve it, there's a tendency to diminish the value of it, to say, "Well, it's not big enough to matter. We have not used a framework that you can really see it."

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

NYSDOT agrees that the CAFE standards should not be based on speculative scenarios. However, a multitude of states and municipalities around the nation are committing to achieve an 80% reduction in greenhouse gas emissions by the year 2050. Indeed, this goal is the hallmark of the Waxman-Markey Bill and the majority of carbon emissions reduction initiatives at the local, state, and international level. In light of the growing consensus to achieve this magnitude of carbon emissions reductions, NYSDOT recommends that NHTSA and EPA consider the contribution of the transportation sector to achieving progress to attain the "80 by 50" goal.

Response

Climate change is a global phenomenon. GHGs can persist in the atmosphere for decades to centuries, and the effects of a given level of emissions in one location can occur over large scales such as globally. NHTSA has presented emissions data in a number of contexts but believes that it is appropriate to evaluate the effects of this rulemaking in terms of its relation to global emissions and global climate conditions using year 2100 as an endpoint. This is a common approach for climate modeling. While Sections 3.4 and 4.4 of the FEIS show small differences in climate effects (CO_2 concentration, temperature, sea-level rise, precipitation) when expressed in terms of climate endpoints, i.e., the results at the end of an analysis period, NHTSA believes that this is likely true for any given GHG emission mitigation strategy when taken alone. A suite of many GHG emission reduction policies in many countries and environmental sectors would need to be implemented to mitigate climate change substantially. NHTSA's analysis of the rule's effect on global climate conditions is not intended to downplay the effectiveness or importance of the regulatory options in reducing CO_2 emissions and global warming impacts, but to quantify these potential reductions in the proper context for climate change.

NHTSA recognizes the importance of the climate change problem. The agency is acting within its statutory authority to increase average fuel economy and in so doing to reduce annual U.S. vehicle emissions of CO_2. Under EPCA, as amended by EISA, NHTSA has the authority to set fuel economy standards for passenger cars and light trucks. Emissions from these vehicles constitute about 60.6 percent of total U.S. transportation sector emissions. U.S. transportation sector emissions are about 31.5 percent of total annual U.S. CO_2 emissions. Because U.S. emissions constitute 17.2 percent of global CO_2 emissions, U.S. light duty vehicle emissions (those that NHTSA has the authority to regulate under EPCA) account for roughly 3.7 percent of global annual CO_2 emissions. NHTSA recognizes the important role that transportation plays in addressing global climate change issues.

To get a sense of the relative impact of these emissions reductions resulting from CAFE standards, it can be helpful to consider the relative importance of emissions from passenger cars and light trucks as a whole, as discussed above. In fact, throughout the DEIS, NHTSA did indicate the important role that transportation plays in addressing global climate change issues, and attempted to put the impacts of the alternative CAFE standards in the context of passenger car and light truck emissions. See DEIS Sections S.5, 2.6.1.3.1, 3.4.2, and 3.4.4.1. However, NHTSA has added additional graphs and figures to place the impacts of the agency's action in the context of total U.S. GHG emissions, and in the context of total U.S. transportation sector emissions. See FEIS Summary p. S-23.

NHTSA recognizes that such comparisons present the proposed action and the impacts of the alternatives under consideration in perspective for the public and decisionmakers. The agency has emphasized the context discussions in the EIS Summary so that they are more prominent in the document. NHTSA has revised the Summary to focus on communicating the importance of the impacts of the agency's action in a non-technical, and average-reader-friendly way. This summary contains (1) a general discussion of the greenhouse effect and climate change, (2) a summary of impacts expected with climate change, (3) a brief discussion of the direct, indirect, and cumulative effects of alternatives on GHG emissions as well as atmospheric CO_2 concentration, global mean surface temperature, sea-level rise, and precipitation, (4) graphical depictions of impacts of the agency action on U.S. passenger car and light truck emissions, and (5) additional context to help decisionmakers and the public understand the differences among the alternatives and how this action fits into larger U.S. GHG reduction goals (see below). NHTSA will enable for download a separate file containing only the Summary, in full color, on the agency's website *alongside the full EIS. This separate file will provide interested members of the public with easy access to a summary of the environmental impacts of NHTSA's action of setting CAFE standards.*

NHTSA has also added an analysis in the FEIS showing the differences in CO_2 emissions among the alternatives in 2016 (the final year of the rulemaking) expressed as the equivalent number of passenger cars and light trucks removed from the road in those years. NHTSA has also added a brief discussion of the magnitude of CO_2 emission reductions under this action in terms of the relative contribution of passenger cars and light trucks towards the recently stated White House goal of reducing U.S. GHG emissions in the range of 17% below 2005 levels by 2020. These discussions of impacts and comparisons of alternatives have been added to the Summary of the EIS, in an effort to differentiate among the alternatives in a way that is more relevant to the decisionmaker and the public.

NHTSA believes that comparing the differences among alternatives against the transportation sector's contribution to a near-term goal for 2020 provides a more meaningful context for this rulemaking than comparisons against longer term goals (e.g., 2050). The 17% by 2020 goal is an estimate of the reductions that could be achieved with existing technologies, and assumes continued widespread use of fossil fuels. The 80% by 2050 goal, which one commenter suggested NHTSA use as a basis for comparison, is in a legislative proposal that has not been adopted. However, the greater level of reductions targeted by such a goal by 2050 would require substantial increases in technology innovation from today's levels, and would require an economy and vehicle fleet that has largely moved away from the use of fossil fuels. That goal does not provide context that is as useful for the reader as a nearer term goal because NHTSA's action of setting CAFE standards through MY 2016 cannot make such giant leaps.

10.3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

10.3.1 Common Methodologies

Comments

Docket Number: 0019
Organization: Individual
Commenter: Gail Gilbert

I worry that loopholes will creep in as they have in the past. For example, one new provision could underestimate the heat-trapping emissions of "zero-emission" vehicle technologies such as plug-in hybrids and electric vehicles. The rules do not count heat-trapping emissions associated with generating the electricity that charges those vehicles.

Docket Number:
Organization: Individual
Commenter: James Adcock

The assumption that PHEVs will be charged from a dirty electricity source doesn't make sense given that owners have the option to purchase "green electricity" and green electricity reduces carbon footprint much less expensively than PHEVs. . . . Thus emissions due to PHEV charging should be assumed to be zero.

Response

NHTSA believes that these comments refer to one of EPA's proposed credits, which is designed to encourage the commercialization of advanced technology vehicles, including electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles. EPA proposed to assign a value of 0 grams per mile CO_2 for EVs and the electric portion of PHEVs, since traditionally mobile source tailpipe standards do not consider upstream emissions. However, EPA did request public comment on the issue of whether upstream emissions should be considered. A number of similar comments were received on the joint NHTSA-EPA NPRM, and EPA will address these issues in the forthcoming joint NHTSA-EPA Final Rule. For purposes of NHTSA's environmental analysis, however, including estimates of emissions from generation of electricity consumed by plug-in hybrid and electric vehicles would not significantly affect the environmental impacts projected to result from increased CAFE standards for MYs 2012-2016 passenger cars and light trucks, because the agency's modeling analysis does not require significant penetration levels for these technologies in the rulemaking timeframe.

10.3.2 Air Quality

10.3.2.1 Methodology

Comments

Docket Number: 0051.1
Organization: Missouri Department of Natural Resources
Commenter: Dru Buntin

Compared to the no action alternative, any of the alternatives that will increase the CAFE standard would result in lower levels of most criteria pollutants, including nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). According to the report, ozone levels are more difficult to determine since it is a secondary pollutant, formed by combining NOx with volatile organic compounds (VOCs). However, the study does project that VOC levels will also be reduced by increasing the CAFE standard. The final report on the revised CAFE standards is expected to contain modeling that will better determine the results of ozone levels resulting from the increase in CAFE values.

Response

In response to concerns raised by commenters to the current EIS and the agency's 2008 EIS, this FEIS includes a photochemical air quality modeling analysis that estimates the changes in ambient air quality and serves as an input to the analysis of associated health outcomes and health-related costs due to the alternative CAFE standards. Emissions estimates from the analysis conducted in the DEIS alone do not account for the complex chemical transformations that nitrogen oxides (NO_x), particulate matter (PM), sulfur oxides (SO_x), and volatile organic compounds (VOC) emissions undergo while being dispersed and transported in the atmosphere. These transformations include reactions of NO_x and VOCs that lead to formation of ozone. The photochemical air quality modeling and health impacts analysis accounts for this atmospheric chemistry as well as local variability in meteorology, population density, exposure, and baseline health incidence rates, all of which may lead to differing localized pollutant concentrations and related human health impacts. By accounting for these factors the photochemical air quality modeling analysis in the FEIS provides additional spatial and temporal detail to more completely and accurately estimate changes in ambient levels of these pollutants and their associated health and welfare impacts. The photochemical air quality modeling analysis is included as Appendix F in this FEIS.

10.3.2.2 Consequences

Comments

Docket Number: 0051.1
Organization: Missouri Department of Natural Resources
Commenter: Dru Buntin

For a number of the toxics that appear in gasoline, all of the proposed alternatives result in a number of toxics at higher levels than taking no action. This is again attributed to the rebound effect, increasing emissions more than would be compensated for by the reduction in the total number of gallons used. Again, the study's baseline calculation is based on the belief that the rebound effect will result in an increase in VMTs that will negate the decrease in gallons of fuel used that results from higher CAFE standards. By using the report methodology, emission reductions would be very conservative in regards to actual emissions reductions attributed to vehicle miles traveled.

Localized Calculation of Emissions Reductions

The study also examined the effects of the proposed alternative CAFE standards on nonattainment and maintenance areas. Because the majority of these areas do not have petroleum production or refining within their boundaries, and the study assumed that petroleum was not transported through urban areas, the localized results showed that very little emissions reductions would result in nonattainment or maintenance areas from any of the alternative CAFE standards. In fact, it was projected that some urban areas may have an increased level of criteria and toxic emissions resulting from the rebound effect. These results for nonattainment and maintenance areas are of particular concern because of the air quality status of the two largest urban areas in Missouri. St. Louis is currently designated as nonattainment for ozone and PM. Kansas City is designated as a maintenance area for ozone. The specific criteria pollutants of concern in Kansas City and St. Louis are outlined below:

Ozone - Kansas City

The Kansas City Metropolitan Area is a maintenance area under the previous one-hour ozone standard, and was designated attainment for the 8-hour ozone standard. As such, the area is required to have a maintenance plan under the current 8-hour ozone standard. Also, the area has numerous local controls implemented as a result of the previous ozone violations under the one-hour ozone standard. These controls are found in the Kansas City Ozone portion of the Missouri State Implementation Plan, and in Title 10, Division 10, Chapter 2 of the Missouri Code of State Regulations. Finally, the new 8-hour ozone maintenance plan for the Kansas City Maintenance Area was approved by EPA in 2007. This plan includes additional local control measures that are required to be implemented in two phases when triggered. The first phase was triggered by the quality assured violation of the 8-hour ozone standard during the 2007 ozone season. This phase includes a heavy-duty diesel idle reduction measure and emissions reductions from sources that fall under the Clean Air Interstate Rule.

It is also anticipated that the Kansas City area will be designated as a nonattainment area for ozone under the recently revised 2008 ozone standard, which may require additional emission controls for the area.

Ozone - St. Louis

The St. Louis area counties of Jefferson, Franklin, St. Charles, and St Louis and St. Louis City are an ozone nonattainment area under the 1997, 8-hour ozone standard. As such, the area is required to have emission reduction plans to achieve attainment. The area also has numerous local emissions controls on various types of emission sources, which are found in the St. Louis portion of the Missouri State Implementation Plan.

It is also anticipated that the St. Louis area will continue to be designated as a nonattainment area for ozone under the recently revised 2008 ozone standard, which may require additional emission controls for the area.

Particulate Matter - St. Louis

The St. Louis area contains the only part of the state designated as nonattainment for particulate matter under the 1997 PM 2.5 Standard. The St. Louis particulate matter nonattainment area includes the City of St. Louis and the counties of St. Louis, St. Charles, Franklin, and Jefferson.

Response

Toxics Pollutant Emissions

The commenter notes correctly that the additional tailpipe emissions due to the VMT rebound effect would tend to offset the decreases in upstream emissions due to lower fuel consumption. If the actual VMT rebound effect were less than was assumed in the DEIS, then total emissions would be lower and the emission reductions would be greater than were estimated in the DEIS. The same is true of the FEIS. For a discussion of NHTSA's and EPA's assumptions regarding the rebound effect, see FEIS Section 10.2.3.4.1; NPRM, 74 FR 49454, 49608, 49671-49672 (Sep. 28, 2009); Draft Joint Technical Support Document, Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Docket No. NHTSA-2009-0059-0029, § 4.2.5; NHTSA PRIA, Corporate Average Fuel Economy for MY 2012 – MY 2016 Passenger Cars and Light Trucks, Docket No. NHTSA-2009-0059-0016.1, 355-361.

Localized Calculation of Emissions Reductions

The commenter noted that the DEIS projected that some areas including nonattainment and maintenance areas may have an increased level of criteria pollutants and toxic emissions resulting from the rebound effect. The commenter states that these results are of particular concern because of the air quality status of the two largest urban areas in Missouri. The commenter also states that the St. Louis area is currently designated as a nonattainment area for ozone and PM. Kansas City is designated as a maintenance area for ozone. Table 3.3.3-7 of the FEIS shows that the maximum increase in NO_x emissions in any nonattainment area is estimated to be 149 tons per year, and the maximum increase in PM of 2.5 microns diameter or less ($PM_{2.5}$) emissions in any nonattainment area is estimated to be 23 tons per year. By comparison, in 2002 (the most recent data available from the EPA National Emissions Inventory) the total emissions of NO_x and $PM_{2.5}$ in the St. Louis nonattainment area were 185,870 tons and 29,684 tons, respectively. The total 2002 emissions of NO_x and $PM_{2.5}$ in the Kansas City maintenance area were104,748 tons and 13,552 tons, respectively.[12] The maximum increase in emissions predicted in the FEIS for any nonattainment area are small in the context of the total emissions inventories in the St. Louis nonattainment area and the Kansas City maintenance area. No VOC emissions increases were predicted for any nonattainment area.

Ozone – Kansas City

The Kansas City Metropolitan Area was not analyzed individually in the DEIS because the area is currently designated as an attainment area for the 8-hour ozone standard. The maximum emissions increases given in Table 3.3.3-7 suggest that if the Kansas City Metropolitan Area had been included in the analysis, and if any increases in NO_x or VOC emissions were predicted to occur in the Kansas City Metropolitan Area, then such increases would likely be small.

Ozone – St. Louis

The data given in Appendix C of the FEIS show that emissions of NO_x and VOC in the St. Louis ozone nonattainment area are predicted to decrease under every action alternative for all analysis years.

Particulate Matter – St. Louis

The data given in Appendix C of the FEIS show that emissions of $PM_{2.5}$ in the St. Louis $PM_{2.5}$ nonattainment area are predicted to decrease under every action alternative for all analysis years. Accordingly, the proposed CAFE standards would not jeopardize the area's progress toward attainment of the $PM_{2.5}$ standard.

Air quality chemistry is complex, and projected changes in emissions do not account for meteorology, pollutant transport, pollutant formation in the atmosphere, and other local factors. Nevertheless, the projected changes in emissions under the action alternatives provide an indication that there would be no adverse impacts on attainment in the St. Louis and Kansas City nonattainment areas. Conclusions about localized attainment/nonattainment impacts should not be based upon information gleaned from emission inventory estimates alone. Instead, potential attainment impacts should be evaluated based upon full-scale photochemical air quality modeling data that are consistent with guidelines for determining attainment status (see U.S. EPA (2007) Guidance on the Use of Models and Other Analyses For Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze; EPA-454/B-07-002; Research Triangle Park, NC; April 2007). EPA is conducting full-scale air quality modeling for the

[12] *EPA (U.S. Environmental Protection Agency). 2009. Emissions by Category Report – Criteria Air Pollutants. Last Revised: November 6, 2009. Available: http://www.epa.gov/oar/data/emcatrep.html. Accessed December 30, 2009.*

forthcoming joint NHTSA-EPA Final Rule to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards and will provide a description of the PM and ozone attainment impacts of the EPA GHG rule in the final regulatory impact analysis.

10.3.3 Climate Tipping Points

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The DEIS fails to adequately address climate change tipping points.

The DEIS acknowledges the risk that continued petroleum consumption and the subsequent emission of greenhouse gases can exceed "tipping point" thresholds, resulting in abrupt and irreversible climate change. "Exceeding one or more tipping points, which 'occur when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause' (National Research Council 2002 in EPA 2009b), could result in abrupt changes in the climate or any part of the climate system. These changes would likely produce impacts at a rate and intensity far greater than the slower, steady changes currently being observed (and in some cases, planned for) in the climate system (EPA 2009b)." DEIS at 3-83. "The CCSP report summarizes scientific studies suggesting that there are several 'triggers' of abrupt climate change and that 'anthropogenic forcing could increase the risk of abrupt climate change…'" DEIS at 4-163.

* * * * *

Nearly every piece of information in any EIS contains levels of uncertainty, yet an agency is expected to make a good faith effort to consider impacts that are reasonably certain to occur. In this case, it is now certain that tipping points will be reached if global warming remains unchecked, and there is more than sufficient knowledge of climate tipping points and the potential for a stringent CAFE rule to be one of the most significant components of a national greenhouse gas emissions reduction program that would significantly decrease the likelihood of surpassing them. The threat of climate tipping points is well established and understood. A recent analysis of "tipping elements" indicates that contrary to the IPCC's conservative projections, there is a strong chance that tipping points will be crossed within this century. Furthermore, NHTSA does not need to identify times or atmospheric conditions leading to tipping points with specificity in order to quantify the benefits and priority for greater, earlier reductions in greenhouse gas emissions. What NHTSA must do is analyze alternative outcomes with reasonable detail to arrive at reasonable conclusions concerning how best to avoid disastrous consequences.

Under all scenarios considered in the DEIS, the atmospheric CO2 concentrations would reach 550 ppm or greater. This is well above the threshold for abrupt and catastrophic climate change caused by crossing tipping points. As a result, no alternatives adequately address the need for deep reductions in CO2 emissions.

We acknowledge the obvious point that action by the U.S. alone cannot avert catastrophic results. In its proposed Endangerment Finding, however, EPA has finally publicly debunked the legally erroneous and morally repugnant position that the U.S. therefore either cannot or should not take the amount of action necessary to contribute its share of needed greenhouse gas emission reductions. Unfortunately, that laudatory reversal of position is not reflected in the analysis of the DEIS, which remains fatally flawed. (Some citations omitted.)

Response

While many scientists assert that if thresholds relating to the climate system are exceeded, this may result in severe and abrupt climate changes and impacts, there remains substantial uncertainty surrounding the existence of a single tipping point, and, if there is a single level, whether it corresponds to a specific CO_2 concentration (e.g., 450 parts per million (ppm)) or increase in annual average temperature (e.g., 2 ºC over pre-industrial levels). For example, there are indicators of multiple tipping points within various global systems, as noted in scientific observations, peer-reviewed scientific literature, and paleoclimatic data. See FEIS Section 4.5.9; DEIS Section 4.5.9. These points might occur when CO_2 concentrations are lower or higher than 450 ppm and would have varying direct and indirect impacts.

The EIS discusses the impacts on various climate systems of reaching or passing various climate tipping points. See FEIS Section 4.5.9.2; DEIS Section 4.5.9.2. That section contains discussions of potential impacts resulting from tipping points being reached for glaciers and ice sheets, the likelihood and persistence of drought, potential impacts on Amazon rainforests, and potential impacts on other climate systems.

NHTSA does not believe that examining the alternatives in relation to reaching tipping points triggered by CO_2 emissions is practicable. In the context of this EIS, due to the uncertainty surrounding the precise global temperature change or CO_2 concentration level that would constitute a tipping point, it is not currently practicable to attempt to estimate how this action could delay or mitigate the triggering of tipping points in any quantitative manner. Thus, it would not be possible for NHTSA to relate the reductions in CO_2 emissions, sea-level rise, precipitation changes, and temperatures to tipping-point thresholds or to determine to what extent the different alternatives would affect tipping points. This federal action alone, even as analyzed under the most stringent alternative, is not likely to produce enough reductions in CO_2 emissions to avert CO_2 levels that some have identified as corresponding to abrupt and severe climate change. In fact, CO_2 emissions of passenger cars and light trucks account for roughly 3.3 percent of global annual CO_2 emissions. Even if NHTSA could set standards that reduced emissions from this sector to zero, tipping-point thresholds (whether they occur at 550 ppm or any other level of that general order of magnitude) would not likely be avoided without other significant global actions. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions growth, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. Moreover, while NHTSA's action alone does not produce sufficient CO_2 emissions reductions, it is one of several federal programs, that, together, could make substantial contributions in averting levels of abrupt and severe climate change.

These conclusions are not meant to express the view that tipping points in climate-related systems are not areas of concern for policymakers. Addressing abrupt and severe climate-change tipping points (whatever they may be) requires a global effort, including CO_2-reduction initiatives beyond the scope of the current rulemaking. Due to the largely incomplete and unavailable state of information surrounding this issue, the only conclusion NHTSA can reach at this time is that the reduction in CO_2 emissions expected under this rulemaking to a limited degree will lower the risk of abrupt climate change. However, NHTSA recognizes the potential severity of the consequences and the desire for unified national and international action to avert the possible impacts associated with abrupt climate change. The EIS discussions of tipping points and abrupt climate change, thus, include discussions of potential impacts and possible severity of those impacts. See FEIS Section 4.5.9.2.

10.3.4 Other Potentially Affected Resource Areas

10.3.4.1 Safety and Other Human Health Impacts

Comments

Docket Number: 0042
Organization: Centers for Disease Control
Commenter: Andrew Dannenberg

Fleet Design Changes and Human Health:

As the DEIS acknowledges in Appendix D, we agree that vehicle and transportation safety is a common and legitimate public health concern. Decreasing vehicle fleet disparities in size and weight can act to decrease crash-related injury to those driving lighter-weight automobiles and trucks as well as other modes of transportation such as bicycles, motorcycles, and scooters. Changing CAFE Standards will affect fleet design and therefore have the potential to increase or decrease crash-related injury. For example, to comply with new CAFE Standards, size/weight disparities in the new fleet might increase, potentially leading to increased injury, or decrease, causing a potential reduction in crash-related injuries. To adequately promote and protect human health assuming shifts in the US automobile fleet make-up: Potential fleet design and composition by which vehicle manufacturers will comply with new CAFE Standards warrants further analysis. Modeling these projections is critical to an adequate analysis of the impact that new CAFE Standards will have on the human environment.

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Fuel Consumption Changes and Human Health:

Additional consideration of the effects of increasing demand and consumption of fossil fuel in an era of decreased availability on human health and well-being is needed. Decreasing the dependence, demand, and consumption of motor vehicle fuels in the United States may benefit mental health, reduce stress, and increase economic stability. These health determinants and/or direct health outcomes are critical elements of a stable society and should be considered as factors affected by CAFE Standards, Therefore:

The health-related consequences of concurrent factors, such as increasing demand and decreased availability of fossil fuels, ought to be included in the scope of analysis pursuant to NEPA.

Collaboration with public health professionals is suggested.

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

Other critics argue that the new CAFE standards will compromise safety because auto makers will be forced to make their vehicles smaller and lighter. Others counter that technology will again intervene to reduce the significance of this concern. Stronger, lighter materials are available that can reduce a car's weight while still increasing its overall ability to withstand impacts. In addition, today's new vehicles are much more maneuverable than in the past.

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

ESC, Side Air bags, and the introduction of the Crossover segment so changes the market and the safety aspects of the market as to moot the results of Kahane—parts of which are based on car and truck designs which are now almost 20 years old.

We find based on the IIHS 2007 "Driver Deaths" report that it is moderate sized SUVs which are most likely to roll over, not small cars. In any case the HUGE safety record disparities in similarly sized vehicles show that it is the quality of the engineering design NOT size which is the ultimate determinant of vehicle safety.

In fact, based on Kahane, we see no "safety" rationale for using wheelbase as a factor in the CAFE metric at all.

By not including ESC in the safety studies NHTSA forces consumers to pay for this degree of safety twice, once for the ESC which is not included in the safety studies, and secondly by requiring a larger footprint than would be required if the positive benefits of ESC had been properly accounted for. Same arguments goes for side air bags—NHTSA is making consumers pay for the same degree of safety "twice."

…Witness for example the wide variation in fatality rates within class. Also the cab design failure of a well-known pickup. Also consider all the well-known as-yet unresolved design issues and incompatibilities: Poor SSF, roof crush, sill height incompatibility, bumper height incompatibility, etc. We find it disingenuous that NHTSA blame MPG when so much unrelated regulatory improvements are possible!

We note that just the reduced air pollution fatalities due to reducing fuel consumption alone may offset the Kahane assumed fatalities due to potential downsizing. Even the excess highway deaths due to extreme weather events caused by global warming exceed the downsizing risks.

Given 1,300 million metric tons CO2 from LDVs. EIA estimates 31,000 million metric tons CO2 worldwide emissions. 150,000 global warming deaths a year (World Health Org.) Or about 6,300 global warming deaths a year can be attributed to US LDV GHG emissions—which is 10X as large as Kahane assumed risk of deaths due to downsizing. Kahane page 20 car to truck collisions cause 4X more fatalities in the car. This goes to the issue of "freedom of choice" and Environmental Justice where some vehicle choices are effectively denied to consumers due to risk of being crushed by a large truck. This is unacceptable, and NHTSA must work harder to reduce these car/truck incompatibilities—which in turn keep consumer from being able to choose smaller more fuel efficient vehicles.

Kahane's statistics DO NOT in fact show that large cars are safer than middle sized cars. What the statistics do show is that small cars are more dangerous.

Response

Several commenters raised concerns that NHTSA's proposed rule must appropriately take into account the impacts of setting CAFE standards on safety. In particular, one commenter suggested specific factors that NHTSA should take into account when considering safety. As outlined below, NHTSA has considered impacts to safety in analyzing the consequences of the agency's action. NHTSA believes that under any analysis of the potential downweighting associated with attribute-based standards, the overall *societal benefits of the Preferred Alternative CAFE standards far outweigh projected costs, supporting the reasonableness of the agency's Preferred Alternative.*

As explained in detail in the NPRM, NHTSA has long considered the potential for adverse safety consequences when establishing CAFE standards. See, e.g., 74 FR 49454, 49462. This practice is recognized approvingly in case law.[13] *Under the universal or "flat" CAFE standards that NHTSA was previously authorized to establish, the primary risk to safety came from the possibility that manufacturers would respond to higher standards by building smaller, less safe vehicles in order to "balance out" the larger, safer vehicles that the public generally preferred to buy. Under the attribute-based standards of the current rulemaking, that risk is reduced because building smaller vehicles tends to raise a manufacturer's overall CAFE obligation, rather than only raising its fleet average CAFE.*

In the 2002 congressionally-mandated report entitled "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards,"[14] *a committee of the National Academy of Sciences (NAS) ("2002 NAS Report") concluded that the then-existing form of passenger car and light truck CAFE standards permitted vehicle manufacturers to comply in part by downweighting and even downsizing their vehicles and that these actions had led to additional fatalities. The committee explained that this safety problem arose because, at that time, the CAFE standards subjected all passenger cars to the same fuel economy target and all light trucks to the same target, regardless of their weight, size, or load-carrying capacity.*[15] *The committee said that this experience suggests that consideration should be given to developing a new system of fuel economy targets that reflects differences in such vehicle attributes. Without a thoughtful restructuring of the program, there would be trade-offs that must be made if CAFE standards were increased by any significant amount.*[16]

As outlined in the NPRM, attribute-based standards reduce the incentive for manufacturers to respond to CAFE in ways harmful to safety.[17] *74 FR 49454, 49685. Because each vehicle model has its own target (based on the attribute chosen), attribute-based standards provide no incentive to build smaller vehicles simply to meet a fleet-wide average. Id. Since smaller vehicles are subject to more stringent fuel economy targets, a manufacturer's increasing its proportion of smaller vehicles would simply cause its compliance obligation to increase. Id.*

In response to the conclusions of the 2002 NAS Report, NHTSA issued attribute-based CAFE standards for light trucks and sought legislative authority to issue attribute-based CAFE standards for passenger cars. Congress went a step further in enacting EISA, not simply authorizing the issuance of attribute-based standards, but mandating them. See 49 U.S.C. § 32902(b)(3)(A) (requiring the agency to prescribe

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[13] *As the United States Court of Appeals pointed out in upholding NHTSA's exercise of judgment in setting the 1987-1989 passenger car standards, "NHTSA has always examined the safety consequences of the CAFE standards in its overall consideration of relevant factors since its earliest rulemaking under the CAFE program." Competitive Enterprise Institute v. NHTSA (CEI I), 901 F.2d 107, 120 at n.11 (D.C. Cir. 1990).*

[14] *National Research Council, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," National Academy Press, Washington, DC (2002). Available at http://www.nap.edu/openbook.php?isbn=0309076013 (last accessed August 9, 2009). The conference committee report for the Department of Transportation and Related Agencies Appropriations Act for FY 2001 (Pub. L. 106-346) directed NHTSA to fund a study by NAS to evaluate the effectiveness and impacts of CAFE standards (H. Rep. No. 106-940, p. 117-118). In response to the direction from Congress, NAS published this lengthy report.*

[15] *NHTSA formerly used this approach for CAFE standards. EISA prohibits its use after MY 2010.*

[16] *NAS, p. 9.*

[17] *The 2002 NAS Report described at length and quantified the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry. See NAS Report at 5, finding 12.*

fuel economy standards "based on 1 or more vehicle attributes related to fuel economy and express each standard in the form of a mathematical function").

In this joint rulemaking, NHTSA and EPA reconsidered the appropriate attribute for setting CAFE and CO_2 *standards, and concluded that footprint best provides the ability to address safety concerns without creating undue risk that program benefits will be lost to induced mix shifting. See 74 FR 49454, 49635. There are several policy reasons why NHTSA and EPA both believe that footprint is the most appropriate attribute on which to base the standards, as discussed below.*

As discussed in the NPRM, in NHTSA's judgment, it is important that the CAFE standards be set in a way that does not encourage manufacturers to respond by selling vehicles that are less safe. See 74 FR 49454, 49685. Footprint-based standards provide an incentive to use advanced lightweight materials and structures that would be discouraged by weight-based standards, because manufacturers can use them to improve a vehicle's fuel economy without necessarily causing a change in the vehicle's target level of fuel economy. Id.

Even under attribute-based standards, there is still concern that manufacturers might rely on downweighting to improve their fuel economy (for a given vehicle at a given footprint target) in ways that may reduce safety. NHTSA has reviewed recent research in this area, and has given full consideration to the comments on both the DEIS and the joint NPRM concerning safety, and will fully discuss its consideration of safety in the agencies' forthcoming joint NHTSA-EPA Final Rule. In sum, NHTSA believes that even taking the most pessimistic prediction of manufacturer downweighting (for a given vehicle at a given footprint target), the overall societal benefits of the Preferred Alternative CAFE standards far outweigh the projected costs, supporting the reasonableness of the agency's Preferred Alternative.

A commenter suggested that "[d]ecreasing the dependence, demand, and consumption of motor vehicle fuels in the United States may benefit mental health, reduce stress, and increase economic stability" and that therefore, "[t]he health-related consequences of . . . increasing demand and decreased availability of fossil fuels, ought to be included in the scope of analysis pursuant to NEPA." The Supreme Court has held that NEPA does not require an agency to consider potential mental health effects caused by risk related to the agency's actions. See Metropolitan Edison Company v. People Against Nuclear Energy, 460 U.S. 766, 778-79 (1983). This is because a mental health effect related to risk is "not an effect on the physical environment." Id. at 775.

NHTSA notes, however, that the cumulative impacts of this action include direct impacts on human health. As detailed in the FEIS in Section 4.5, the effects of the Preferred Alternative and other alternatives on climate – CO_2 *concentrations, temperature, precipitation, and sea-level rise—can translate to impacts to key natural and human resources. The Preferred Alternative and other alternatives result in different periods of* CO_2 *emissions associated with the operation of U.S. vehicles. These emissions, in combination with U.S. GHG emissions from other sources (power plants, natural gas use, and agricultural production) and with emissions of all GHGs globally, would alter atmospheric concentrations of GHGs. Different atmospheric concentrations of GHGs will be associated with long-term changes in global climate variables. These climate changes would result in changes to a range of natural and human resources and systems, including human health. Specifically, climate change has contributed to human mortality and morbidity, and could increase the risk of flooding; increase the incidence of heat waves; change the severity, duration, and location of extreme weather; increase surface temperature; and alter precipitation intensity and frequency. These events can affect human health either directly through temperature and weather or indirectly through changes in water, air, food quality, vector ecology, ecosystems, agriculture, industry, and settlements. For additional discussion, see FEIS Section 4.5.*

10.3.4.2 Environmental Justice

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

Choosing a footprint model which does not meaningfully discourage the sale of large trucks represents an environmental injustice because less wealthy Americans are more likely to own smaller cars which emit a smaller share of CO_2 pollution yet are more likely to be killed in a collision with the likely more wealthy owner of the large truck. Further, as Kahane discusses, the owner of the small car is more likely to be a female killed in a collision with a male driving a large truck, going to the issue of gender equity.

Mfgs "opting out" and just paying penalties goes to the issue of Environmental Justice since these are mostly luxury or premium sports car Mfgs. Thus wealthy Americans purchasing these vehicles are not doing their part towards protecting fellow Americans from the dangers of global warming. We suggest the "opt out" penalties need to be maximized in the interest of Environmental Justice. It is inappropriate that the wealthy owners of vehicles failing to meet CAFE standards strike and kill the less wealthy owners of small vehicles which did meet the CAFE standards!

We suggest that both the truck and car upper cutoff be set to a footprint equivalent to approx. 4000 lbs. and that the lower cutoffs be set equivalent to approx. 2000 lbs. To do otherwise belies the issue of Environmental Justice.

Response

Section 3.5.9 of this EIS discusses all reasonably foreseeable potential impacts to environmental justice populations, including those stemming from the consequences of global climate change. CEQ has provided guidance on how federal agencies should identify and address environmental justice concerns in a NEPA analysis.[18] That guidance describes environmental justice issues as "disproportionately high and adverse human health or environmental effects" of federal actions, programs or policies on minority populations and low-income populations. We believe the commenter misapplies the concept of environmental justice impacts to the agency's action. The purported relationship between small vehicles and lower-income populations described by the commenter is unsubstantiated. To the extent that such a relationship exists, however, it is not a causal effect of this rulemaking action. The setting of CAFE standards will not change the fact that vehicles of varying sizes and weights will be marketed to consumers. There is no evidence that this rulemaking will alter the purchasing preferences of consumers, including low-income populations.

Significantly, the commenter provided no studies that support the premise that environmental justice populations and women purchase smaller cars, and NHTSA is not aware of any data or studies that show that such populations are more likely than others to purchase or operate smaller vehicles. As a separate matter, NHTSA considered the potential safety concerns of making vehicles lighter (i.e., downweighting) in the NPRM (see Section IV.G.7).

The commenter suggests that NHTSA increase compliance penalties in the interest of environmental justice. Through EPCA, Congress has mandated a fairly prescriptive penalty system for non-compliance

[18] *See CEQ, Environmental Justice: Guidance Under the National Environmental Policy Act (1997), available at http://ceq.hss.doe.gov/nepa/regs/ej/justice.pdf (last accessed Jan. 19, 2009).*

with CAFE standards. See 49 U.S.C. § 32912. The penalty is standardized under the statute – $5.50 per tenth of an mpg by which a manufacturer misses the applicable standard, times the number of vehicles in the manufacturer's fleet that misses the standard – NHTSA does not have the option of "maximizing" penalties for manufacturers that choose to pay fines. EPCA does have a provision for prescribing a higher penalty than the standardized penalty, but that provision requires NHTSA to show that the increase in penalty "will result in, or substantially further, substantial energy conservation for automobiles in model years for which the increased penalty may be imposed," which is a specific and demanding requirement. 49 U.S.C. § 32912(c). NHTSA refers readers to Section IV of the NPRM for additional details on CAFE compliance and enforcement.

10.3.5 Unavoidable Impacts and Irreversible and Irretrievable Resource Commitment

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

"Unavoidable Adverse Impacts": We believe that Strong Hybrids, PHEVs and EVs - if NHTSA set stringency high enough to require them, reduce the UAI due to the reduced total running time of the combustion engine. Thus these adverse impacts are in fact "Avoidable."

"Commitment of Resources": Actually, NHTSA analysis would lead one to believe that Mfgs commitment of these resources leads to a much greater nationwide reduction in the consumption of resources.

Response

Pursuant to the CEQ regulations implementing NEPA, NHTSA has included a summary of the Unavoidable Adverse Impacts of this rulemaking in the Environmental Consequences section of the EIS, see Section 3.6.1. (40 CFR Section 1502.10). For all alternatives, these include energy consumption, GHG emissions, and the effects of climate change. NHTSA has concluded that these adverse impacts will occur as a result of either the Preferred Alternative or those that require higher mpg levels. We note that even if manufacturers produce greater numbers of vehicles that reduce running time of combustion engines, vehicle emissions and their impact on global climate change will continue.

As discussed in Section 3.6.3, Irreversible and Irretrievable Commitment of Resources, of the EIS, NHTSA cannot mandate or predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the eight action alternatives. Existing, advanced technologies and existing vehicle production facilities can be applied to meet the CAFE standards under the eight action alternatives. However, some vehicle manufacturers might commit additional resources to existing, redeveloped, or new production facilities. The specific amounts and types of irretrievable resources (such as electricity and other energy consumption) manufacturers might expend in meeting the CAFE standards depends on the specific methods and technologies manufacturers choose to implement. Commitment of resources for manufacturers to comply with the CAFE standards tends to be offset by the fuel savings from implementing the standards.

10.4 CUMULATIVE IMPACTS

10.4.1 Reasonably Foreseeable Future Actions

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

Furthermore, it is reasonably foreseeable that California will continue to extend regulations for greenhouse gas emissions from motor vehicles, and to implement more stringent standards beyond 2016. In fact, in late 2009, the California Air Resources Board initiated a rulemaking to develop such standards. However, NHTSA makes no attempt to consider the impact of these standards on approximately 40 percent of the U.S. light duty vehicle market. Likewise, NHTSA does not consider reasonably foreseeable actions to reduce growth in VMT, a goal that has been cited as a priority of many transportation policy experts and agencies. For example, California is currently undertaking rulemaking that would develop regional plans to curb urban sprawl and reduce VMTs, pursuant to the requirements of California's Global Warming Solutions Act (AB 32) and SB 375. In addition, NHTSA fails to consider the commitment by President Obama at the G8 summit this July to limit global warming to 2 degrees C above historic levels, a goal that will require drastic reductions in greenhouse gas emissions by the U.S. and others. Without comparative analysis, decision makers are without the tools necessary to assess the effect this rulemaking will have to accomplish this or any other alternative goal.

* * * * *

NHTSA failed to consider many reasonably foreseeable actions that would affect fuel efficiency standards and greenhouse gas emissions from the transportation sector.

A cumulative impact is defined under NEPA as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7. However, the DEIS fails to consider many reasonably foreseeable actions that are likely to affect greenhouse gas emissions, including actions by other agencies likely to affect greenhouse gas emissions from the transportation sector. These actions include continued regulation of greenhouse gases by California and the states, and policies to reduce vehicle miles traveled (VMT).

Docket Number: TRANS01
Organization: Sierra Club
Commenter: Ann Mensikoff

NHTSA fails to consider additional increases beyond 2016 aside from those nominal ones projected by AEO. It can foresee and models out massive VMT increases, changes in how many vehicles will be owned and what the fleet will look like. NHTSA should therefore have the capacity to model out reasonably foreseeable maximum feasible standards beyond 2016, beyond 2020, and into 2030, not prejudging what future standards that the agency will set but there has to be a way if you're going to go out to 2030, 50 and 2100 with certain assumptions about how many miles we're driving, you have to be able to then project what the fuel economy could be based upon the technology assessments that's fully within the agency's capacity.

Docket Number: TRANS02
Organization: Public Citizen
Commenter: Lena Pons

The range of alternatives does not consider all reasonably foreseeable actions. The National Environmental Policy Act states that NHTSA must consider reasonably foreseeable actions and their impacts. NHTSA has not considered all of the reasonably foreseeable actions, nor has it considered scenarios where other agencies regulate the other variables related to transportation emissions.

NHTSA has sensibly identified the problem that you cannot regulate greenhouse gas emissions for motor vehicles by regulating fuel economy alone. But the agency does not consider actions outside the jurisdiction as required by NEPA.

These actions that have not been considered include continued regulation of greenhouse gases by California and the states and policies to reduce vehicle miles traveled. It is reasonably foreseeable that California will continue to extend regulations for greenhouse gas emissions for motor vehicles and intend to do so for years beyond 2017.

NHTSA makes no attempt to consider the impacts of these standards for a substantial share of the U.S. light duty vehicle market. Likewise, it does not consider a reasonably foreseeable action to reduce the (inaudible) growth, something that has been cited as a priority of many transportation policy experts and agencies and was cited as necessary to contain the costs of maintaining surface transportation infrastructure by the National Surface Transportation Infrastructure and Funding Commission.

Response

Commenters requested that NHTSA consider: (1) the impact of actions by California and other U.S. states to regulate fuel economy beyond 2016 which commenters consider to be reasonably foreseeable; (2) the impact of actions by states and local governments to enact policies to reduce VMT growth; (3) scenarios where other agencies regulate variables related to transportation emissions; and (4) President Obama's commitment at the recent G8 summit.

Pursuant to CEQ NEPA regulations, cumulative effects are "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions." 40 CFR § 1508.7. Accordingly, under NHTSA's cumulative effects analysis the FEIS needs to account for future emissions-reduction strategies if they are reasonably foreseeable. Because California, other states and local governments have not established in law or regulation improvements in CO_2 emissions after 2016 or reductions in VMT growth, and other agencies have not established regulations related to transportation emissions, explicitly including these presumed actions would be uncertain in the context of NEPA. The uncertainty is compounded by the likelihood of litigation as was spawned by the initial California CO_2 regulations that other states adopted. However, the EIS does implicitly consider various combinations of emissions reductions strategies as reasonably foreseeable in the form of modeling different global emissions scenarios as discussed in Section 4.4.3.3.

Multilateral agreements and actions to limit global warming to 2 °C above historic levels are not concluded and therefore not reasonably foreseeable. The Congress has not yet taken any action to implement this commitment by the President, and has not yet established the regulatory structure or allocated the budget to do so. Therefore the timing of the impacts of this commitment is uncertain. In its analysis of cumulative impacts, NHTSA assumes a moderate level of global GHG reductions, resulting in a global atmospheric CO_2 concentration of roughly 650 ppm by 2100. See FEIS Section 4.4.3.3. NHTSA *believes that the regional, national, and international initiatives and programs established to reduce GHG emissions and/or energy use illustrate an existing and continuing trend of U.S. and global awareness, emphasis, and efforts toward significant GHG reductions. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA. Addressing climate change to limit global warming to 2 °C above historic levels would require much greater actions from the United States and the global community.*

In this rulemaking, NHTSA will establish CAFE standards through MY 2016; EPCA gives NHTSA authority to set CAFE standards for up to five model years at once. 49 U.S.C. § 32902(b)(3)(B). For MYs 2011-2020, EPCA requires that separate standards for passenger cars and for light trucks be set at levels high enough to ensure that the average fuel economy level of the industry-wide combined fleet of new passenger cars and light trucks reaches at least 35 mpg not later than MY 2020. 49 U.S.C. § 32902(b)(2)(A). NHTSA's analysis takes this into account as a reasonably foreseeable future action in the EIS's cumulative effects analysis. See FEIS Section 4.1.3. Beyond MY 2016, the agency's cumulative effects analysis uses the Annual Energy Outlook (AEO) fuel economy level forecasts through 2030 to estimate projected gains in fuel economy. Id. These projected gains are reasonably foreseeable because they are associated with future government actions as needed to achieve the EISA requirement of 35 mpg in 2020, and future consumer and industry actions that are projected to result in ongoing mpg gains through 2030. The AEO fuel economy projections are based on consumer demand and technology advances associated with ongoing projected increases in fuel price through 2030. The AEO reference case projections are regarded as the official U.S. Government energy projections by both the public and private sectors.

10.4.2 Climate Methodology

Comments

Docket Number: 0053.1
Organization: Center for Biological Diversity, Public Citizen, and the Sierra Club
Commenter: Brian Nowicki

The DEIS fails to consider the need to reduce atmospheric greenhouse gas concentrations to 350 ppm.

The DEIS refers to previous comments regarding the need to reduce atmospheric greenhouse gas concentrations to 350 ppm. "The CBD cited recent published reports that contend that it will be necessary to limit CO2 concentrations to 350 ppm to avoid climate catastrophe, CBD requested that a maximum 350 ppm scenario should be included as an upper limit for defining the range of alternatives. CBD suggests using the function in MAGGIC that controls future emissions so that atmospheric CO2 concentrations do not exceed values ranging from 350 to 750 ppm." DEIS at 1-15. However, the DEIS addresses this concern only once. "Hansen's more recent publications have suggested a target atmospheric CO2 concentration of 350 ppm (Hansen et al. 2008) – lower than the CO2-equivalent concentration, including the offsetting effects of aerosols, is today." DEIS at 4-167.

Recent scientific evidence indicates that to avoid tipping points and climate catastrophe, it will be necessary to reduce atmospheric CO2 concentrations to 350 ppm [citing Hansen et al., Target Atmospheric CO2: Where Should Humanity Aim? The Open Atmospheric Science Journal, 2008, 2, 217-231.]. This study uses the most comprehensive analysis to date of both slow and fast feedback loopson climate and reaches the conclusion that global CO2 concentrations must be capped and reduced to 350 ppm to avoid dangerous and irreversible climate change. Much of the data is based on paleoclimate records, as opposed to computer modeling. The study provides evidence of large changes in sea level on decadal time scales as well as past rates of sea level rise in excess of 1 m/century, correlated to global

CO2 concentration levels. Thus, a 350 ppm scenario to be reached over several alternative time intervals, along with a number of other CO2 concentration level alternatives, should be included as context for analysis of cumulative impacts. This analysis is entirely possible because MAGICC, the software used by the NHTSA to model the climate change impacts of each alternative, already includes various alternative scenarios in which future emissions are controlled so that atmospheric CO2 concentrations do not exceed values ranging from 350 to 750 ppm.

Response

As noted by the commenter, NHTSA disclosed in the DEIS that 350 ppm has been suggested as a target atmospheric CO_2 concentration. While it may be technically possible to model global emissions trajectories needed to reach 350 ppm, NHTSA believes this analysis would be inconsistent with a cumulative effects analysis required under NEPA because it would not put the projected emissions from NHTSA's proposal into the context of "reasonably foreseeable" future actions, as defined in the CEQ NEPA Regulations. See 40 CFR § 1508.7 and § 1508.8. NHTSA also believes that modeling this global emission trajectory for the cumulative effects analysis in the EIS would not help inform the public and decisionmakers of the differences among the alternatives. The differences in the climate change risks and impacts between alternatives are already disclosed in detail in the EIS, within a broad discussion of climate change.

The regulatory alternatives evaluated by NHTSA predict continued increases in GHG emissions from passenger cars and light trucks over time for each alternative because growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use (annual vehicle-miles traveled), is projected to result in growth in total passenger car and light truck travel. This growth in travel overwhelms improvements in fuel economy for each of the alternatives, resulting in projected increases in total fuel consumption by U.S. passenger cars and light trucks. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks. NHTSA estimates that the CAFE standards will reduce fuel consumption and CO_2 emissions from what they otherwise are estimated to be in the absence of the CAFE program.

Although NHTSA estimates that each of the alternative increases in CAFE standards analyzed in this EIS would reduce fuel consumption and CO_2 emissions from their levels under the No Action Alternative, the agency projects that the consumption of petroleum-based fuels and resulting CO_2 emissions by U.S. passenger cars and light trucks would continue to increase over the long-term future under even those action alternatives that would require the most rapid increases in CAFE standards. This result also reflects the fact that NHTSA's and EPA's models currently project that the U.S. light-duty vehicle fleet will continue to be powered primarily by fossil fuels through at least the next several decades.

Because the current global atmospheric CO_2 concentration is approximately 385 ppm[19] and there is considerable "momentum" inherent in the global climate system, however, reaching the 350 ppm concentration target would require reversing the current upward trend in GHG emissions and ending the continued reliance on conventional vehicle technologies and petroleum-based fuels that it reflects. Thus, achieving the 350 ppm target appears inconsistent with the assumptions in the agency's analysis (as well as in EIA's forecasts of future energy consumption) on reasonably foreseeable global energy use and fuel sources.

[19] National Oceanic & Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, http://www.esrl.noaa.gov/gmd/ccgg/trends/ (last accessed Dec. 28, 2009).

As a consequence, NHTSA has elected not to employ an emissions scenario that is consistent with achieving the 350 ppm concentration target in the modeling of climate impacts the agency conducted for this EIS. The agency's decision to not model the 350 ppm emissions scenario is not intended to convey a position regarding the prospects for achieving the 350 ppm concentration goal. However, for this rulemaking, the agency has concluded that the global emissions scenario that would achieve the 350 ppm target is inconsistent with the analyses of fuel use and GHG emissions conducted for each action alternative, and is thus beyond the scope of the GHG reduction programs identified in Section 4.4.3.3 as reasonably foreseeable.

The Model for Assessment of Greenhouse Gas-Induced Climate Change (MAGICC) is capable of running using various long-term global emissions scenarios which each represent different assumptions about key drivers of GHG emissions, e.g., population changes, economic growth, land and labor productivity growth, technological options, and resource endowments. Different scenarios represent various levels of implementation of global GHG emissions reduction policies. See FEIS Section 4.4.3.3; DEIS Section 4.4.3.3. While MAGICC 5.3 does include two scenarios of global emissions (the 350NFB and WRE350 scenarios[20]) where global concentrations would decrease and stabilize at 350 ppm, these scenarios do not, in fact, attain the 350 ppm stabilization target by 2100 (the endpoint of the EIS modeling analysis), but rather by about 2150 (WRE350) and 2200 (350NFB). Thus, to develop an analysis with the MAGICC model that would reduce concentrations to 350 ppm within the simulation period (i.e., by 2100), NHTSA would have to develop a new emission scenario that would not appear to disclose any additional information about the incremental impact of NHTSA's rule on the risks and impacts of climate change. Further, given NHTSA's reliance on peer-reviewed emission scenarios for the EIS, it would be inconsistent to develop new scenarios for this purpose. To do so would be outside the range of scenarios that have been used for previous climate change modeling, and outside the range of scenarios that are well accepted in the scientific community.

Finally, although 350 ppm has been discussed as a concentration target to avoid adverse impacts of climate change, several other concentration targets have been identified (e.g., 450 ppm; 550 ppm), and there is not widespread acceptance that 350 ppm is more appropriate than these other targets (or that concentration targets are more meaningful than increases in annual average global temperature or other measures). NHTSA's decision not to model the 350 ppm emissions scenario is not intended to convey a position regarding the 350 ppm concentration goal. However, for this rulemaking, the 350 ppm global emissions scenario would not be consistent with other assumptions used by NHTSA and EPA to project environmental impacts of NHTSA's and EPA's standards. Therefore, NHTSA does not believe it is reasonable or necessary to model the 350 ppm global emissions concentration scenario.

[20] *The 350NFB scenario is a 350 ppm atmospheric CO_2 concentration scenario with no climate feedbacks, as described by Tom Wigley (Wigley, T. 2004. Overshoot Pathways to CO_2 Concentration Stabilization. National Center for Atmospheric Research. Workshop on GHG Stabilization Scenarios. Tsukuba, Japan. Pgs. 37). The WRE350 scenario is a 350 ppm scenario that refers to the three authors who developed it – Wigley, Richels, and Edmonds (Wigley, T.M.L; R. Richels and J.A. Edmonds. 1996. Economic and Environmental Choices in the Stabilization of Atmospheric CO_2 Concentrations. Nature. Vol. 379. January 18. Pgs. 240-243).*

10.5 MITIGATION

Comments

Docket Number: 0098
Organization: New York Department of Transportation
Commenter: Stanley Gee

In light of the growing consensus to achieve this magnitude of carbon emissions reductions, NYSDOT recommends that NHTSA and EPA consider the contribution of the transportation sector to achieving progress to attain the "80 by 50" goal. As appropriate, the DEIS should be revised to discuss the mitigation strategies needed to offset the significant increases in future emissions.

Response

Pursuant to CEQ regulations, which require an EIS to discuss the "[m]eans to mitigate adverse environmental impacts," Chapter 5 of the EIS discusses mitigation measures for impacts related to NHTSA's action of setting CAFE standards. 40 CFR § 1502.16(h). As explained in Chapter 5, NEPA does not obligate an agency to adopt a mitigation plan. However, NEPA requires an agency to discuss measures that could be adopted. Chapter 5 accordingly discusses possible measures that could mitigate the effects of NHTSA's action. These include current and future actions that NHTSA or other federal agencies could take.

As the commenter implies, and as NHTSA explains throughout the EIS, annual passenger car and light truck GHG emissions will continue to increase regardless of what level NHTSA sets CAFE standards. NHTSA's setting of CAFE standards will reduce the rate at which these emissions will increase. See Figure 2.6-1. We agree with the commenter that mitigation of this sector's emissions is desirable. Emissions mitigation in this sector can only be discussed in the context of larger national emissions reductions policies and strategies. GHG emission reductions of the order of magnitude necessary to mitigate climate change will require concurrent efforts from many different international actors, from both the public and private sectors. For this reason, mitigation of global GHG emissions presents a unique set of challenges reaching far beyond this rulemaking. That said, in the light duty vehicle sector, some policies that could be explored to contribute towards this sector's GHG mitigation include expanding and improving mass transit, raising gas taxes or other driving-associated fees to deter VMT growth, and setting lower speed limits. NHTSA has supplemented the existing discussion by adding a discussion of these strategies in Chapter 5 of the EIS.

10.6 RULEMAKING

10.6.1 Alternative Fuel Credits

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

We suggest NHTSA ask Congress for authority that Alt Fuel Vehicles only get the credit when sold in states where at least one in three gas stations actually carry that Alt Fuel for sale to the general public.

* * * * *

We suggest that NHTSA and EPA should phase-out FFV benefits as quickly as possible, since recent scientific studies have found no environmental benefits for FFV - only rising food prices and environmental damage. Current FFV rules lack a rational basis.

Response

EPCA provides manufacturers an incentive under the CAFE program for production of duel-fueled or flexible-fuel vehicles (FFV) and dedicated alternative fuel vehicles by specifying that their fuel economy is determined using a special calculation procedure that results in those vehicles being assigned a higher fuel economy level than would otherwise occur. This is typically referred to as an FFV credit. See 74 FR 49454. However, as the commenter indicates, EPCA does not premise the availability of FFV credits on actual use of alternative fuel. Id. We recognize that under NHTSA's current EPCA authority, FFV credits are independent of actual use of alternative fuel, and that this potentially undermines the purpose of credits if a FFV uses less alternative fuel than anticipated – because alternative fueling stations are not available, or for other reasons. However, for this rulemaking, the agency must implement CAFE credits as Congress has directed. We note, that EISA amended EPCA to phase out FFV credits by MY 2019. 49 U.S.C. § 32906(a). The commenter's suggestion has been noted for consideration in future actions. For additional details on Flex-Fuel and Alternative Fuel Vehicle Credits, the agency refers readers to Sections I and IV of the NPRM.

10.6.2 Regulatory Compliance Penalties

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

Regulatory Compliance Penalties: We believe these penalties should be consistent with NHTSA estimates of the social costs of the fuel not saved - excluding the retail cost of the fuel itself- and that NHTSA should seek Congressional authority to set fines at this level.

Response

NHTSA's CAFE enforcement program and the compliance flexibilities available to manufacturers are largely established by statute, and EPCA and EISA are prescriptive. See 49 U.S.C. § 32912. In the event *that a manufacturer does not comply with a CAFE standard, even after the consideration of credits, EPCA provides for the assessment of civil penalties. The Act specifies a precise formula for determining the amount of civil penalties for such noncompliance. The penalty, as adjusted for inflation by law, is $5.50 for each tenth of an mpg that a manufacturer's average fuel economy falls short of the standard for a given model year multiplied by the total volume of those vehicles in the affected fleet (i.e., import or domestic passenger car, or light truck), manufactured for that model year. The amount of the penalty may not be reduced except under the unusual or extreme circumstances specified in the statute. For additional details of CAFE compliance and enforcement, the agency refers readers to Section IV of the NPRM.*

10.6.3 Vehicle Performance Characteristics

Comments

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

"Compromising Performance" is only a compromise to the extent that consumers WANT their "performance" measured on a "0 to 60" basis. To the extent consumers want their "performance" measured on an "MPG" basis then downsizing engines cost the Mfgs "Less than Nothing" - thus NHTSA standards based on an assumed "no change in performance" [meaning no change in "0 to 60"] are in fact being set too low - because at least some consumers measure "performance" on an MPG basis, not on a "0 to 60" basis.

Response

For purposes of this rulemaking and this FEIS, NHTSA refers to "performance" in this context as reductions in horsepower, torque, towing and hauling capacity, etc., and not as fuel economy performance, or how far the vehicle can go on a gallon of fuel. Thus, when NHTSA describes the agency's attempt to "hold performance constant" in the analysis of which technologies can feasibly be applied to vehicles in order to achieve compliance with the standards, NHTSA is referring to maintaining a performance-neutral position in the analysis, as the agency believes that manufacturers could meet the standards adopted as part of this rulemaking at the estimated compliance costs without noticeably affecting vehicle performance or utility. However, we do not require manufacturers to pursue the technology path that we model in our analysis as their way of achieving compliance with the standards – manufacturers are free to choose any technologies or technological solutions, some of which may include reducing "performance" as the agency defines it. For example, at the time of this rulemaking, the agency notes that some manufacturers have announced downsized engines for the U.S. market as a strategy to improve fuel economy in their model lineups. These pre-production announcements indicate that future, more advanced downsized engines will mostly maintain, or have slightly reduced, power output levels in comparison with the larger optional engines previously or concurrently offered by the manufacturer in the same vehicle.

Nevertheless, while NHTSA recognizes that there may be specific situations where performance reduction may be a cost-effective compliance strategy for certain manufacturers, the agency believes that the net cost of reducing performance must generally be comparable to or higher than that of technological approaches to fuel economy improvement. Thus the outcome of this rulemaking process is not significantly affected by omission of performance reduction as an explicit compliance strategy.

NHTSA continues to monitor the U.S. vehicle market sales and, specifically, the penetration of smaller displacement and/or reduced cylinder count engines. For future rulemakings, NHTSA may assess the market acceptance of downsized engines with potentially reduced performance yielding possible modification of the agency's modeling analysis along with other potential changes driven by the evolution of technology application and vehicle market mix.

10.6.4 Cost and Benefits of the Proposed Rule

Comments

Docket Number: 0050.1
Organization: Environmental Consultants of Michigan
Commenter:

The Agency incorrectly calculated the costs and benefits of their GHG rule. The Agency should have calculated the incremental cost above the cost of compliance with the NHTSA fuel economy standard and compared this with only the incremental benefits. The current EPA method double counts the benefits of the duplicative rule.

Response

The cost-benefit analyses are one of the important factors that the agencies consider when making a judgment as to the appropriate standards to propose. While EPCA neither requires nor precludes the use of any type of cost-benefit analysis as a tool to help inform the balancing process required to set maximum feasible fuel economy standards, considerations relating to costs and benefits remain an important part of CAFE standard setting. In drafting the joint proposal, both agencies considered the overall costs and benefits of their respective proposed standards in relation to a baseline scenario where the proposed standards are not in place. This method accounts for the incremental costs and benefits of the proposed standards alone if they were enacted. Had we summed the results of the separate NHTSA and EPA analyses, the claim that the method double counts the costs and benefits of the rule would be valid. However, this was not the case in the proposal, nor will it be the case in the final analysis. For additional details on each agency's method of calculating the associated costs and benefits of the joint rule, refer to Sections III and IV of the NPRM which discuss the EPA Proposal for Greenhouse Gas Vehicle Standards and NHTSA Proposal for Passenger Car and Light Truck CAFE Standards for MYs 2012–2016 respectively.

10.6.5 Vehicle Classification

Comments

Docket Number: 0046
Organization: Tennessee Department of Transportation
Commenter: Gerald Nicely

In the past, loopholes in fuel economy rules, such as allowing automakers to reclassify cars as "light trucks" to decrease fuel economy requirements and incorporating weight thresholds that allowed vehicles like the Hummer to evade fuel economy regulations, seriously weakened CAFE requirements. The current NHTSA proposal calls for strong new standards and closes certain loopholes that have long been used by the automobile industry. The final standards must guard against potential loopholes or other efforts to weaken the effectiveness of the program.

Docket Number: 0049
Organization: Individual
Commenter: James Adcock

Reformed CAFE DOES offer an advantage to Mfgs to upsize vehicles—specifically to jack up 4x4 station wagons in order to qualify them as "trucks."… In general we are concerned about gaming the car vs. truck designation in order to gain four years of regulatory leniency simply by increasing clearance height—while simultaneously increasing clearance height—while simultaneously increasing rollover fatalities by raising CG and thereby reducing SSF. Thus, in practice, NHTSA car vs. truck classification rules increase fatalities it does not reduce them.

We are concerned about the possibility of footprint "gaming" by adding wheel-well flares and/or 4 wheel rear axles on pickup trucks. We suggest that base model design—without flares nor 4 wheel read axles be used as the measure of track widths in these situations—and that mere name changes not be sufficient to determine a new model.

We suggest that to the extent possible by law "off-road capable" should be defined by an actual NHTSA off-road obstacle course.. Many of NHTSA's "off-road capable" vehicles have no nexus to off-roading. We believe Congress intended "off-road capable" to allow enthusiasts to drive their Jeeps on highway to the back country NOT to allow Mfgs to jack up station wagons and thereby receive an additional four year of regulatory leniency.

Luxury vehicles should be excluded from the "truck" classification because they are in practice being used as passenger vehicles not work vehicles.

We are concerned that "wide tire" performance options "gaming" will not in practice improve safety while actually decreasing MPG [while increasing measured track width.]

In general we believe EPA and NHTSA are offering way too many loopholes, credits, and footprint "gaming" opportunities to make for an effective regulation actually reducing fuel consumption.

Response

Commenters suggested that the standards do not reflect the fact that many light trucks are used as passenger vehicles. As NHTSA discussed in the joint NPRM, the fact that vehicles are used for personal transportation does not make them passenger vehicles for purposes of CAFE. This is because the statutory definition of "passenger automobile" is "an automobile that the Secretary decides by regulation is manufactured primarily for transporting not more than 10 individuals . . . ." 42 U.S.C. § 32901(a)(18). Notably, the statute does not employ the phrase "used primarily."

Under EPCA, NHTSA has the discretion to further define a "passenger automobile" for the purposes of setting CAFE standards based on particular vehicle characteristics (e.g., gross vehicle weight). 49 U.S.C. § 32901(a)(18). For additional information on this issue, NHTSA refers readers to the discussion in the 2012-2016 CAFE NPRM at 74 FR 49454, 49732-49734 (Sep. 28, 2009) and the discussion of EPCA's legislative history in the proposal and final rule establishing NHTSA's vehicle definition regulation. EPCA 501(2), 89 Stat. 901. 41 FR 55368, 55369-71 (Dec. 20, 1976); 42 FR 38362, 38365-67 (Jul. 28, 1977).

Starting with MY 2011 vehicles, NHTSA tightened its regulatory definition of "light truck" to ensure that vehicles are properly classified under the CFR Part 523 – Vehicle Classification. As defined under 49 CFR § 523.5(b), in order to be properly classifiable as a light truck, a two-wheel drive SUV must either *be over 6,000 lbs GVWR and meet 4 out of 5 ground clearance characteristics to make it off-highway capable, or it must meet one of the functional characteristics under § 523.5(a) (e.g., cargo carrying capacity that is greater than passenger carrying capacity). This amendment resulted in the reclassification of an average of 1,400,000 two-wheel drive SUVs from light trucks to passenger cars in each of the five model years covered by the standards. The result of this reclassification would be an average increase of 0.8 mpg in the combined passenger car and light truck standards over MYs 2012-2016, resulting in substantial fuel savings and reduction in CO_2 emissions during the useful life of vehicles sold during these model years. All of the alternatives and scenarios analyzed in this FEIS reflect this re-classification.*

One commenter suggested that manufacturers can "game" vehicle definitions. However, the current definitions are tighter than the commenter suggests. With regard to the commenter's argument that the standards allow manufacturers to "game" the definitions by making minor changes to vehicles to obtain a light truck classification and thus, a lower fuel economy target, NHTSA notes that fairly major changes would be required to redesign a vehicle classified as a passenger car so it is classified as a light truck. To make a two-wheel drive SUV a light truck, for example, manufacturers would need either to add a third row of seats, convert it to four-wheel drive, or raise its GVWR over 6,000 lbs and ensure that it meets the specified ground clearance requirements to be deemed off-road capable. See 49 CFR § 523.5(b). These changes are not minor, and likely can be made only every several years at the time of a periodic vehicle redesign. Additionally, the minor benefit to be gained by a manufacturer in terms of a lower target must be balanced against consumer demand.

With regard to the comment that the existing definitions do not ensure that "vehicles that more closely resemble large cars and station wagons" (which NHTSA takes to refer to crossovers) are classified as passenger cars, we note that as a result of the tightened implementation of our vehicle definitions, many crossovers are in fact now properly classified as passenger cars. To the extent that crossovers are not classified as passenger cars, it is, we believe, only because they either (1) have four-wheel drive and meet 4 out of 5 ground clearance characteristics; (2) are over 6,000 lbs GVWR and meet 4 out of 5 ground clearance characteristics; or (3) have three rows of seats, enabling the passenger-carrying capabilities normally associated with light trucks. In addition, NHTSA has sought comment in the 2012-2016 CAFE program NPRM regarding vehicle classification. NHTSA will be assessing this feedback in future rulemaking development. In conclusion, we believe that NHTSA's recent revisions to the vehicle classification regulations address the commenter's concern. See 49 CFR Part 523. NHTSA will continue to monitor the effectiveness of current vehicle classifications through CAFE compliance to ensure that manufacturer classification of vehicles occurs as NHTSA and Congress intended.