Draft Environmental Impact Statement

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

September 2009

National Highway Traffic
Safety Administration

NHTSA
www.nhtsa.gov

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

SEP 15 2009

1200 New Jersey Avenue SE.
Washington, DC 20590

In Reply Refer To:
Draft Environmental Impact Statement for
New Corporate Average Fuel Economy
Standards, Passenger Cars and Light Trucks,
MY 2012-2016
Docket No. NHTSA-2009-0059

TO THE PARTY ADDRESSED:

I am pleased to enclose for your review a copy of the National Highway Traffic Safety Administration's (NHTSA's) Draft Environmental Impact Statement (EIS) for new Corporate Average Fuel Economy (CAFE) standards required by the Energy Independence and Security Act of 2007 (EISA).

Concurrent with this DEIS, NHTSA and EPA are announcing a joint proposed rulemaking whose benefits would address the urgent and closely intertwined challenges of energy independence and security and global warming. *See* NHTSA-2009-0059. The joint proposal rulemaking is consistent with the National Fuel Efficiency Policy announced by President Obama on May 19, 2009. NHTSA is proposing Corporate Average Fuel Economy standards under the Energy Policy and Conservation Act, as amended, and EPA is proposing greenhouse gas emissions standards under the Clean Air Act. These standards apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles, covering model years 2012 through 2016. They require these 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 and represent a harmonized and consistent national program (National 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. The proposal can achieve substantial improvements in fuel economy and reductions of greenhouse gas (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.

In connection with NHTSA's proposed CAFE standards, NHTSA prepared the enclosed Draft EIS, which analyzes the environmental impact of the proposed standards for MY 2012-2016. I invite you to submit written comments on the Draft EIS using the instructions below. For your convenience, NHTSA's Draft EIS and the Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards are also available at: http://www.nhtsa.dot.gov/.

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 light trucks. *See* 49 United States Code (U.S.C.) § 32901 *et seq.* 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. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States.[1] NHTSA is delegated responsibility for implementing EPCA fuel economy requirements assigned to the Secretary of Transportation.[2]

In December 2007, the EISA[3] 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 MY 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking[4] (NPRM). On March 21, 2008, NHTSA issued a Notice of Intent to prepare an EIS for the MY 2011-2015 CAFE standards.[5] On October 10, 2008, NHTSA submitted to the EPA its Final Environmental Impact Statement, Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011–2015. EPA published a Notice of Availability of the Final EIS in the *Federal Register* on October 17, 2008.[6] On January 7, 2009, the Department of Transportation announced that the Bush Administration would not issue the final rule.[7]

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 Secretary of Transportation and the NHTSA Administrator.[8] The memorandum requested that NHTSA divide the MYs 2011-2015 rulemaking into two parts: (1) MY 2011 standards, and (2) standards for MY 2012 and beyond. In accordance with President Obama's memorandum, on March 30, 2009, NHTSA issued a final rule adopting CAFE standards for MY 2011.[9]

For MYs 2012 and beyond, the President requested that, before promulgating a final rule concerning the model years after model year 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.

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[1] 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 Code of Federal Regulations (CFR) §§ 1.50, 501.2(a) (8).
[2] Accordingly, the Secretary of Transportation, DOT, and NHTSA are used interchangeably in the Draft EIS.
[3] 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. EISA is Public Law 110-140, 121 Stat. 1492 (Dec. 19, 2007).
[4] 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).
[5] 73 *FR* 16615 (Mar. 28, 2008).
[6] 73 *FR* 38204 (Jul. 3, 2008).
[7] 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).
[8] Memorandum for the Secretary of Transportation and the Administrator of the National Highway Traffic Safety Administration, 74 *FR* 4907 (Jan. 26, 2009).
[9] 74 *FR* 14196 (Mar. 30, 2009).

On April 1, 2009, NHTSA published a NOI to prepare an EIS for the MY 2012-2016 CAFE standards. The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[10] by requesting public input on the scope of the environmental analysis to be conducted.[11]

Overview

The Draft EIS discusses the potential environmental impacts of the proposed standards and various alternative standards pursuant to the National Environmental Policy Act (NEPA), 42 U.S.C. §§ 4321-4347, and implementing regulations issued by the Council on Environmental Quality (CEQ) and the Department of Transportation. To inform decision makers and the public, the Draft EIS compares the environmental impacts of the agency's proposal and reasonable alternatives, including a "no action" alternative. The Draft EIS considers direct, indirect, and cumulative impacts and discusses impacts "in proportion to their significance."[12]

Among other potential impacts, NHTSA has analyzed the direct and indirect impacts related to fuel and energy use, emissions including carbon dioxide (CO_2) and its effects on temperature and climate change, air quality, natural resources, and the human environment. NHTSA also considered the cumulative impacts of the proposed standards for MY 2012-2016 automobiles together with estimated impacts of other reasonably foreseeable actions, as prescribed by the CEQ regulations and related CEQ guidance.[13]

In developing the proposed standards and possible alternatives, NHTSA considered the four EPCA factors underlying maximum feasibility (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy)[14] as well as relevant environmental and safety considerations. NHTSA also is guided by President Obama's memorandum to the DOT on January 26, 2009, as described in the Background.

Under the proposed standard for passenger cars, the required average fuel economy (in miles per gallon, or mpg) would range from 33.6 mpg in MY 2012 to 38.0 mpg in MY 2016. Under the proposed standard for light trucks, the required average fuel economy would range from 25.0 mpg in MY 2012 to 28.3 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 29.8 mpg in MY 2012 to 34.1 mpg in MY 2016.

Invitation to Comment

I invite your organization to submit written comments and to participate in a public hearing on the Draft EIS during the upcoming 45-day public comment period. In addition, please share this letter and the enclosed Draft EIS with interested parties within your organization. To ensure consideration, it is important that NHTSA receives your comments before the date specified below. All comments and

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[10] 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.

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

[12] 40 CFR § 1502.2.

[13] 40 CFR § 1508.7; *Guidance on the Consideration of Past Actions in Cumulative Effects Analysis* (June 24, 2005), *available at* http://www.nepa.gov/nepa/regs/guidance.html (last visited Aug. 5, 2009); *Considering Cumulative Effects Under the National Environmental Policy Act* (January 1997), *available at* http://www.nepa.gov/nepa/ccenepa/ccenepa.htm (last visited Aug. 5, 2009).

[14] *See* 49 U.S.C. § 32902(f).

materials received, including the names and addresses of the commenters who submit them, will become part of the administrative record and will be posted on the web at http://www.regulations.gov. Please carefully follow these instructions to ensure that your comments are received and properly recorded:

- **Send an original and two copies of your comments to**:

  Docket Management Facility, M-30
  U.S. Department of Transportation, West Building
  Ground Floor, Room W12-140
  1200 New Jersey Avenue, SE
  Washington, DC 20590

- Reference Docket No. **NHTSA-2009-0059**.

- **Mail your comments so that they will be received in Washington, DC on or before November 9, 2009.**

NHTSA encourages electronic filing of any comments. To submit comments electronically, go to http://www.regulations.gov and follow the online instructions for submitting comments by clicking on "Help" or "FAQ." **Comments submitted electronically must be submitted by November 9, 2009.**

Comments may also be submitted by fax at: 202-493-2251.

NHTSA also will hold a public hearing on the Draft EIS on Friday, October 30, 2009, at the National Transportation Safety Board Conference Center, 429 L'Enfant Plaza, SW, Washington, DC 20594. NHTSA will publish a *Federal Register* notice in the near future providing details on the public hearing and instructions for participating.

After the comments are reviewed, any significant new issues are investigated, and appropriate modifications are made to the Draft EIS, NHTSA will publish and distribute a Final EIS. The Final EIS will address timely comments received on the Draft EIS. Notices published in the *Federal Register* will announce the availability of NHTSA's NEPA documents concerning the proposed CAFE standards and opportunities for public participation throughout the NEPA process. NHTSA also plans to continue to post information about its environmental review for the new CAFE standards on its website (www.nhtsa.dot.gov).

The Draft EIS has been placed in the public files of NHTSA and is available for distribution and public inspection at:

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

A limited number of hardcopies and CD-ROMs of the Draft EIS are available from the DOT Library, identified above. This Draft EIS is also available for public viewing on the CAFE website at http://www.nhtsa.dot.gov. Copies of the Draft EIS have been mailed to parties on NHTSA's CAFE NEPA mailing list, including federal, state, and local agencies; Native American tribes, industry, and public interest groups; and individuals who requested a copy of the Draft EIS or provided comments during scoping.

Additional information about the project is available from NHTSA's Fuel Economy Division, Office of International Vehicle, Fuel Economy and Consumer Standards, at 1-202-366-0846 or on the NHTSA CAFE Internet Website identified above. For assistance, please contact NHTSA though 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 Internet Website also provides access to the texts of formal documents issued by the NHTSA, such as orders, notices, and rulemakings.

Thank you for your continued cooperation.

Sincerely yours,

Ronald L. Medford

Ronald L. Medford
Acting Deputy Administrator

DRAFT ENVIRONMENTAL IMPACT STATEMENT

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

SEPTEMBER 2009

LEAD AGENCY:
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

COOPERATING AGENCY:
U.S. ENVIRONMENTAL PROTECTION AGENCY

Table of Contents

List of Appendices

The appendices to this Draft Environmental Impact Statement (DEIS) have been provided electronically on the accompanying CD.

List of Tables

List of Figures

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
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
LDV	light-duty vehicle
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

S.1 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 year (MY) 2012-2016 Corporate Average Fuel Economy (CAFE) standards for the total fleet of passenger and non-passenger automobiles (later 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.

S.2 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. NHTSA is delegated responsibility for implementing the EPCA fuel economy requirements assigned to the Secretary of Transportation.[3]

In December 2007, the Energy Independence and Security Act of 2007 (EISA)[4] amended the EPCA CAFE Program requirements, providing DOT additional rulemaking authority and responsibilities. Pursuant to EISA, on April 22, 2008, NHTSA proposed CAFE standards for MY 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking (NPRM).[5] On March 28, 2008, NHTSA issued a Notice of Intent (NOI) to prepare an EIS for proposed MY 2011-2015 CAFE standards.[6] 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. EPA published a Notice of Availability of the Final Environmental Impact Statement (FEIS) in the *Federal Register* on October 17, 2008.[7] On January 7, 2009, the DOT announced that the

[1] NEPA is codified at 42 United States Code (U.S.C.) §§ 4321-4347. CEQ NEPA implementing regulations are codified at 40 Code of Federal Regulations (CFR) Parts 1500-1508. NHTSA NEPA implementing regulations are codified at 49 CFR Part 520.
[2] 49 U.S.C. § 32901-32919
[3] Accordingly, the Secretary of Transportation, DOT, and NHTSA are used interchangeably in this Summary.
[4] EISA amends and builds on EPCA 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).
[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] Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 *FR* 16615 (Mar. 28, 2008).
[7] Environmental Impact Statements; Notice of Availability, 73 *FR* 38204 (Jul. 3, 2008).

Bush Administration would not issue the final rule.[8] 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.[9] In accordance with President Obama's memorandum, on March 30, 2009, NHTSA issued a final rule adopting CAFE standards for MY 2011.[10] On April 1, 2009, NHTSA published an NOI to prepare an EIS for proposed MY 2012-2016 CAFE standards.[11] 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.[12]

On May 19, 2009 President Obama announced a National Fuel Efficiency Policy aimed at both increasing fuel economy and reducing greenhouse gas pollution 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 greenhouse gas emissions while preserving the legal authorities of the Department of Transportation, the Environmental Protection Agency and the State of California. The program covers model year 2012 to model year 2016 and ultimately requires the equivalent of an average fuel economy of 35.5 mpg in 2016, if all CO_2 reduction were achieved through fuel economy improvements. In conjunction with the President's announcement, the Department of Transportation and the Environmental Protection Agency issued on May 19, 2009, a Notice of Upcoming Joint Rulemaking to propose a strong and coordinated fuel economy and greenhouse gas National Program for Model Year (MY) 2012-2016 light duty vehicles.

Today, concurrent with this DEIS, NHTSA and EPA are each announcing joint proposed rules whose benefits would 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 and fuel economy program for passenger cars, light-duty-trucks, and medium-duty passenger vehicles (hereafter light-duty vehicles), referred to as the National Program. The proposed rules can achieve substantial improvements in fuel economy and reductions of greenhouse gas (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.

Consistent, harmonized, and streamlined requirements under the National Program hold out the promise of delivering 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 makes it possible for the standards of two different federal agencies and the standards of California and other states to act in a unified fashion in providing these benefits. Establishing a harmonized approach to regulating light-duty vehicle greenhouse gas (GHG) emissions and fuel economy is critically important given the interdependent goals of addressing climate change and ensuring energy independence and security. Additionally, establishing a harmonized approach may help to mitigate the cost to manufacturers of having to comply with multiple sets of federal and state standards

[8] The DOT January 7, 2008, statement can be found at: http://www.dot.gov/affairs/dot0109.htm (last accessed Jun. 9, 2009).
[9] Memorandum for the Secretary of Transportation and the Administrator of the National Highway Traffic Safety Administration, 74 *FR* 4907 (Jan. 26, 2009).
[10] Final Rule, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 *FR* 14196 (Mar. 30, 2009).
[11] *See* Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 74 *FR* 14857 (Apr. 1, 2009).
[12] 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.

Under NEPA, 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).[13] To inform its development of the new MY 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.

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.[14] 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 the NHTSA invitation and agreed to become a cooperating agency. EPA's environmental analysis of its proposed rulemaking is summarized and referenced in the appropriate sections of this EIS.[15]

S.3 PURPOSE AND NEED FOR THE PROPOSED ACTION

For this EIS, the NHTSA Proposed Action is to set passenger car and light truck CAFE standards for MY 2012-2016 in accordance with EPCA, as amended by EISA. As mentioned above, in the NHTSA-EPA joint NPRM, NHTSA and EPA propose coordinated and harmonized CAFE standards and vehicle GHG emissions standards for passenger cars, light-duty trucks, and medium-duty passenger vehicles built in MY 2012-2016. NEPA requires that a proposed action's alternatives be developed based on the action's purpose and need.

EPCA/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."[16] 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."[17] NHTSA interprets the statutory factors as including

[13] 42 U.S.C. § 4332.
[14] 40 CFR § 1501.6.
[15] Consistent with the National Fuel Efficiency Policy that the President announced 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 the EPA proposed rule on GHG emissions could be considered a "connected action" under the CEQ regulation at 40 CFR Section 1508.25. For purposes of this EIS, however, NHTSA has decided to treat the EPA 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 expressly exempts from NEPA requirements EPA action taken under the CAA. *See* 15 U.S.C. § 793(c)(1). The NHTSA discussion of the EPA 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.
[16] 49 U.S.C. § 32902(a).
[17] 49 U.S.C. § 32902(f).

environmental issues and permitting the consideration of other relevant societal issues, such as safety.[18] The purpose of this EIS is to analyze and disclose the potential environmental impacts of the standards and alternatives for consideration by NHTSA decisionmakers.

EPCA/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."[19] 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 5 model years.[20] NHTSA also is guided by President Obama's memorandum to DOT on January 26, 2009, as described in Section S.2 and Chapter 1.

S.4 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 factors NHTSA must consider in determining maximum feasible CAFE levels – technological feasibility, economic practicability, the need to conserve energy, and the effect of other standards of the Government on fuel economy – form the purpose of and need for the MY 2012-2016 CAFE standards and, therefore, inform the range of alternatives for consideration in this NEPA analysis. The NHTSA decision process balances the four EPCA factors and must also be informed by the environmental considerations of NEPA. In developing its reasonable range of alternatives, NHTSA identified alternative stringencies that represent the full spectrum of potential environmental impacts and safety considerations. This EIS analyzes the impacts of eight "action" alternatives and the impacts that would be expected if NHTSA imposed no new requirements (the No Action Alternative).

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.[21] 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 abide by, assuming NHTSA does not issue a rule. NHTSA is also proposing to consider 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.

[18] *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).
[19] 49 U.S.C. § 32902(b)(2)(A).
[20] 49 U.S.C. §§ 32902(b)(2)(C), 32902(b)(3)(B).
[21] 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).

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 average annual increases in mpg of 3 percent to 7 percent from 2012 to 2016. Because the percentage increases in stringency are "average" increases, they can be constant throughout the period or can vary from year to year.

NHTSA also added three alternatives to the list of alternatives first proposed in the NOI to prepare an EIS – 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 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 under EPCA, based on balancing statutory and other relevant considerations. *See* Section S.3. 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, the discount rate, and rebound effect). For further discussion of the economic assumptions, *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. The 6-percent Alternative results in required mpg in 2016 that is slightly higher than 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. 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.

Table S-1 shows the required fuel economy levels for each alternative. 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, *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-2 shows the estimated[22] achieved fuel economy levels for each alternative. Comparing Table S-2 with Table S-1 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. Achieved combined mpg would equal required combined mpg under Alternative 2.

[22] As discussed above, the CAFE level required under an attribute-based standard depends on the mix of vehicles produced for sale in the U .S. 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.

Table S-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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
2012									
Passenger Cars	30.5	31.5	32.1	33.6	32.7	33.4	33.0	33.3	33.8
Light Trucks	24.3	24.3	24.3	25.0	24.4	26.4	24.6	24.8	26.7
Combined	27.9	28.4	28.7	29.8	29.0	30.4	29.2	29.5	30.8
2013									
Passenger Cars	30.5	32.9	33.6	34.4	34.2	36.0	34.9	35.5	36.7
Light Trucks	24.2	24.5	25.0	25.6	25.5	27.7	26.0	26.5	28.0
Combined	27.9	29.3	29.9	30.6	30.4	32.5	31.0	31.6	33.0
2014									
Passenger Cars	30.5	33.8	34.8	35.2	35.8	38.1	36.9	37.9	39.0
Light Trucks	24.2	25.2	26.0	26.2	26.7	28.8	27.5	28.3	29.2
Combined	27.9	30.2	31.0	31.4	31.9	34.2	32.9	33.8	34.8
2015									
Passenger Cars	30.5	34.7	36.1	36.4	37.5	39.5	38.9	40.4	40.8
Light Trucks	24.1	25.9	26.9	27.1	28.0	30.1	29.0	30.1	30.9
Combined	28.0	31.1	32.3	32.6	33.5	35.6	34.8	36.2	36.8
2016									
Passenger Cars	30.5	35.6	37.4	38.0	39.3	40.9	41.1	43.1	42.7
Light Trucks	24.1	26.6	27.9	28.3	29.3	30.6	30.7	32.2	31.5
Combined	28.0	32.0	33.6	34.1	35.2	36.8	36.9	38.7	38.1

Table S-2

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
2012									
Passenger Cars	32.4	32.7	33.0	33.3	33.2	33.5	33.4	33.5	33.7
Light Trucks	24.2	24.5	24.7	25.0	24.8	25.5	24.9	25.1	25.5
Combined	28.6	29.0	29.2	29.5	29.3	29.9	29.5	29.7	30.0
2013									
Passenger Cars	32.4	34.0	34.5	34.9	35.1	36.0	35.7	36.1	36.3
Light Trucks	24.3	25.0	25.5	25.9	25.9	27.2	26.3	26.7	27.3
Combined	28.7	29.9	30.4	30.9	30.9	32.1	31.5	31.8	32.3
2014									
Passenger Cars	32.4	34.6	35.5	35.9	36.5	37.8	37.4	38.0	38.2
Light Trucks	24.2	25.5	26.3	26.7	27.1	28.6	27.8	28.3	28.8
Combined	28.8	30.5	31.5	31.8	32.3	33.8	33.2	33.7	34.1
2015									
Passenger Cars	32.5	35.2	36.5	36.8	37.5	39.1	38.8	39.4	39.6
Light Trucks	24.1	26.0	27.1	27.4	28.2	29.7	29.2	29.9	30.1
Combined	28.9	31.3	32.5	32.8	33.6	35.1	34.7	35.4	35.6
2016									
Passenger Cars	32.5	36.0	37.5	37.9	39.1	40.4	40.5	41.4	41.4
Light Trucks	24.2	26.5	27.7	28.1	29.0	30.3	30.3	31.0	30.8
Combined	29.0	32.0	33.4	33.8	34.9	36.2	36.2	37.1	37.0

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 comply fully with passenger car or light truck standards under some alternatives. 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]

S.5 POTENTIAL ENVIRONMENTAL CONSEQUENCES

This EIS describes potential environmental impacts to a variety of resources. Resources that the proposed action and alternative could affect include water resources, biological resources, land use and development, safety, hazardous materials and regulated wastes, noise, socioeconomics, and environmental justice. NHTSA assesses these resource areas qualitatively.[26] This section focuses on the resources for which NHTSA performed a quantitative assessment – energy, air quality, and climate.

Tables and figures in this section summarize the direct, indirect, and cumulative effects of the alternatives on energy, air quality, and climate. NHTSA recognizes the national interest in addressing global climate change issues and the role that transportation plays. "Global climate change" refers to long-term fluctuations in global surface temperatures, precipitation, sea level, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen by an average of about 0.74 degree Celsius (°C) (1.3 degrees Fahrenheit [°F]) 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.

Most scientists now agree that climate change is very likely due to GHG emissions from human activities. Most GHGs are naturally occurring, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone. 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.

[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.

[26] *See* 42 United States Code (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).

Levels of atmospheric CO_2 have been rising rapidly. For about 10,000 years prior to the Industrial Revolution, atmospheric CO_2 levels were 280 parts per million (ppm) (+/- 20 ppm). Since the Industrial Revolution, CO_2 levels have risen to 386 ppm (+/- 20 ppm) in 2008.

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 comprise about 15 to 20 percent of total global emissions. The U.S. transportation sector contributed 35.7 percent of total U.S. CO_2 emissions in 2007, with passenger cars and light trucks accounting for 60.8 percent of total U.S. CO_2 emissions from transportation. Thus, 21.7 percent of total U.S. CO_2 emissions comes 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 3.7 percent of global CO_2 emissions.

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 proposed 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. This EIS frequently cites these sources and the studies they review.

Because of the link between the transportation sector and GHG emissions, NHTSA recognizes the need to consider possible impacts on climate and global climate change in the analysis of the effects of these fuel economy standards. NHTSA also recognizes the difficulties and uncertainties involved in such an impacts analysis. Accordingly, consistent with CEQ regulations on addressing incomplete or unavailable information in environmental impact analyses, NHTSA has reviewed existing credible scientific evidence relevant to this analysis and summarized it in this EIS. NHTSA has also employed and summarized the results of research models generally accepted in the scientific community.

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 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 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 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.

The proposed action before NHTSA is to establish the CAFE standards for MY 2012-2016 passenger cars and light trucks, which has a primary goal of energy conservation. At the same time, the reduction of CO_2 emissions is a substantial by-product of that conservation. Further, the stringency of fuel economy standards is based on the valuation of both direct (fuel savings) and indirect (*e.g.*, the reduction of CO_2 emissions) benefits. To the extent the CAFE standards reduce fuel consumption, they play a role in reducing vehicle emissions that would have occurred absent such conservation.

Consequently, as discussed in this EIS, the proposed action will indirectly contribute to reducing impacts on and associated with the ongoing process of global climate change.

Although the alternatives have the potential to decrease GHG emissions substantially, they do not prevent climate change, but only result in reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level. They would also, to a small degree, reduce the impacts and risks of climate change. As discussed below, NHTSA presumes that these reductions in climate effects will be reflected in reduced impacts on affected resources.

NHTSA informed the public through notice in the *Federal Register* of its intent to prepare a EIS for this proposed action.[27] The purpose of this notice was to request from the public its views and comments on the scope of the NEPA analysis, including the impacts and alternatives the EIS should address, and to inform NHTSA of any available studies that would assist in the impact analysis for global climate-change issues. NHTSA reviewed and considered the public scoping comments and the studies commenters suggested. The predominant request by commenters during the scoping process was that NHTSA focus the EIS on the possible impact of the standards on both air quality and global climate change.

NHTSA consulted with various federal agencies in the development of this EIS, including EPA, the Bureau of Land Management, the Centers for Disease Control and Prevention, the Minerals Management Service, the National Park Service, the U.S. Army Corps of Engineers, the U.S. Forest Service, and the Advisory Council on Historic Preservation. NHTSA is also exploring its Section 7 obligations under the Endangered Species Act with the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration Fisheries Service.

S.5.1 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 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 S.5.1.1 through S.5.1.3 summarize the direct and indirect effects of the proposed action and alternatives on energy, air quality, and climate.

S.5.1.1 Energy

Tables S-3 and S-4 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 S-3 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 (Alternative 1) is 173.5 billion gallons in 2060. Fuel consumption ranges from 156.1 billion gallons under Alternative 2 (3-Percent Alternative) to 139.7 billion gallons under Alternative 9 (TCTB). Fuel consumption is 150.9 billion gallons under the Preferred Alternative (Alternative 4).

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

Table S-3

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.4	65.7	64.3	63.9	63.0	61.8	61.9	61.2	61.1
2030	97.9	89.5	86.4	85.5	83.5	81.0	80.9	79.4	79.4
2040	121.7	110.9	106.9	105.9	103.2	100.1	99.9	98.0	98.1
2050	145.7	132.8	128.0	126.7	123.5	119.8	119.6	117.3	117.3
2060	173.5	158.2	152.4	150.9	147.1	142.7	142.4	139.7	139.7
Fuel Savings Compared to No Action									
2020	--	3.7	5.1	5.5	6.4	7.6	7.6	8.2	8.3
2030	--	8.4	11.5	12.3	14.4	16.8	17.0	18.4	18.4
2040	--	10.8	14.8	15.9	18.5	21.6	21.8	23.7	23.7
2050	--	12.9	17.7	19.0	22.2	25.9	26.2	28.4	28.4
2060	--	15.4	21.1	22.6	26.5	30.9	31.2	33.9	33.8

Table S-4

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.6	66.4	65.2	64.9	64.2	63.0	63.3	62.7	62.6
2030	66.0	61.6	59.6	59.0	57.6	55.8	55.9	55.0	55.1
2040	73.0	67.4	64.9	64.2	62.4	60.3	60.3	59.1	59.3
2050	85.5	78.7	75.7	74.8	72.7	70.2	70.1	68.7	69.0
2060	101.4	93.3	89.7	88.7	86.1	83.1	83.1	81.3	81.7
Fuel Savings Compared to No Action									
2020	--	2.3	3.4	3.8	4.4	5.6	5.3	5.9	6.0
2030	--	4.4	6.4	7.0	8.3	10.1	10.0	11.0	10.9
2040	--	5.6	8.1	8.8	10.6	12.8	12.7	14.0	13.7
2050	--	6.8	9.8	10.7	12.8	15.4	15.4	16.9	16.5
2060	--	8.1	11.7	12.7	15.3	18.3	18.4	20.1	19.7

For light trucks, fuel consumption under the No Action Alternative is 101.4 billion gallons in 2060. Fuel consumption ranges from 93.3 billion gallons under Alternative 2 to 81.3 billion gallons under Alternative 8 (7-percent annual increase in mpg). Fuel consumption is 88.7 billion gallons under the Preferred Alternative.

S.5.1.2 Air Quality

Table S-5 summarizes the total annual national criteria and mobile source air toxic (MSAT) 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 (Alternative 1) and Alternatives 2 through 4 (3-Percent, 4-Percent, and Preferred Alternatives) are generally smaller than those between the No Action Alternative and Alternatives 5 through 9. In the case of particulate matter with an aerodynamic diameter equal to or less than 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. Across Alternatives 4 through 9 (MNB, 6-Percent, 7-Percent, TCTB Alternatives) 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 carbon monoxide (CO), emissions under Alternatives 2 through 4 are slightly higher than under the No Action Alternative. Emissions of CO decline as fuel economy standards increase across Alternatives 5 through 9.

Table S-5

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Criteria Pollutant Emissions									
Carbon monoxide (CO)	17,766,186	17,875,841	17,857,900	17,830,426	17,374,361	16,933,532	16,692,592	16,584,083	16,544,125
Nitrogen oxides (NO_x)	1,467,596	1,453,694	1,445,588	1,443,013	1,416,117	1,390,714	1,379,863	1,370,822	1,368,895
Particulate matter ($PM_{2.5}$)	76,589	74,147	73,316	73,321	73,122	73,349	73,725	73,362	73,382
Sulfur oxides (SO_x)	201,502	186,242	180,661	179,415	178,313	176,493	178,441	176,043	176,396
Volatile organic compounds (VOCs)	1,668,085	1,596,544	1,564,323	1,553,482	1,514,436	1,469,438	1,456,616	1,439,159	1,438,649
Toxic Air Pollutant Emissions									
Acetaldehyde	6,631	6,665	6,683	6,678	6,710	6,721	6,733	6,748	6,751
Acrolein	342	345	348	351	366	385	393	398	399
Benzene	27,706	27,667	27,602	27,551	27,171	26,758	26,569	26,466	26,440
1,3-butadiene	3,610	3,631	3,637	3,638	3,615	3,597	3,584	3,581	3,579
Diesel particulate matter (DPM)	106,046	97,820	94,519	93,731	91,502	89,134	89,055	87,536	87,606
Formaldehyde	8,875	8,884	8,927	8,938	9,198	9,440	9,573	9,652	9,672

The trend for toxic air pollutant emissions across the alternatives is mixed. Annual emissions of acetaldehyde in 2030 are lowest under Alternative 1, increase with each successive alternative (except for Alternative 4), and are highest under Alternative 9. Annual emissions of acrolein and formaldehyde increase under each successive alternative from Alternative 1 to Alternative 9. Annual emissions of benzene and DPM decrease under each successive alternative from Alternative 1 to Alternative 9. Annual emissions of 1,3-butadiene increase under each successive alternative from Alternative 1 to Alternative 4, and then decrease under each successive alternative from Alternative 5 to Alternative 9 in 2030.

The reductions in emissions are expected to lead to reductions in adverse health effects. Table S-6 summarizes the national annual 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 through 9 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.

Table S-6

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Mortality (ages 30 and older), Pope *et al.*									
2030	0	-153	-210	-217	-253	-276	-267	-296	-296
Mortality (ages 30 and older), Laden *et al.*									
2030	0	-392	-537	-554	-648	-705	-683	-758	-758
Chronic bronchitis									
2030	0	-100	-138	-142	-167	-182	-177	-196	-196
Emergency Room Visits for Asthma									
2030	0	-140	-191	-198	-226	-244	-233	-258	-258
Work Loss Days									
2030	0	-18,031	-24,750	-25,522	-30,036	-32,758	-31,811	-35,301	-35,306

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 S-7 lists the corresponding reductions in annual health costs in 2030 under Alternatives 2 through 9 compared to the No Action Alternative. Reductions in health costs are given for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health costs.

Table S-7

Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
3% Discount Rate									
Pope *et al.*									
2030	0	-1,361	-1,867	-1,926	-2,253	-2,452	-2,374	-2,635	-2,634
Laden *et al.*									
2030	0	-3,334	-4,574	-4,720	-5,520	-6,007	-5,816	-6,454	-6,451
7% Discount Rate									
Pope *et al.*									
2030	0	-1,234	-1,693	-1,747	-2,044	-2,224	-2,154	-2,390	-2,389
Laden *et al.*									
2030	0	-3,012	-4,131	-4,264	-4,987	-5,426	-5,254	-5,830	-5,827

a/ Negative changes indicate economic benefit; positive changes indicate economic costs.
b/ Changes in outcome under 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.

S.5.1.3 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 CAFE standard. NHTSA used the publicly available modeling software, Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) version 5.3.v2 to estimate changes in key direct and indirect effects. The application of MAGICC 5.3.v2 uses the emissions estimates for CO_2, CH_4, N_2O, CO, NO_x, SO_2, and VOCs from the Volpe model. NHTSA performed a sensitivity analysis to examine the relationship among selected CAFE alternatives and likely climate sensitivities,[28] and the associated direct and indirect effects for each combination. These relationships can be used to infer the effect of emissions associated with the action alternatives on direct and indirect climate effects.

For the analysis using MAGICC, NHTSA assumed that global emissions consistent with the No Action Alternative (Alternative 1) follow the trajectory provided by the Representative Concentration Pathway (RCP) 4.5 MiniCAM (Mini Climate Assessment Model) reference scenario.[29] The Synthesis and Assessment Product (SAP) 2.1 global emissions scenarios were 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) developed more than a decade ago.

The results rely primarily on the RCP 4.5 MiniCAM reference scenario to represent an emissions scenario; that is, future global emissions assuming no additional climate policy. Each alternative was simulated by calculating the difference in annual GHG emissions in relation to the No Action Alternative and subtracting this change from the RCP 4.5 MiniCAM reference scenario to generate modified global-scale emissions scenarios, which each show the effect of the various regulatory alternatives on the global emissions path.

To estimate changes in global precipitation, this EIS uses increases in global mean surface temperature combined with a scaling approach and coefficients from the IPCC Fourth Assessment Report.

For all of the climate change analyses, 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. The climate sensitivity analysis provides a basis for determining climate responses to varying climate sensitivities under the No Action Alternative and the Preferred Alternative (Alternative 4). Although 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.

[28] 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.

[29] The reference scenario for global emissions assumes the absence of significant global GHG control policies. 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 emissions estimates for non-CO_2 gases.

S.5.1.3.1 GHG Emissions

Table S-8 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), the effect of the alternatives is to slow this increase by varying amounts. Emissions for the period range from 201,200 million metric tons of CO_2 ($MMTCO_2$) under the 7%/year Increase (Alternative 8) to 243,600 $MMTCO_2$ under the No Action Alternative. Compared to the No Action Alternative, projections of emissions reductions over the period 2012 to 2100 due to the MY 2012-2016 CAFE standards range from 19,300 to 42,400 $MMTCO_2$. 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 0.8 percent.

Table S-8

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

Alternative	Emissions	Emissions Reductions Compared to the No Action Alternative
1 No Action	243,600	0
2 3%/year Increase	224,300	19,300
3 4%/year Increase	216,700	26,900
4 ~4.3%/year Increase, Preferred	214,700	29,000
5 5%/year Increase	210,100	33,500
6 ~5.9%/year Increase, MNB	204,500	39,100
7 6%/year Increase	204,800	38,800
8 7%/year Increase	201,200	42,400
9 ~6.7%/year Increase, TCTB	201,500	42,100

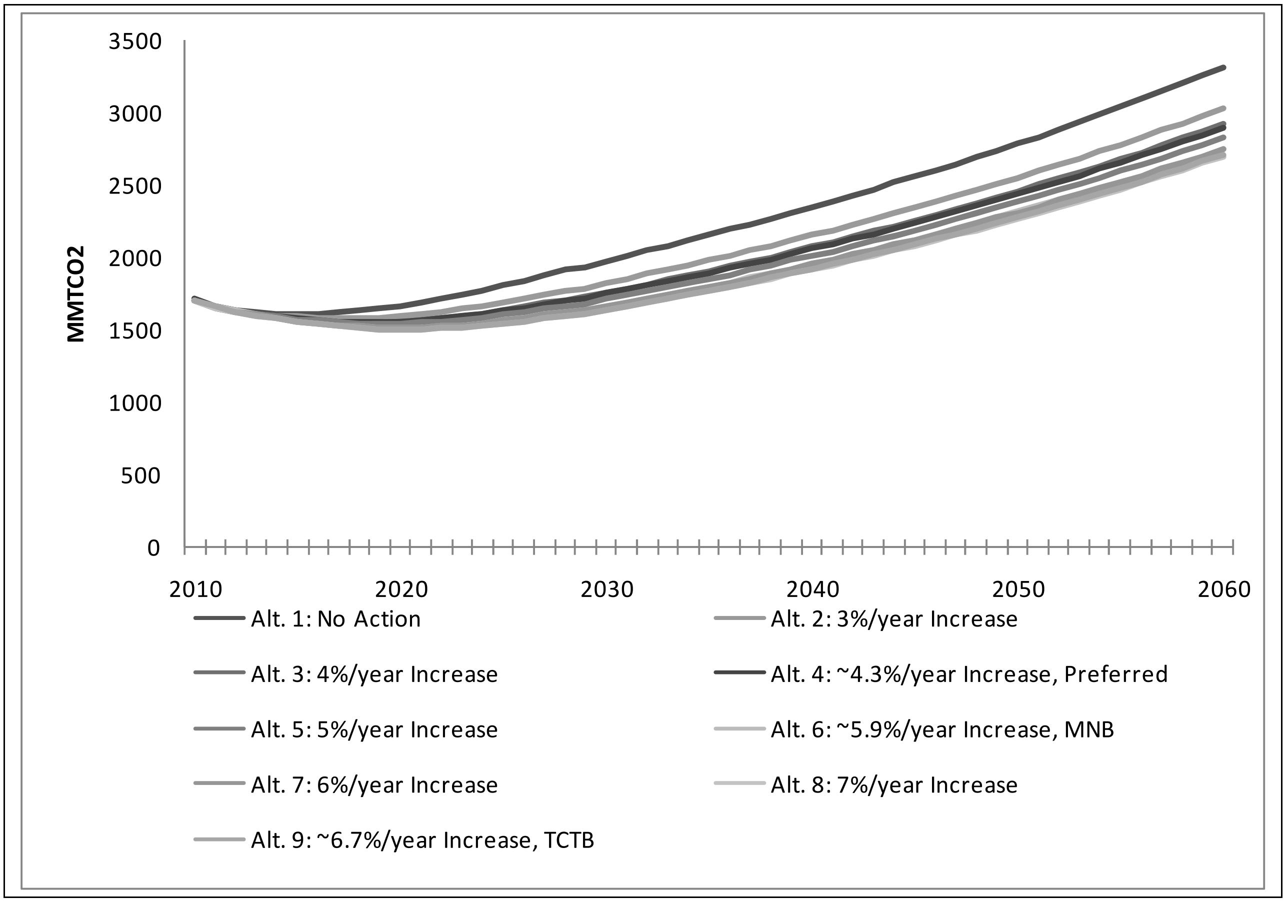
To get a sense of the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from passenger cars and light trucks as a whole and to compare them against emissions projections from the transportation sector. As mentioned earlier, U.S. passenger cars and light trucks account for significant CO_2 emissions in the United States. With the action alternatives reducing U.S. passenger car and light truck CO_2 emissions by 7.9 to 17.4 percent, 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 3.6 to 7.8 percent in 2100. As another comparison of the magnitude of these reductions, average annual CO_2 emission reductions from the CAFE alternatives range from 217 to 476 $MMTCO_2$ over 2012-2100, equivalent to the annual CO_2 emissions of 47 to 103 coal-fired power plants.[30] Figure S-1 shows projected annual emissions from passenger cars and light trucks under the MY 2012-2016 alternative CAFE standards.

As explained above, 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

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

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.

Figure S-1. Projected Annual Emissions (MMTCO₂) by Alternative



Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger car and light truck fleets represented about 3.7 percent of total global emissions of CO_2 in 2005. However, 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).

S.5.1.3.2 CO_2 Concentration, Global Mean Surface Temperature, Sea-level Rise, and Precipitation

Table S-9 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 S-2 through S-5 graphically illustrate estimated CO_2 concentrations and reductions for the eight action alternatives.

Table S-9 lists the impacts on sea-level rise under the alternatives and shows sea-level rise in 2100 ranging from 38.00 centimeters (15.00 inches) under the No Action Alternative to 37.86 centimeters (14.9 inches) under the TCTB Alternative. Thus, the CAFE action alternatives will result in a maximum reduction of sea level rise equal to 0.14 centimeters (0.10 inch) by 2100 under the No Action Alternative (i.e., from the levels that sea level is otherwise projected to rise).

Estimated CO_2 concentrations for 2100 range from 779.0 ppm under the most stringent alternative (TCTB) 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 described 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. Under the No Action Alternative, the temperature increase from 1990 is 0.92 °C (1.7 °F) for 2030, 1.56 °C (2.8 °F) for 2050, and 3.14 °C (3.1 °F) for 2100. The differences among alternatives are small, as shown in Figures S-2 through S-5. For 2100, the reduction in temperature increase, in relation to the No Action Alternative, ranges from 0.007 °C (0.01 °F) to 0.015 °C (0.03 °F).

Table S-9

CO_2 Concentration, 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	781.2	0.922	1.554	3.129	8.38	15.16	37.94
3 4%/year Increase	441.6	514.1	780.4	0.922	1.553	3.126	8.38	15.15	37.92
4 ~4.3%/year Increase, Preferred	441.5	514.0	780.3	0.922	1.553	3.125	8.38	15.15	37.91
5 5%/year Increase	441.5	513.9	779.8	0.922	1.553	3.124	8.38	15.15	37.89
6 ~5.9%/year Increase, MNB	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
7 6%/year Increase	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
8 7%/year Increase	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86
9 ~6.7%/year Increase, TCTB	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86
Reductions under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.5	1.8	0.001	0.002	0.007	0.00	0.01	0.06
3 4%/year Increase	0.2	0.7	2.6	0.001	0.003	0.010	0.00	0.02	0.08
4 ~4.3%/year Increase, Preferred	0.3	0.8	2.7	0.001	0.004	0.010	0.00	0.02	0.09
5 5%/year Increase	0.3	0.9	3.2	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
7 6%/year Increase	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
8 7%/year Increase	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14

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 S-2. CO_2 Concentrations (ppm)

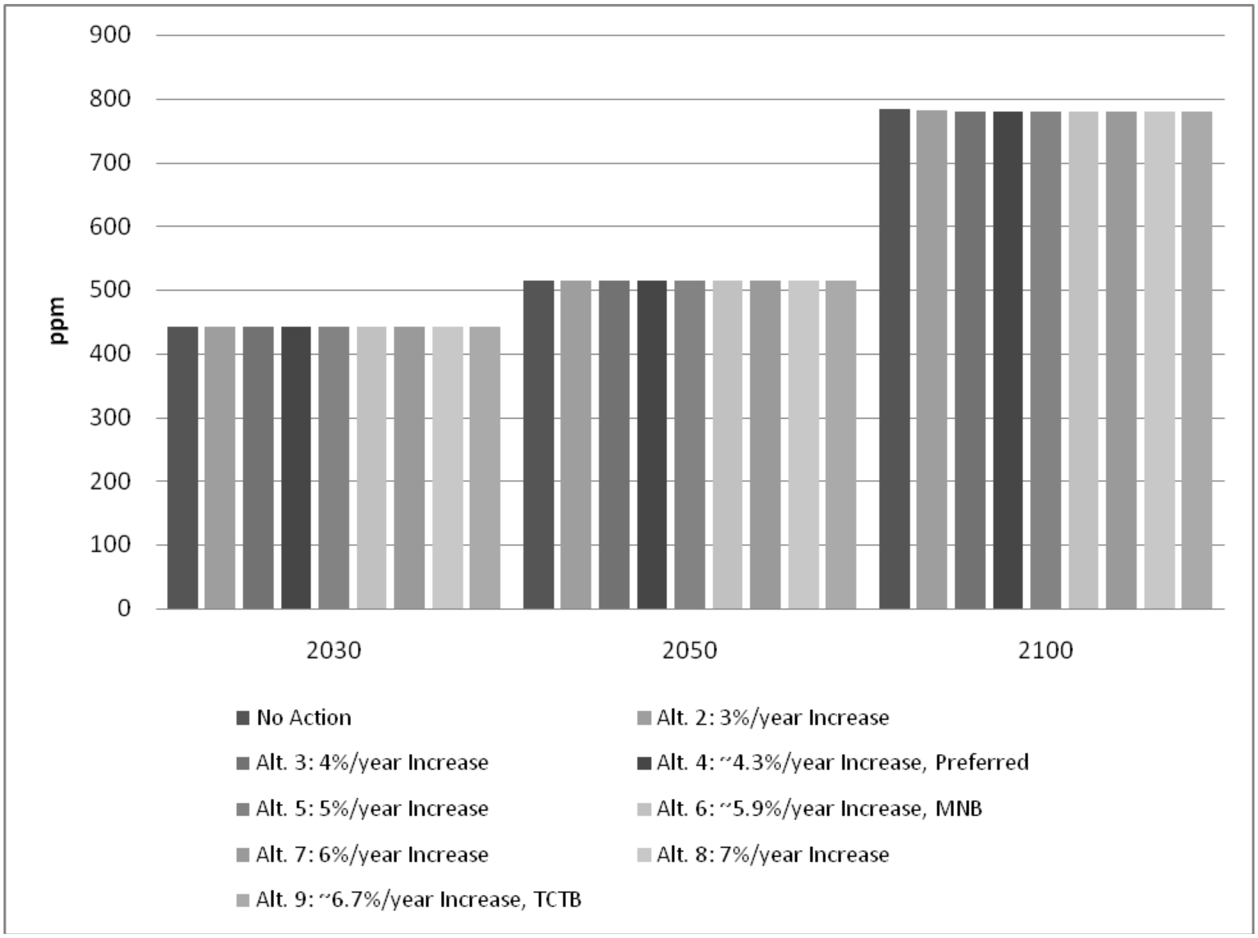


Figure S-3. Global Mean Surface Temperature Increase (°C)

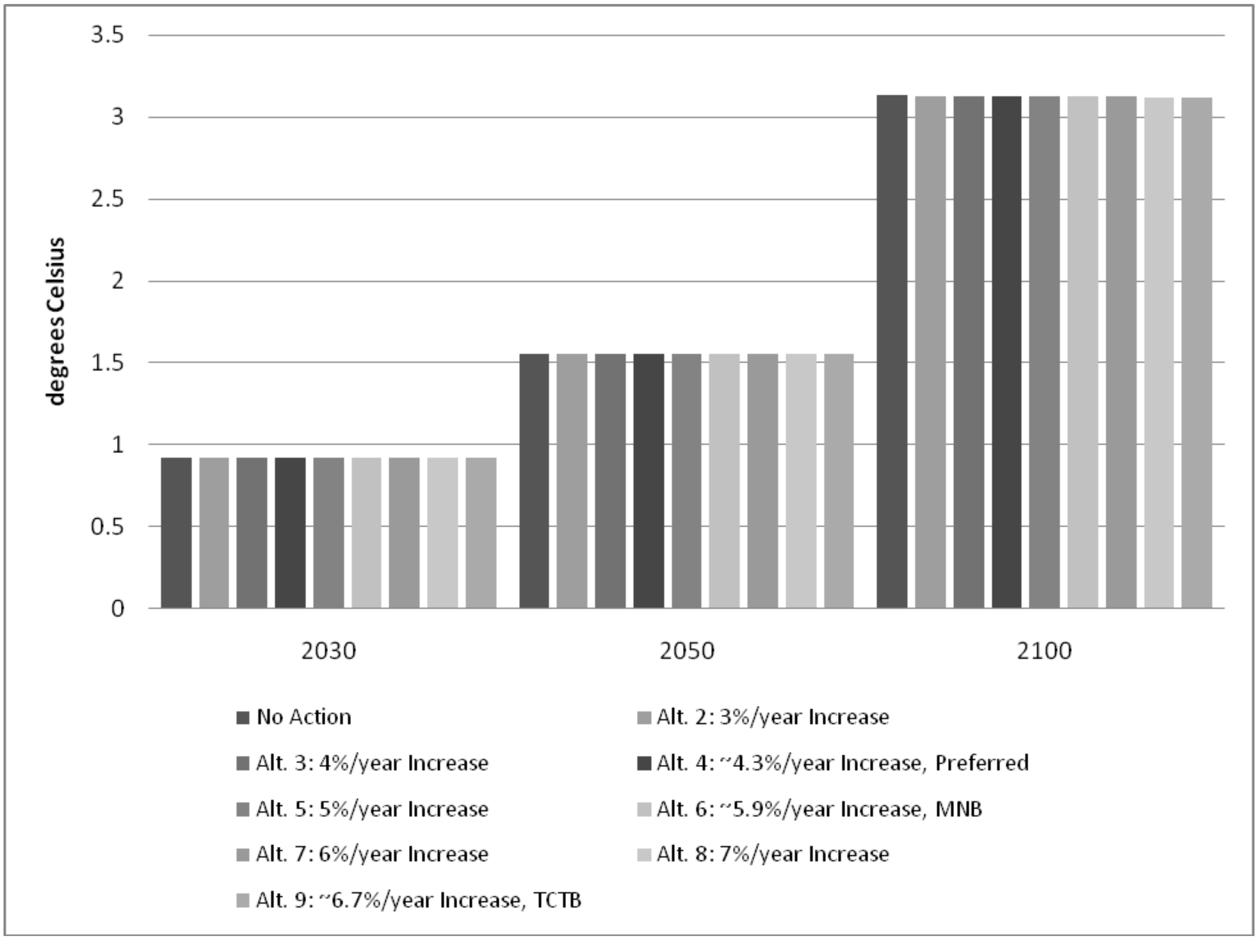


Figure S-4. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

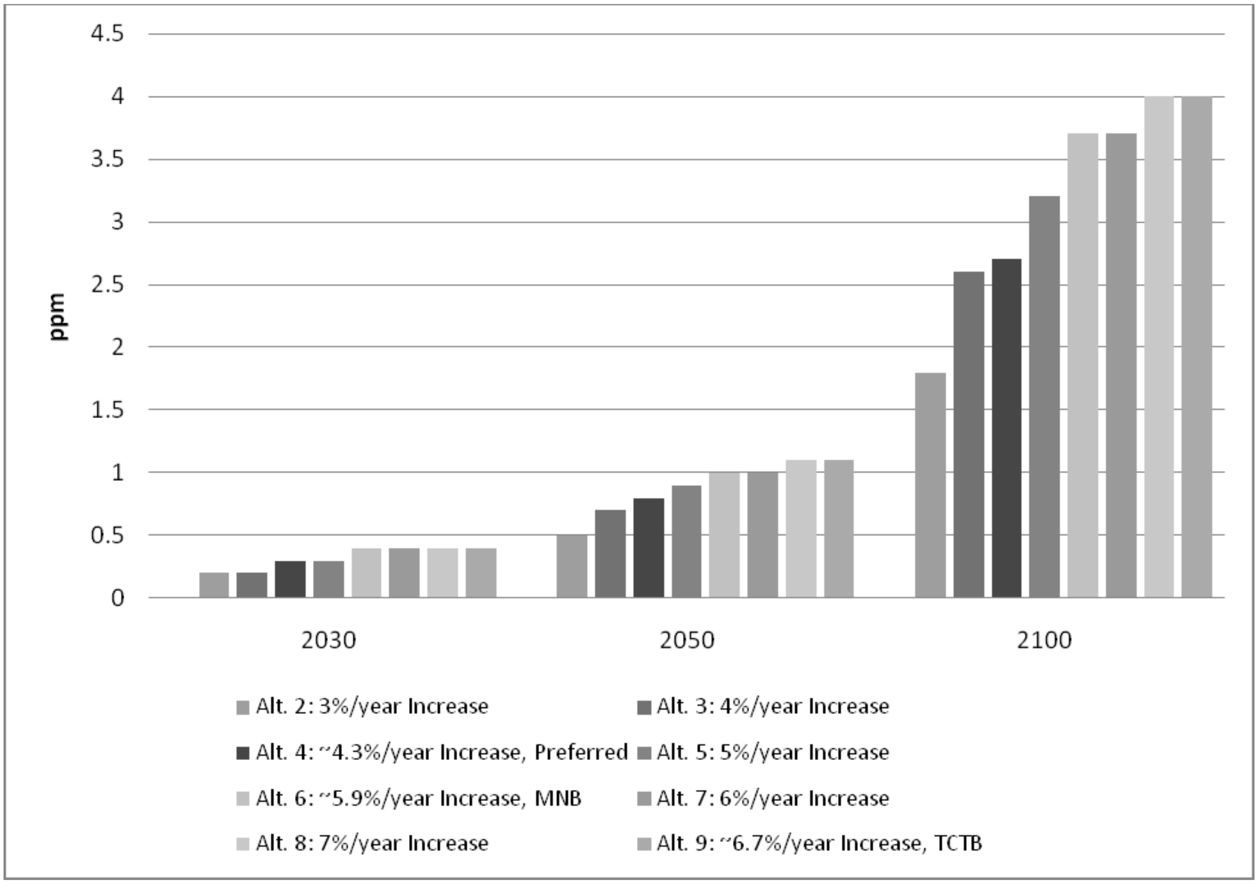


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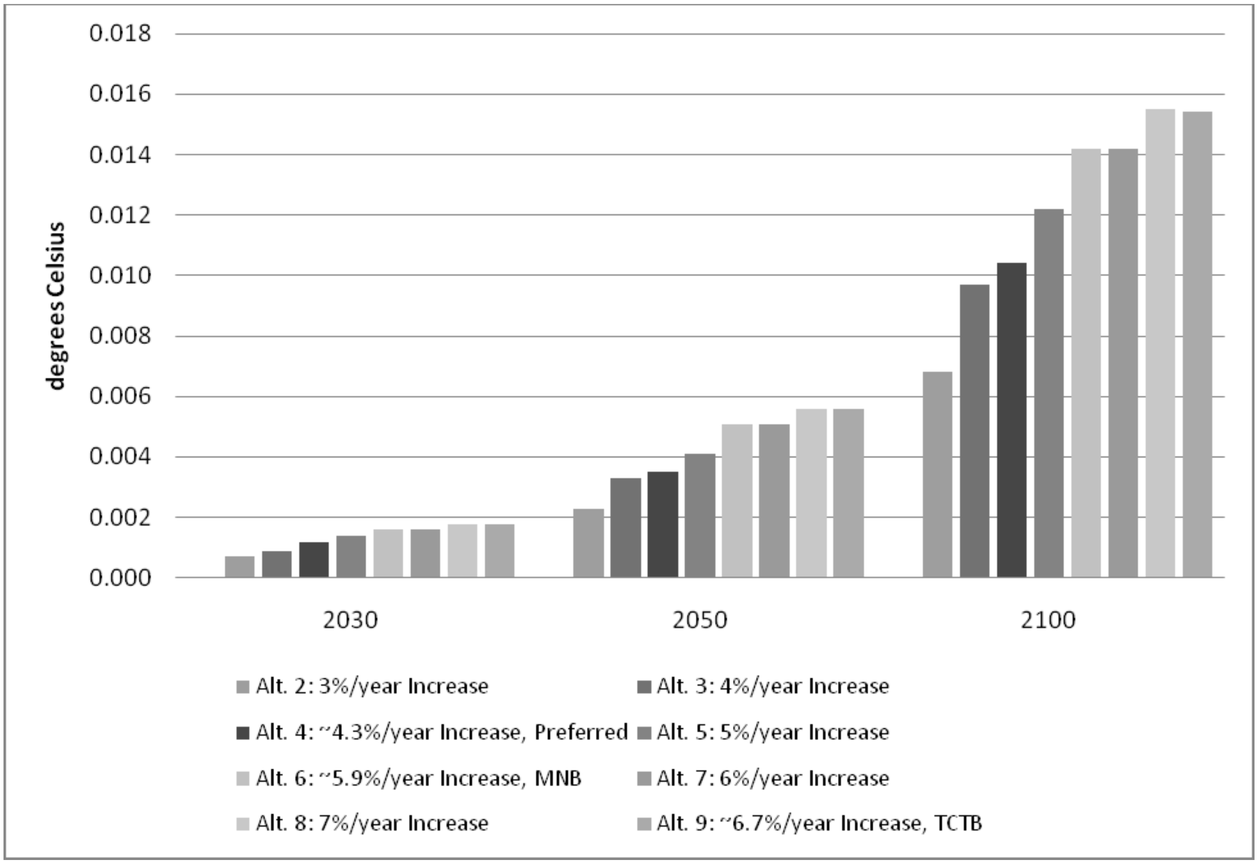
Figure S-5. Reduction in Global Mean Temperature Compared to the No Action Alternative



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 S-10.

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.[31] 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 (3.6, 5.4, and 8.1 °F) for a doubling of CO_2 concentrations in the atmosphere. NHTSA performed the sensitivity analysis for only two CAFE alternatives because this was deemed sufficient to assess the effect of various climate sensitivities on the results.

[31] 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 S-10

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	2.810
3 4%/year Increase	0.648	1.712	2.807
4 ~4.3%/year Increase, Preferred	0.648	1.712	2.807
5 5%/year Increase	0.648	1.711	2.805
6 ~5.9%/year Increase, MNB	0.648	1.710	2.803
7 6%/year Increase	0.648	1.710	2.803
8 7%/year Increase	0.648	1.709	2.802
9 ~6.7%/year Increase, TCTB	0.648	1.709	2.802
Reduction in Global Temperature (ºC) for Alternative CAFE Standards, Mid-level Results (Compared to the 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	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.007	0.014
9 ~6.7%/year Increase, TCTB	0.000	0.007	0.014
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%	2.59%	4.58%
4 ~4.3%/year Increase, Preferred	0.94%	2.58%	4.57%
5 5%/year Increase	0.94%	2.58%	4.57%
6 ~5.9%/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%	4.57%
9 ~6.7%/year Increase, TCTB	0.94%	2.58%	4.57%
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to the No Action Alternative)			
2 3%/year Increase	0.00%	0.00%	0.01%
3 4%/year Increase	0.00%	0.01%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.01%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

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.

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 S-11, 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 2.7 to 2.8 ppm.

Table S-11

CO_2 Concentration, Temperature, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives a/

CAFE Alternative	Climate Sensitivity (°C for 2 × CO_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	510.0	762.4	0.698	1.166	2.284	28.61
	3.0	441.5	514.0	780.3	0.922	1.553	3.125	37.91
	4.5	443.3	518.7	802.5	1.166	1.987	4.119	48.55
Reduction compared to No Action								
	2.0	0.3	0.7	2.7	0.001	0.003	0.008	0.07
	3.0	0.3	0.8	2.7	0.001	0.004	0.010	0.09
	4.5	0.3	0.8	2.8	0.001	0.004	0.013	0.12

a/ Values in this table are rounded.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, as also shown in Table S-11. In 2030, the impact is low, due primarily to the slow rate at which global mean surface temperature increases in response to increases in radiative forcing.[32] 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 0.008 °C (0.014 °F) for the 2.0 °C (3.6 °F) climate sensitivity to 0.013 °C (0.02 °F) for the 4.5 °C (8.1 °F) 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 S-11. 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 under the Preferred Alternative compared to the No Action Alternative.

[32] As defined by the IPCC, "radiative forcing" is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered. Positive forcing tends to warm the surface while negative forcing tends to cool it.

S.5.2 Cumulative Effects

CEQ identifies the impacts federal agencies must address and consider to satisfy NEPA requirements. These include permanent, temporary, direct, indirect, and cumulative impacts. CEQ regulations 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. Sections S.5.2.1 through S.5.2.3 describe the cumulative effects of the proposed action and alternatives on energy, air quality, and climate.

The methodology for evaluating cumulative effects includes the reasonably foreseeable projected average annual passenger car and light truck mpg estimates from 2016 through 2030 that differ from mpg estimates reflected in the Chapter 3 analysis, as described in Section S.5.1. The Chapter 3 analysis reflects the direct and indirect impacts of MY 2012-2016 fuel economy requirements under each of the action alternatives, assuming no further increases in average new passenger car or light truck mpg after 2016. The Chapter 4 evaluation of cumulative effects projects 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, along with *Annual Energy Outlook* (AEO) April 2009 (updated) Reference Case projections of annual percentage gains of 0.51 percent in passenger-car mpg and 0.86 percent in light-truck mpg through 2030.[33] Both the public and private sectors regard AEO Reference Case projections as the official U.S. Government energy projections.

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 (3-Percent, 4-Percent, and Preferred Alternatives) 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 and indirect impacts in Chapter 3 when comparing cumulative impacts among Alternatives 4 through 9 (Preferred, 5-Percent, MNB, 6-Percent, 7-Percent, and TCTB Alternatives), but not when comparing cumulative impacts among Alternatives 2 through 4.

Another important difference in the methodology for evaluating cumulative effects is that the No Action Alternative also reflects the AEO Reference Case projected annual percentage gains of 0.51 percent in passenger car mpg and 0.86 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. The No Action Alternative assumes there is no action under the National Program, 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 manufacturers' required level of average fuel economy for MY 2011. The No Action Alternative, by definition, would not satisfy the EPCA requirement to set standards such that the passenger car and light truck fleet achieves a combined average fuel economy of at least 35 mpg for MY 2020 (nor would it satisfy the

[33] NHTSA considers these AEO projected mpg increases to be reasonably foreseeable future actions 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. Because the AEO forecasts do not extend beyond the year 2030, the mpg estimates for MY 2030 through MY 2060 remain constant.

EPCA requirement to adopt annual fuel economy standard increases).[34] The revised No Action Alternative in Chapter 4 is consistent with the concept of a No Action Alternative, because the projected annual percentage gains of 0.51 percent in passenger car mpg and 0.86 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 GHG emissions, such as regional, national, and international initiatives and programs to reduce GHG emissions. For a more detailed description of these initiatives, *see* Section S.5.2.3.

S.5.2.1 Energy

The nine alternatives evaluated 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 GHGs and criteria air pollutants. Table S-12 lists the cumulative annual fuel consumption and fuel savings of passenger cars from the onset of the proposed new CAFE standards. By 2060, annual fuel consumption reaches 162.8 billion gallons under the No Action Alternative (Alternative 1). Consumption falls across the alternatives, from 140.7 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 131.3 billion gallons under the TCTB Alternative (Alternative 9), representing an annual fuel savings of 22.1 to 31.5 billion gallons in 2060 compared to fuel consumption projected under the No Action Alternative.

Table S-13 lists the cumulative annual fuel consumption and fuel savings for light trucks from the onset of the proposed new CAFE standards. Fuel consumption by 2060 reaches 91.2 billion gallons per year under the No Action Alternative. Consumption declines across the alternatives, from 80.1 billion gallons per year under the 3-Percent Alternative to 73.3 billion gallons per year under Alternative8. This represents an annual fuel savings of 11.1 to 17.9 billion gallons in 2060 compared to fuel consumption projected under the No Action Alternative.

[34] 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.

Table S-12

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.1	64.7	63.8	63.6	62.8	61.6	61.6	61.0	60.9
2030	94.5	82.6	82.2	82.3	80.7	78.3	78.2	76.8	76.8
2040	114.7	99.1	99.1	99.3	97.3	94.5	94.2	92.5	92.5
2050	136.7	118.1	118.2	118.4	116.0	112.6	112.4	110.3	110.3
2060	162.8	140.7	140.7	141.0	138.2	134.1	133.8	131.3	131.3
Fuel Savings Compared to No Action									
2020	0	4.4	5.3	5.6	6.3	7.5	7.5	8.1	8.2
2030	0	11.9	12.2	12.2	13.8	16.2	16.3	17.7	17.7
2040	0	15.6	15.5	15.4	17.3	20.2	20.4	22.2	22.2
2050	0	18.6	18.5	18.3	20.7	24.1	24.4	26.5	26.4
2060	0	22.1	22.1	21.8	24.6	28.7	29.0	31.5	31.5

Table S-13

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.3	65.6	64.9	64.6	64.0	62.8	63.1	62.5	62.4
2030	62.8	56.8	56.5	56.3	55.0	53.3	53.4	52.5	52.6
2040	66.7	58.9	58.9	58.7	57.1	55.2	55.2	54.1	54.3
2050	77.1	67.8	67.8	67.6	65.7	63.4	63.4	62.1	62.4
2060	91.2	80.1	80.1	79.9	77.6	74.9	74.9	73.3	73.7
Fuel Savings Compared to No Action									
2020	0	2.7	3.4	3.7	4.4	5.6	5.3	5.8	5.9
2030	0	6.0	6.3	6.6	7.8	9.5	9.4	10.3	10.2
2040	0	7.7	7.8	8.0	9.5	11.5	11.5	12.6	12.3
2050	0	9.3	9.3	9.5	11.4	13.7	13.7	15.0	14.7
2060	0	11.1	11.1	11.3	13.6	16.3	16.3	17.9	17.5

S.5.2.2 Air Quality

Table S-14 summarizes the cumulative impacts for national toxic and criteria pollutants in 2050.[35] The table lists the action alternatives (Alternatives 2 through 9) left to right in order of increasing fuel

[35] 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

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 $PM_{2.5}$ under Alternatives 3 and 4 and Alternatives 6 and 8; and SO_x under Alternatives 3 through 5, and 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, though not consistently, as fuel economy standards increase across Alternatives 2 through 9.

Table S-14

Cumulative Effects of 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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Criteria Pollutant Emissions (Calendar Year 2050)									
Carbon monoxide (CO)	24,155,097	24,530,976	24,385,367	24,315,810	23,541,753	22,770,712	22,314,840	22,130,779	22,061,720
Nitrogen oxides (NO_x)	1,809,786	1,786,720	1,780,335	1,778,462	1,733,908	1,690,190	1,667,885	1,653,446	1,650,090
Particulate matter ($PM_{2.5}$)	107,387	102,210	102,469	102,885	102,501	102,698	103,025	102,490	102,512
Sulfur oxides (SO_x)	262,948	229,228	230,352	231,083	230,124	227,819	230,366	227,019	227,650
Volatile organic compounds (VOC)	1,803,222	1,652,075	1,645,210	1,640,518	1,587,401	1,522,744	1,501,494	1,476,771	1,476,595
Toxic Air Pollutant Emissions (Calendar Year 2050)									
Acetaldehyde	7,953	8,070	8,064	8,048	8,074	8,068	8,068	8,088	8,088
Acrolein	411	418	422	426	449	478	490	498	478
Benzene	28,048	28,111	27,984	27,901	27,253	26,534	26,164	25,993	25,945
1,3-butadiene	4,180	4,249	4,239	4,235	4,189	4,148	4,117	4,111	4,106
Diesel particulate matter (DPM)	138,391	120,407	120,494	120,706	118,016	114,922	114,724	112,629	112,810
Formaldehyde	10,901	10,966	11,022	11,036	11,416	11,775	11,970	12,092	12,118

The trend for toxic air pollutant emissions across the alternatives is mixed. Annual cumulative emissions of acetaldehyde in 2050 are lowest under Alternative 1 and increase, though not consistently across the alternatives, and are highest under Alternative 9. Annual emissions of acrolein and formaldehyde increase under each successive alternative from Alternative 1 to Alternative 9. Annual emissions of benzene and DPM decrease, though not consistently across the alternatives, and are lowest under Alternative 9 for benzene and Alternative 8 for DPM. Annual emissions of 1,3-butadiene increase from Alternative 1 to Alternative 2, and then decrease under each successive alternative from Alternative 5 to Alternative 9.

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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 vehicle miles traveled (VMT) these vehicles account for would be even higher – 99 percent for passenger cars and 94 percent for light trucks.

As with criteria pollutants, annual cumulative emissions of most toxic air pollutants would decrease from one alternative to the next more stringent alternative. The exceptions are acrolein under Alternative 9; benzene under Alternatives 3 through 9; 1,3-butadiene under Alternatives 3 through 9; and formaldehyde under Alternatives 3 through 6. The changes in toxic air pollutant emissions, whether positive or negative, generally would be small in relation to Alternative 1 emissions levels.

Cumulative emissions generally would be less than noncumulative emissions for the same combination of pollutant, year (excluding 2016, which is equivalent to the noncumulative emissions in all cases), and alternative because of differing changes in VMT and fuel consumption under the cumulative case compared to the noncumulative case. The exceptions are acrolein for all alternatives except Alternative 9, 1,3-butadiene for all alternatives except Alternative 2, and CO for all alternatives.

The reductions in emissions are expected to lead to reductions in cumulative adverse health effects. Table S-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. 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 decrease from Alternative 2 through Alternative 4, and then increase under Alternatives 5 through Alternative 9. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_2.

Table S-15

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

Outcome and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action b/	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Mortality (ages 30 and older)									
Pope *et al.* 2002									
2050	0	-364	-356	-339	-406	-453	-455	-504	-504
Laden *et al.* 2006									
2050	0	-930	-911	-867	-1,037	-1,157	-1,162	-1,287	-1,288
Chronic bronchitis									
2050	0	-230	-226	-215	-259	-290	-292	-323	-323
Emergency Room Visits for Asthma									
2050	0	-323	-315	-300	-347	-382	-377	-417	-416
Work Loss Days									
2050	0	-39,749	-38,969	-37,043	-44,648	-49,958	-50,334	-55,754	-55,808

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 S-16 lists the corresponding annual reductions in health costs in 2050 under the action alternatives compared to the No Action Alternative. Reductions in health costs are given for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health costs.

Table S-16

Cumulative Nationwide Changes in Health Costs (U.S. million dollars/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
Discount and Year	No Action b/	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
3-% Discount Rate									
Pope *et al.* 2002									
2050	0	-3,292	-3,225	-3,067	-3,672	-4,097	-4,116	-4,558	-4,560
Laden *et al.* 2006									
2050	0	-8,069	-7,903	-7,518	-8,999	-10,040	-10,083	-11,167	-11,171
7-% Discount Rate									
Pope *et al.* 2002									
2050	0	-2,985	-2,924	-2,782	-3,331	-3,716	-3,733	-4,134	-4,136
Laden *et al.* 2006									
2050	0	-7,287	-7,138	-6,790	-8,128	-9,068	-9,107	-10,087	-10,090

a/ Negative changes indicate economic benefit; positive changes indicate economic costs.
b/ Changes in outcome under 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.

S.5.2.3 Climate Change

As with the analysis of the direct and indirect effects of the proposed action and alternatives on climate change, for the cumulative impacts analysis this EIS uses MAGICC version 5.3.v2 to estimate the changes in CO_2 concentrations, global mean surface temperature, and changes in sea level for each alternative CAFE standard. To estimate changes in global precipitation, NHTSA uses increases in global mean surface temperature combined with a scaling approach and coefficients from the IPCC Fourth Assessment Report. NHTSA performed a sensitivity analysis to examine the relationship among the 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 regulatory alternatives on direct and indirect climate effects.

One of the key categories of inputs to MAGICC is a time series of global GHG emissions. In assessing the cumulative effects on climate, NHTSA used 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 alternatives can be measured.

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 emissions reductions under the alternatives were held constant.

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; the EPA Proposed GHG Emissions Standards (H.R. 2454, American Clean Energy and Security Act ["Waxman-Markey Bill"]; Renewable Fuel Standard (RFS2); Program Activities of DOE's Office of Fossil Energy; Program Activities of DOE's Office of Nuclear Energy; United Nation's Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol and upcoming Conference of the Parties (COP) 15 in Copenhagen, Denmark; G8 Declaration – Summit 2009; and the Asia Pacific Partnership on Clean Development and Climate.[36]

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. Each of the action alternatives was simulated by calculating the difference in annual GHG emissions in relation to the No Action Alternative, and subtracting this change in the MiniCAM Level 3 scenario to generate modified global-scale emissions scenarios, which each show the effect of the various regulatory alternatives on the global emissions path.

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 emissions scenarios. The sensitivity analysis provides a basis for determining climate responses to varying levels of climate sensitivities and global emissions and 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.

S.5.2.3.1 Cumulative GHG Emissions

Table S-17 shows total GHG emissions and emissions reductions from new passenger cars and light trucks from 2012 through 2100 under each of the nine alternatives. Projections of emissions reductions over the 2012 through 2100 period due to the MY 2012-2016 CAFE standards and other reasonably foreseeable future actions (i.e., forecasted AEO fuel economy increases resulting from projected demand for fuel economy) ranged from 27,300 to 39,100 $MMTCO_2$. 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 0.7 to 1.0 percent from their projected levels under the No Action Alternative.

[36] These regional, national, and international initiatives and programs are those NHTSA has tentatively concluded are reasonably foreseeable past, present, 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 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.

Table S-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	227,600	0
2 3%/year Increase	200,300	27,300
3 4%/year Increase	200,200	27,300
4 ~4.3%/year Increase, Preferred	200,300	27,300
5 5%/year Increase	196,700	30,900
6 ~5.9%/year Increase, MNB	191,600	36,000
7 6%/year Increase	191,800	35,800
8 7%/year Increase	188,500	39,100
9 ~6.7%/year Increase, TCTB	188,790	38,791

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger-car and light-truck fleet represented about 3.7 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 rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions).

S.5.2.3.2 CO_2 Concentration, Global Mean Surface Temperature, Sea-level Rise, and Precipitation

Table S-18 and Figures S-6 through S-9 provide 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. As Figures S-8 and S-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 under 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 654 ppm under the TCTB Alternative to 657.5 ppm under the No Action Alternative. 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. While these effects are small, they occur on a global scale and are long-lived.

Table S-18 also shows the MAGICC simulations of mean global surface air temperature increases. For all alternatives, the cumulative global mean surface temperature increase is about 0.80 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.[37] The differences among alternatives are small.[38] 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).

[37] 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.
[38] While these effects are small, they occur on a global scale and are long-lived.

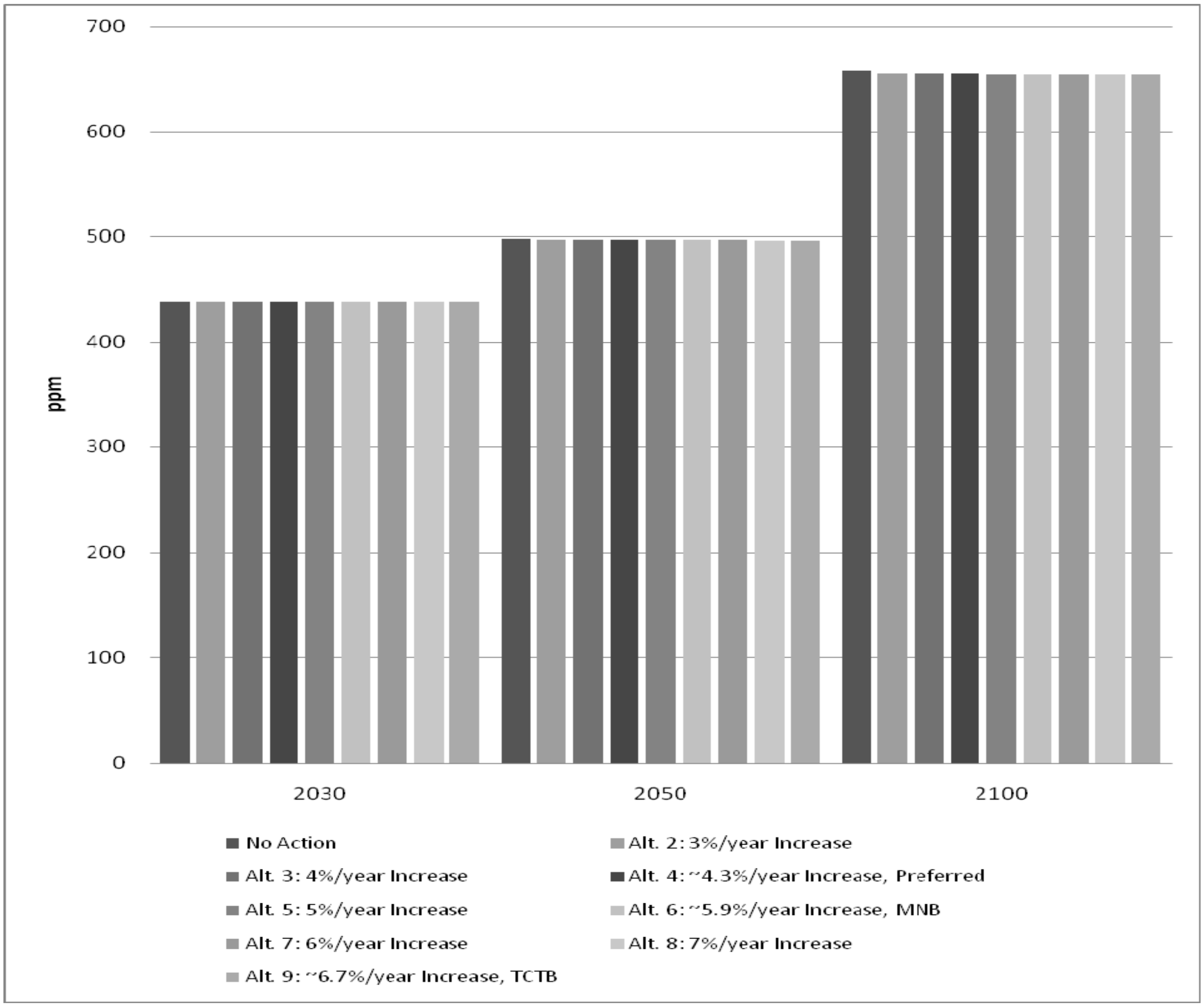
Table S-18

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	657.5	0.805	1.327	2.611	7.83	13.67	32.84
2 3%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
3 4%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
4 ~4.3%/year Increase, Preferred	438.5	497.3	655.1	0.804	1.323	2.600	7.83	13.65	32.75
5 5%/year Increase	438.4	497.2	654.7	0.804	1.323	2.599	7.83	13.65	32.73
6 ~5.9%/year Increase, MNB	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
7 6%/year Increase	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
8 7%/year Increase	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70
9 ~6.7%/year Increase, TCTB	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
3 4%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
4 ~4.3%/year Increase, Preferred	0.2	0.7	2.4	0.001	0.004	0.011	0.00	0.02	0.09
5 5%/year Increase	0.3	0.8	2.8	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
7 6%/year Increase	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
8 7%/year Increase	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14

a/ Values in this table are rounded.

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



1

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

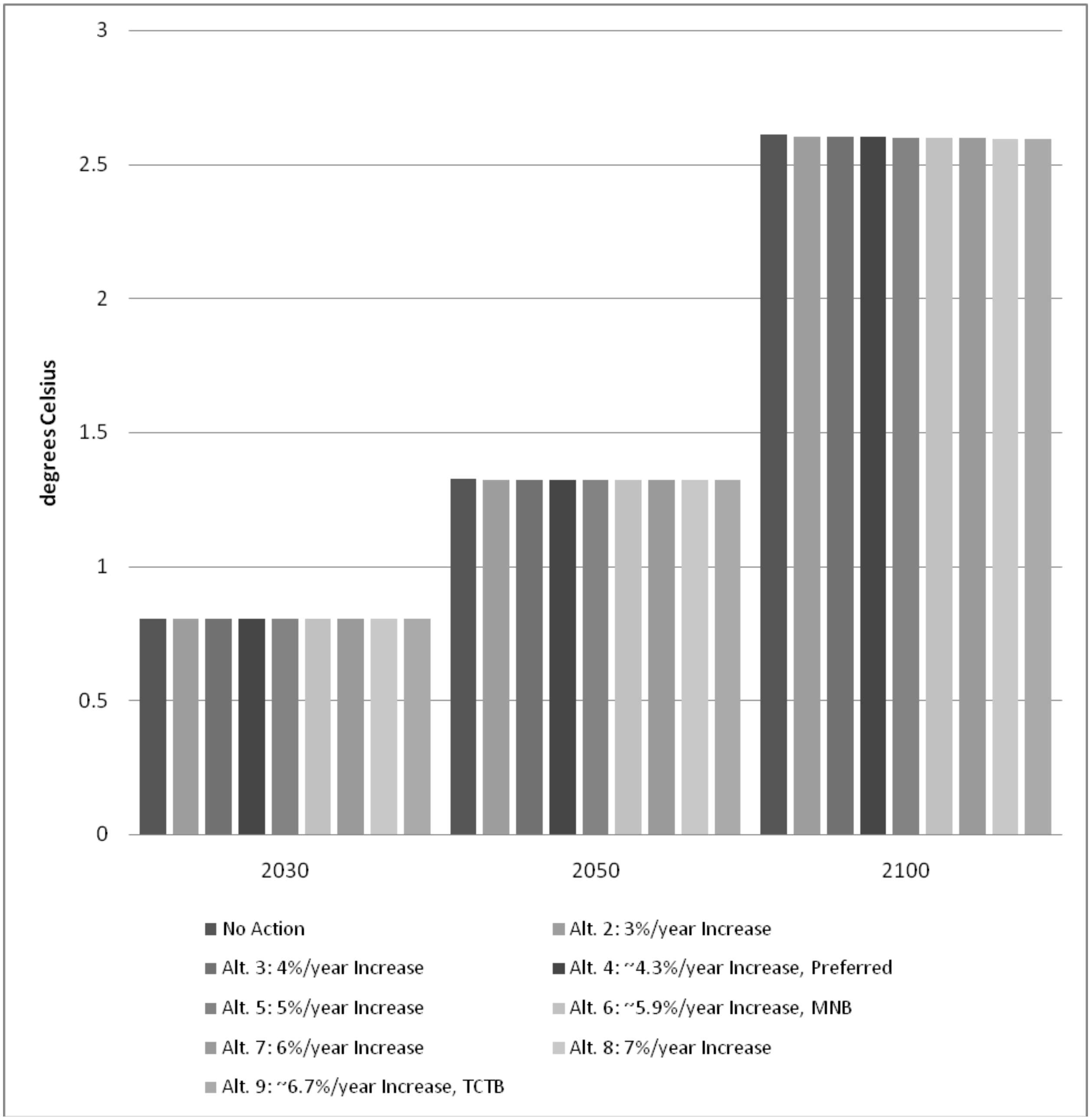
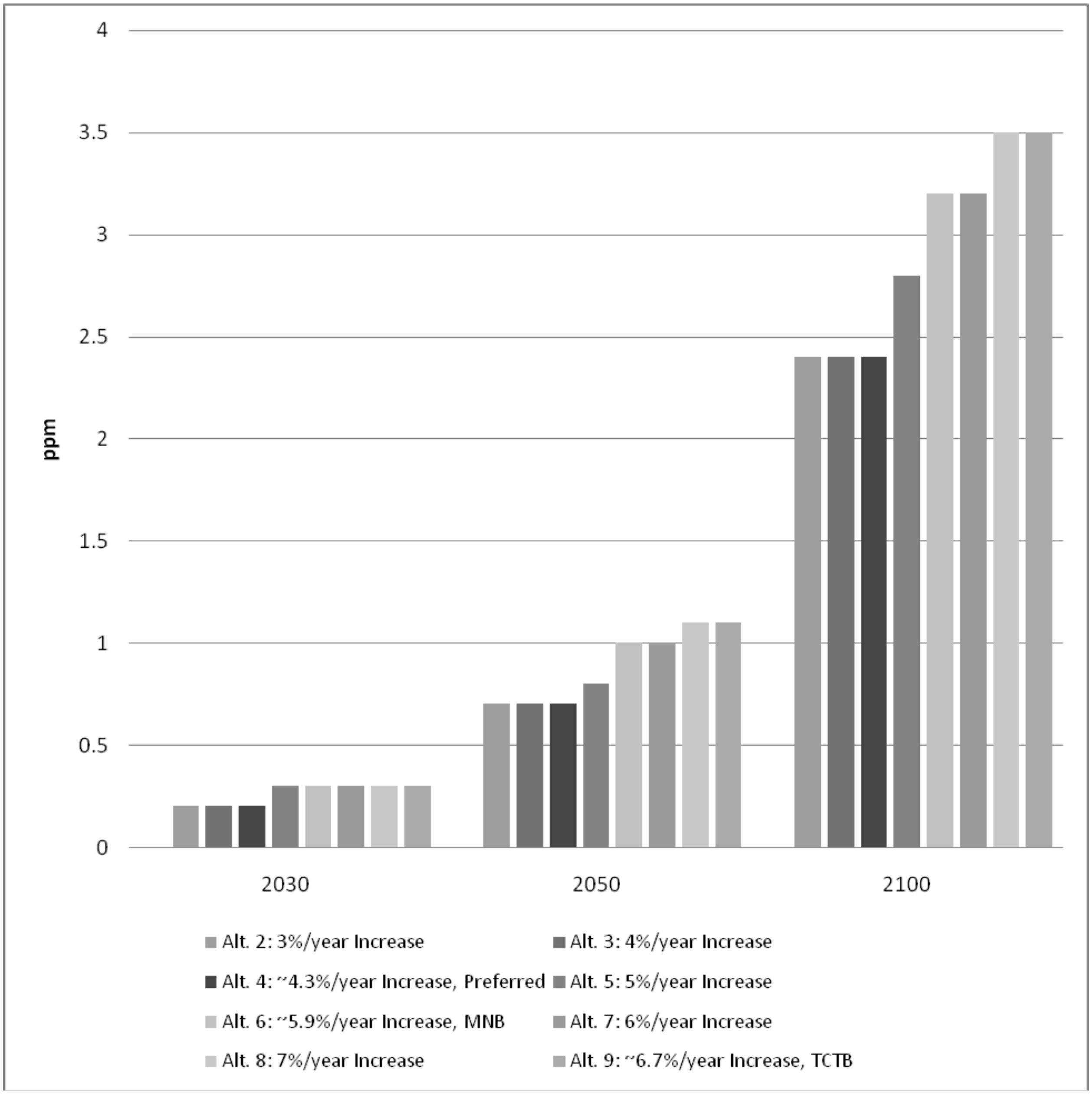


Figure S-8. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)



1

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

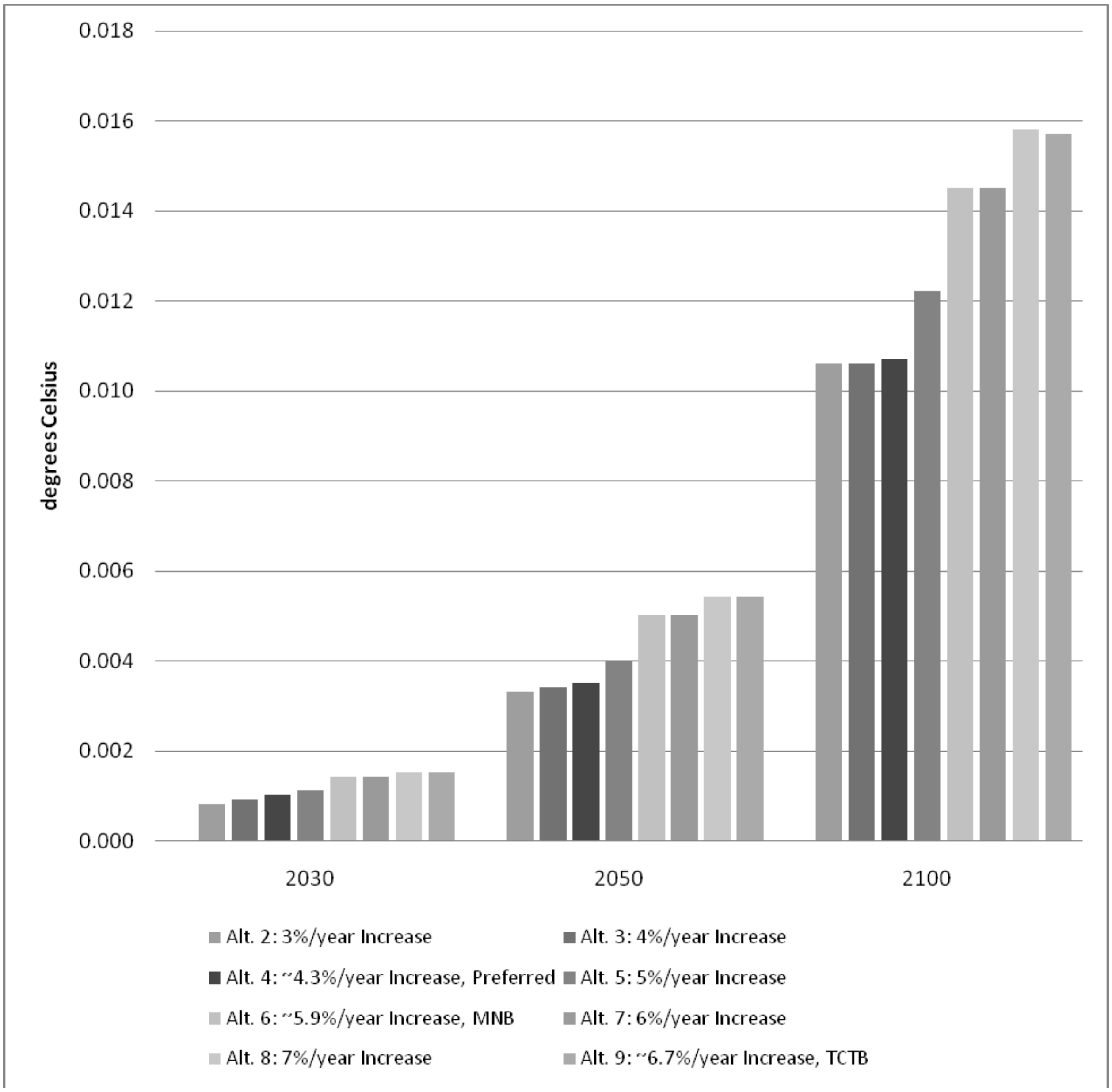


Table S-18 lists the impact on sea-level rise from the scenarios and shows sea-level rise in 2100 ranging from 32.84 centimeters (12.93 inches) under the No Action Alternative (Alternative 1) to 32.70 centimeters (12.87 inches) under the TCTB Alternative (Alternative 9). Thus, the CAFE action alternatives will result in a maximum reduction of sea level rise equal to 0.14 centimeters by 2100 from the No Action Alternative (i.e., from the levels that sea level is otherwise projected to rise).

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 S-19.

Table S-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	2.406
3 4%/year Increase	0.586	1.462	2.406
4 ~4.3%/year Increase, Preferred	0.586	1.462	2.406
5 5%/year Increase	0.586	1.461	2.405
6 ~5.9%/year Increase, MNB	0.586	1.460	2.403
7 6%/year Increase	0.586	1.460	2.403
8 7%/year Increase	0.586	1.459	2.401
9 ~6.7%/year Increase, TCTB	0.586	1.459	2.402
Reduction in Global Temperature (°C) for Alternative CAFE Standards, Mid-level Results (Compared to the No Action Alternative)			
2 3%/year Increase	0.000	0.004	0.009
3 4%/year Increase	0.000	0.004	0.009
4 ~4.3%/year Increase, Preferred	0.000	0.004	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.006	0.014
9 ~6.7%/year Increase, TCTB	0.000	0.006	0.014
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 ~5.9%/year Increase, MNB	0.85%	2.20%	3.92%
7 6%/year Increase	0.85%	2.20%	3.92%
8 7%/year Increase	0.85%	2.20%	3.91%
9 ~6.7%/year Increase, TCTB	0.85%	2.20%	3.91%
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to the No Action Alternative)			
2 3%/year Increase	0.00%	0.01%	0.01%
3 4%/year Increase	0.00%	0.01%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

a/ Values in this table are rounded.

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.[39] This is due primarily to the global and multi-sectoral nature of the climate problem. While these effects are small, they occur on a global scale and are long-lived.

[39] 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.

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 (3.6, 5.4, and 8.1 °F) 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). NHTSA performed the sensitivity analysis only for two alternatives because 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 (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 S-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 Case) 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 2.2 to 2.7 ppm. The Reference Case using the MiniCAM Level 3 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of 2.4 ppm.

Table S-20 also shows the sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100. 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 0.008 °C (0.014 °F) for the 2.0 °C (3.6 °F) climate sensitivity to 0.012 °C (0.022 °F) for the 4.5 °C (8.2 °F) climate sensitivity for the MiniCAM Level 3 emissions scenario.

The impact on global mean surface temperature due to assumptions concerning global emissions of GHGs is also important. The scenario with the higher global emissions of GHGs (*viz.*, the MiniCAM Reference) has a slightly lower reduction in global mean surface temperature, and the scenario with lower global emissions (*viz.*, the MiniCAM Level 2) has a slightly higher reduction. This is largely due to the non-linear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are higher and, as a result, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

Table S-20

Cumulative Effects on CO_2 Concentration, Temperature, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives a/

Emissions Scenario	CAFE Alternative	Climate Sensitivity (°C for 2 × CO_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	483.0	551.3	0.612	0.986	1.546	22.32
		3.0	435.7	486.5	563.5	0.812	1.324	2.177	29.92
		4.5	437.4	490.5	578.8	1.034	1.705	2.948	38.76
	Reduction compared to No Action								
		2.0	0.2	0.8	2.2	0.001	0.003	0.009	0.08
		3.0	0.3	0.8	2.4	0.001	0.004	0.012	0.11
		4.5	0.2	0.8	2.5	0.001	0.004	0.015	0.12
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	493.8	641.0	0.606	0.987	1.880	24.60
		3.0	438.5	497.3	655.1	0.804	1.323	2.600	32.75
		4.5	440.1	501.3	672.6	1.023	1.702	3.461	42.12
	Reduction compared to No Action								
		2.0	0.3	0.7	2.4	0.001	0.003	0.008	0.08
		3.0	0.2	0.7	2.4	0.001	0.004	0.011	0.09
		4.5	0.2	0.7	2.6	0.001	0.004	0.014	0.12
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	510.0	762.6	0.699	1.166	2.285	28.61
		3.0	441.5	514.1	780.4	0.922	1.553	3.126	37.91
		4.5	443.3	518.8	802.6	1.166	1.987	4.120	48.55
	Reduction compared to No Action								
		2.0	0.3	0.7	2.5	0.001	0.003	0.007	0.07
		3.0	0.3	0.7	2.6	0.001	0.003	0.010	0.09
		4.5	0.3	0.8	2.7	0.001	0.004	0.012	0.12

a/ Values in this table are rounded.

The sensitivity of the simulated sea-level rise to changes in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table S-20. 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 under the Preferred Alternative compared to the No Action Alternative.

S.5.2.4 Health, Societal, and Environmental Impacts of Climate Change

The effects of the alternatives on climate – CO_2 concentrations, temperature, precipitation, and sea-level rise – can translate into impacts on key resources, including terrestrial and freshwater ecosystems; marine, coastal systems, and low-lying areas; food, fiber, and forest products; industries, settlements, and society; and human health. 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 CO_2, 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.[40]

NHTSA examined the impacts resulting from global climate change due to all global emissions on the U.S. and global scales. Impacts to freshwater resources could include changes in precipitation patterns; decreasing aquifer recharge in some locations; changes in snowpack and timing of snowmelt; salt-water 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 because of increased atmospheric CO_2. Impacts to coastal ecosystems, primarily from predicted sea-level rise, 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 and several key economic sectors 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.

S.5.2.5 Non-climate Cumulative Impacts of CO_2 Emissions

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 begin that increase 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. This effect could have positive

[40] *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).

ramifications for agricultural productivity and forest growth. The available evidence indicates that different plants respond in different ways to enhanced CO_2 concentrations.

As with the climate effects of CO_2, the changes in non-climate impacts associated with the alternatives are difficult to assess quantitatively. 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.

S.5.3 Mitigation

CEQ regulations for implementing the procedural requirements of NEPA implicitly require that the discussion of alternatives in an 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).

Under NEPA, an EIS should contain "a reasonably complete discussion of possible mitigation measures."[41] Essentially, "[t]he mitigation must 'be discussed in sufficient detail to ensure that environmental consequences have been fairly evaluated.'"[42] Under NEPA, an agency does not have to formulate and adopt a complete mitigation plan,[43] 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 CFR § 1505.2(c).

Generally, emissions from criteria pollutants and MSATs are anticipated to decline, although emissions of CO, acrolein, and 1,3-butadiene could increase under certain alternatives and analysis years, compared to the No Action Alternative (Alternative 1). NHTSA notes that the analysis for acrolein emissions is incomplete because upstream emissions factors are not available. Upstream emissions decrease due to fuel savings and reduced emissions from fuel refining and transportation. If upstream emissions of acrolein were included in the analysis, total acrolein emissions would show smaller increases or might decrease. Thus, the acrolein emissions reported in this EIS represent an upper bound.

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. Also, vehicle manufacturers can choose which technologies to employ to reach the new CAFE standards. Some of their choices regarding which technologies to use result in higher or lower impacts for these emissions. Nevertheless, there is the potential that some air pollutant emissions will increase in some years under 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 standards under the action alternatives. These increases would represent a slight decline in the rate of reductions being achieved by implementation of CAA standards.

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[41] *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)).
[42] *Id.* (citing *City of Carmel-By-The-Sea v. U.S. Dept. of Transp.*, 123 F.3d 1142, 1154 (9th Cir. 1997)).
[43] *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).

Regarding 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 states may use for projects on any federal aid. As state and local agencies recognize the need to reduce emissions of CO, acrolein, and 1,3-butadiene (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, under the CAA, EPA has the authority to continue to improve vehicle emissions standards, which could result in future reductions as EPA promulgates new regulations.

Each of the action alternatives would reduce energy consumption and 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 call attention to 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 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 the EIS. The programs are also indicative of the types of programs that might be available in the future at all government levels for even further mitigation.

- EPA administers Renewable Fuel Standards under Section 211(o) of the CAA. 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. The livability principles are an extension of ongoing national awareness and interest in Smart Growth.
- 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.[44]
- 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; it is a voluntary program that facilitates information sharing.[45]

[44] Office of Policy and International Affairs, Department of Energy, *Climate Overview*, http://www.pi.energy.gov/climateoverview.html (last visited on Jul. 15, 2009).
[45] *Id*.

- DOE's Clean Cities Program develops government-industry partnerships designed to reduce petroleum consumption.[46]
- 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.[47]

[46] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Clean Cities: Fact Sheet (2009).
[47] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, *About the Program*, http://www1.eere.energy.gov/vehiclesandfuels/about/index.html (last visited on Jul. 15, 2009).

Chapter 1 Purpose and Need for the Proposed Action

1.1 INTRODUCTION

The Energy Policy and Conservation Act of 1975[1] (EPCA) 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 year (MY) 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 to prepare an EIS for the MY 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, MY 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, the Department of Transportation 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 United States Code (U.S.C.) § 32901 *et seq.*

[2] 49 U.S.C. § 32901-32919.

[3] 49 Code of Federal Regulations (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 MY 2011-2015 rulemaking into two parts: (1) MY 2011 standards, and (2) standards for MY 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 for the purposes of CAFE standard setting to be October 1, 2010.

For MY 2012 and beyond, the President requested that, before promulgating a final rule concerning the model years after model year 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 appropriate under applicable law and policy.

1.2 JOINT RULEMAKING AND NEPA PROCESS

Concurrent with this DEIS, NHTSA and EPA are each announcing joint proposed rules whose benefits would 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 and fuel economy program for passenger cars, light-duty-trucks, and medium-duty passenger vehicles (hereafter light-duty vehicles), referred to as the National Program. The proposed rules can achieve substantial improvements in fuel economy and reductions of greenhouse gas (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 of establishing consistent, harmonized, and streamlined requirements that would improve fuel economy and reduce greenhouse gas emissions for all new passenger cars and light trucks sold in the United States.[11] 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 different 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

[10] Memorandum for the Secretary of Transportation and the Administrator of the National Highway Traffic Safety Administration, 74 *FR* 4907 (Jan. 26, 2009).

[11] 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).

also consistent with the Notice of Upcoming Joint Rulemaking signed by DOT and EPA on May 19[12] and responds to the President's January 26, 2009 memorandum on CAFE standards for model years 2011 and beyond.[13]

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 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.[14] 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 the Energy Policy and Conservation Act (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 ones having energy independence and security, environmental and foreign policy implications. Fuel economy gains since 1975, due both to the standards and market factors, have resulted in saving billions of barrels of oil and avoiding billions of metric tons of CO_2 emissions. In December 2007, Congress enacted the Energy Independence and Securities Act (EISA), amending EPCA to require substantial, continuing increases in fuel economy standards.

The CAFE standards address most, but not all, of the 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[16] 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. 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 of CO_2 and hydrofluorocarbons (HFCs) related to operation of the air conditioning system.

[12] 74 FR 24007 (May 22, 2009).
[13] Available at: http://www.whitehouse.gov/the_press_office/Presidential_Memorandum_Fuel_Economy/ (last accessed on August 18, 2009)
[14] Panel on Policy Implications of Greenhouse Warming, National Academy of Sciences, National Academy of Engineering, Institute of Medicine, "Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base," National Academies Press, 1992. p. 287.
[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 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 order of the Environmental Protection Agency (EPA) denying a petition for rulemaking to regulate greenhouse gas emissions from motor vehicles under section 202(a) of the Clean Air Act (CAA).[18] The Court held that greenhouse gases were air pollutants for purposes of the Clean Air Act and further held that the Administrator must 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. 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 proposed to find 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] Today's proposal represents the second phase of EPA's response to the 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 not only CO_2, but also other GHGs. Since then, thirteen 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 model years 2009 through 2016 and require reductions in CO2 emissions for passenger cars and some light trucks of 323 g/mil 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.

1.2.2 Joint Proposal for a National Program

On May 19, 2009, the Department of Transportation and the Environmental Protection Agency issued a Notice of Upcoming Joint Rulemaking to propose a strong and coordinated fuel economy and greenhouse gas National Program for Model Year (MY) 2012-2016 light duty vehicles.

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[17] 549 U.S. 497 (2007).
[18] 68 FR 52922 (Sept. 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. There is a comprehensive discussion of the litigation's history, the Supreme Court's findings, and subsequent actions undertaken by the Bush Administration and the EPA from 2007-2008 in response to the Supreme Court remand.
[21] 74 FR 18886 (Apr. 24, 2009).
[22] 74 FR 32744 (July 8, 2009).

NHTSA and EPA are proposing a harmonized and coordinated National Program with the following key elements:

1.2.2.1 Level of the Standards

NHTSA and EPA are proposing two separate sets of standards, each under its respective statutory authorities. NHTSA is proposing CAFE standards for passenger cars and light trucks under 49 U.S.C. § 32902. These standards would require them to meet an estimated combined average fuel economy level of 34.1 mpg in model year 2016. EPA is proposing national CO_2 emissions standards for light-duty vehicles under section 202 (a) of the Clean Air Act. These standards would require these vehicles to meet an estimated combined average emissions level of 250 grams/mile of CO_2 in model year 2016. The proposed standards for both agencies begin with the 2012 model year, with standards increasing in stringency through model year 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 hydrofluorocarbons (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.[23] 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.

These differences regarding the treatment of air conditioning improvements (related to CO_2 and HFC reductions) affect the relative stringency of the EPA standard and NHTSA standard. The 250 grams per mile of CO_2 equivalent emissions limit is equivalent to 35.5 mpg[24] if the automotive industry were to meet this CO_2 level all 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 is proposing 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.

1.2.2.2 Form of the Standards

In this rule, NHTSA and EPA are proposing 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 model years 2008-2011,[25] and recently extended this approach to passenger cars in the CAFE rule for MY 2011 as required by EISA.[26] Under an attribute-based standard, every vehicle model has a performance target (fuel economy for the CAFE standards, and CO_2 g/mile for the GHG emissions standards), the level of which depends on the vehicle's attribute (for today's proposal, footprint). The

[23] There is no such statutory limitation with respect to light trucks.
[24] 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.
[25] 71 FR 17566 (Apr. 6, 2006).
[26] 74 FR 14196 (Mar. 30, 2009).

manufacturers' fleet average performance is determined by the production-weighed[27] average (for CAFE, harmonic average) of those targets.

NHTSA and EPA are proposing 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 TSD.

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 grams/mile 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. While 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.[28] 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 thus causing concern that 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 include 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 the curves proposed by each agency is 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 are proposing 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 the agencies jointly and separately contemplated in developing the program include CAFE/CO_2 Credits Earned Based on Fleet Average

[27] Production for sale in the United States.
[28] 74 FR 14407-14409 (Mar. 30, 2009).

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.[29]

1.2.2.4 Compliance

NHTSA and EPA propose 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 the manufacturers. In a coordinated approach, compliance mechanisms for both programs would be consistent and non-duplicative.

Under NEPA 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).[30] To inform its development of the new MY 2012-2016 CAFE standards required under EPCA, as amended by EISA, NHTSA prepared this draft 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.[31] 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 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.[32] 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, the 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 the 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 Clean Air Act (CAA), including the EPA proposed vehicle greenhouse gas 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

[29] *See* the discussion of compliance flexibilities in Section 3.1.4.1 of the joint NHTSA-EPA NPRM.
[30] 42 U.S.C. § 4332.
[31] 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.
[32] 40 CFR § 1501.6.

Upcoming Joint Rulemaking to ensure a coordinated Federal 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 the EIS for NHTSA decision makers and the public, EPA's environmental analysis of its proposed rulemaking is summarized and referenced within the appropriate sections of this EIS. [33]

1.3 PROPOSED ACTION

For this EIS, NHTSA's Proposed Action is setting passenger car and light truck CAFE standards for MY 2012 through 2016, in accordance with EPCA, as amended by EISA.

As mentioned above, in the joint NHTSA-EPA NPRM issued concurrently with this Draft EIS, NHTSA and EPA are proposing coordinated and harmonized CAFE standards and vehicle greenhouse gas 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 and the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the NEPA analysis. [34] In accordance with EPCA, as amended by EISA, one of the purposes of the Joint Rulemaking action is to establish MY 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."[35] The implication of this requirement is that it calls for exceeding the minimum requirement if the agency determines that the manufacturers can achieve a higher level. 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 standards of the Government on fuel economy, and the need of the United States to conserve energy.[36] 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.[37]

[33] Pursuant to the National Program announced by the President on May 19, 2009, EPA and NHTSA published their Notice of Upcoming Joint Rulemaking to ensure a coordinated Federal 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 Council on Environmental Quality's regulation at 40 CFR Section 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 decision makers 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 Clean Air Act 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 Clean Air Act and places no obligation on EPA to comply with NEPA in promulgating its rule or taking any other action covered by the exemption.

[34] 40 CFR § 1502.13.

[35] 49 U.S.C. § 32902(a).

[36] 49 U.S.C. §§ 32902(a), 32902(f).

[37] *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).

NHTSA has historically defined the aforementioned considerations as follows:[38]

- "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,[39] 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 MY 2011-2020 passenger cars and light trucks, subject to two principal requirements.[40] First, the standards are subject to a minimum requirement regarding stringency: they must be set at levels high enough to ensure that the combined US passenger car and light truck fleet achieves an average fuel economy level of not less than 35 mpg not later than MY 2020.[41] 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.[42]

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."[43] In any single rulemaking, standards may be established for not more than five model years.[44]

NHTSA is also guided by President Obama's memorandum to the Department of Transportation (DOT) on January 26, 2009, as described in Section 1.1.

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[38] 74 *FR* 14196 (Mar. 30, 2009).

[39] 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 Clean Air Act allows States to adopt and enforce State standards different from the Federal ones.

[40] 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.

[41] 49 U.S.C. § 32902(b)(2)(A).

[42] 49 U.S.C. § 32902(a).

[43] 49 U.S.C. § 32902(a)(3)(A).

[44] 49 U.S.C. §§ 32902(b)(3)(A), 32902(b)(3)(B).

1.5 PUBLIC REVIEW AND COMMENT

On April 1, 2009, NHTSA published a Notice of Intent (NOI) to prepare an EIS for the MY 2012-2016 CAFE standards. The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[45] by requesting public input on the scope of the environmental analysis to be conducted.[46] 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 a brief discussion in the EIS.[47] Scoping should "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[48] Consistent with NEPA and its implementing regulations, on April 2, 2009, NHTSA mailed the April 1 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 had 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 MY 2012-2016 CAFE standards, including auto industry organizations, environmental organizations, and other organizations that had expressed interest in prior CAFE rules.

NHTSA used its letters transmitting the April 1 NOI to develop a contact list for future notices about the NEPA process for the MY 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 their representative to provide contact information for the state's lead office on 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 the contact list form. NHTSA asked contacts at other stakeholder organizations to let NHTSA know 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.

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[45] 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.
[46] *See* Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 74 *FR* 14857 (Apr. 1, 2009).
[47] 40 CFR §§ 1500.4(g), 1501.7(a).
[48] 40 CFR § 1500.4(g).

1.5.1 Agency Consultation

On May 5, 2009, NHTSA invited the EPA to become a cooperating agency with NHTSA in the development of the EIS for the CAFE rulemaking for MY 2012-2016 passenger cars and light trucks in accordance with 40 CFR § 1501.6 of the NEPA implanting regulations issued by CEQ. Under 40 CFR § 1501.6, a federal agency which has special expertise with respect to any environmental issue which 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 expertise:

- The significant issues to be analyzed in the EIS from a climate change and air quality perspective.
- Assist 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).
- Participate in coordination meetings, as appropriate.
- Review and comment on the draft EIS and final EIS prior to publication.

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. 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.

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.

1.5.2 Summary of Scoping Comments

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

1.5.2.1 Federal Agencies

The United States Environmental Protection Agency (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 Final EIS in a judicious manner, recommending that NHTSA take into account 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 stands alone as 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 the 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 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,"[49] which states that while no single greenhouse gas source category dominates on the global scale, many could be very significant contributors. In particular, EPA states that motor vehicle source categories contribute 24 percent of total U.S. greenhouse gas emissions, and that total U.S. greenhouse gas emissions make up about 18 percent of the world's greenhouse gas emissions. The Attorneys General concluded by stating that NHTSA should put the CAFE rules in context by demonstrating their importance for reducing greenhouse gas emissions and reducing global warming. The Attorneys General listed some ways to provide the proper context, including: comparing carbon dioxide 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 doing its fair share to address global warming; and evaluating whether the rules will help prevent us from reaching a "tipping point" beyond which cataclysmic damages occur due to non-linear changes in the climate. Refer to Section 3.4 and 4.4 of this EIS, which discusses 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 (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.

[49] 74 *FR* 18886, 18907 (Apr. 24, 2009).

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 MY 2011–2015 CAFE EIS have been addressed in previous documents. NHTSA has re-examined all of these comments and has taken them into consideration 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 MY 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 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 light duty vehicle 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 practicability" provisions of EPCA and its case law. AAM suggested that NHTSA should keep historical rates of fuel efficiency change in mind 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 for evaluating the effects of proposed standards on 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,"[50] 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.

[50] 49 CFR § 520.23(a).

Lastly, AAM suggested that regulation of motor vehicle greenhouse gases will increase the price of vehicles, thereby reducing fleet turnover and leading to increases in criteria pollutant emissions. They recommended that the EIS should fully explore the relationship 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 MY 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.[51] 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 the EPA's role as a cooperating agency.

AAM incorporated by reference its comments submitted during the 2008 scoping period. In this 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, Summary of Scoping Comments and NHTSA's Responses, in the 2008 FEIS for an explanation of how NHTSA addressed these concerns in the 2008 FEIS. NHTSA is taking a fresh approach to this EIS. In this EIS, these comments are addressed in Chapters 1, 2, and 4.

AAM 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).

In general, 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 more 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 more 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 MY 2012-2016 CAFE standards for more detailed discussions of the updated Volpe model and the new assumptions.

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

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, they contend that NHTSA artificially constrains the range of alternatives analyzed in the 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. We again refer the reader to Sections 2.2.1 (Volpe Model) and Section 2.2.3 (Technology Assumptions) of this EIS, and to the NPRM for MY 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 if 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. 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. 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.

Lastly, CBD contended that NHTSA must initiate consultation with the U.S. Fish and Wildlife Service and National Marine Fisheries Service on the impact of the greenhouse gas 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 the Endangered Species Act (ESA) pursuant to both Section 7 of that law and the National Environmental Policy Act. NHTSA is taking a fresh look at Section 7 consultations under the ESA for the MY 2012-2016 CAFE rulemaking. We are currently exploring our obligations under the ESA and welcome comments from the public regarding this issue.

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 standards to 100 mpg. 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.

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 fewer years at a time to allow itself flexibility to readdress fuel economy standards. Refer to Section 1.3 (Purpose and Need) of this EIS for a discussion of why the specific timescale implemented was chosen. He 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 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 MY 2012-2016 CAFE standards for a discussion of the safety impacts of the proposed action and alternatives.

Mr. Adcock commented on a number of the assumptions used in the 2008 EIS. He recommended that NHTSA indicate what discount rate is being utilized 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 auto market. Furthermore, he recommended that NHTSA consider the global costs of carbon dioxide externalities instead of just the domestic costs. Similarly, he claimed that NHTSA should assume that carbon dioxide 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 also suggested that NHTSA allow an alternative certification path for vehicles in the U.S., accept European Community vehicle certification standards, and permit the importation of higher fuel efficiency European cars. The Vehicle Safety Act that mandates NHTSA set motor vehicle safety standards that are practicable, meet the need for motor vehicle safety, and are stated in objective terms.[52] 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.[53] NHTSA believes that the federal motor vehicle safety standards incorporate the appropriate balance between the codified statutory considerations and that adoption of the European Community standards would be in contravention of Congressional mandate.

[52] 49 U.S.C. 30111. The Secretary has delegated authority for these standards to the National Highway Traffic Safety Administration (NHTSA). *See* 49 CFR 1.50.
[53] *See* 49 U.S.C. 30112 (prohibiting the importation of vehicles that do not comply with applicable standards).

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 Next Steps in the NEPA Process and CAFE Rulemaking

This draft EIS is being published concurrently with the notice of Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards issued jointly by NHTSA and EPA. The draft EIS is being circulated for public review and will have a public comment period. Public hearings, where interested parties can present oral testimony, will be announced in the *Federal Register* and through NHTSA's contact list for the EIS. Individuals may also submit their written comments, identified by the docket number, NHTSA-2009-0059, by any of the following methods:

- Federal eRulemaking Portal: Go to http://www.regulations.gov. Follow the instructions for submitting comments on the electronic docket site by clicking on "Help" or "FAQ."
- Mail: Docket Management Facility, M-30, U.S. Department of Transportation, 1200 New Jersey Avenue SE, West Building, Ground Floor, Room W12-140, Washington, D.C. 20590.
- Hand Delivery: 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12-140, between 9 a.m. and 5 p.m. Eastern Time, Monday through Friday, except federal holidays.
- Fax: 202-493-2251.

The FEIS is expected to be released in early 2010. The FEIS will address comments received on the draft EIS. No sooner than 30 days after the availability of the FEIS is announced in the *Federal Register* by EPA, NHTSA will publish a final rulemaking by NHTSA and EPA and a Record of Decision. The Record of Decision 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 (MY) 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 MY 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] For instance, NHTSA has placed monetary values on environmental externalities, including the benefits of reductions in carbon dioxide (CO_2) emissions. 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 MY 2012-16 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 DEIS, to the NPRM, and to the

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[1] 42 United States Code (U.S.C.) § 4332(2)(C). NEPA is codified at 42 U.S.C. § 4321, *et seq*.
[2] 40 Code of Federal Regulations (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 *FR* 24352, 24364 (May 2, 2008).

accompanying PRIA. The majority of the alternatives considered by the agency are defined as average percentage increases in 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, fuel savings by consumers; 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.

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 and the Microsoft .NET framework installed (the latter available without charge from Microsoft). The executable version of the model, with all of its codes 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 vehicles 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, 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 fit coefficients defining an attribute-based standard, and 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 accompanying Notice of Proposed Rulemaking (NPRM) for MY 2012-2016 CAFE standards (included in the docket for this DEIS), NHTSA's Preliminary Regulatory Impact Analysis (PRIA) (*see* Appendix D), and the NHTSA-U.S. Environmental Protection Agency (EPA) joint technical support document (included in the docket for this DEIS).

Although NHTSA has used the Volpe model as a tool to inform its consideration of potential CAFE standards, the Volpe model, alone, 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 light vehicles for sale in the United States. For this rulemaking, and as explained in the Technical Support Document (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 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, estimated vehicle wheelbase and track widths using data from Motortrend.com and Edmunds.com. This information is necessary for estimating 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 projected-car and truck-volumes for this period from the Energy Information Administration (EIA) 2009 Annual Energy Outlook (AEO) (EIA 2009).[6] However, AEO projects sales

[6] The agencies have also used fuel price forecasts from AEO 2009. Both agencies regard AEO a credible source not only of such forecasts, but also of many underlying forecasts, including forecasts of the size the future light vehicle market.

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, 2016 estimates from CSM should be available for the final rule. Using these percentages normalized to the AEO projected volumes then provided the manufacturer-specific market share and model-specific sales for model years 2011-2016.

The processes for constructing the MY 2008 baseline vehicle fleet and subsequently adjusting sales volumes to construct the MY 2011-2016 baseline vehicle fleet are presented in detail in the Technical Support Document. For a detailed discussion of this issue, *see* Chapter 1 of the TSD prepared jointly by NHTSA and EPA. For a detailed discussion of NHTSA's historical prior product plan approach and the current baseline vehicle fleet approach used by NHTSA and EPA for this rulemaking, including, but not limited to, the differences, advantages and disadvantages between the two approaches, *see* Section 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 MY 2005-2007 and MY 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, and that was used by EPA in developing its advance NPRM to regulate greenhouse gas 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 MY 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 proposed CO_2 standards in the joint NPRM. 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 (available in the docket for this DEIS) and in NHTSA's Regulatory Impact Analysis (RIA) (*see* Appendix D).

[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 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 valve timing 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, relative to 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-, seven-, and eight-speed automatic transmissions* – the gear ratio spacing and transmission ratio are optimized for a broader range of engine 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 transmission ratios with an infinite number of gears, enabling finer optimization of transmission torque multiplication under different operating conditions so that the engine can operate at higher efficiency.

- *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 improving fuel economy and reducing CO_2 emissions.

- *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 air conditioning 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 a belt-driven enhanced power starter-alternator, 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. 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 wiring harness. 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 forecast, economic assumptions, and estimates of parameters used by the Volpe CAFE model. These proposed economic values play a significant role in determining the reductions in fuel consumption, changes in emissions of criteria air pollutants and GHGs, and 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 assumptions information includes the following:

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

- Assumptions about the fraction of these vehicles that remain in service at different ages and how rapidly their use declines with increasing age.

- Forecasts of fuel prices over the expected lifetimes of MY 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. Detailed descriptions of the proposed sources of forecast information, the rationale underlying each economic assumption, and the agency's preliminary choices of specific parameter values are presented in Section IV.C.3 of the NPRM and Chapter VIII of NHTSA's Preliminary Regulatory Impact Assessment accompanying this DEIS, as well as in Chapter IV of the joint EPA-NHTSA Technical Support Document for fuel economy and motor vehicle CO_2 emission standards.

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	1.1%
Fuel Prices (2012-50 average, $/gallon)	
Retail gasoline price	$ 3.77
Pre-tax gasoline price	$ 3.40
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) and CO_2 equivalents of other GHGs	$5,10,20,34,56
Annual Increase in CO_2 Damage Cost	3%
External Costs from Additional Automobile Use ($/vehicle-mile)	
Congestion	$ 0.054
Accidents	$ 0.023
Noise	$ 0.001
Total External Costs	$ 0.078
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%, 7%

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 when using 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.

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 MY 2008-2011 light trucks.[9] In May 2008, NHTSA proposed separate standards for MY 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.

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 MY 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 abide by, 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 that 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.

fuel economy of at least 35 mpg for MY 2020; nor would it satisfy the EPCA requirement to adopt annual fuel economy standard increases).[13]

NHTSA is also proposing to consider 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 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 alternatives, *see* Sections VII and VIII of NHTSA's PRIA.

[13] 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). Under this alternative, NHTSA would not issue a rule regarding CAFE standards for MY 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.[14]

NEPA requires agencies to consider a No Action Alternative in their NEPA analyses,[15] 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.[16] 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 35.6 mpg for passenger cars and 26.6 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 37.4 mpg for passenger cars and 27.9 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 38.0 mpg for passenger cars and 28.3 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 tentative 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 can be found in Section IV.F of the joint preamble of Notice of Proposed Rulemaking.

This alternative, along with EPA's proposed 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.

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

[15] S*ee* 40 CFR § 1502.14(d).

[16] 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).

2.3.5 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 39.3 mpg for passenger cars and 29.3 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 5.9-percent average annual increase in mpg, resulting in a required MY 2016 fleetwide 40.9 mpg for passenger cars and 30.6 mpg for light trucks. The MNB Alternative also results in a combined required fleetwide 36.8 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 41.1 mpg for passenger cars and 30.7 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 slightly higher than 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 43.1 mpg for passenger cars and 32.2 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 6.7-percent on average annual increase in mpg, resulting in a required MY 2016 fleetwide 42.7 mpg for passenger cars and 31.5 mpg for light trucks. The TCTB Alternative also results in a combined required fleetwide 38.1 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 Alternatives

Table 2.3-1 shows the required fuel economy levels for each alternative.

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**	**~5.9%/year Increase MNB**	**6%/year Increase**	**7%/year Increase**	**~6.7%/year Increase TCTB**
2012									
Passenger Cars	30.5	31.5	32.1	33.6	32.7	33.4	33.0	33.3	33.8
Light Trucks	24.3	24.3	24.3	25.0	24.4	26.4	24.6	24.8	26.7
Combined	27.9	28.4	28.7	29.8	29.0	30.4	29.2	29.5	30.8
2013									
Passenger Cars	30.5	32.9	33.6	34.4	34.2	36.0	34.9	35.5	36.7
Light Trucks	24.2	24.5	25.0	25.6	25.5	27.7	26.0	26.5	28.0
Combined	27.9	29.3	29.9	30.6	30.4	32.5	31.0	31.6	33.0
2014									
Passenger Cars	30.5	33.8	34.8	35.2	35.8	38.1	36.9	37.9	39.0
Light Trucks	24.2	25.2	26.0	26.2	26.7	28.8	27.5	28.3	29.2
Combined	27.9	30.2	31.0	31.4	31.9	34.2	32.9	33.8	34.8
2015									
Passenger Cars	30.5	34.7	36.1	36.4	37.5	39.5	38.9	40.4	40.8
Light Trucks	24.1	25.9	26.9	27.1	28.0	30.1	29.0	30.1	30.9
Combined	28.0	31.1	32.3	32.6	33.5	35.6	34.8	36.2	36.8
2016									
Passenger Cars	30.5	35.6	37.4	38.0	39.3	40.9	41.1	43.1	42.7
Light Trucks	24.1	26.6	27.9	28.3	29.3	30.6	30.7	32.2	31.5
Combined	28.0	32.0	33.6	34.1	35.2	36.8	36.9	38.7	38.1

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. [17]

[17] 49 U.S.C. § 32902(f).

Table 2.3-2 shows the estimated[18] 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. Achieved combined mpg would equal required combined mpg under Alternative 2. 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 comply fully with passenger-car or light-truck standards under some alternatives. Estimated achieved and required fuel economy levels differ because manufacturers will, on average, undercomply[19] in some model years and overcomply[20] in others.[21]

Table 2.3-2

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
2012									
Passenger Cars	32.4	32.7	33.0	33.3	33.2	33.5	33.4	33.5	33.7
Light Trucks	24.2	24.5	24.7	25.0	24.8	25.5	24.9	25.1	25.5
Combined	28.6	29.0	29.2	29.5	29.3	29.9	29.5	29.7	30.0
2013									
Passenger Cars	32.4	34.0	34.5	34.9	35.1	36.0	35.7	36.1	36.3
Light Trucks	24.3	25.0	25.5	25.9	25.9	27.2	26.3	26.7	27.3
Combined	28.7	29.9	30.4	30.9	30.9	32.1	31.5	31.8	32.3
2014									
Passenger Cars	32.4	34.6	35.5	35.9	36.5	37.8	37.4	38.0	38.2
Light Trucks	24.2	25.5	26.3	26.7	27.1	28.6	27.8	28.3	28.8
Combined	28.8	30.5	31.5	31.8	32.3	33.8	33.2	33.7	34.1

[18] 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.

[19] 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.

[20] 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).

[21] 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 (continued)

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
2015									
Passenger Cars	32.5	35.2	36.5	36.8	37.5	39.1	38.8	39.4	39.6
Light Trucks	24.1	26.0	27.1	27.4	28.2	29.7	29.2	29.9	30.1
Combined	28.9	31.3	32.5	32.8	33.6	35.1	34.7	35.4	35.6
2016									
Passenger Cars	32.5	36.0	37.5	37.9	39.1	40.4	40.5	41.4	41.4
Light Trucks	24.2	26.5	27.7	28.1	29.0	30.3	30.3	31.0	30.8
Combined	29.0	32.0	33.4	33.8	34.9	36.2	36.2	37.1	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 reduced GHG emissions. EPA is proposing greenhouse gas emissions standards under Section 202(a) of the Clean Air Act, and NHTSA is proposing Corporate Average Fuel Economy standards under the Energy Policy and Conservation Act, 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 model year 2016. The proposed standards for both agencies begin with the 2012 model year, with standards increasing in stringency through model year 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 their projected overall fleet-wide CO_2 equivalent emission levels.[22] 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

[22] 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.

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 MY 2012 through 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 can be seen in Table 2.3-4, the projected achieved levels are slightly higher for MY 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 combinations of economic assumptions that can be used to estimate the costs and benefits of the alternatives, including future fuel prices, the value of CO_2 emissions reductions (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 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" model inputs:

- American Energy Outlook (AEO)April 2009 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 that reduce the cost per mile travelled);
- \$20 SCC (dollar value of per metric ton of CO_2 emission reductions);
- \$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, and that, with respect to Alternatives 6 and 9, both the achieved fuel economy standards and their resulting environmental impacts 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 CO_2, oil import externalities, and the rebound effect influence the estimates of fuel consumption over the period from 2012 to 2060 under each Alternative. 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 and associated environmental impacts. 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.

Table 2.4-1

Sensitivity Analysis of Fuel Consumption (2012-60; 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	~5.9%/year Increase MNB	~6.7%/year Increase TCTB
Expected Value Model Inputs	9,260	8,593	8,250	7,878	7,339
High AEO Fuel Price Forecast	8,499	7,878	7,549	7,202	6,745
Low AEO Fuel Price Forecast	11,444	10,656	10,211	9,920	9,088
7% Discount Rate	9,260	8,593	8,250	7,933	7,339
5% Rebound Effect	9,908	9,152	8,763	8,343	7,739
15% Rebound Effect	8,612	8,029	7,727	7,396	6,924
\$56/ton CO_2 Value	9,260	8,593	8,250	7,872	7,343
\$34/ton CO_2	9,260	8,593	8,250	7,875	7,343
\$10/ton CO_2	9,260	8,593	8,250	7,875	7,339
\$5/ton CO_2	9,260	8,593	8,250	7,875	7,339
5¢/gal Oil Import Externality	9,260	8,593	8,250	7,878	7,339

The Expected Value model inputs result in 9,260 billion gallons of fuel consumption from 2012 to 2060 under the No Action Alternative, and 7,339 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 8.1 percent to 8.6 percent from its estimated level under the same 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 values the same) increases projected 2012-2060 fuel consumption for each alternative by 23 percent to 26 percent from its level under the same alternative using the Expected Value model inputs (including the AEO Reference Case fuel price forecast).

Changing the rebound effect input to 5 percent (while leaving other model inputs values the same, including the Reference Case fuel price forecast) increases projected 2012-2060 fuel consumption for each alternative by 5 percent to 7 percent from its level under the same alternative with a 10 percent rebound effect (the Expected Value model input). Increasing the rebound effect input to 15 percent reduces projected 2012-2060 fuel consumption for each alternative by 5 percent to 7 percent. The sensitivity analysis in Table 2.4-1 shows that changes in the input values for the discount rate, 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 0.01-percent for 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.[23] 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, and the value of petroleum import externalities has no effect on vehicle use under any alternative. At the same time, 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 resulting economic costs and benefits. As a consequence, changes in assumptions about these variables have little effect on total fuel consumption, as Table 2.4-1 illustrates, although these variables *do* have significant effects on the 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 equipped with advanced technologies at a rate that is not possible in 5 years, as well as the elimination of some lower mpg vehicles for which there is some 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 established supply contracts.[24] 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 MY 2012-2016 CAFE rules contribute to reducing greenhouse gas emissions and addressing global warming by

[23] Mathematically, the rebound effect is equal 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.

[24] 49 U.S.C. § 32902(f) (establishing the considerations for decisions on maximum feasibility are: technological feasibility, economic practicability, the effect of other motor vehicle standards on fuel economy, and the need of the United States to conserve energy).

evaluating whether the new CAFE rules could constitute a stabilization wedge. While NHTSA agrees that this is one possible approach, the agency declines to pursue a wedge analysis to fulfill its requirements under NEPA. CEQ regulations require NHTSA to rigorously explore all reasonable alternatives and examine their direct and indirect effects on climate change.[25] 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 MY2011 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 all CAFE standards be based on one or more vehicle attributes.[26] 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 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.[27] CEQ regulations also indicate that a major purpose of an EIS is to facilitate public

[25] *See* 40 CFR § 1502.14-16.
[26] 49 U.S.C. § 32902(b)(3)(A); *see* 73 *FR* 24352, 24354-24355 (May 2, 2008).
[27] 40 CFR § 1502.8.

involvement in and knowledge of the NEPA process.[28] 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 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. We consider our range of alternatives to represent a reasonable range of possible agency actions.

2.6 COMPARISON OF ALTERNATIVES

The CEQ NEPA regulations[29] 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. CEQ regulations[30] 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.

This section summarizes the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality, and climate. 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.

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.

[28] *See* 40 CFR § 1500.1(b).
[29] *See* 40 CFR Part 1500.2(e).
[30] See 40 CFR 1502.14.

2.6.1.1 Energy

Tables 2.6-1 and 2.6-2 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 173.5 billion gallons in 2060. Fuel consumption ranges from 158.2 billion gallons under Alternative 2 (3-Percent Alternative) to 139.7 billion gallons under Alternative 9 (TCTB). Fuel consumption is 150.9 billion gallons under the Preferred Alternative.

Table 2.6-1

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.4	65.7	64.3	63.9	63.0	61.8	61.9	61.2	61.1
2030	97.9	89.5	86.4	85.5	83.5	81.0	80.9	79.4	79.4
2040	121.7	110.9	106.9	105.9	103.2	100.1	99.9	98.0	98.1
2050	145.7	132.8	128.0	126.7	123.5	119.8	119.6	117.3	117.3
2060	173.5	158.2	152.4	150.9	147.1	142.7	142.4	139.7	139.7
Fuel Savings Compared to No Action									
2020	--	3.7	5.1	5.5	6.4	7.6	7.6	8.2	8.3
2030	--	8.4	11.5	12.3	14.4	16.8	17.0	18.4	18.4
2040	--	10.8	14.8	15.9	18.5	21.6	21.8	23.7	23.7
2050	--	12.9	17.7	19.0	22.2	25.9	26.2	28.4	28.4
2060	--	15.4	21.1	22.6	26.5	30.9	31.2	33.9	33.8

Table 2.6-2

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.6	66.4	65.2	64.9	64.2	63.0	63.3	62.7	62.6
2030	66.0	61.6	59.6	59.0	57.6	55.8	55.9	55.0	55.1
2040	73.0	67.4	64.9	64.2	62.4	60.3	60.3	59.1	59.3
2050	85.5	78.7	75.7	74.8	72.7	70.2	70.1	68.7	69.0
2060	101.4	93.3	89.7	88.7	86.1	83.1	83.1	81.3	81.7
Fuel Savings Compared to No Action									
2020	--	2.3	3.4	3.8	4.4	5.6	5.3	5.9	6.0
2030	--	4.4	6.4	7.0	8.3	10.1	10.0	11.0	10.9
2040	--	5.6	8.1	8.8	10.6	12.8	12.7	14.0	13.7
2050	--	6.8	9.8	10.7	12.8	15.4	15.4	16.9	16.5
2060	--	8.1	11.7	12.7	15.3	18.3	18.4	20.1	19.7

For light trucks, fuel consumption under the No Action Alternative is 101.4 billion gallons in 2060. Fuel consumption ranges from 93.3 billion gallons under Alternative 2 (3-Percent Alternative) to 81.3 billion gallons under Alternative 8 (7-percent annual increase in mpg). Fuel consumption is 88.7 billion gallons under the Preferred Alternative (Alternative 4).

2.6.1.2 Air Quality

Table 2.6-3 summarizes the total national criteria and air toxic pollutant emissions in 2030 for the nine alternatives, left to right in order of 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 decline as fuel economy standards increase across Alternatives 5 through 9.

Table 2.6-3

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Criteria Pollutant Emissions									
Carbon monoxide (CO)	17,766,186	17,875,841	17,857,900	17,830,426	17,374,361	16,933,532	16,692,592	16,584,083	16,544,125
Nitrogen oxides (NO_x)	1,467,596	1,453,694	1,445,588	1,443,013	1,416,117	1,390,714	1,379,863	1,370,822	1,368,895
Particulate matter ($PM_{2.5}$)	76,589	74,147	73,316	73,321	73,122	73,349	73,725	73,362	73,382
Sulfur oxides (SO_x)	201,502	186,242	180,661	179,415	178,313	176,493	178,441	176,043	176,396
Volatile organic compounds (VOCs)	1,668,085	1,596,544	1,564,323	1,553,482	1,514,436	1,469,438	1,456,616	1,439,159	1,438,649
Toxic Air Pollutant Emissions									
Acetaldehyde	6,631	6,665	6,683	6,678	6,710	6,721	6,733	6,748	6,751
Acrolein	342	345	348	351	366	385	393	398	399
Benzene	27,706	27,667	27,602	27,551	27,171	26,758	26,569	26,466	26,440
1,3-butadiene	3,610	3,631	3,637	3,638	3,615	3,597	3,584	3,581	3,579
Diesel particulate matter (DPM)	106,046	97,820	94,519	93,731	91,502	89,134	89,055	87,536	87,606
Formaldehyde	8,875	8,884	8,927	8,938	9,198	9,440	9,573	9,652	9,672

The trends for toxic air pollutant emissions across the alternatives are mixed. Annual emissions of nearly all toxic air pollutants are highest under the No Action Alternative, except for those of acrolein, which increases with each successive alternative and are highest under Alternative 9. The acrolein emissions in Table 2.6-3 are an upper-bound estimate and actual emissions might be less. Annual emissions in 2030 of acetaldehyde increase under each successive alternative from Alternative 1 to Alternative 9, except for Alternative 4. Annual emissions in 2030 of benzene and formaldehyde decrease under each successive alternative from Alternative 1 to Alternative 9. Annual emissions of 1,3-butadiene in 2030 increase under each successive alternative from Alternative 1 to Alternative 4, and then decrease under each successive alternative from Alternative 5 to Alternative 9 in 2030. Annual emissions of DPM in 2030 decrease with successive alternatives from Alternative 1 to Alternative 8 and decrease in Alternative 9.

The reductions in emissions are expected to lead to reductions in adverse health effects. Table 2.6-4 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.

Table 2.6-4

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Mortality (ages 30 and older), Pope et al.									
2030	0	-153	-210	-217	-253	-276	-267	-296	-296
Mortality (ages 30 and older), Laden et al.									
2030	0	-392	-537	-554	-648	-705	-683	-758	-758
Chronic bronchitis									
2030	0	-100	-138	-142	-167	-182	-177	-196	-196
Emergency Room Visits for Asthma									
2030	0	-140	-191	-198	-226	-244	-233	-258	-258
Work Loss Days									
2030	0	-18,031	-24,750	-25,522	-30,036	-32,758	-31,811	-35,301	-35,306

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.

The economic value of health impacts would vary proportionally with changes in health outcomes. Table 2.6-5 lists the corresponding annual reductions in health costs in 2030 under Alternatives 2 (3-Percent Alternative) through 9 (TCTB) compared to the No Action Alternative. Reductions in health costs are given for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health costs.

Table 2.6-5

Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
3% Discount Rate									
Pope et al.									
2030	0	-1,361	-1,867	-1,926	-2,253	-2,452	-2,374	-2,635	-2,634
Laden et al.									
2030	0	-3,334	-4,574	-4,720	-5,520	-6,007	-5,816	-6,454	-6,451
7% Discount Rate									
Pope et al.									
2030	0	-1,234	-1,693	-1,747	-2,044	-2,224	-2,154	-2,390	-2,389
Laden et al.									
2030	0	-3,012	-4,131	-4,264	-4,987	-5,426	-5,254	-5,830	-5,827

a/ Negative changes indicate economic benefit; positive emissions changes indicate economic costs.
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 2.6-6 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), the effect of the alternatives is to slow this increase by varying amounts. Emissions for the period range from

Table 2.6-6

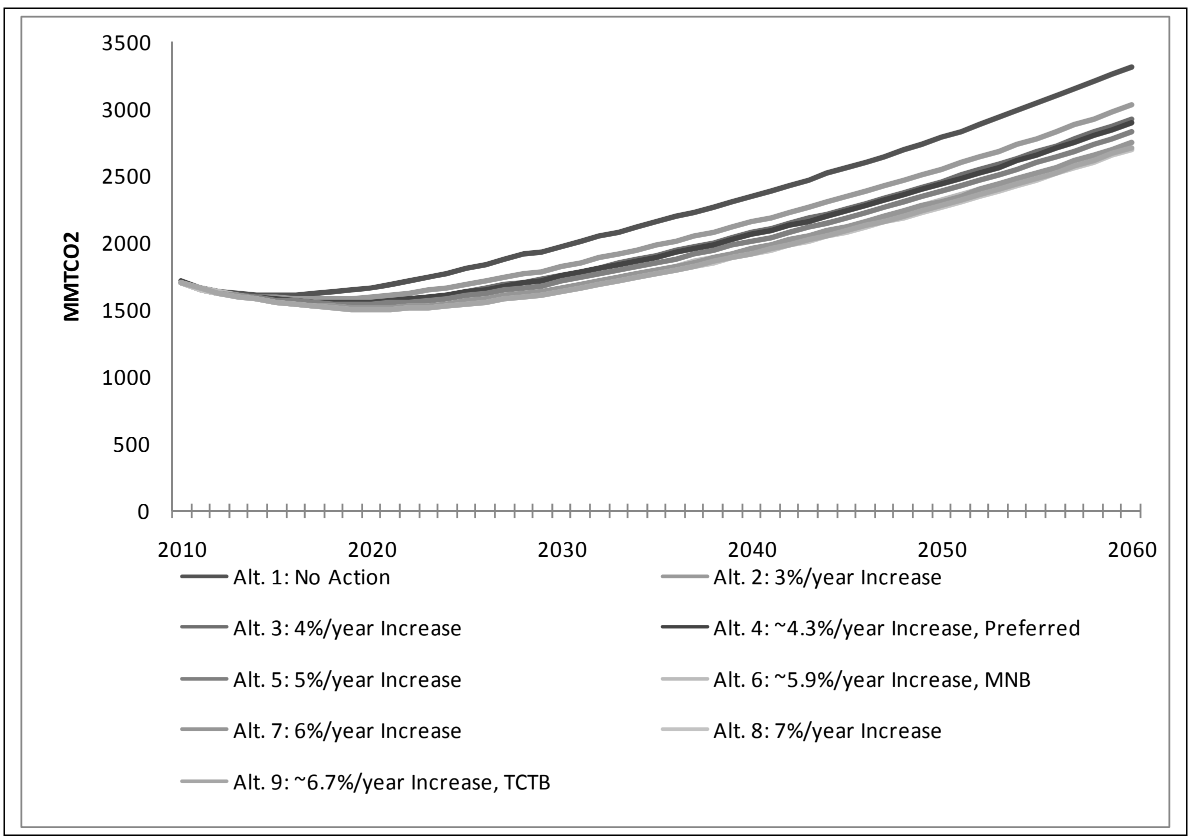
Emissions and Emissions Reductions ($MMTCO_2$) from 2012-2100 by Alternative

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	243,600	0
2 3%/year Increase	224,300	19,300
3 4%/year Increase	216,700	26,900
4 ~4.3%/year Increase, Preferred	214,700	29,000
5 5%/year Increase	210,100	33,500
6 ~5.9%/year Increase, MNB	204,500	39,100
7 6%/year Increase	204,800	38,800
8 7%/year Increase	201,200	42,400
9 ~6.7%/year Increase, TCTB	201,500	42,100

201,200 million metric tons of CO_2 ($MMTCO_2$) for the 7%/year Increase (Alternative 8) to 243,600 $MMTCO_2$ 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 MY 2012-2016 CAFE standards range from 19,300 to 42,400 $MMTCO_2$. 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 0.8 percent.

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. As mentioned earlier, U.S. passenger cars and light trucks currently account for significant CO_2 emissions in the United States. With the action alternatives reducing U.S. passenger car and light truck CO_2 emissions by 7.9 to 17.4 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 3.6 to 7.8 percent in 2100. As another comparison of the magnitude of these reductions, average annual CO_2 emission reductions from the CAFE alternatives range from 217 to 476 $MMTCO_2$ over 2012 to 2100, equivalent to the annual CO_2 emissions of 47 to 103 coal-fired power plants.[31] Figure 2.6-1 shows projected annual emissions from passenger cars and light trucks under the MY 2012-2016 alternative CAFE standards.

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



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

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 3.7 percent of total global emissions of CO_2 in 2005.[32] Although substantial, this source is a still 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 2.6-7 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 2.6-7 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 37.86 centimeters under the TCTB Alternative (Alternative 9), for a maximum reduction of 0.14 centimeters by 2100 from the No Action Alternative.

Table 2.6-7

CO_2 Concentration, 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	781.2	0.922	1.554	3.129	8.38	15.16	37.94
3 4%/year Increase	441.6	514.1	780.4	0.922	1.553	3.126	8.38	15.15	37.92
4 ~4.3%/year Increase, Preferred	441.5	514.0	780.3	0.922	1.553	3.125	8.38	15.15	37.91
5 5%/year Increase	441.5	513.9	779.8	0.922	1.553	3.124	8.38	15.15	37.89
6 ~5.9%/year Increase, MNB	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
7 6%/year Increase	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
8 7%/year Increase	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86
9 ~6.7%/year Increase, TCTB	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86

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

Table 2.6-7 (continued)

CO_2 Concentration, 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**
Reductions under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.5	1.8	0.001	0.002	0.007	0.00	0.01	0.06
3 4%/year Increase	0.2	0.7	2.6	0.001	0.003	0.010	0.00	0.02	0.08
4 ~4.3%/year Increase, Preferred	0.3	0.8	2.7	0.001	0.004	0.010	0.00	0.02	0.09
5 5%/year Increase	0.3	0.9	3.2	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
7 6%/year Increase	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
8 7%/year Increase	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14

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 2.6-2. CO_2 Concentrations (ppm)

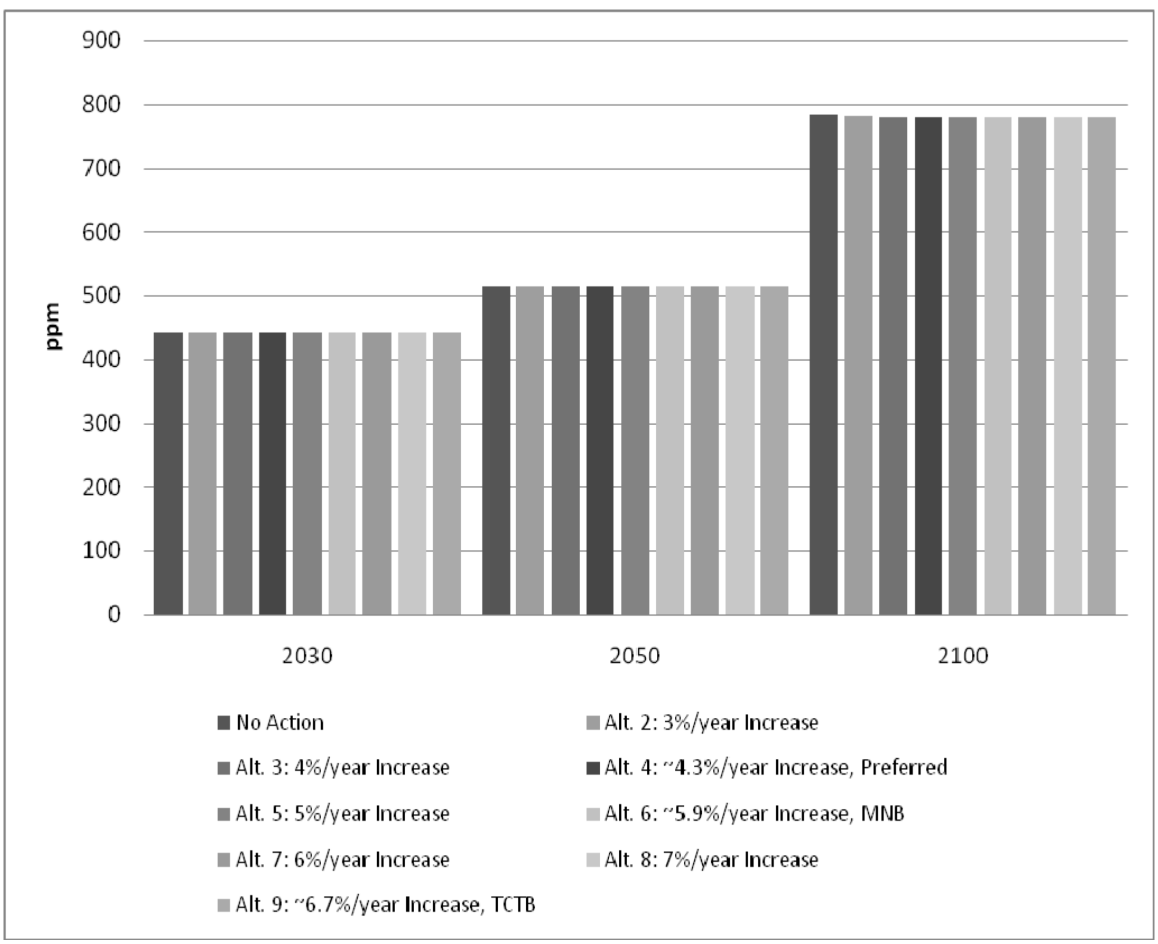


Figure 2.6-3. Global Mean Surface Temperature Increase (°C)

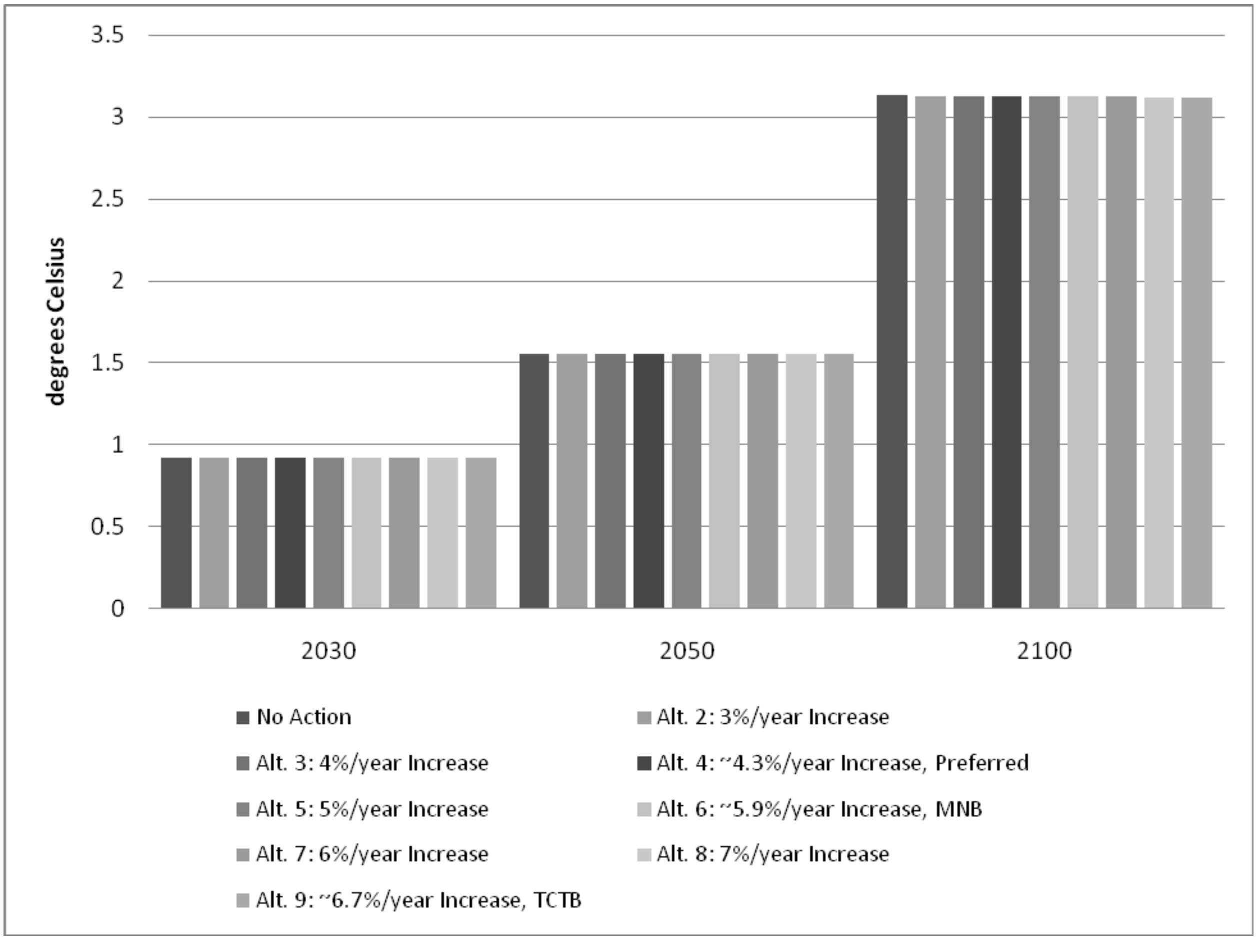


Figure 2.6-4. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

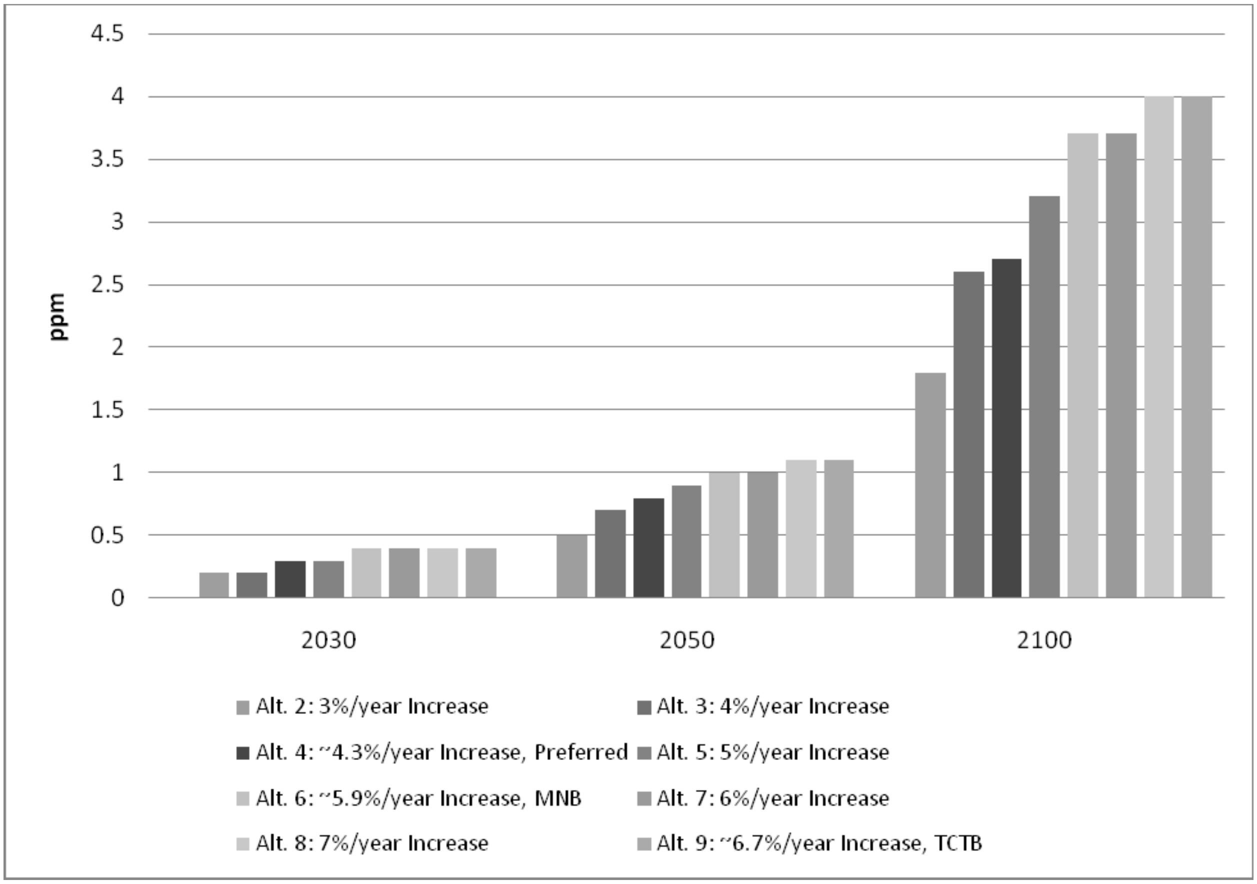
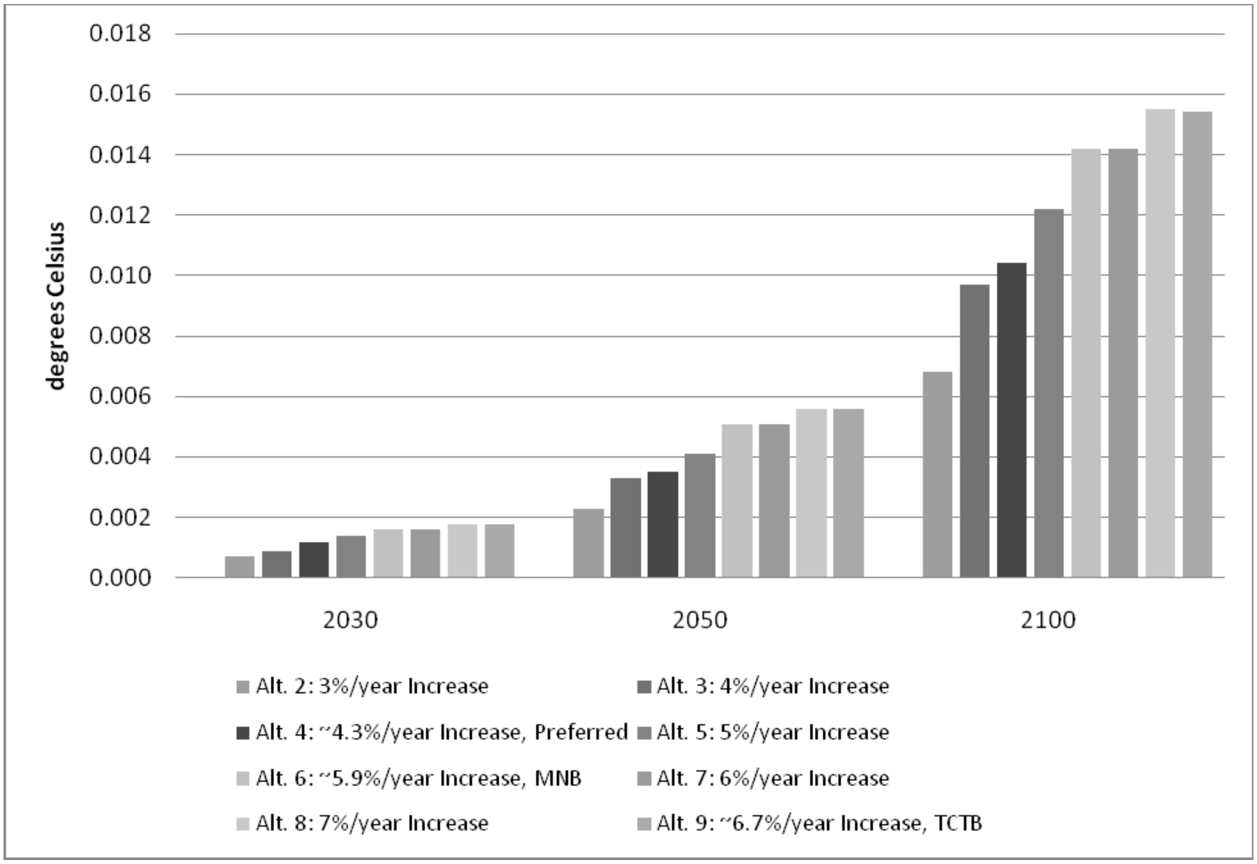


Figure 2.6-5. Reduction in Global Mean Temperature Compared to the No Action Alternative



Estimated CO_2 concentrations for 2100 range from 779.0 ppm under the most stringent alternative (TCTB) 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 for 2030, 1.56 °C for 2050, and 3.14 °C 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 to 0.015 °C.

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 2.6-8.

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.[33] 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.

[33] 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
(continued on bottom of next page)

Table 2.6-8

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	2.810
3 4%/year Increase	0.648	1.712	2.807
4 ~4.3%/year Increase, Preferred	0.648	1.712	2.807
5 5%/year Increase	0.648	1.711	2.805
6 ~5.9%/year Increase, MNB	0.648	1.710	2.803
7 6%/year Increase	0.648	1.710	2.803
8 7%/year Increase	0.648	1.709	2.802
9 ~6.7%/year Increase, TCTB	0.648	1.709	2.802
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	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.007	0.014
9 ~6.7%/year Increase, TCTB	**0.000**	**0.007**	**0.014**
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%	2.59%	4.58%
4 ~4.3%/year Increase, Preferred	0.94%	2.58%	4.57%
5 5%/year Increase	0.94%	2.58%	4.57%
6 ~5.9%/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%	4.57%
9 ~6.7%/year Increase, TCTB	0.94%	2.58%	4.57%
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%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.01%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

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.

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.

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 2.6-9, 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 2.7 to 2.8 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, is also shown in Table 2.6-9. 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 0.008 °C for the 2.0 °C climate sensitivity to 0.013 °C for the 4.5 °C climate sensitivity.

Table 2.6-9

CO_2 concentration (ppm), Temperature (degrees C) 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	510.0	762.4	0.698	1.166	2.284	28.61
	3.0	441.5	514.0	780.3	0.922	1.553	3.125	37.91
	4.5	443.3	518.7	802.5	1.166	1.987	4.119	48.55
Reduction compared to No Action								
	2.0	0.3	0.7	2.7	0.001	0.003	0.008	0.07
	3.0	0.3	0.8	2.7	0.001	0.004	0.010	0.09
	4.5	0.3	0.8	2.8	0.001	0.004	0.013	0.12

a/ Values in this table are rounded.

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 2.6-9. 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 alternative continue to increase in fuel economy consistent with AEO April 2009 (updated) Reference Case projections of annual percentage gains of 0.51 percent in passenger-car mpg and 0.86 percent in light-truck mpg through 2030.[34] 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 2.6-10 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 162.8 billion gallons under the No Action Alternative (Alternative 1). Consumption falls across the alternatives, from 140.7 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 131.3 billion gallons under the TCTB Alternative (Alternative 9) representing a fuel savings of 22.1 to 31.5 billion gallons in 2060, as compared to fuel consumption projected under the No Action Alternative.

Table 2.6-11 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 91.2 billion gallons under the No Action Alternative (Alternative 1). Consumption declines across the alternatives, from 80.1 billion gallons under the 3-Percent Alternative (Alternative 2) to 73.3 billion gallons under Alternative 8 (7-percent annual increase in mpg). This represents a fuel savings of 11.1 to 17.9 billion gallons in 2060, as compared to fuel consumption projected under the No Action Alternative.

[34] 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. Since the AEO forecasts do not extend beyond the year 2030, the mpg estimates for MY 2030 through MY 2060 remain constant.

Table 2.6-10

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

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.1	64.7	63.8	63.6	62.8	61.6	61.6	61.0	60.9
2030	94.5	82.6	82.2	82.3	80.7	78.3	78.2	76.8	76.8
2040	114.7	99.1	99.1	99.3	97.3	94.5	94.2	92.5	92.5
2050	136.7	118.1	118.2	118.4	116.0	112.6	112.4	110.3	110.3
2060	162.8	140.7	140.7	141.0	138.2	134.1	133.8	131.3	131.3
Fuel Savings Compared to No Action									
2020	--	4.4	5.3	5.6	6.3	7.5	7.5	8.1	8.2
2030	--	11.9	12.2	12.2	13.8	16.2	16.3	17.7	17.7
2040	--	15.6	15.5	15.4	17.3	20.2	20.4	22.2	22.2
2050	--	18.6	18.5	18.3	20.7	24.1	24.4	26.5	26.4
2060	--	22.1	22.1	21.8	24.6	28.7	29.0	31.5	31.5

Table 2.6-11

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

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.3	65.6	64.9	64.6	64.0	62.8	63.1	62.5	62.4
2030	62.8	56.8	56.5	56.3	55.0	53.3	53.4	52.5	52.6
2040	66.7	58.9	58.9	58.7	57.1	55.2	55.2	54.1	54.3
2050	77.1	67.8	67.8	67.6	65.7	63.4	63.4	62.1	62.4
2060	91.2	80.1	80.1	79.9	77.6	74.9	74.9	73.3	73.7
Fuel Savings Compared to No Action									
2020	--	2.7	3.4	3.7	4.4	5.6	5.3	5.8	5.9
2030	--	6.0	6.3	6.6	7.8	9.5	9.4	10.3	10.2
2040	--	7.7	7.8	8.0	9.5	11.5	11.5	12.6	12.3
2050	--	9.3	9.3	9.5	11.4	13.7	13.7	15.0	14.7
2060	--	11.1	11.1	11.3	13.6	16.3	16.3	17.9	17.5

2.6.2.2 Air Quality

Table 2.6-12 summarizes the cumulative impacts for national toxic and criteria pollutants in 2050.[35] The table lists the action alternatives (Alternatives 2 through 9) left to right in order of 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 Alternative 7; $PM_{2.5}$ under Alternatives 3 and 4, and Alternatives 8 and 9; SO_x under Alternatives 3 through 5, and Alternatives 7 and 9; and VOCs under Alternative 7. 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 2.6-12

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	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Criteria Pollutant Emissions (Calendar Year 2050)									
Carbon monoxide (CO)	24,155,097	24,530,976	24,385,367	24,315,810	23,541,753	22,770,712	22,314,840	22,130,779	22,061,720
Nitrogen oxides (NO_x)	1,809,786	1,786,720	1,780,335	1,778,462	1,733,908	1,690,190	1,667,885	1,653,446	1,650,090
Particulate matter ($PM_{2.5}$)	107,387	102,210	102,469	102,885	102,501	102,698	103,025	102,490	102,512
Sulfur oxides (SO_x)	262,948	229,228	230,352	231,083	230,124	227,819	230,366	227,019	227,650
Volatile organic compounds (VOC)	1,803,222	1,652,075	1,645,210	1,640,518	1,587,401	1,522,744	1,501,494	1,476,771	1,476,595
Toxic Air Pollutant Emissions (Calendar Year 2050)									
Acetaldehyde	7,953	8,070	8,064	8,048	8,074	8,068	8,068	8,088	8,088
Acrolein	411	418	422	426	449	478	490	498	478
Benzene	28,048	28,111	27,984	27,901	27,253	26,534	26,164	25,993	25,945
1,3-butadiene	4,180	4,249	4,239	4,235	4,189	4,148	4,117	4,111	4,106
Diesel particulate matter (DPM)	138,391	120,407	120,494	120,706	118,016	114,922	114,724	112,629	112,810
Formaldehyde	10,901	10,966	11,022	11,036	11,416	11,775	11,970	12,092	12,118

[35] 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.

As with criteria pollutants, annual emissions of most toxic air pollutants would decrease from one alternative to the next more stringent alternative. The exceptions are acrolein under Alternative 9; benzene under Alternatives 3 through 9; 1,3-butadiene under Alternatives 3 through 9; and formaldehyde under Alternatives 3 through 6. The changes in toxic air pollutant emissions, whether positive or negative, generally would be small in relation to Alternative 1 emissions levels.

Cumulative emissions generally would be less than noncumulative emissions for the same combination of pollutant, year (excluding 2016 which is equivalent to the noncumulative emissions in all cases), and alternative because of differing changes in VMT and fuel consumption under the cumulative case compared to the noncumulative case. The exceptions are acrolein for all alternatives except Alternative 9, 1,3-butadiene for all alternatives except Alternative 2, and CO for all alternatives.

The reductions in emissions are expected to lead to reductions in cumulative adverse health effects. Table 2.6-13 summarizes the national annual changes in health outcomes in 2050 for the nine alternatives, left to right in order of increasing fuel economy requirements. 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 decrease from Alternative 2 through Alternative 3, with mixed results under Alternatives 4 through 7, and decreasing again under Alternatives 8 and 9. These reductions primarily reflect the projected $PM_{2.5}$ reductions, and secondarily the reductions in SO_2.

Table 2.6-13

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

Outcome and Year	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
	No Action b/	3%/year Increase	4%/year Increase	~4.3%/year Increase Preferred	5%/year Increase	~5.9%/year Increase MNB	6%/year Increase	7%/year Increase	~6.7%/year Increase TCTB
Mortality (ages 30 and older)									
Pope et al. 2002									
2050	0	-364	-356	-339	-406	-453	-455	-504	-504
Laden et al. 2006									
2050	0	-930	-911	-867	-1,037	-1,157	-1,162	-1,287	-1,288
Chronic bronchitis									
2050	0	-230	-226	-215	-259	-290	-292	-323	-323
Emergency Room Visits for Asthma									
2050	0	-323	-315	-300	-347	-382	-377	-417	-416
Work Loss Days									
2050	0	-39,749	-38,969	-37,043	-44,648	-49,958	-50,334	-55,754	-55,808

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 2.6-14 lists the corresponding annual reductions in health costs in 2050 under the action alternatives compared to the No Action Alternative. Reductions in health costs are given for two alternative assumptions of the discount rate, 3 percent and 7 percent, consistent with EPA policy for presentation of future health costs.

Table 2.6-14

Cumulative Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
3-% Discount Rate									
Pope et al. 2002									
2050	0	-3,292	-3,225	-3,067	-3,672	-4,097	-4,116	-4,558	-4,560
Laden et al. 2006									
2050	0	-8,069	-7,903	-7,518	-8,999	-10,040	-10,083	-11,167	-11,171
7-% Discount Rate									
Pope et al. 2002									
2050	0	-2,985	-2,924	-2,782	-3,331	-3,716	-3,733	-4,134	-4,136
Laden et al. 2006									
2050	0	-7,287	-7,138	-6,790	-8,128	-9,068	-9,107	-10,087	-10,090

a/ Negative changes indicate economic benefit; positive emissions changes indicate economic costs.
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.

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 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. 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.

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; H.R. 2454: American Clean Energy and Security Act ("Waxman-Markey Bill"); Renewable Fuel Standard (RFS2); Program Activities of DOE's Office of Fossil Energy; Program Activities of DOE's Office of Nuclear Energy; United Nation's Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol and upcoming Conference of the Parties (COP) 15 in Copenhagen, Denmark; G8 Declaration – Summit 2009; and the Asia Pacific Partnership on Clean Development and Climate.[36]

[36] 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
(continued on bottom of next page)

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 and 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.

2.6.2.2.1 Cumulative GHG Emissions

Table 2.6-15 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 MY 2012-2016 CAFE standards and other reasonably foreseeable future actions ranged from 27,300 to 39,100 $MMTCO_2$. 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 0.7 to 1.0 percent from their projected levels under the No Action Alternative.

Table 2.6-15

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	227,600	0
2 3%/year Increase	200,300	27,300
3 4%/year Increase	200,200	27,300
4 ~4.3%/year Increase, Preferred	200,300	27,300
5 5%/year Increase	196,700	30,900
6 ~5.9%/year Increase, MNB	191,600	36,000
7 6%/year Increase	191,800	35,800
8 7%/year Increase	188,500	39,100
9 ~6.7%/year Increase, TCTB	188,790	38,791

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger-car and light-truck fleet represented about 3.7 percent of total global emissions of CO_2 in 2005.[37] Although substantial, this source is a still 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).

towards significant GHG reductions. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA.

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

2.6.2.2.2 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 2.6-16 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 654.0 ppm for the TCTB Alternative (Alternative 9) to 657.5 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 2.6-16. For all alternatives, the cumulative global mean surface temperature increase is about 0.80 °C to 0.81 °C as of 2030; 1.32 to 1.33 °C as of 2050; and 2.60 to 2.61 °C as of 2100.[38] 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.

The impact on sea-level rise from the scenarios is presented in Table 2.6-16, showing sea-level rise in 2100 ranging from 32.84 centimeters under the No Action Alternative (Alternative 1) to 32.70 centimeters under the TCTB Alternative (Alternative 9), for a maximum reduction of 0.14 centimeters by 2100 from the action alternatives.

Table 2.6-16

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	657.5	0.805	1.327	2.611	7.83	13.67	32.84
2 3%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
3 4%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
4 ~4.3%/year Increase, Preferred	438.5	497.3	655.1	0.804	1.323	2.600	7.83	13.65	32.75
5 5%/year Increase	438.4	497.2	654.7	0.804	1.323	2.599	7.83	13.65	32.73
6 ~5.9%/year Increase, MNB	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
7 6%/year Increase	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
8 7%/year Increase	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70
9 ~6.7%/year Increase, TCTB	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70

[38] 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.

Table 2.6-16 (continued)

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
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
3 4%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
4 ~4.3%/year Increase, Preferred	0.2	0.7	2.4	0.001	0.004	0.011	0.00	0.02	0.09
5 5%/year Increase	0.3	0.8	2.8	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
7 6%/year Increase	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
8 7%/year Increase	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14

a/ Values in this table are rounded.

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

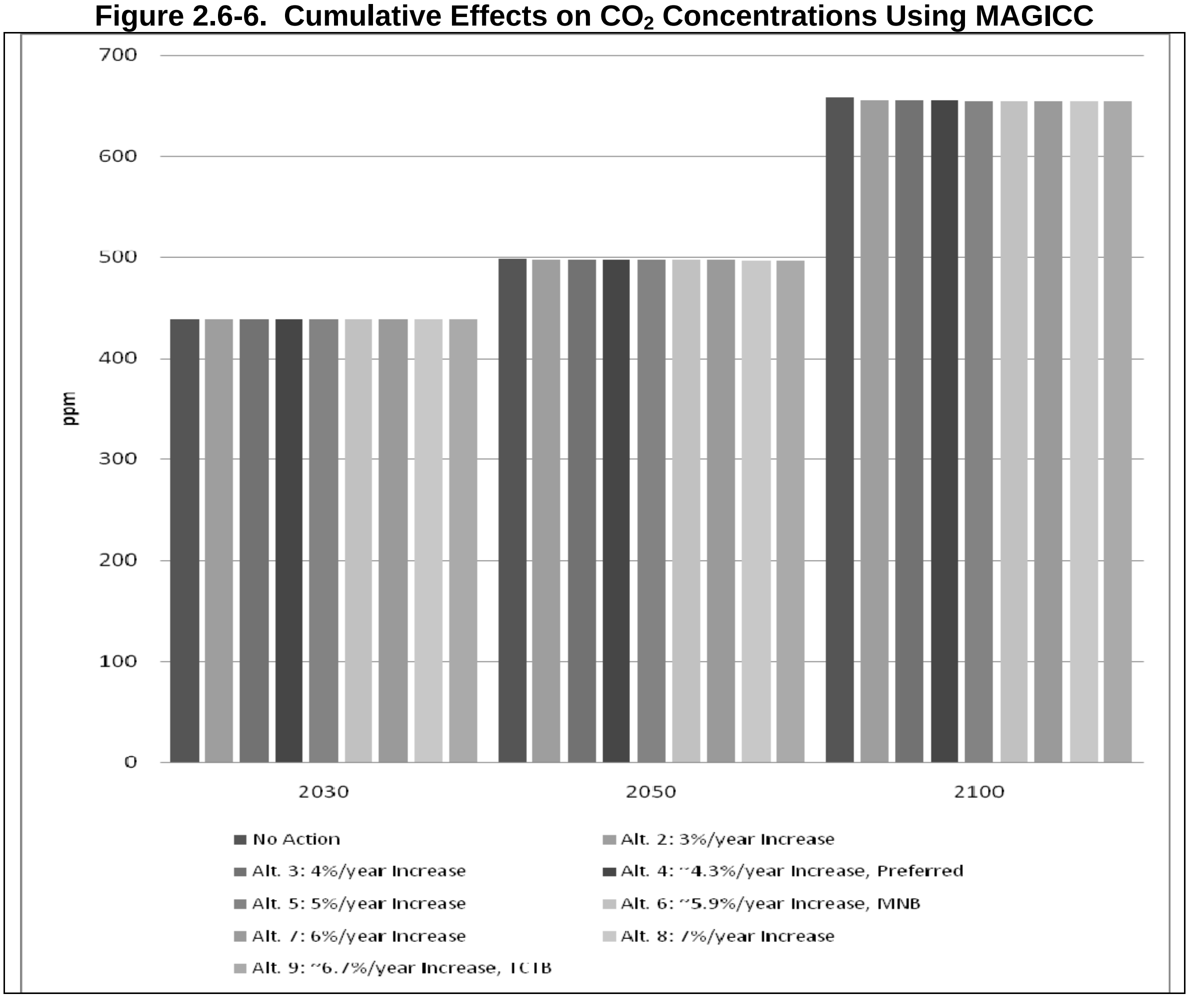
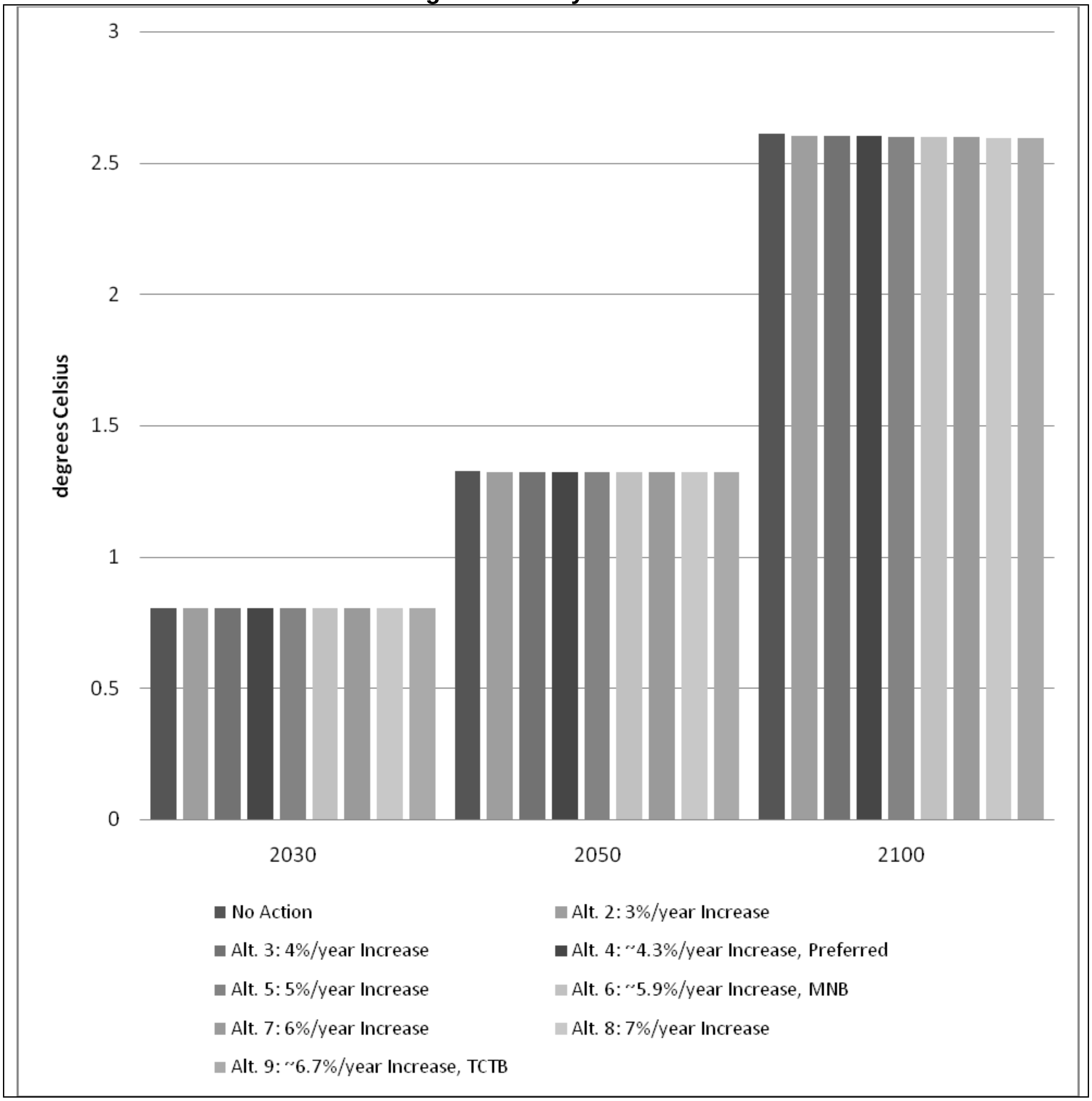


Figure 2.6-7. Cumulative Effects on the Global Mean Surface Temperature Increase Using MAGICC by Alternative



1

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

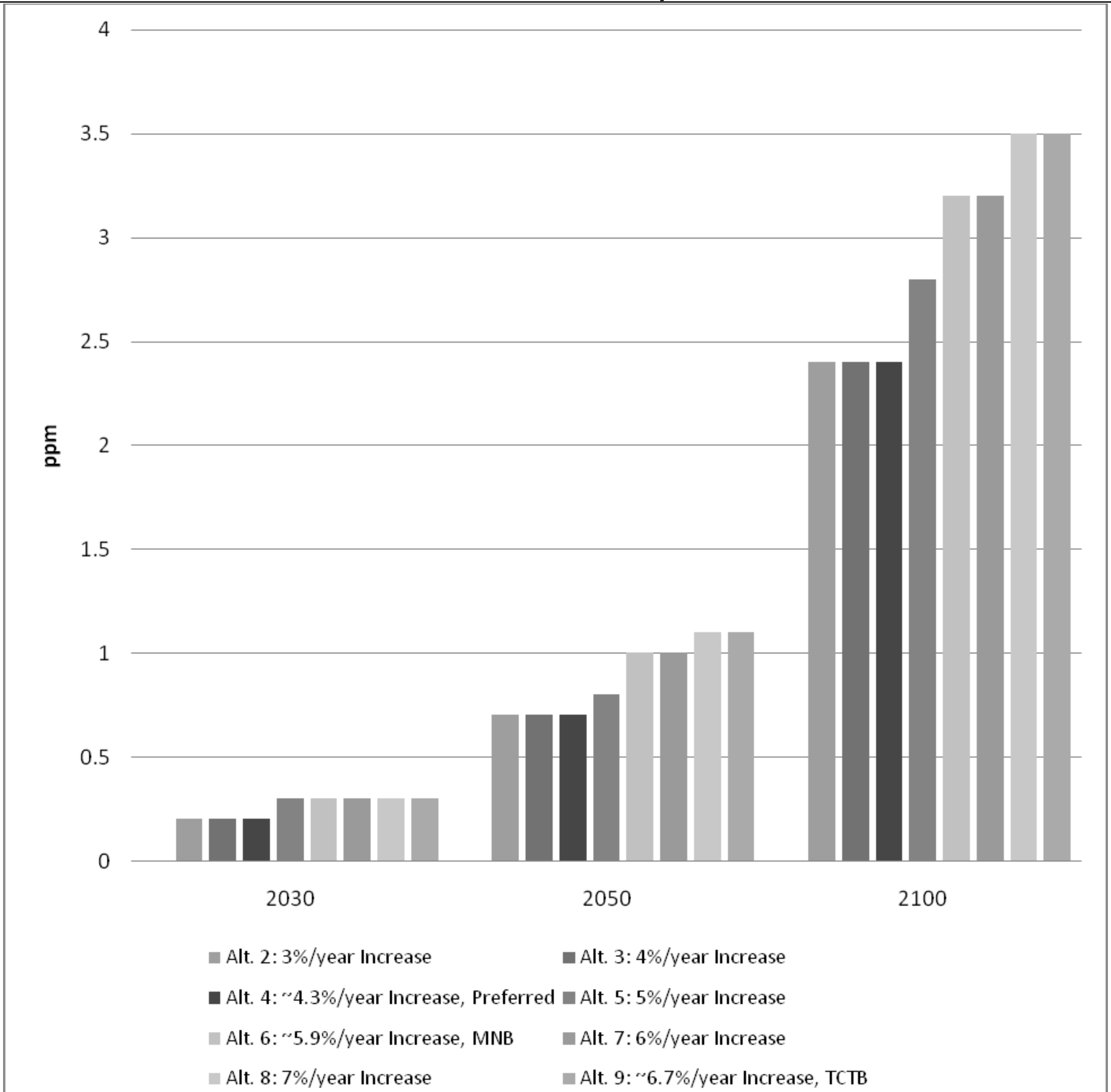
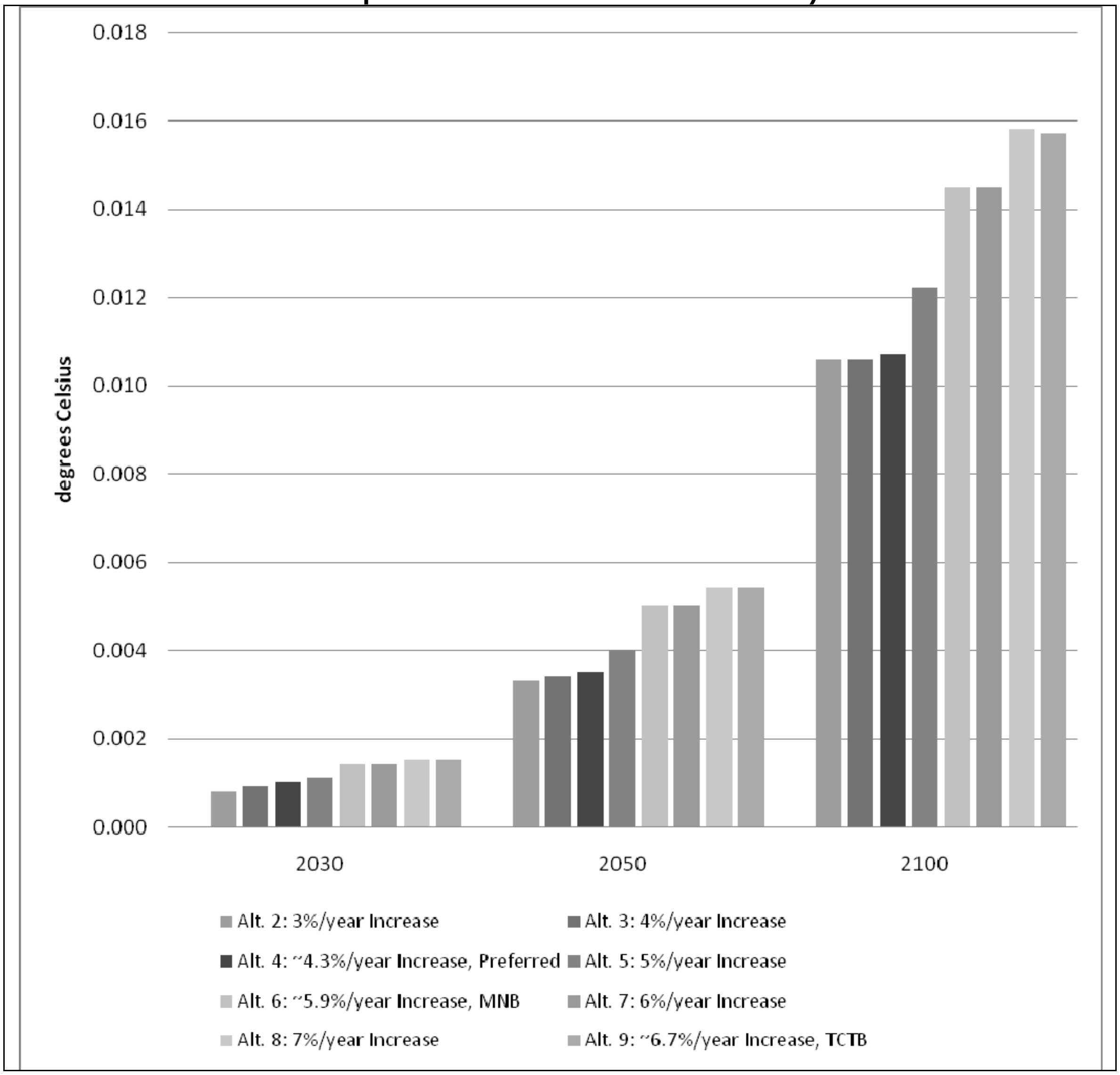


Figure 2.6-9. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)



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 2.6-17.

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.[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.

[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 2.6-17

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	2.406
3 4%/year Increase	0.586	1.462	2.406
4 ~4.3%/year Increase, Preferred	0.586	1.462	2.406
5 5%/year Increase	0.586	1.461	2.405
6 ~5.9%/year Increase, MNB	0.586	1.460	2.403
7 6%/year Increase	0.586	1.460	2.403
8 7%/year Increase	0.586	1.459	2.401
9 ~6.7%/year Increase, TCTB	0.586	1.459	2.402
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	0.009
3 4%/year Increase	0.000	0.004	0.009
4 ~4.3%/year Increase, Preferred	0.000	0.004	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.006	0.014
9 ~6.7%/year Increase, TCTB	0.000	0.006	0.014
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 ~5.9%/year Increase, MNB	0.85%	2.20%	3.92%
7 6%/year Increase	0.85%	2.20%	3.92%
8 7%/year Increase	0.85%	2.20%	3.91%
9 ~6.7%/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%	0.01%
3 4%/year Increase	0.00%	0.01%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

a/ Values in this table are rounded.

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[40] (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 2.6-18, 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 2.2 to 2.7 ppm. The Reference Case using the MiniCAM Level 3 scenario and a 3.0 °C climate sensitivity has an impact of 2.4 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 is also shown in Table 2.6-18. 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 0.008 °C for the 2.0 °C climate sensitivity to 0.014 °C for the 4.5 °C climate sensitivity, for the MiniCAM Level 3 emissions scenario.

The impact on global mean surface temperature due to assumptions concerning global emissions of GHGs is also important. The scenario with the higher global emissions of GHGs (*viz.*, the MiniCAM Reference) has a slightly lower reduction in global mean surface temperature, and the scenario with lower global emissions (*viz.*, the MiniCAM Level 2) has a slightly 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 higher and, as a result, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

[40] 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.

Table 2.6-18

Cumulative Effects on CO_2 Concentration, Temperature, 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	483.0	551.3	0.612	0.986	1.546	22.32
		3.0	435.7	486.5	563.5	0.812	1.324	2.177	29.92
		4.5	437.4	490.5	578.8	1.034	1.705	2.948	38.76
	Reduction compared to No Action								
		2.0	0.2	0.8	2.2	0.001	0.003	0.009	0.08
		3.0	0.3	0.8	2.4	0.001	0.004	0.012	0.11
		4.5	0.2	0.8	2.5	0.001	0.004	0.015	0.12
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	493.8	641.0	0.606	0.987	1.880	24.60
		3.0	438.5	497.3	655.1	0.804	1.323	2.600	32.75
		4.5	440.1	501.3	672.6	1.023	1.702	3.461	42.12
	Reduction compared to No Action								
		2.0	0.3	0.7	2.4	0.001	0.003	0.008	0.08
		3.0	0.2	0.7	2.4	0.001	0.004	0.011	0.09
		4.5	0.2	0.7	2.6	0.001	0.004	0.014	0.12
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	510.0	762.6	0.699	1.166	2.285	28.61
		3.0	441.5	514.1	780.4	0.922	1.553	3.126	37.91
		4.5	443.3	518.8	802.6	1.166	1.987	4.120	48.55
	Reduction compared to No Action								
		2.0	0.3	0.7	2.5	0.001	0.003	0.007	0.07
		3.0	0.3	0.7	2.6	0.001	0.003	0.010	0.09
		4.5	0.3	0.8	2.7	0.001	0.004	0.012	0.12

a/ Values in this table are rounded.

The sensitivity of the simulated sea-level rise to changes in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 2.6-18. 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.

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 Code of Federal Regulations (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

3.1.3.1 CEQ Regulations

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;

[1] *See* 42 United States Code (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).

3. A summary of existing credible scientific evidence 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.

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 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 MY2011 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. 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 many 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
  - 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
  - Upstream CO_2 and criteria pollutant emissions rates (that is, U.S. emissions resulting from the production and distribution of each fuel);

[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 fleets 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.

- 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.

- 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 “multiyear 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 given manufacturer’s ability to apply foresight, adding “extra” technology to a given model year to facilitate compliance in later model 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]

[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).

- 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;
- 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 (EIA 2008).

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 fit coefficients defining the shape and level of attribute-based CAFE-standard curves, and 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. The agency uses such 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, alone, 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 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.

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.

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

[4] Domestic full-fuel-cycle emissions include the emissions associated with production, transportation, and refining operations, and the CO_2 emissions from fuel combustion.

also revised provisions regarding the creation and application of CAFE credits. 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. AMFA credits allow manufacturers to increase their CAFE levels through MY 2019 by producing alternative fuel vehicles. The AMFA amended EPCA 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 building dual-fuel 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 multiyear 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 multiyear planning?
- Having earned CAFE credits in one fleet (*i.e.*, passenger or nonpassenger), to which fleet would a given manufacturer most likely apply those credits?

[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.

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 multiyear planning effects, 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 flexibilities increases 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.

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[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 2030, with energy intensity reaching 5.58 million British thermal units per dollar of GDP (in year 2000 dollars) in the latter year (EIA 2009b). 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. 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

The energy projections NHTSA uses in this section are from the DOE Energy Information Administration (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 laws and regulations that are in force at the time of the modeling.

In the case of the AEO 2009, EIA issued an updated Reference Case in April 2009 to incorporate the impacts of the American Recovery and Reinvestment Act of 2009,[1] the MY 2011 CAFE standards, and an update of the macroeconomic assumptions (EIA 2009b). 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. Over half of U.S. energy consumption in the transportation sector can be attributed to passenger cars and light trucks, ranging from 58 percent in 2010 to 53 percent by 2030. 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 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 projections, the biofuels share of energy consumption in the transportation sector will rise to 10 percent by 2030.

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

Table 3.2.1-1

Energy Consumption By Sector

Sector (Quadrillion BTU c/)	Actual a/				Forecast b/				
	1990	1995	2000	2004	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), http://www.eia.doe.gov/aer/pdf/pages/sec2_4.pdf
Actual World data: EIA (2009d), http://www.eia.doe.gov/pub/international/iealf/tablee1.xls

b/ Forecasted United States data: EIA (2009c), http://www.eia.doe.gov/oiaf/aeo/supplement/arra/excel/suptab_10.xls
Forecasted World data: EIA (2009d), http://www.eia.doe.gov/oiaf/ieo/excel/ieoendusetab_1.xls

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. 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.[2] 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

[2] 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 (April 2009 release), 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, and in part due to high prices – will fall to 48 percent of liquid fuel supply in 2020 and then decline further to 40 percent in 2030. The further decrease in 2030 is due in part due 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 MY 2005-2007 and MY 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. 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 MY 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 and in NHTSA's RIA, which can be found in the docket for this action. *See* Section 3.1.4 for further information on the Volpe model.

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.[3] 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 MY 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.[4] For MY 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 MY 2017-2060 remains constant at their levels estimated for MY 2016 under each action alternative.[5]

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 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 173.5 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 158.2 billion gallons under Alternative 2 (3-percent annual increase in mpg) to 139.7 billion gallons under Alternatives 8 and 9 (TCTB). In 2060, fuel consumption under the TCTB Alternative amounts to 9.1 million barrels of fuel per day, while under Alternative 4 (the Preferred Alternative), daily fuel consumption amounts to 9.8 million barrels per day.[6] As a point of reference, NHTSA projects that fuel consumption under the No Action Alternative would be 11.3 million barrels per day in 2060. In 2007, the United States consumed 9.3 million barrels of fuel per day (EIA 2009a).

[3] 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.
[4] 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.
[5] See footnote 2 in this chapter.
[6] 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 gasoline equivalent) by Alternative

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.4	65.7	64.3	63.9	63.0	61.8	61.9	61.2	61.1
2030	97.9	89.5	86.4	85.5	83.5	81.0	80.9	79.4	79.4
2040	121.7	110.9	106.9	105.9	103.2	100.1	99.9	98.0	98.1
2050	145.7	132.8	128.0	126.7	123.5	119.8	119.6	117.3	117.3
2060	173.5	158.2	152.4	150.9	147.1	142.7	142.4	139.7	139.7
Fuel Savings Compared to No Action									
2020	--	3.7	5.1	5.5	6.4	7.6	7.6	8.2	8.3
2030	--	8.4	11.5	12.3	14.4	16.8	17.0	18.4	18.4
2040	--	10.8	14.8	15.9	18.5	21.6	21.8	23.7	23.7
2050	--	12.9	17.7	19.0	22.2	25.9	26.2	28.4	28.4
2060	--	15.4	21.1	22.6	26.5	30.9	31.2	33.9	33.8

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 101.4 billion gallons in 2060, and to decline progressively under the action alternatives, from 93.3 billion gallons under Alternative 2 to 81.3 billion gallons under Alternative 8. These represent fuel savings compared to the No Action Alternative that range from 8.1 billion gallons annually under Alternative 2 to 20.1 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 gasoline equivalent) by Alternative

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.6	66.4	65.2	64.9	64.2	63.0	63.3	62.7	62.6
2030	66.0	61.6	59.6	59.0	57.6	55.8	55.9	55.0	55.1
2040	73.0	67.4	64.9	64.2	62.4	60.3	60.3	59.1	59.3
2050	85.5	78.7	75.7	74.8	72.7	70.2	70.1	68.7	69.0
2060	101.4	93.3	89.7	88.7	86.1	83.1	83.1	81.3	81.7
Fuel Savings Compared to No Action									
2020	--	2.3	3.4	3.8	4.4	5.6	5.3	5.9	6.0
2030	--	4.4	6.4	7.0	8.3	10.1	10.0	11.0	10.9
2040	--	5.6	8.1	8.8	10.6	12.8	12.7	14.0	13.7
2050	--	6.8	9.8	10.7	12.8	15.4	15.4	16.9	16.5
2060	--	8.1	11.7	12.7	15.3	18.3	18.4	20.1	19.7

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[1] (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 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.[2]

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 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 crops or vegetation, and damage to buildings or other property. Because each criteria pollutant has

[1] "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 pollutants," by contrast, refer to substances defined as hazardous by the 1990 CAA amendments. These substances include certain VOCs, pesticides, herbicides, and radionuclides that present tangible hazards, based on scientific studies of exposure to humans and other mammals.

[2] 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.

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 µg/m^3	Rolling 3-month average	Same as Primary	
Nitrogen dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)	Same as Primary	
Particulate matter (PM_{10})	150 µg/m^3	24 hours c/	Same as Primary	
Particulate matter ($PM_{2.5}$)	15.0 µg/m^3	Annual d/ (Arithmetic Mean)	Same as Primary	
	35 µg/m^3	24 hours e/	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8 hours f/	Same as Primary	
	0.08 ppm (1997 std.)	8 hours g/ h/	Same as Primary	
Sulfur dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm (1300 µg/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 (µg/m^3).
b/ Not to be exceeded more than once per year.
c/ Not to be exceeded more than once per year on average over 3 years.
d/ 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 µg/m^3.
e/ 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 µg/m^3 (effective December 17, 2006).
f/ 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).
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 0.08 ppm.
h/ 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 2009f.

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 (µg/m^3) to 35 µg/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 NO_2 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 of 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 largest source of CO emissions nationally. 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, light-duty gasoline onroad vehicles are no longer a major source of lead pollution.

SO_2, one of various oxides of sulfur (SO), 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 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 MY 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.

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-duty 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.

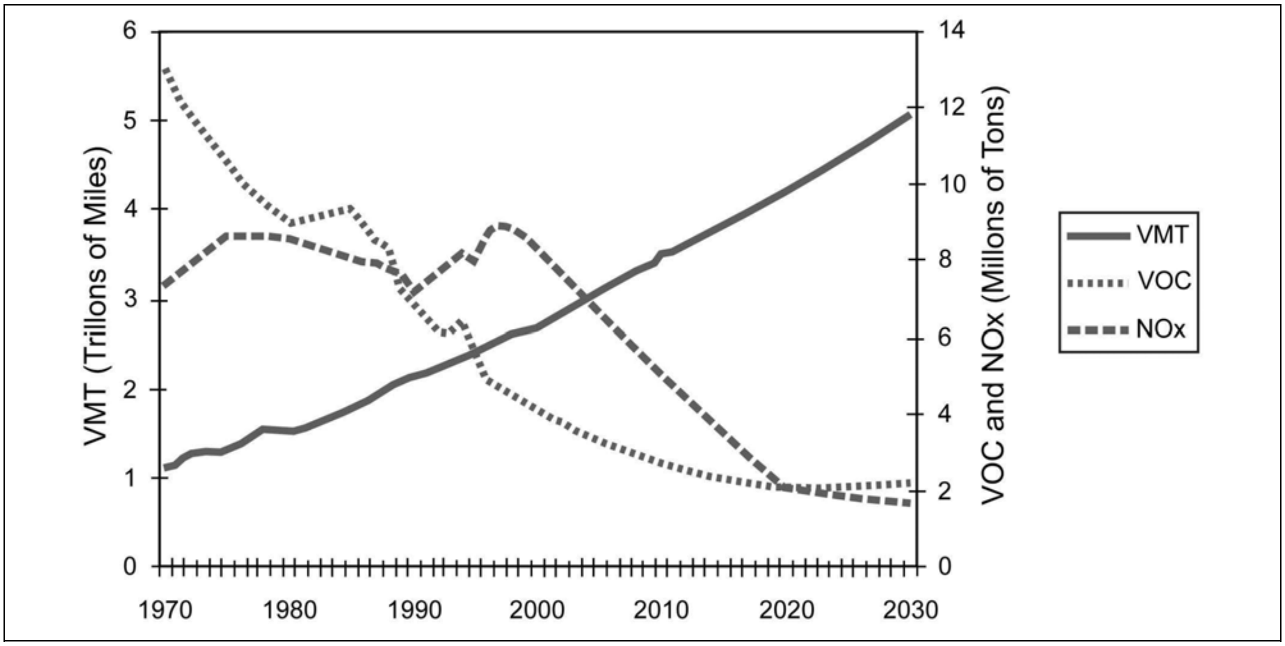
EPA is addressing air toxics through its MSAT rules (EPA 2007). These rules limit the benzene content of gasoline beginning in 2011. They also limit exhaust emissions of hydrocarbons (many VOCs and MSATs are hydrocarbons) from passenger cars and light trucks when they are operated at cold temperatures. 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.

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



- 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 number 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[3] 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.

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

[3] 74 *FR* 24904, May 26, 2009

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.[4] The air quality analysis considers the emissions that 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 MY 2012-2016 would also continue for many years. The influence

[4] 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 98^{th} 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.

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.

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 MY 2012-2016 would remain in force indefinitely at the 2016 level; NHTSA did not include potential CAFE standards for MY 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 MY 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[5]); by this point a large proportion of passenger-car and light-truck VMT would be accounted for by vehicles that meet the MY 2012-2016 standards; first year of complete implementation of potential MY 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 MY 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 MY 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.

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

[5] 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.

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	Moderate	Nonattainment	100	100
Columbus, OH	Subpart 1	Nonattainment	100	100
Dallas-Fort Worth, TX	Moderate	-	100	-
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

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	$PM_{2.5}$
Houston-Galveston-Brazoria, TX	Moderate	-	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	Subpart 1	-	100	100
Providence (All RI), RI	Moderate	-	100	-
Reading, PA	-	Nonattainment	-	100
Riverside Co., CA (Coachella Valley)	Serious	-	50	-
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

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	$PM_{2.5}$
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 2008, 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 occurs 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.

For the final EIS, NHTSA will use a complete set of EPA county-level data for these pollutants to allocate the emission reductions from GREET.

3.3.2.4.2 Health Outcomes and Costs

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 dollar value of benefits or the number of health outcomes between that alternative and the No Action Alternative.

NHTSA estimated only the PM2.5-related human health impacts that are expected to result from reduced population exposure to atmospheric concentrations of PM2.5. The estimates are derived from PM2.5-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 - NOx, SO2, and VOCs - are included in the analysis as precursor emissions that contribute to PM2.5 not emitted directly from a source, but instead formed by chemical reactions in the atmosphere (secondary PM2.5). 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. The agency is using PM-related benefits-per-ton values as an interim approach to estimating the PM-related benefits of the proposal. To model the ozone and PM air quality benefits of the final rule, the analysis will utilize ambient concentration data derived from full-scale photochemical air quality modeling.

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.[6]

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 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

[6] 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

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).[7] 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% 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 (*see* 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.

[7] 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 Premature Mortality – Pope *et al.* 2002b

	All Sources b/		**Stationary (Non-EGU c/) Sources**		**Mobile Sources**	
Year a/	**SO_x**	**VOC**	**NO_x**	**Direct $PM_{2.5}$**	**NO_x**	**Direct $PM_{2.5}$**
			Premature Mortality – Pope *et al.* 2002[b]			
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. 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 MY 2012-2016 passenger cars and light trucks. Due to the unique nature of the joint NHTSA-EPA rulemaking, and as a component of the National Program, EPA's air quality modeling analysis of its GHG standards will provide insight into the uncertainties associated with the use of monetary benefits-per-ton estimates.

- 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.

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.

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 manufacturer's 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 decline 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 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 4 through 9 due to the interaction of VMT, fuel economy, and the share of VMT accrued by diesel vehicles. 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.

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 3.3.3-1

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon monoxide (CO)									
2016	18,046,737	18,055,567	18,054,219	18,049,276	17,990,071	17,954,866	17,943,080	17,930,498	17,927,150
2020	15,996,845	16,026,834	16,022,019	16,011,136	15,852,005	15,731,014	15,677,635	15,642,513	15,630,338
2030	17,766,186	17,875,841	17,857,900	17,830,426	17,374,361	16,933,532	16,692,592	16,584,083	16,544,125
Nitrogen oxides (NO_x)									
2016	2,043,669	2,040,386	2,038,801	2,038,077	2,035,890	2,033,211	2,033,658	2,032,473	2,031,999
2020	1,612,106	1,604,439	1,600,822	1,599,457	1,591,815	1,584,855	1,584,110	1,581,036	1,580,355
2030	1,467,596	1,453,694	1,445,588	1,443,013	1,416,117	1,390,714	1,379,863	1,370,822	1,368,895
Particulate matter ($PM_{2.5}$)									
2016	63,686	63,201	63,010	62,991	63,145	63,149	63,315	63,249	63,205
2020	62,698	61,520	61,109	61,096	61,212	61,368	61,681	61,529	61,510
2030	76,589	74,147	73,316	73,321	73,122	73,349	73,725	73,362	73,382
Sulfur Oxides (SO_x)									
2016	164,406	161,493	160,246	159,818	160,089	159,031	159,855	159,312	159,006
2020	169,832	162,689	159,941	159,199	159,114	157,754	159,065	157,885	157,789
2030	201,502	186,242	180,661	179,415	178,313	176,493	178,441	176,043	176,396
Volatile organic compounds (VOCs)									
2016	2,307,062	2,293,122	2,286,048	2,282,711	2,275,408	2,264,296	2,265,703	2,261,824	2,259,827
2020	1,943,639	1,909,647	1,893,787	1,887,837	1,869,970	1,847,814	1,845,130	1,836,676	1,835,092
2030	1,668,085	1,596,544	1,564,323	1,553,482	1,514,436	1,469,438	1,456,616	1,439,159	1,438,649

Figure 3.3.3-1. Nationwide Criteria Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative

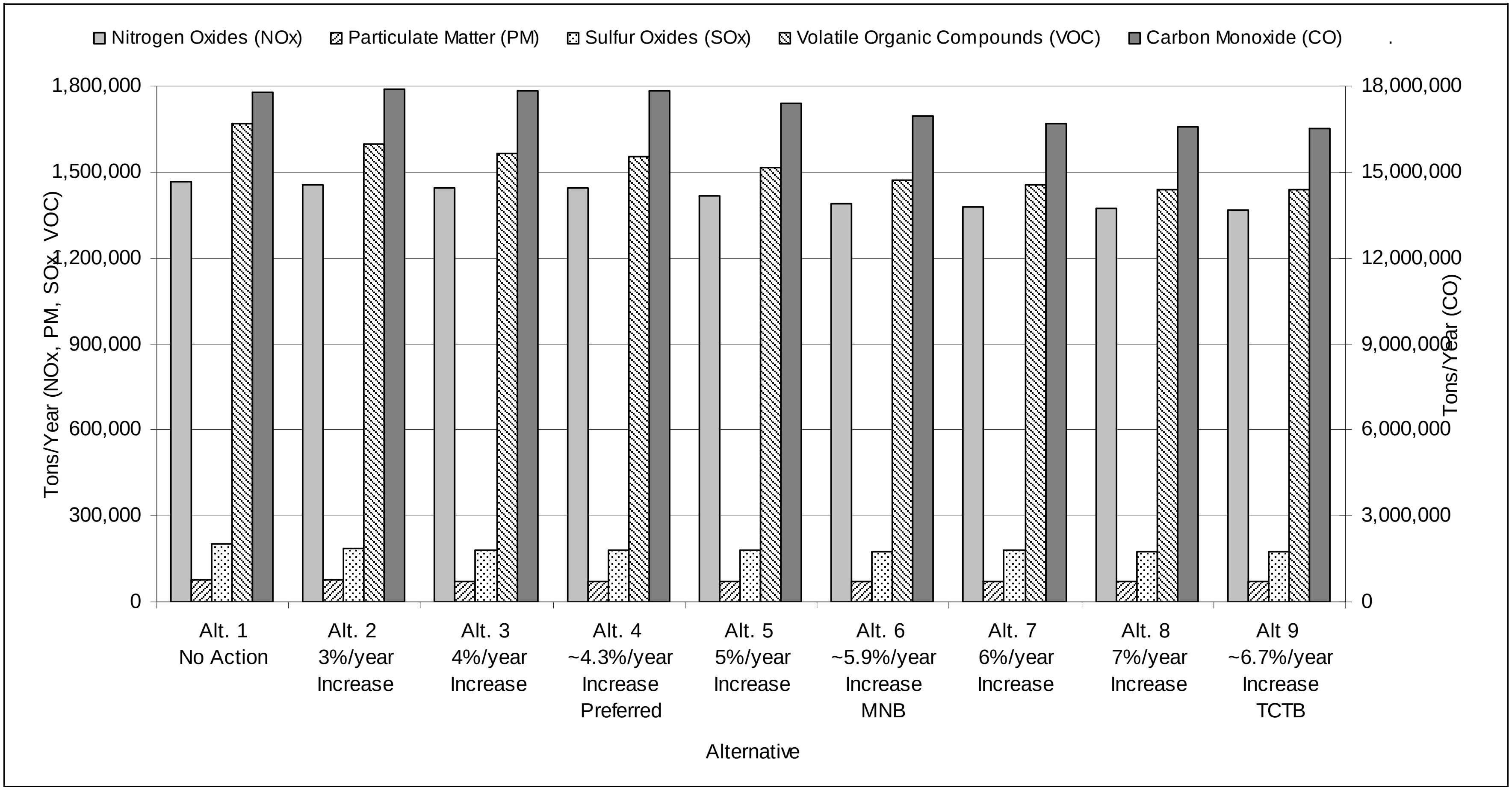


Table 3.3.3-2

Nationwide Criteria Pollutant Emissions in 2030 from Passenger Cars and Light Trucks, by Vehicle Type by Alternative (tons/year)

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon monoxide (CO)									
Car Tail	7,878,750	7,937,359	7,955,806	7,918,203	7,943,240	7,855,275	7,853,156	7,864,806	7,872,234
Car Up	53,101	48,746	47,151	47,013	45,909	45,327	45,282	44,542	44,493
Truck Tail	9,798,206	9,855,973	9,821,999	9,832,640	9,351,783	8,999,460	8,759,619	8,640,473	8,592,916
Truck Up	36,129	33,762	32,944	32,569	33,429	33,470	34,535	34,262	34,482
Total	17,766,186	17,875,841	17,857,900	17,830,426	17,374,361	16,933,532	16,692,592	16,584,083	16,544,125
Nitrogen oxides (NO_x)									
Car Tail	356,847	359,498	360,336	358,668	359,796	355,896	355,804	356,333	356,663
Car Up	166,236	152,516	147,473	146,902	143,439	141,283	141,128	138,785	138,654
Truck Tail	831,560	836,147	834,927	835,741	809,211	790,193	776,714	770,460	767,712
Truck Up	112,953	105,533	102,852	101,702	103,672	103,342	106,217	105,244	105,866
Total	1,467,596	1,453,694	1,445,588	1,443,013	1,416,117	1,390,714	1,379,863	1,370,822	1,368,895
Particulate matter ($PM_{2.5}$)									
Car Tail	20,921	21,211	21,364	21,562	21,627	22,147	22,165	22,251	22,225
Car Up	22,635	20,783	20,106	20,055	19,585	19,355	19,337	19,022	19,000
Truck Tail	17,624	17,752	17,788	17,807	17,607	17,501	17,398	17,374	17,345
Truck Up	15,409	14,400	14,058	13,897	14,303	14,346	14,825	14,715	14,812
Total	76,589	74,147	73,316	73,321	73,122	73,349	73,725	73,362	73,382
Sulfur Oxides (SO_x)									
Car Tail	18,336	16,737	16,130	15,922	15,533	14,954	14,922	14,638	14,647
Car Up	101,646	93,341	90,306	90,097	87,987	86,998	86,918	85,509	85,407
Truck Tail	12,306	11,477	11,056	10,956	10,432	9,926	9,774	9,544	9,546
Truck Up	69,215	64,688	63,168	62,440	64,362	64,616	66,828	66,351	66,796
Total	201,502	186,242	180,661	179,415	178,313	176,493	178,441	176,043	176,396
Volatile organic compounds (VOCs)									
Car Tail	235,488	237,323	238,032	237,683	238,339	237,644	237,637	238,061	238,159
Car Up	554,868	505,473	486,552	478,608	466,733	445,352	444,215	435,352	435,870
Truck Tail	507,103	508,318	508,451	508,635	505,087	502,838	501,083	500,401	499,985
Truck Up	370,625	345,430	331,288	328,556	304,277	283,605	273,681	265,346	264,635
Total	1,668,085	1,596,544	1,564,323	1,553,482	1,514,436	1,469,438	1,456,616	1,439,159	1,438,649

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon monoxide (CO)									
2016	0	8,829	7,482	2,539	-56,666	-91,872	-103,657	-116,240	-119,587
2020	0	29,989	25,174	14,291	-144,840	-265,831	-319,210	-354,332	-366,507
2030	0	109,654	91,714	64,239	-391,826	-832,654	-1,073,594	-1,182,103	-1,222,062
Nitrogen oxides (NO_x)									
2016	0	-3,283	-4,868	-5,592	-7,779	-10,458	-10,011	-11,196	-11,670
2020	0	-7,667	-11,284	-12,649	-20,291	-27,251	-27,996	-31,070	-31,752
2030	0	-13,902	-22,008	-24,583	-51,479	-76,882	-87,733	-96,775	-98,702
Particulate matter ($PM_{2.5}$)									
2016	0	-486	-677	-696	-541	-538	-371	-438	-482
2020	0	-1,178	-1,589	-1,602	-1,486	-1,330	-1,017	-1,169	-1,188
2030	0	-2,442	-3,273	-3,268	-3,467	-3,240	-2,864	-3,227	-3,208
Sulfur Oxides (SOx)									
2016	0	-2,912	-4,160	-4,588	-4,316	-5,375	-4,551	-5,094	-5,400
2020	0	-7,143	-9,891	-10,633	-10,718	-12,078	-10,767	-11,947	-12,042
2030	0	-15,261	-20,842	-22,087	-23,189	-25,009	-23,061	-25,459	-25,106
Volatile organic compounds (VOCs)									
2016	0	-13,941	-21,014	-24,352	-31,654	-42,766	-41,359	-45,238	-47,235
2020	0	-33,992	-49,852	-55,802	-73,669	-95,825	-98,509	-106,963	-108,548
2030	0	-71,541	-103,762	-114,603	-153,648	-198,646	-211,468	-228,925	-229,436

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.

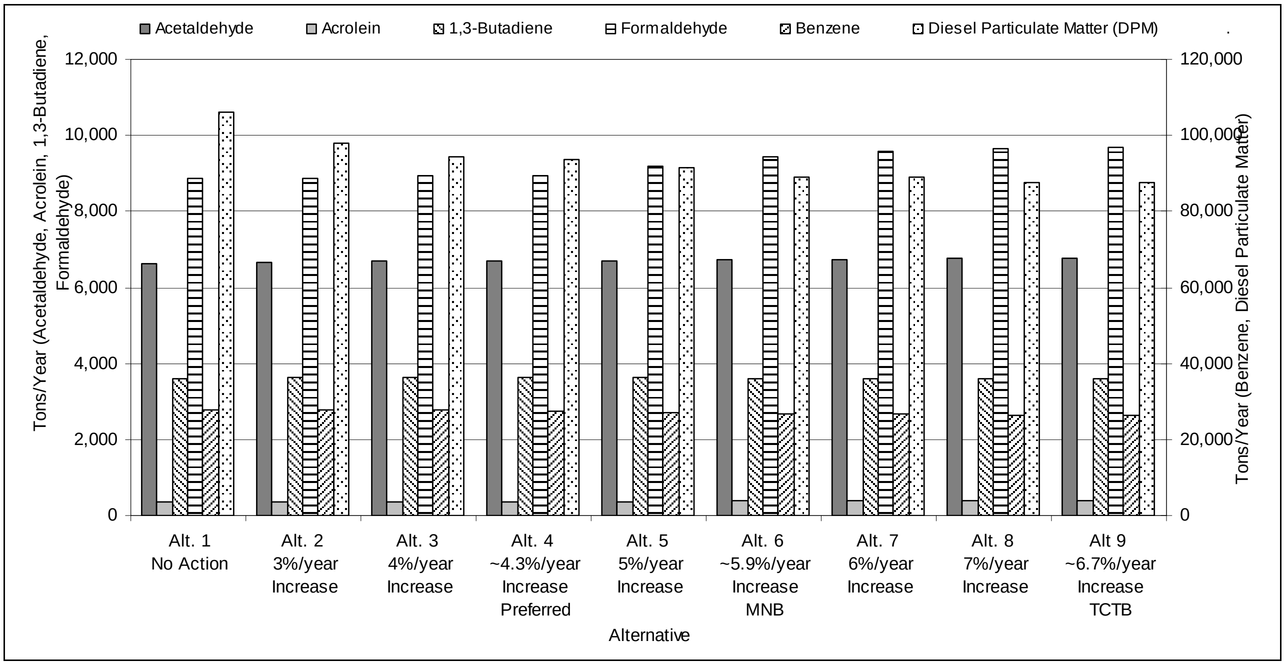
Table 3.3.3-4 summarizes the total national emissions of toxic air pollutants from passenger cars and light trucks by alternative for each of the pollutants and analysis years. Figure 3.3.2-2 lists the total national emissions of toxic air pollutants from passenger cars and light trucks by alternative. Emissions of benzene and DPM are highest under the No Action Alternative, and emissions of acetaldehyde, acrolein, and formaldehyde are highest under Alternative 9. Emissions of 1,3-butadiene are highest under Alternative 9 in 2016 and 2020, but highest under Alternative 4 in 2030.

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Acetaldehyde									
2016	10,039	10,041	10,045	10,047	10,071	10,087	10,090	10,097	10,100
2020	7,928	7,938	7,947	7,947	7,986	8,017	8,033	8,046	8,051
2030	6,631	6,665	6,683	6,678	6,710	6,721	6,733	6,748	6,751
Acrolein									
2016	521	521	522	522	527	531	531	533	533
2020	410	411	412	413	423	432	435	438	439
2030	342	345	348	351	366	385	393	398	399
Benzene									
2016	52,316	52,296	52,283	52,272	52,222	52,177	52,171	52,157	52,151
2020	39,693	39,653	39,623	39,601	39,466	39,340	39,302	39,265	39,256
2030	27,706	27,667	27,602	27,551	27,171	26,758	26,569	26,466	26,440
1,3-Butadiene									
2016	5,704	5,706	5,707	5,708	5,709	5,711	5,711	5,712	5,712
2020	4,504	4,510	4,513	4,514	4,512	4,514	4,514	4,515	4,515
2030	3,610	3,631	3,637	3,638	3,615	3,597	3,584	3,581	3,579
Diesel particulate matter (DPM)									
2016	86,700	85,133	84,397	84,123	83,788	82,953	83,249	82,892	82,695
2020	89,445	85,599	83,968	83,503	82,523	81,119	81,313	80,551	80,431
2030	106,046	97,820	94,519	93,731	91,502	89,134	89,055	87,536	87,606
Formaldehyde									
2016	12,851	12,848	12,856	12,863	12,954	13,014	13,028	13,051	13,062
2020	10,204	10,198	10,219	10,226	10,398	10,539	10,608	10,656	10,672
2030	8,875	8,884	8,927	8,938	9,198	9,440	9,573	9,652	9,672

Figure 3.3.3-2. Nationwide Toxic Air Pollutant Emissions (tons/year) from Passenger Cars and Light Trucks for 2030 by Alternative



The trends for toxic air pollutant emissions across the alternatives are mixed. Table 3.3.3-4 shows that emissions of acetaldehyde increase under each successive alternative from Alternative 1 to Alternative 9, except for Alternative 4 in 2020 and 2030. Emissions of acrolein increase under each successive alternative from Alternative 1 to Alternative 9. Emissions of benzene decrease under each successive alternative from Alternative 1 to Alternative 9. Emissions of 1,3-butadiene in 2016 increase under each successive alternative from Alternative 1 to Alternative 9, except under Alternative 7; emissions of 1,3-butadiene in 2020 increase under each successive alternative from Alternative 1 to Alternative 9, except under Alternatives 5 and 7; emissions of 1,3-butadiene in 2030 increase under each successive alternative from Alternative 1 to Alternative 4, and then decrease under each successive alternative from Alternative 5 to Alternative 9. Emissions of DPM decrease under each successive alternative from Alternative 1 to Alternative 9, except for Alternative 7 in 2016 and 2020 and Alternative 9 in 2030. Emissions of formaldehyde in 2016 and 2020 decrease from Alternative 1 to Alternative 2, and then increase under each successive alternative from Alternative 3 through Alternative 9; in 2030 emissions of formaldehyde increase under each successive alternative from Alternative 1 through Alternative 9. 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.

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 3.3.3-5

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Acetaldehyde									
Car Tail	2,851	2,875	2,884	2,878	2,887	2,875	2,874	2,880	2,881
Car Up	59	54	52	52	50	49	49	48	48
Truck Tail	3,681	3,699	3,710	3,713	3,737	3,763	3,775	3,786	3,787
Truck Up	40	37	36	36	35	34	34	34	34
Total	6,631	6,665	6,683	6,678	6,710	6,721	6,733	6,748	6,751
Acrolein									
Car Tail	141	143	144	147	147	154	154	155	154
Car Up	8	7	7	7	7	7	7	7	7
Truck Tail	188	189	192	192	207	220	227	232	233
Truck Up	5	5	5	5	5	5	5	5	5
Total	342	345	348	351	366	385	393	398	399
Benzene									
Car Tail	9,584	9,654	9,677	9,638	9,667	9,578	9,576	9,591	9,598
Car Up	1,201	1,095	1,055	1,041	1,015	975	972	954	954
Truck Tail	16,117	16,168	16,148	16,157	15,813	15,566	15,395	15,312	15,278
Truck Up	805	750	722	716	676	639	625	610	609
Total	27,706	27,667	27,602	27,551	27,171	26,758	26,569	26,466	26,440
1,3-Butadiene									
Car Tail	1,526	1,540	1,546	1,545	1,550	1,549	1,549	1,553	1,553
Car Up	13	12	12	12	11	11	11	11	11
Truck Tail	2,062	2,071	2,072	2,073	2,046	2,028	2,015	2,009	2,006
Truck Up	9	8	8	8	8	8	9	9	9
Total	3,610	3,631	3,637	3,638	3,615	3,597	3,584	3,581	3,579
Diesel particulate matter (DPM)									
Car Tail	11	98	166	361	360	854	869	905	875
Car Up	63,320	57,856	55,797	55,180	53,840	52,080	51,980	51,018	51,032
Truck Tail	113	119	174	173	577	897	1,098	1,212	1,247
Truck Up	42,601	39,747	38,382	38,017	36,725	35,304	35,108	34,401	34,453
Total	106,046	97,820	94,519	93,731	91,502	89,134	89,055	87,536	87,606

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Formaldehyde									
Car Tail	3,535	3,575	3,594	3,610	3,621	3,662	3,664	3,674	3,673
Car Up	444	407	393	389	380	370	370	363	363
Truck Tail	4,595	4,622	4,668	4,670	4,933	5,149	5,279	5,358	5,379
Truck Up	300	280	271	269	265	259	261	257	258
Total	8,875	8,884	8,927	8,938	9,198	9,440	9,573	9,652	9,672

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.

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Acetaldehyde									
2016	0	3	7	8	32	48	51	58	61
2020	0	9	19	18	58	88	104	118	122
2030	0	34	52	48	79	91	103	118	120
Acrolein									
2016	0	0	1	1	6	10	10	12	12
2020	0	1	2	3	13	22	25	28	29
2030	0	3	6	8	24	43	50	55	56
Benzene									
2016	0	-19	-33	-43	-93	-139	-144	-159	-164
2020	0	-40	-70	-92	-227	-353	-390	-427	-437
2030	0	-39	-104	-154	-534	-948	-1,137	-1,240	-1,266
1,3-Butadiene									
2016	0	2	3	3	5	7	6	7	8
2020	0	6	9	9	8	10	10	11	11
2030	0	21	27	28	5	-13	-26	-29	-31
Diesel particulate matter (DPM)									
2010	0	-1,567	-2,302	-2,577	-2,911	-3,747	-3,451	-3,807	-4,005
2020	0	-3,846	-5,477	-5,942	-6,922	-8,327	-8,132	-8,894	-9,015
2030	0	-8,225	-11,527	-12,315	-14,544	-16,912	-16,991	-18,510	-18,439
Formaldehyde									
2010	0	-4	5	11	103	163	177	200	210
2020	0	-6	16	23	194	336	404	452	469
2030	0	9	52	63	324	565	698	778	798

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.

3.3.3.2.3 Health Outcomes and Costs

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 effects and health-related costs that occur under current trends would continue. The No Action Alternative would not result in any other increase or decrease in human health effects and health-related costs 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 0.2 to 0.9 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 3.2 percent, SO_x emissions would be reduced 1.8 to 7.6 percent, and VOC emissions would be reduced 0.6 to 4.3 percent. There would be increases of CO emissions. CO emissions would increase 0.05 to 0.6 percent under Alternative 2, depending on the year.

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.

3.3.3.3.2 Toxic Air Pollutants

There would be reductions in nationwide emissions of benzene and DPM in all analysis years, and formaldehyde in 2030, under Alternative 2 compared to the No Action Alternative. Emissions for the other toxic air pollutants and years are 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 lower emissions of acetaldehyde, acrolein, and formaldehyde. For 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.

Table 3.3.3-7

Criteria Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area by 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.

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 Costs

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 153 (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 18,031.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 2 compared to the No Action Alternative. Alternative 2 would reduce health costs by $1.36 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al.*, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less.

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Mortality (ages 30 and older), Pope *et al.*									
2016	0 a/	-26 b/	-36	-39	-36	-41	-34	-38	-41
2020	0	-64	-89	-93	-97	-102	-90	-101	-103
2030	0	-153	-210	-217	-253	-276	-267	-296	-296
Mortality (ages 30 and older), Laden *et al.*									
2016	0	-66	-93	-99	-92	-106	-87	-98	-105
2020	0	-165	-227	-237	-248	-263	-231	-259	-263
2030	0	-392	-537	-554	-648	-705	-683	-758	-758
Chronic bronchitis									
2016	0	-17	-25	-26	-24	-28	-23	-26	-28
2020	0	-44	-61	-63	-66	-70	-62	-69	-71
2030	0	-100	-138	-142	-167	-182	-177	-196	-196
Emergency Room Visits for Asthma									
2016	0	-24	-34	-37	-34	-39	-32	-37	-39
2020	0	-62	-85	-89	-91	-97	-85	-95	-97
2030	0	-140	-191	-198	-226	-244	-233	-258	-258
Work Loss Days									
2010	0	-3,365	-4,776	-5,093	-4,713	-5,423	-4,444	-5,045	-5,390
2020	0	-8,308	-11,439	-11,925	-12,494	-13,231	-11,672	-13,077	-13,277
2030	0	-18,031	-24,750	-25,522	-30,036	-32,758	-31,811	-35,301	-35,306

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

Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
3% Discount Rate									
Pope *et al.*									
2016	0 a/	-215 b/	-306	-326	-302	-348	-285	-324	-346
2020	0	-560	-771	-805	-840	-890	-785	-879	-892
2030	0	-1,361	-1,867	-1,926	-2,253	-2,452	-2,374	-2,635	-2,634
Laden *et al.*									
2016	0	-528	-749	-800	-739	-853	-699	-793	-847
2020	0	-1,372	-1,889	-1,972	-2,057	-2,181	-1,922	-2,153	-2,185
2030	0	-3,334	-4,574	-4,720	-5,520	-6,007	-5,816	-6,454	-6,451

Table 3.3.3-9 (cont'd)

Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
7% Discount Rate									
Pope *et al.*									
2016	0	-196	-277	-296	-274	-316	-259	-294	-314
2020	0	-508	-700	-730	-762	-808	-712	-797	-809
2030	0	-1,234	-1,693	-1,747	-2,044	-2,224	-2,154	-2,390	-2,389
Laden *et al.*									
2010	0	-477	-677	-723	-668	-770	-631	-716	-765
2020	0	-1,240	-1,707	-1,781	-1,859	-1,970	-1,736	-1,945	-1,974
2030	0	-3,012	-4,131	-4,264	-4,987	-5,426	-5,254	-5,830	-5,827

a/ Negative changes indicate economic benefit; positive emissions changes indicate economic costs.
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 1.5 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.3 percent, SO_x emissions would be reduced 2.5 to 10.3 percent, and VOC emissions would be reduced 0.9 to 6.2 percent. These emissions reductions are generally greater than would occur under Alternative 2 but less than would occur under Alternatives 4 through 9. There would be increases of CO emissions from 0.04 to 0.5 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. Table 3.3.3-10 summarizes the criteria air pollutant results by 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 all pollutants (except acrolein). Aside from acrolein, Alternative 3 would have higher or equal emissions of all pollutants compared to Alternatives 4 through 9, except for benzene under Alternatives 5 through 7, 1,3-butadiene under Alternative 9 in 2016 and Alternative 4 in 2030, and formaldehyde under Alternatives 8 and 9 in all years.

Table 3.3.3-10

Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area by Alternative a/

Hazardous Air Pollutant	Increase/ Decrease	Change (tons/year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	6.4	2030	9	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	4.6	2030	8	Beaumont/Port Arthur, TX
Acrolein	Maximum Increase	2.7	2030	9	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	0.47	2030	8	Beaumont/Port Arthur, TX
Benzene	Maximum Increase	4.8	2030	2	Los Angeles South Coast Air Basin, CA
	Maximum Decrease	52	2030	9	Houston-Galveston-Brazoria, TX
1,3-Butadiene	Maximum Increase	1.40	2030	4	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	1.4	2030	9	Houston-Galveston-Brazoria, TX
Diesel particulate matter	Maximum Increase	41	2030	9	Atlanta, GA
	Maximum Decrease	1,953	2030	8	Houston-Galveston-Brazoria, TX
Formaldehyde	Maximum Increase	43	2030	9	New York-N. New Jersey-Long Island, NY-NJ-CT
	Maximum Decrease	45	2030	8	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.

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.

3.3.3.4.3 Health Outcomes and Costs

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 210 (under Pope *et al.*; reductions would be 156 percent greater under Laden *et al.*) and the number of work-loss days by 24,750 in 2030.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 3 compared to the No Action Alternative. Alternative 3 would reduce health costs by $1.87 billion in 2030, using a 3-

percent discount rate and estimates from Pope *et al*. Under Laden *et al.*, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 to 1.7 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.3 percent, SO_x emissions would be reduced 2.8 to 11.0 percent, and VOC emissions would be reduced 1.1 to 6.9 percent. These emissions reductions are greater than would occur under Alternative 3 (except for $PM_{2.5}$ in 2030) but less than would occur under Alternatives 5 through 9. There would be increases of CO emissions of 0.01 to 0.4 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 acetaldehyde, acrolein, and formaldehyde, and higher emissions of benzene and DPM. Results would be mixed for 1,3-butadiene, depending on the year and alternative.

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 Costs

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 217 (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 25,222.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 4 compared to the No Action Alternative. Alternative 4 would reduce health costs by $1.93 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 $PM_{2.5}$ in 2016 and 2020 and SO_x in 2016), but less than under Alternatives 6 through 9. Depending on the year, CO emissions would be reduced 0.3 to 2.2 percent, NO_x emissions would be reduced 0.4 to 3.5 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.5 percent, SO_x emissions would be reduced 2.6 to 11.5 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, 1,3-butadiene, and formaldehyde, compared to the No Action Alternative. Compared to Alternatives 6 through 9, Alternative 5 would have lower emissions of acetaldehyde, acrolein, formaldehyde, and 1,3-butadiene (in 2016 and 2020), and higher emissions of benzene, DPM, and 1,3-butadiene (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 Costs

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 253 (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 30,036.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 5 compared to the No Action Alternative. Alternative 5 would reduce health costs by $2.25 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 Alternative 5, but less than under Alternatives 7 through 9 (except for NO_x and VOC in 2016 under Alternative 7). 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 0.5 to 4.7 percent, NO_x emissions would be reduced 0.5 to 5.2 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.2 percent, SO_x emissions would be reduced 3.3 to 12.4 percent, and VOC emissions would be reduced 1.9 to 11.9 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, DPM, and 1,3-butadiene (in 2030), and increased emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde, compared to the No Action Alternative. Compared to Alternatives 7 through 9, Alternative 6 would have equal or lower emissions of acetaldehyde, acrolein, formaldehyde, and 1,3-butadiene (in 2016 and 2020), and higher emissions of benzene, DPM, and 1,3-butadiene (in 2030). 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 Costs

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 276 (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 32,758.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 6 compared to the No Action Alternative. Alternative 6 would reduce health costs by $2.45 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 CO, NO_x, and VOC emissions would be greater than under Alternative 6 (except for NO_x and VOC in 2016), but less than under Alternatives 8 and 9. For $PM_{2.5}$ and SO_x the emission reductions under Alternative 7 would be less than under Alternative 6, 8, and 9. Depending on the year, CO emissions would be reduced 0.6 to 6.0 percent, NO_x emissions would be reduced 0.5 to 6.0 percent, $PM_{2.5}$ emissions would be reduced 0.6 to 3.7 percent, SO_x emissions would be reduced 2.8 to 11.4 percent, and VOC emissions would be reduced 1.8 to 12.7 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, DPM and 1,3-butadiene (in 2030), and increased emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde, compared to the No Action Alternative. Compared to Alternatives 8 and 9, Alternative 7 would have lower emissions of acetaldehyde, acrolein, formaldehyde, and 1,3-butadiene (in 2016 and 2020), and higher emissions of benzene, DPM, and 1,3-butadiene (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 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 Costs

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 267 (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 31,811.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 7 compared to the No Action Alternative. Alternative 7 would reduce health costs by $2.37 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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. Reductions would be greater than under Alternative 7 but less than under Alternative 9 (except for $PM_{2.5}$ and SO_x in 2030). CO emissions would be reduced 0.6 to 6.7 percent, NO_x emissions would be reduced 0.5 to 6.6 percent, $PM_{2.5}$ emissions would be reduced 0.7 to 4.2 percent, SO_x emissions would be reduced 3.1 to 12.6 percent, and VOC emissions would be reduced 2.0 to 13.7 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, DPM and 1,3-butadiene (in 2030), and increased emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde, compared to the No Action Alternative. Compared to Alternative 9, Alternative 8 would have equal or lower emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), DPM (in 2030), and formaldehyde, and higher emissions of benzene, 1,3-butadiene (in 2030), and DPM (in 2016 and 2020).

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 Costs

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 296 (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 35,301.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 8 compared to the No Action Alternative. Alternative 8 would reduce health costs by $2.64 billion in 2030, using a 3-

percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 of CO, NO_x, and VOC under Alternative 9 would be greater than with any other alternative. Emissions of $PM_{2.5}$ under Alternative 9 would be lower than under Alternatives 1 and 7, Alternative 2 in 2016, and Alternative 8 in 2016 and 2020; however, $PM_{2.5}$ emissions under Alternative 9 would be higher than under Alternatives 3 through 6, Alternative 2 in 2020, and Alternative 8 in 2030. Emissions of SO_x under Alternative 9 would be less than with any other alternative (except for Alternative 6 in 2020 and Alternative 8 in 2030). Depending on the year, CO emissions would be reduced 0.7 to 6.9 percent, NO_x emissions would be reduced 0.6 to 6.7 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.2 percent, SO_x emissions would be reduced 3.3 to 12.5 percent, and VOC emissions would be reduced 2.0 to 13.8 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 benzene, 1,3-butadiene (in 2030), and DPM, and increased emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde, compared to the No Action Alternative. Emissions reductions of benzene, 1,3-butadiene (in 2030), and DPM (in 2016 and 2020) under Alternative 9 would be greater than with any other 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). 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 Costs

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 296 (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 35,306 days.

Table 3.3.3-9 lists the corresponding reductions in health costs under Alternative 9 compared to the No Action Alternative. Alternative 9 would reduce health costs by $2.63 billion in 2030, using a 3-percent discount rate and estimates from Pope *et al*. Under Laden *et al*., economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less.

3.4 CLIMATE

This section describes how the MY 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 MY 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 MY 2012-2016 standards together with those of reasonably foreseeable future actions, including the continuing increases in CAFE standards for MY 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 its proposed Endangerment and Cause or Contribute Findings for GHGs under the Clean Air Act* – 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 2.7 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)

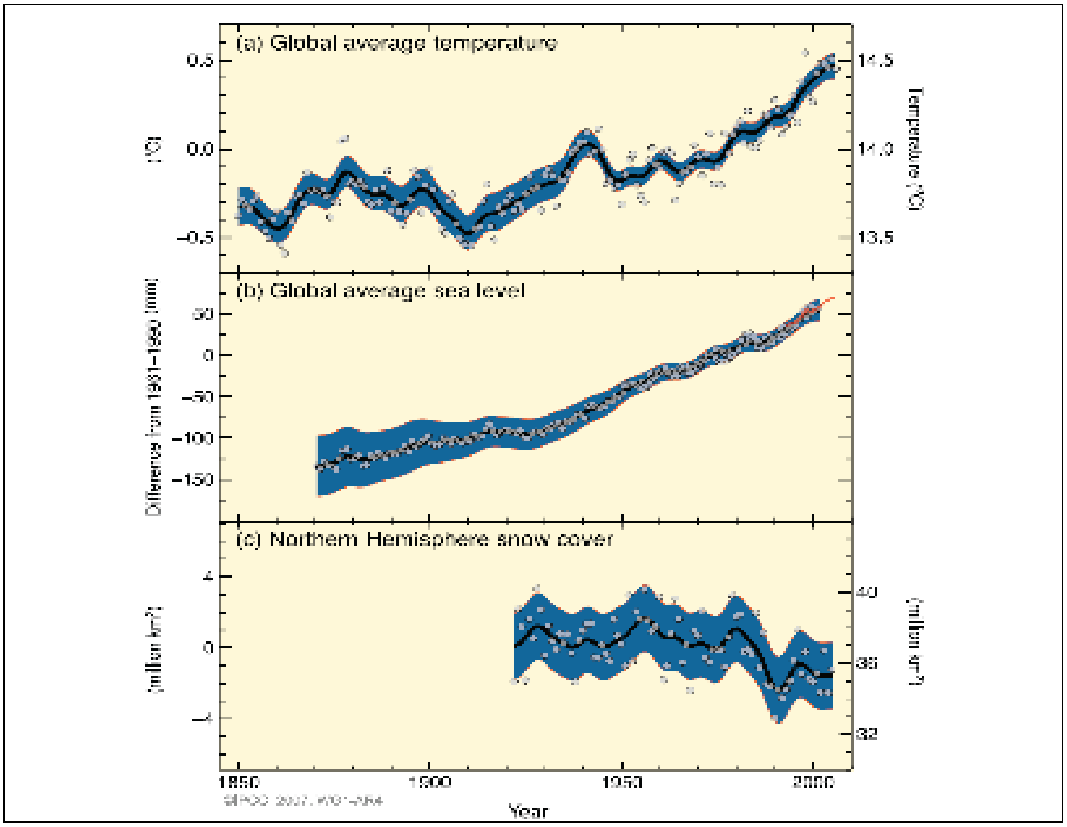
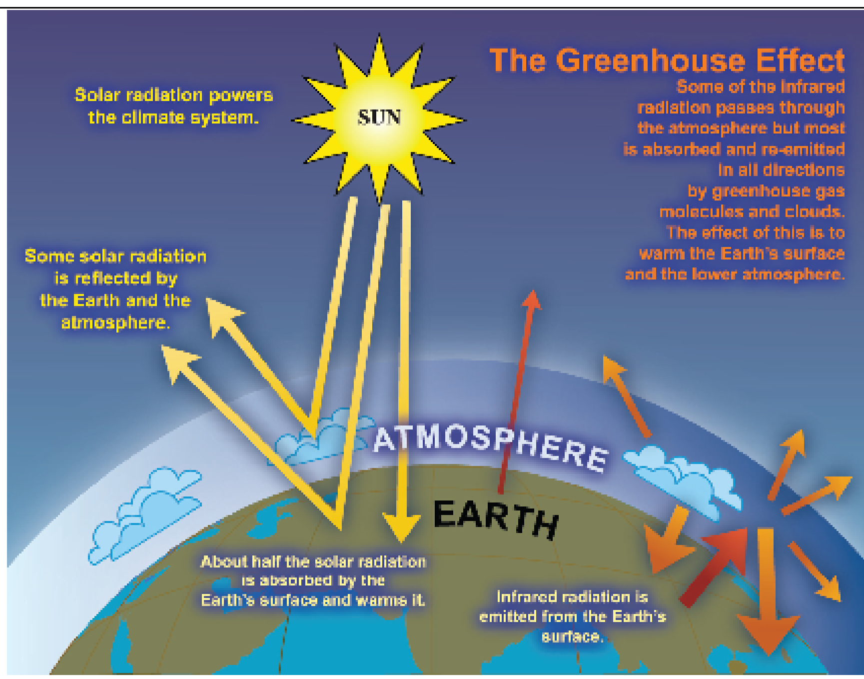


Figure 3.4.1-2. The Greenhouse Effect (Source: Le Treut *et al.* 2007)



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] greenhouse gas concentrations" (EPA 2009b, IPCC 2007b).[1]

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)[2] – 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. The U.S. transportation sector contributed 35.7 percent of total U.S. CO_2 emissions in 2007 (EPA 2009a), with passenger cars and light trucks accounting for 60.8 percent of total U.S. CO_2 emissions from transportation (EPA 2009a). Thus, 21.7 percent (equal to 35.7 percent of 60.8 percent) of total U.S. CO_2 emissions is attributable to the use of passenger cars and light trucks. With the United States accounting for 17.2 percent of global CO_2 emissions (WRI 2009), passenger cars and light trucks in the United States account for roughly 3.7 percent (equal to 21.7 percent of 17.2 percent) of global CO_2 emissions.[3]

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

[1] 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.
[2] This calculation is weighted by global warming potential.
[3] Percentages include land-use change and forestry, and exclude international bunker fuels (*i.e.*, international marine and aviation travel).

(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.[4] 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

[4] 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.

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)[5].

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[6] of clouds while suspended in the air, and (3) reducing the albedo of snow and ice when it falls onto snow and ice fields.

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 2008e). Another study estimates that there is a 50-percent uncertainty in global emissions estimates, while the regional uncertainty in emissions 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 (EPA 2009b); it might be a more important driver of climate change than the increase in the concentrations of CH_4 or N_2O (Ramanathan and Carmichael 2008). Another study found that black carbon in the atmosphere might cause approximately 30 percent or more of warming in the Arctic (Shindell and Faluvegi 2009 in Pew 2009). 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 1980 (Shindell and Faluvegi 2009), and 0.25 °C (0.45 °F) to overall global warming (Tollefson 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 in Tollefson 2009), and caused roughly one-third of the glacial retreat in the past 2 decades (Tollefson 2009).

Because aerosols, including black carbon, play a role in cloud formation, scientists are investigating how black carbon affects clouds, which in turn affect Earth's temperature. Lower clouds reflect substantial amounts of solar radiation back into space, which results in a cooling effect through cloud albedo. Conversely, higher clouds reflect relatively little solar radiation back into space but trap higher amounts of infrared radiation, which leads to a warming effect. Thus, the way black carbon affects cloud formation, and which types of clouds it generally impacts, is important. In warm low-level clouds, water vapor attaches to cloud nuclei and grow as larger cloud drops fall and combine with smaller cloud drops. The cloud drops might eventually grow to the size of a rain drop and fall from the cloud as rain. Some aerosols prevent this combining of drops, thereby extending the life of the cloud and reducing precipitation.

Black carbon, on the other hand, radiatively warms the surrounding air, which leads to evaporation of cloud drops and reduces cloud cover. 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

[5] 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.)

[6] 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.

might cause convection patterns that ultimately lead to cloud formation (Rudich *et al.* 2003 in Ramanathan and Carmichael 2008). The ultimate climate effect of changes in cloud formation depends partly on the types of clouds affected; however, studies often focus on lower-lying clouds, in which case the greater the cloud cover, the greater the cooling effect.

Given the potential for the effect to be substantial, the U.S. Congress is (as of July 2009) considering legislation (proposed Senate bill S.849) that would direct EPA to do a 1-year study on the climate impacts of black carbon and cost-effective technologies and strategies for black carbon reduction.[7]

Two characteristics of black carbon are unique compared to GHGs – its short lifetime in the atmosphere and, in most situations, the concentration of its climate effects near its emission source. First, 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.

Second, while GHGs are considered to be global pollutants (because their impact on climate is the same regardless of where they are emitted), black carbon has greater impacts in the region where it is emitted. Although black carbon can travel great distances in the atmosphere, its concentrations decrease as distance from the emission source increases. Black carbon increases temperatures locally, unlike GHGs, which affect the climate by trapping radiation on a global scale. Thus, increases or decreases in black carbon emissions will have the greatest impact on the area where the black carbon is concentrated, which is typically near the emission sources.

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 new passenger cars that are diesel-powered would rise from zero under the No Action Alternative to 1 to 2 percent under the Preferred Alternative, and would reach 3 to 4 percent under alternatives that would establish the most stringent CAFE standards. At the same time, the agency projects that the diesel fraction of light trucks would rise from less than 2 percent under the No Action Alternative to almost 3 percent under the Preferred Alternative, and would range as high as 15 to 20 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.

[7] S. 849, 111th Cong. (2009).

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.[8]

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[9] were estimated at 7,150.1 million metric tons of carbon dioxide ($MMTCO_2$)[10] (EPA 2009a), and, as noted earlier, contributes about 18 percent of total global emissions[11] (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 35.7 percent of total U.S. CO_2 emissions in 2007, with passenger cars and light trucks accounting for 60.8 percent of total U.S. CO_2 emissions from transportation. Thus, 21.7 percent of total U.S. CO_2 emissions comes from passenger cars

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[8] 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").
[9] Most recent year for which an official EPA estimate is available.
[10] 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).
[11] Based on 2005 data and excludes carbon sinks from forestry and agriculture.

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 3.7 percent of global CO_2 emissions.[12]

Passenger cars and light trucks, which include SUVs, pickup trucks, and minivans, account for more than half of U.S. transportation emissions, and 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 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[13] (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, and 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).[14]

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[12] Percentages include land-use change and forestry, and exclude international bunker fuels.
[13] All GHG estimates cited in this section include contributions from land-use change and forestry, unless noted otherwise.
[14] Values in this paragraph exclude land-use change and forestry.

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 *Global Climate Change Impacts in the United States* (GCRP 2009).

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 (National Science and Technology Council 2008).

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). Sea level does not rise uniformly across the globe, and, as a result of gravitational and centrifugal considerations, parts of the Pacific, Atlantic, and Gulf coasts of the United States would be expected to be subjected in the future to greater sea-level rise compared to global averages (Bamber *et al.* 2009 and Yin *et al.* 2009, both in Pew 2009).

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

(National Science and Technology Council 2008). 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 (National Science and Technology Council 2008).

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 with *very high confidence* that the increase in GHGs since 1750 has led to a global positive radiative forcing of 1.6 watts per meter (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 2009b). 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; [15] 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).

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)[16].

[15] 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.

[16] 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.

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).

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), and summertime sea ice has declined 34 percent since 1979 (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 (Royal Society 2005 and 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.

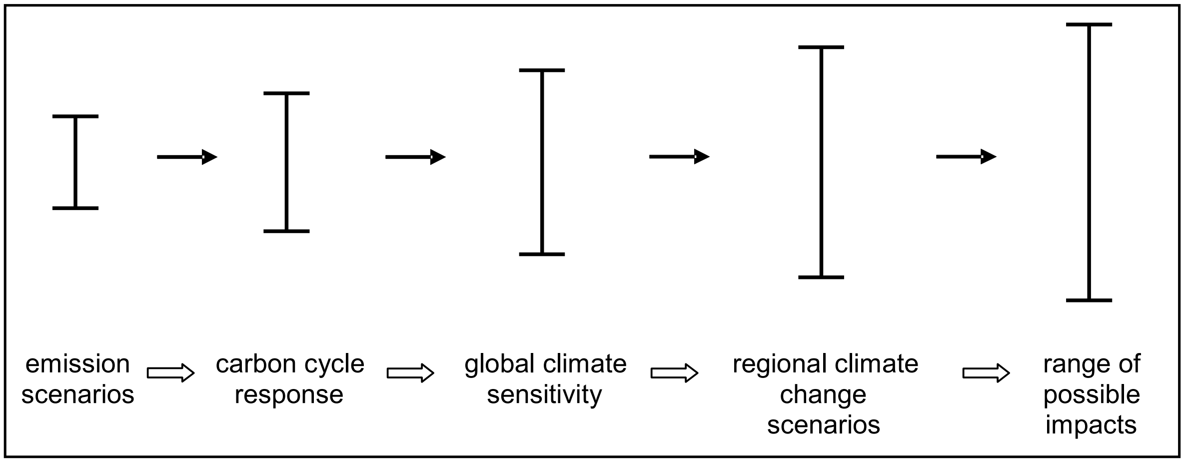
The methods used to characterize emissions and climate effects involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in the transportation sector and other sectors that emit GHGs; changes in the future fuel supply and fuel characteristics that could 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.

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."

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.

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). 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.[17] 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

[17] 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 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.)

entirely to CO_2 during the combustion process.[18] 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) 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.

[18] 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).

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)[19] 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.
- 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)[20] 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

[19] For a discussion of AOGCMs, *see* WGI, Chapter 8 in IPCC (2007a).
[20] The use of different emissions scenarios provides insight into the impact of alternative global emissions scenarios on the effect of the CAFE alternatives.

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.

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[21] (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 2009b). 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.

[21] In this document, the term "climate sensitivity" refers to "equilibrium climate sensitivity."

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.

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).[22]

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.

[22] 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.

- 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.

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 1,660 $MMTCO_2$; the emissions in 2020 under the Alternative 4 (Preferred) are 1,550 $MMTCO_2$ (*see* Table 3.4.4-2). The difference of 110 $MMTCO_2$ 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 110 $MMTCO_2$ less than this reference level, or 37,910 $MMTCO_2$ 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) 2009 (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.[23,24] 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).

[23] 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.

[24] 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).

Figure 3.4.3-2. Average GDP Growth Rates (1990 to 2030)

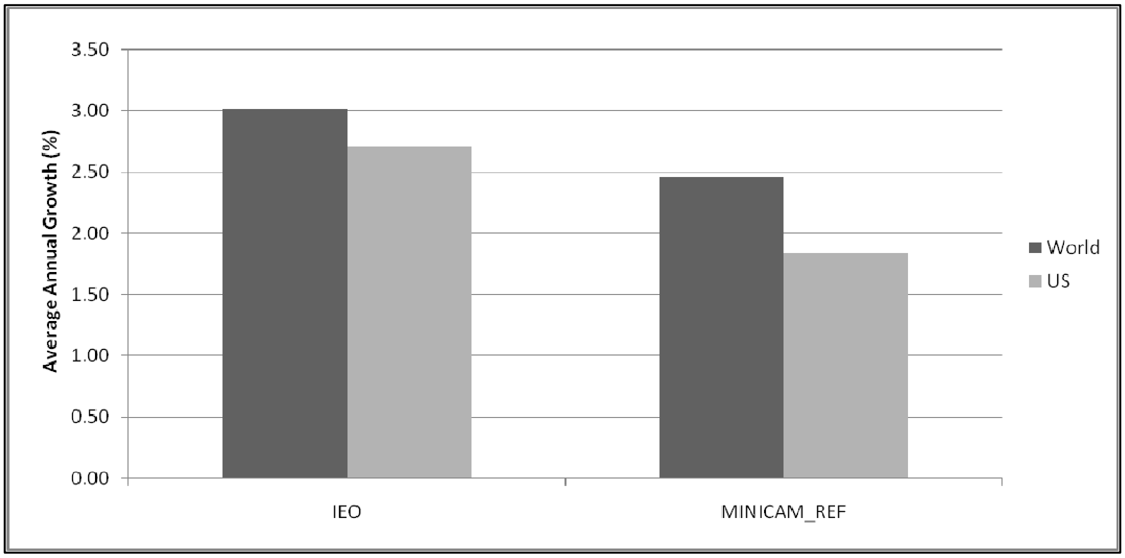


Figure 3.4.3-3. Global CO_2 Emissions from Fossil Fuel Use

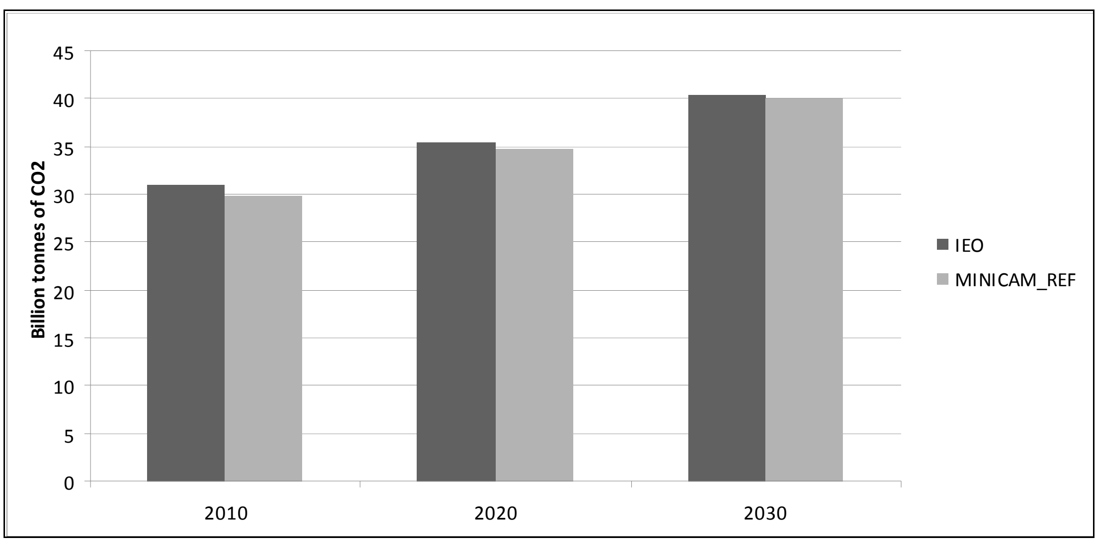


Figure 3.4.3-4. U.S. CO_2 Emissions from Fossil Fuel Use

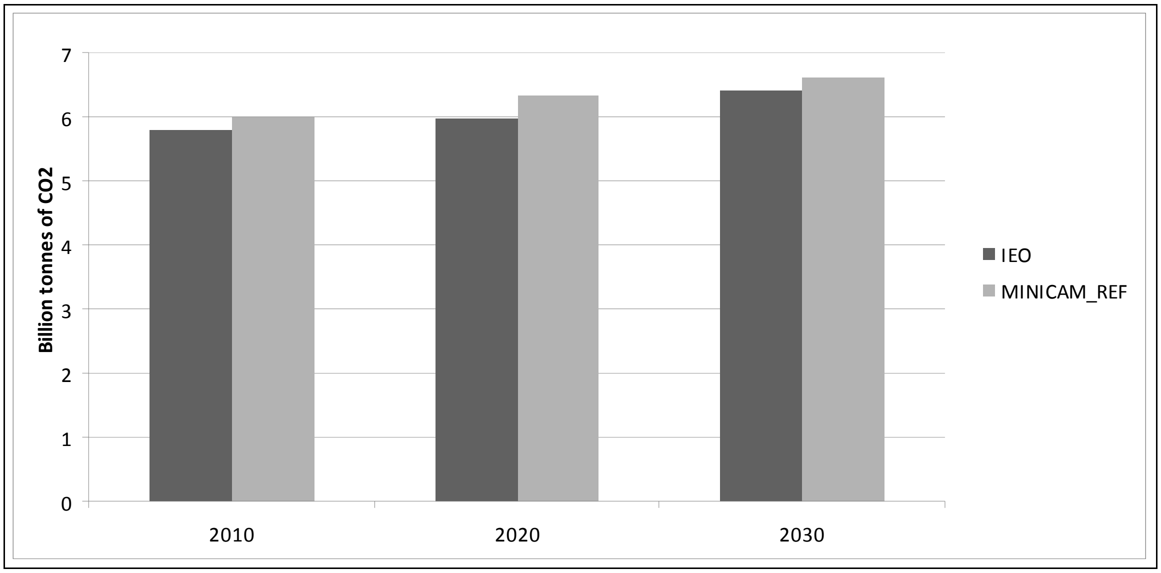


Figure 3.4.3-5. World Primary Energy Use Forecast

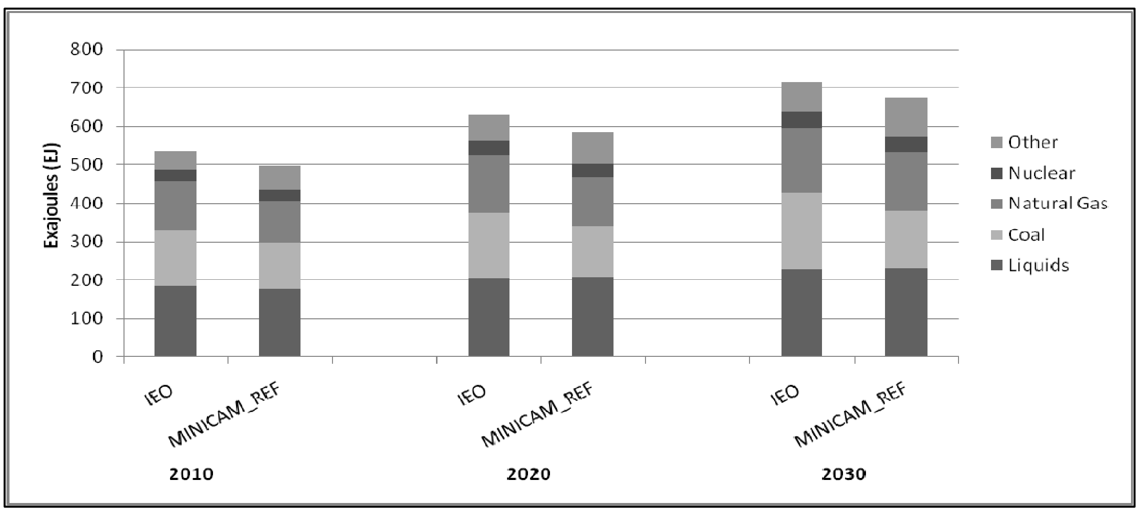
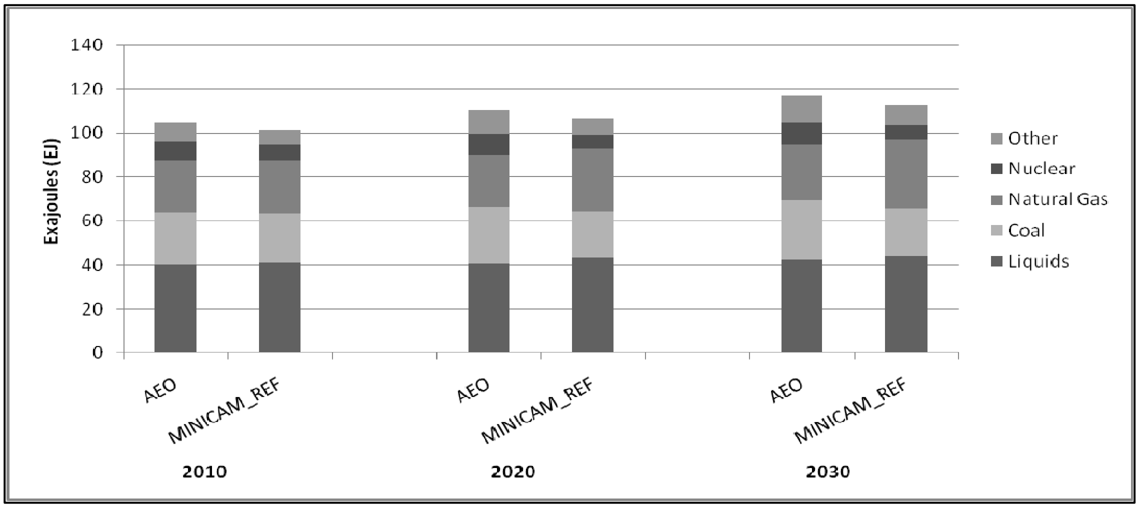


Figure 3.4.3-6. U.S. Primary Energy Use Forecast



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 2009 (EIA 2009b)[25] projection shows an increase in total primary energy use in the United States, but much of the increase is from the use of coal. 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[26] than the MiniCAM reference scenario, resulting in lower CO_2 emissions (*see* Figure 3.4.3-4).

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).

[25] AEO 2009 revised estimates were used for U.S. primary energy consumption and form the basis for the IEO 2009 forecast.
[26] For AEO reference scenario, "other" includes biomass, hydropower, and other renewable fuels.

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,[27] 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” (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).

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.[28]

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.

[27] The cryosphere describes the portion of Earth’s surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

[28] *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).

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 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.[29]

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 MY 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.[30] 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 201,200 $MMTCO_2$ under the 7%/year Increase (Alternative 8) to 243,600 $MMTCO_2$ 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 MY 2012-2016 CAFE standards ranged from 19,300 to 42,400 $MMTCO_2$. 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 0.8 percent from their projected levels under the No Action 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 7.9 to 17.4 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 3.6 to 7.8 percent in 2100. Figure 3.4.4-2 shows projected annual emissions from passenger cars and light trucks under the MY 2012-2016 alternative CAFE standards.

[29] 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.
[30] *See* Section 3.1.3 for a summary of the scope and parameters of the Volpe model.

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	243,600	0
2 3%/year Increase	224,300	19,300
3 4%/year Increase	216,700	26,900
4 ~4.3%/year Increase, Preferred	214,700	29,000
5 5%/year Increase	210,100	33,500
6 ~5.9%/year Increase, MNB	204,500	39,100
7 6%/year Increase	204,800	38,800
8 7%/year Increase	201,200	42,400
9 ~6.7%/year Increase, TCTB	201,500	42,100

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.

Figure 3.4.4-1. Emissions and Emissions Reductions ($MMTCO_2$) from 2010 to 2100 by Alternative

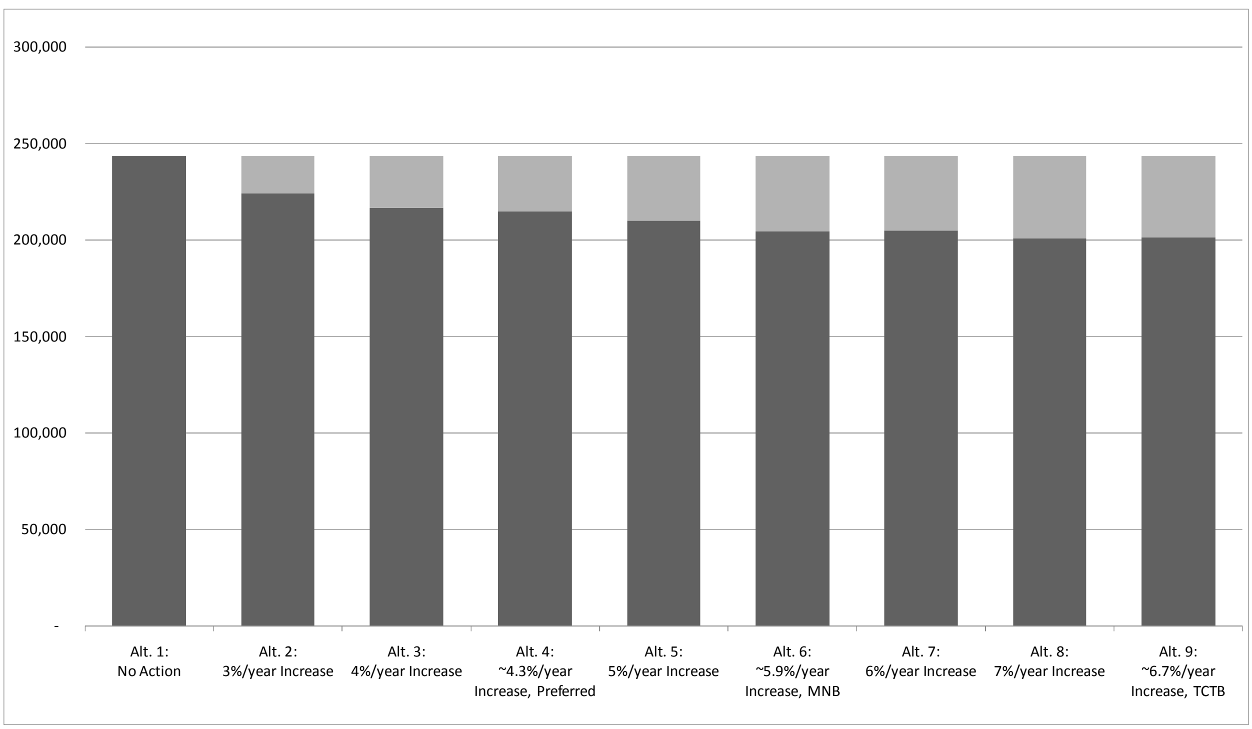
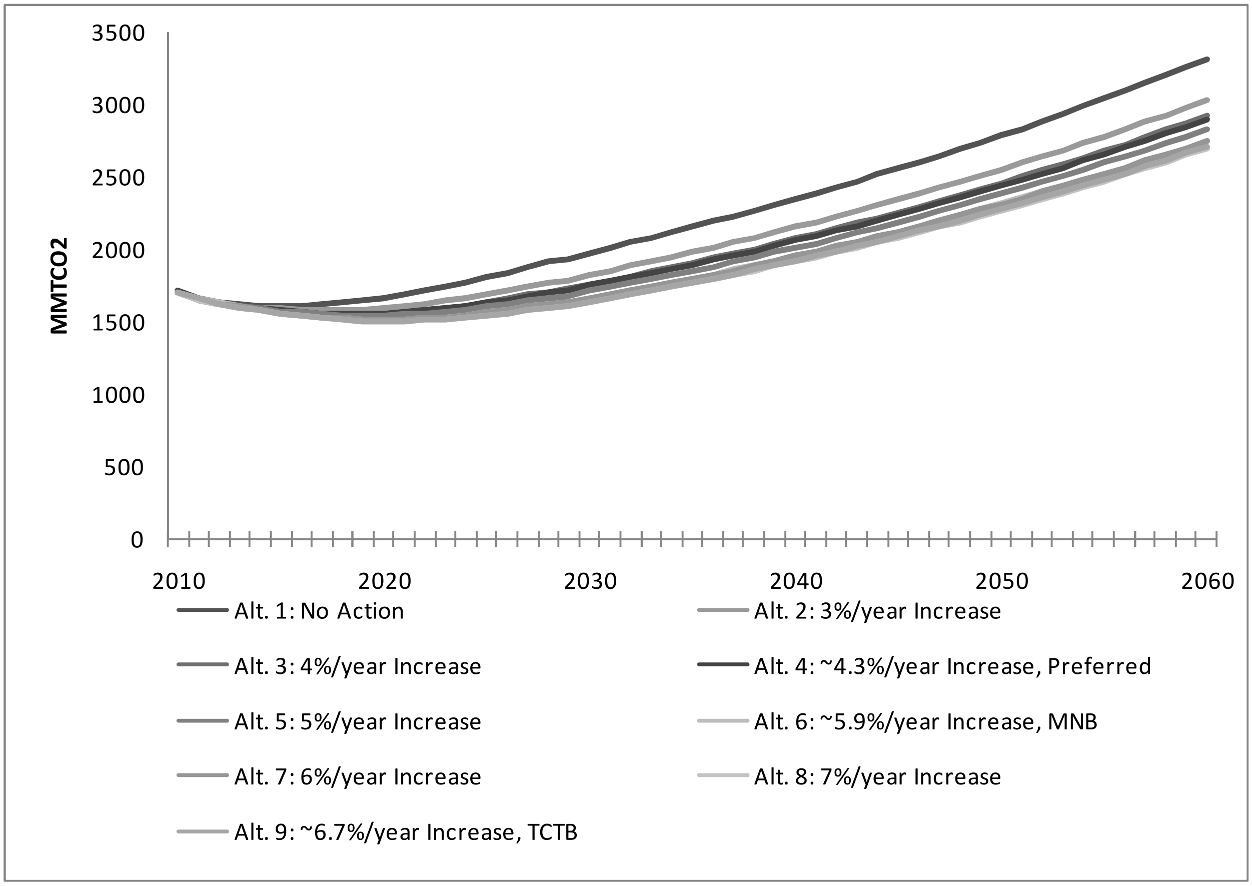


Figure 3.4.4-2. Projected Annual Emissions ($MMTCO_2$) by Alternative



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 full 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 MY 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.

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon dioxide (CO_2)									
2010	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
2020	1,660	1,590	1,560	1,550	1,540	1,510	1,520	1,500	1,500
2030	1,970	1,820	1,760	1,740	1,710	1,660	1,670	1,640	1,640
2040	2,350	2,150	2,073	2,050	2,010	1,950	1,950	1,920	1,920
2050	2,790	2,550	2,460	2,430	2,380	2,310	2,310	2,270	2,270
2060	3,310	3,030	2,920	2,890	2,825	2,750	2,750	2,670	2,700
Methane (CH_4)									
2010	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2020	1.94	1.86	1.82	1.81	1.79	1.76	1.77	1.75	1.75
2030	2.31	2.13	2.06	2.04	2.00	1.94	1.94	1.91	1.91
2040	2.74	2.52	2.43	2.40	2.35	2.28	2.28	2.23	2.24
2050	3.25	2.98	2.88	2.85	2.78	2.70	2.70	2.65	2.65
2060	3.87	3.55	3.42	3.39	3.30	3.21	3.20	3.14	3.15
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	0.03	0.03
2030	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2040	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2050	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2060	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. passenger-car and light-truck fleet represented about 3.7 percent of total global emissions of all CO_2 emissions in 2005 (EPA 2009a, WRI 2009).[31] 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.[32]

In its updated *Annual Energy Outlook 2009*, EIA projects U.S. transportation CO_2 emissions to increase from 1,905 $MMTCO_2$ in 2010 to 2,045 $MMTCO_2$ in 2030,[33] with cumulative U.S. emissions

[31] Includes land-use change and forestry, and excludes international bunker fuels.
[32] 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.
[33] AEO provides projections through 2030, not through 2100 (the relevant period for climate modeling).

from transportation over this period at 41,093 MMTCO$_2$ (EIA 2009a). Over this same period, the cumulative emissions reductions over the range of the CAFE action alternatives are projected to be 1,490 to 3,350 MMTCO$_2$, which would yield a 4- to 8-percent reduction in CO_2 emissions from the transportation sector. The environmental impact from increasing fuel economy standards grows as new vehicles meeting the higher CAFE standards that each action alternative would establish enter the fleet, while older vehicles are retired. For example, in 2030, projected emissions reductions are 150 to 340 MMTCO$_2$, a 7- to 16-percent decrease from projected U.S. transportation emissions of 2,045 MMTCO$_2$ in 2030.

As another measure of the relative environmental impact of this rulemaking, these emissions reductions can 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).[34] If this goal is achieved, emissions levels in 2020 would be 33-percent lower than under the No Action Alternative, 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 690 MMTCO$_2$ over the same period, with emissions levels in 2020 representing a 4- to 10-percent reduction from the future baseline emissions for passenger cars and light trucks.

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).[35] 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 1,540 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.

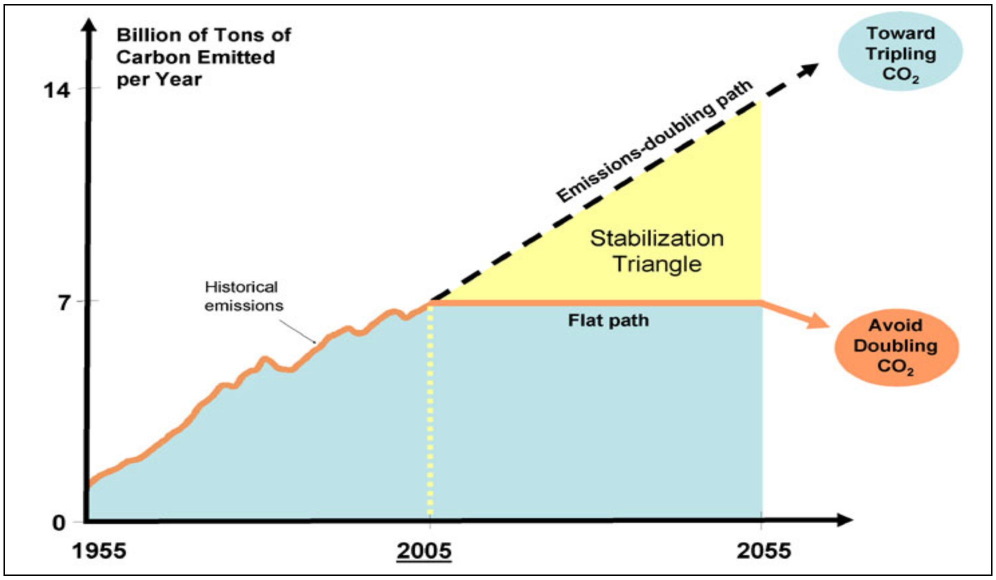
Two features of these comparisons are extremely important to emphasize. First, emissions from the sources addressed in the WCI and RGGI plans are projected to decrease compared to the beginning of the action, while emissions from passenger cars and light trucks are projected to increase under all alternatives 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 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[36] per year

[34] Since this goal was 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 July 14, 2009.
[35] 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.
[36] 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.

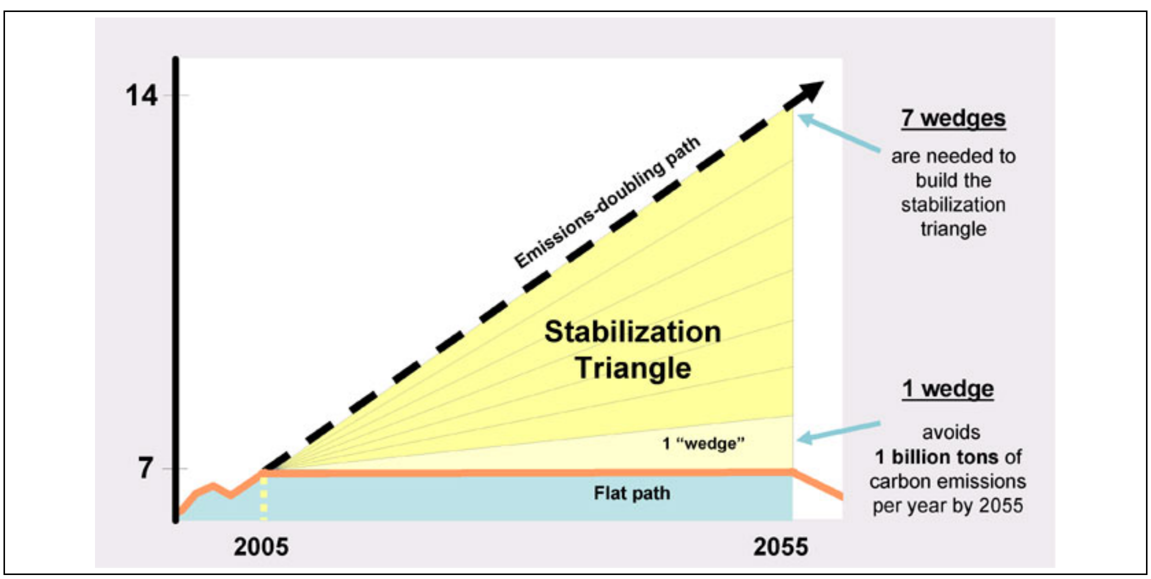
(GtC/year) for the next 50 years. Socolow and Pacala depicted the necessary reductions in emissions from their projected increase over the next 50 years as a triangle, with progressively larger reductions in emissions from their projected level required during each successive future year (*see* Figure 3.4.4-3).

Figure 3.4.4-3. Historical Carbon Emissions with Two Potential Pathways for the Future (Source: Socolow *et al.* 2004)



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 3.4.4-4).

Figure 3.4.4-4. Stabilization Wedges (Source: Socolow *et al.* 2004)



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.

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.[37] Their estimate is based on a global fleet of approximately 2 billion passenger cars and light trucks, averaging 10,000 miles per year.

By comparison, NHTSA estimates that the number of passenger cars and light trucks in use throughout the United States will increase to almost 320 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 19,000 miles. Thus, in total, NHTSA projects that passenger cars and light trucks in the United States will be driven a almost 6.1 trillion miles during 2055 under the No Action Alternative. NHTSA estimates that the progressively higher fuel economy levels required by the under 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 22 billion gallons (under Alternative 2) to as much as 49 billion gallons (under Alternative 8). As a consequence, CO_2 emissions attributable to U.S. passenger-car and light-truck use through 2055 would decline by the equivalent of 8 percent (Alternative 2) to 17 percent (Alternative 9) of one "stabilization wedge."[38]

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.

[37] *Id.*; *see* also http://www.princeton.edu/~cmi/resources/wedgesumtb.htm (listing 15 examples of potential wedges).
[38] 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, slightly later than the 2005 initial year for emissions reductions assumed in the Socolow Pacala analysis.

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.[39] 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.

Table 3.4.4-3

Comparison of MAGICC Modeling Results and Reported IPCC Results (IPCC 2007 a/)

Scenario	CO_2 Concentration (ppm)		Global Mean Increase in Surface Temperature (°C)		Sea-Level Rise (cm)	
	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 3.4.4-5 through 3.4.4-8 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 3.4.4-7 and 3.4.4-8 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 3.4.4-7 and 3.4.4-8, the reduction in increase of CO_2 concentrations by 2100 under Alternative 9 is two and a half times that of Alternative 2. Similarly, the reduction in increase of temperature under Alternative 9 is two and a half times that of Alternative 2.

[39] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C (5.4 °F).

As shown in Table 3.4.4-4 and Figures 3.4.4-5 through 3.4.4-8, estimated CO_2 concentrations for 2100 range from 779.0 ppm under the most stringent alternative (TCTB) 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	781.2	0.922	1.554	3.129	8.38	15.16	37.94
3 4%/year Increase	441.6	514.1	780.4	0.922	1.553	3.126	8.38	15.15	37.92
4 ~4.3%/year Increase, Preferred	441.5	514.0	780.3	0.922	1.553	3.125	8.38	15.15	37.91
5 5%/year Increase	441.5	513.9	779.8	0.922	1.553	3.124	8.38	15.15	37.89
6 ~5.9%/year Increase, MNB	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
7 6%/year Increase	441.4	513.8	779.3	0.921	1.552	3.122	8.38	15.14	37.87
8 7%/year Increase	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86
9 ~6.7%/year Increase, TCTB	441.4	513.7	779.0	0.921	1.551	3.120	8.38	15.14	37.86
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.5	1.8	0.001	0.002	0.007	0.00	0.01	0.06
3 4%/year Increase	0.2	0.7	2.6	0.001	0.003	0.010	0.00	0.02	0.08
4 ~4.3%/year Increase, Preferred	0.3	0.8	2.7	0.001	0.004	0.010	0.00	0.02	0.09
5 5%/year Increase	0.3	0.9	3.2	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
7 6%/year Increase	0.4	1.0	3.7	0.002	0.005	0.014	0.00	0.03	0.13
8 7%/year Increase	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.4	1.1	4.0	0.002	0.006	0.015	0.00	0.03	0.14

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.

Figure 3.4.4-5. CO_2 Concentrations (ppm)

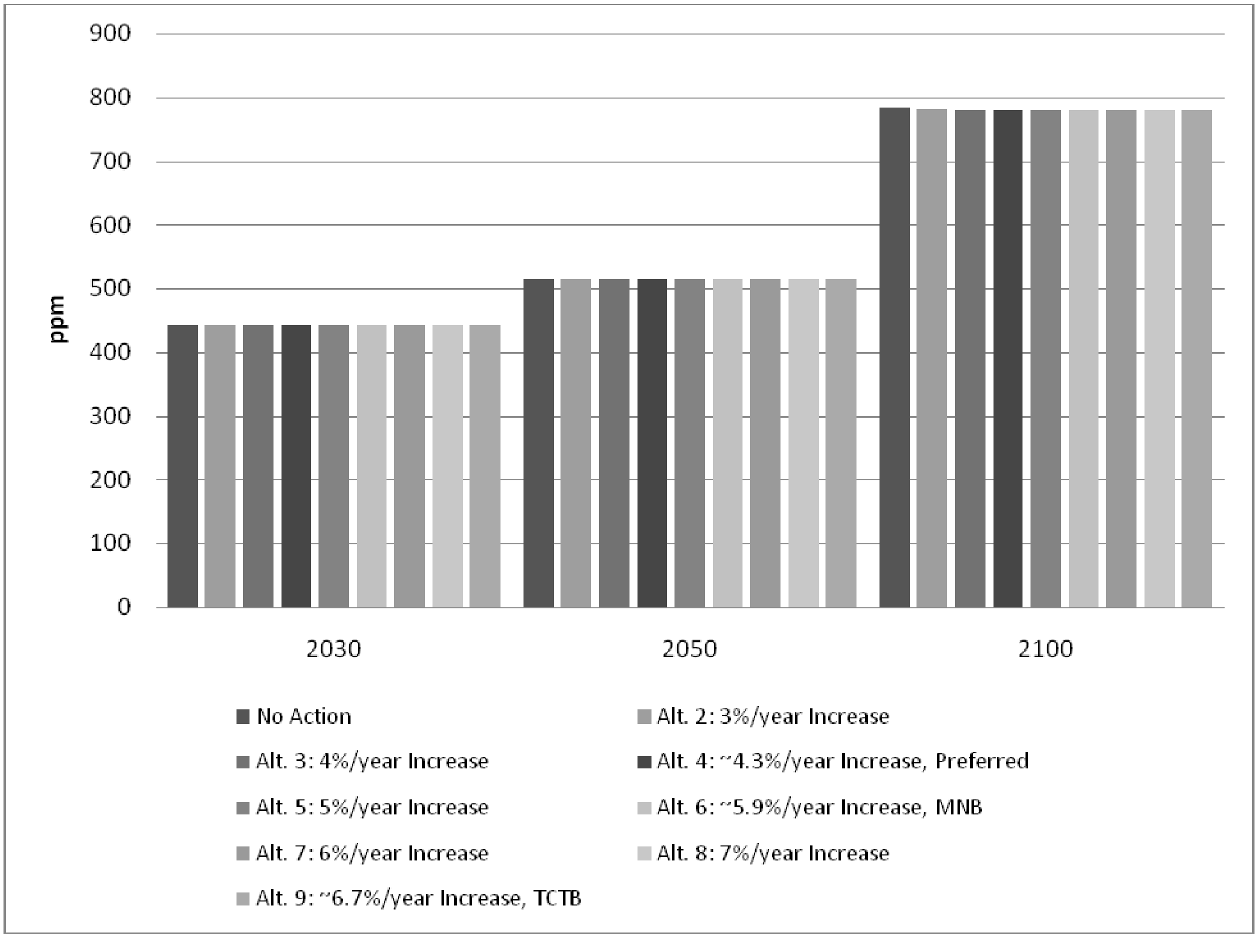


Figure 3.4.4-6. Global Mean Surface Temperature Increase (°C)

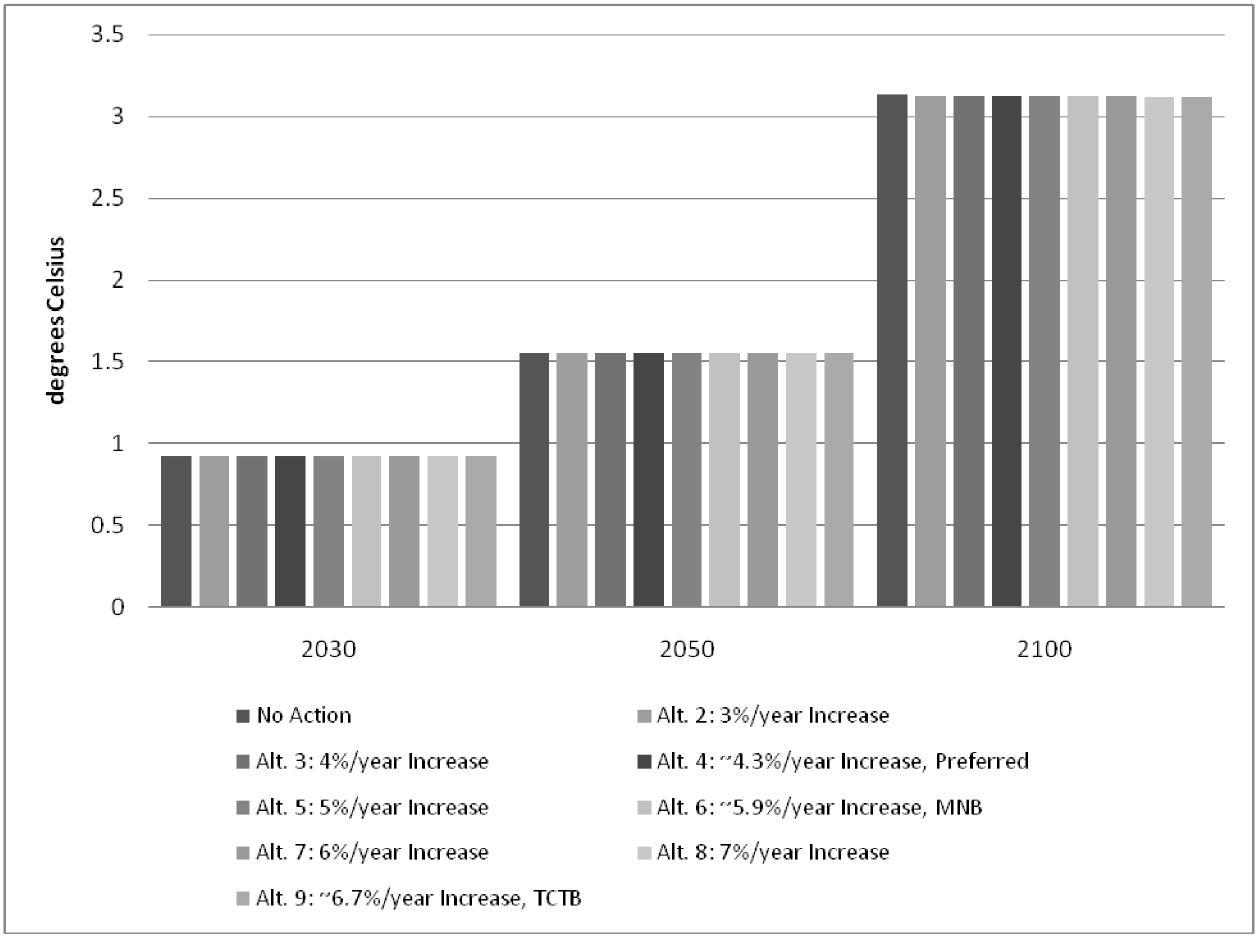


Figure 3.4.4-7. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

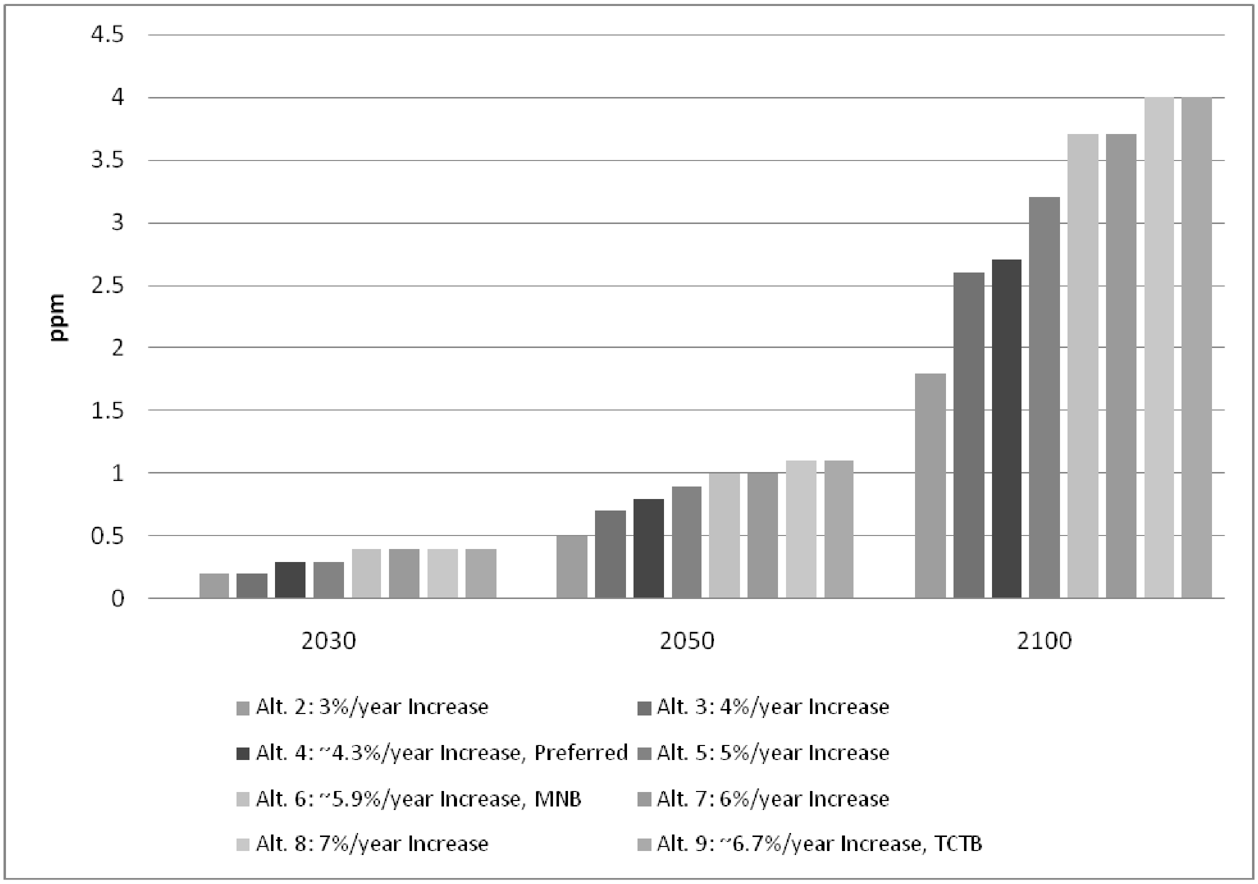
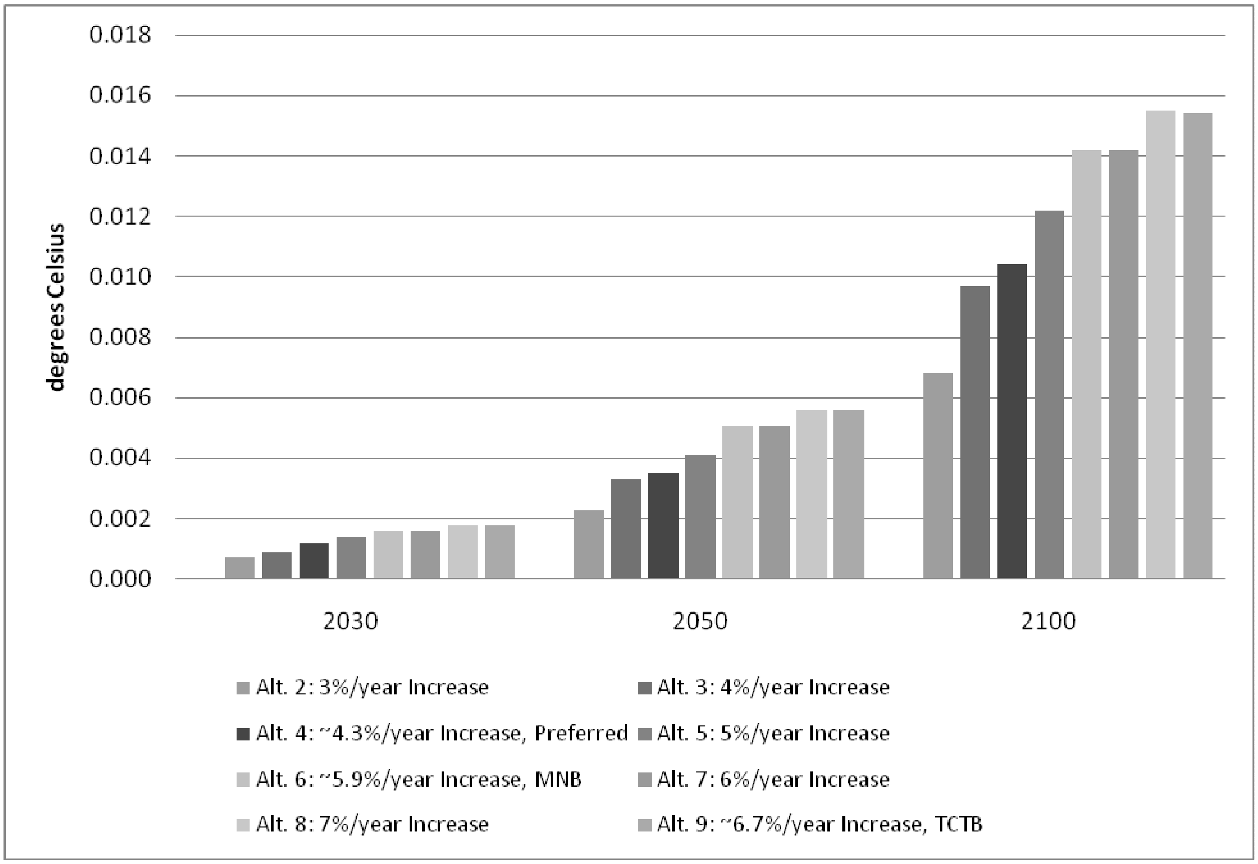


Figure 3.4.4-8. Reduction in Global Mean Temperature Compared to the No Action Alternative



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 0.015 °C (0.027 °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
	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		

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
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.[40] 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 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)[41]. 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).

[40] 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.

[41] 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.

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.[42]

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 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.

[42] Although MAGICC does not estimate changes in precipitation, SCENGEN does.

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	2.810
3 4%/year Increase	0.648	1.712	2.807
4 ~4.3%/year Increase, Preferred	0.648	1.712	2.807
5 5%/year Increase	0.648	1.711	2.805
6 ~5.9%/year Increase, MNB	0.648	1.710	2.803
7 6%/year Increase	0.648	1.710	2.803
8 7%/year Increase	0.648	1.709	2.802
9 ~6.7%/year Increase, TCTB	0.648	1.709	2.802
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	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.007	0.014
9 ~6.7%/year Increase, TCTB	0.000	0.007	0.014
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%	2.59%	4.58%
4 ~4.3%/year Increase, Preferred	0.94%	2.58%	4.57%
5 5%/year Increase	0.94%	2.58%	4.57%
6 ~5.9%/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%	4.57%
9 ~6.7%/year Increase, TCTB	0.94%	2.58%	4.57%

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%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.01%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

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). This projection does not include all changes in ice-sheet flow or the potential for rapid acceleration in ice loss (Alley *et al.* 2005, Gregory and Huybrechts 2006, and Hansen 2005, all in Pew 2007). 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 37.86 centimeters

(14.91 inches) under the TCTB (Alternative 9), for a maximum reduction of 0.14 centimeters (0.055 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.[43] 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 2.7 to 2.8 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 0.008 ºC (0.014 °F) for the 2.0 °C (3.6 °F) climate sensitivity to 0.013 ºC (0.023 °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 0.07 to 0.12 centimeters (0.03 to 0.05 inch), depending on the climate sensitivity.

[43] 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 concentration (ppm), Temperature (degrees C) 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	510.0	762.4	0.698	1.166	2.284	28.61
	3.0	441.5	514.0	780.3	0.922	1.553	3.125	37.91
	4.5	443.3	518.7	802.5	1.166	1.987	4.119	48.55
Reduction compared to No Action								
	2.0	0.3	0.7	2.7	0.001	0.003	0.008	0.07
	3.0	0.3	0.8	2.7	0.001	0.004	0.010	0.09
	4.5	0.3	0.8	2.8	0.001	0.004	0.013	0.12

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.

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 2008c).

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[1] 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 production of biofuels and 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 biofuel production increased, agricultural runoff could increase. 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

[1] 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 increased biofuel use or 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 (2008a) 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). Introduction of large quantities of nitrogen to certain terrestrial systems has also been predicted to lead to an increase in decomposing soil bacteria and subsequent increase in the release of CO_2 into the atmosphere as these bacteria consume organic matter (Black 2008).

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 might also affect 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 negative impacts to some species (*e.g.*, diminished potential for habitat expansion, increased runoff-related impacts).

Increased anthropogenic inputs of nitrogen to terrestrial, aquatic, and microbial communities containing rare plants and animals could also affect 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 the production of biofuels and 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 production of biofuels could result in the conversion of existing food-agricultural lands and non-agricultural areas to biofuel crop production. This change in land use would have implications for environmental issues associated with fertilizer runoff, water-body eutrophication, and sediment runoff effects to aquatic-organism food and spawning habitat. Similarly, 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 increased biofuel use or vehicle downweighting, these potential effects are not quantifiable.

NHTSA is exploring its Section 7 obligations under the Endangered Species Act.

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

The CAFE alternatives could lead to an increase in the production of biofuels and lighter vehicles, 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 production of biofuels could result in the conversion of existing food-agricultural lands and natural areas to the production of these fuel crops. 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 increased biofuel use or 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 an increase in the production of biofuels and 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 biofuel production increased, these could be additional runoff of agricultural fertilizers and pesticides; 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 increased biofuel use or 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, determining if there will be 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 from transportation sources, such as NO_2 and CO from roadway traffic, are often unevenly distributed and tend to remain near their release locations (O'Neill *et al.* 2003). A correlation between this uneven distribution of some pollutants and minority and low income populations has been documented, demonstrating the potential for a disproportionate allocation of the health impacts of these air pollutants to environmental justice populations (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 health effects in the areas of cardiovascular health (Adar and Kaufman 2007), and asthma and respiratory health (Heinrich and Wichmann 2004, Salam *et al.* 2008). The exact nature of the relationship between these health impacts, traffic-related emissions, and the influence of confounding factors such as traffic noise are not known at this time (Samet 2007).

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.

All of the alternatives could lead to an increase in the production of biofuels, depending on the mix of methods manufacturers use to meet the increased CAFE standards, economic demands from consumers and manufacturers, and technological developments. If grain-based biofuel production increases, there could be effects on food prices. However, because of the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the alternatives prescribes increased biofuel use, these potential impacts are not quantifiable.

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 (MY) 2012-2016. Under Alternative 1 (No Action), neither NHTSA nor EPA would issue a rule regarding fuel economy or GHG emissions for MY 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) and acrolein 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 occur only under Alternatives 2 through 4 and are approximately 0.7 percent or less over the No Action Alternative. In addition, as noted in Section 3.3.3, the acrolein emissions reported in the EIS represent an upper bound, and thus potential unavoidable impacts of acrolein emissions might be less.

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 MY 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 and 3.2.3-2 (*see* Section 3.2 of this EIS) summarize fuel consumption under each alternative for passenger cars and light trucks, respectively. For the Preferred Alternative (Alternative 4) the fuel savings[1] 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 MY 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.

[1] 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 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.[1]

This section of the EIS presents EPA's 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.[2] 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

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[1] *See* Notice of Upcoming Joint Rulemaking To Establish Vehicle GHG Emissions and CAFE Standards, 74 FR 24007 (May 22, 2009).

[2] 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.

fleets; flex fueled vehicle credits; and the Temporary Lead-time Allowance Alternative Standards program. NHTSA's CAFE program has its own compliance flexibilities. However, because EPCA prohibits NHTSA from considering 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.

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* NHTSA and EPA's joint preamble and the EPA and NHTSA Draft Regulatory Impact Analysis (DRIA) associated with the joint proposal.

3.7.2 Summary of EPA 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 projections described in the draft Joint Technical Support Document.[3] 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

[3] 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.

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, andCH_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.[4] 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.

In calendar year 2030, EPA analysis projects its proposal to reduce light duty fuel consumption approximately 17 percent relative to the reference scenario.

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[4] 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).

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 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 2020	% Change vs. 2020 Reference	Calendar Year 2030	% Change vs. 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

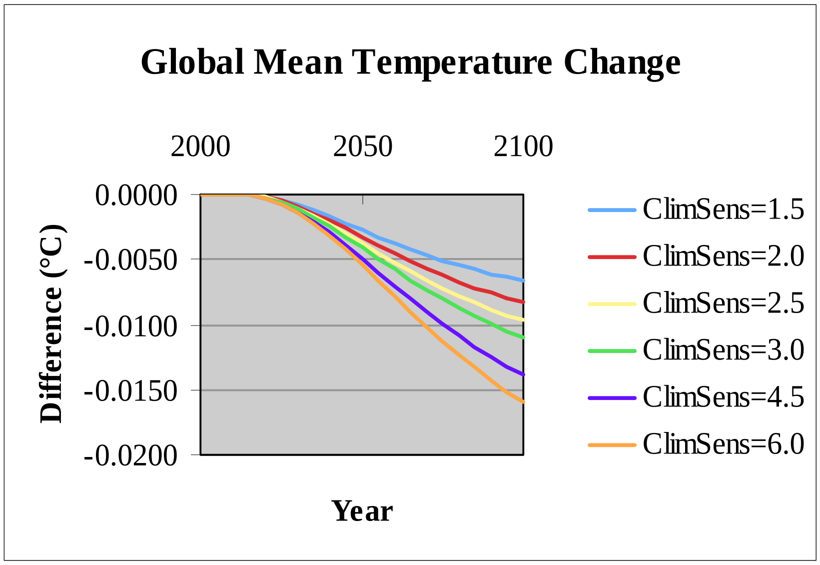
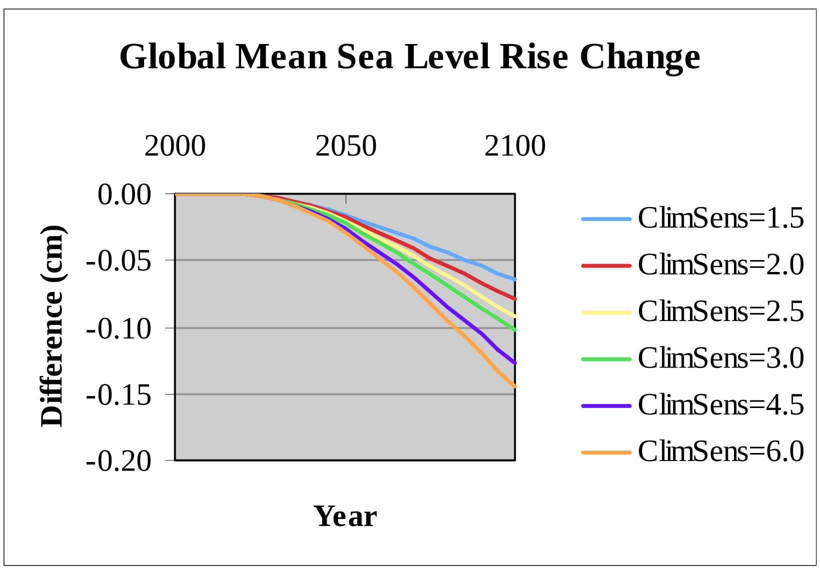


Figure 3.7.2-2. Estimated Projected Reductions in Global Mean Sea-Level Rise from Baseline for Climate Sensitivities Ranging from 1.5–6 °C)



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 Code of Federal Regulations (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 (MY) 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) April 2009 (updated) 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 April 2009 Reference Case reflected in this EIS incorporates effects of the American Recovery and Reinvestment Act, and updated economic 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 0.51 percent in passenger-car mpg and 0.86 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. Because the AEO forecasts do not extend beyond 2030, the mpg estimates for MY 2030 through MY 2060 remain constant. 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	5.75	0.51
New Light Truck	9.94	0.86

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 0.51 percent in passenger-car mpg and 0.86 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 0.51 percent in passenger-car mpg and 0.86 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 0.51 percent in passenger-car mpg and 0.86 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 0.51 percent in passenger-car mpg and 0.86 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 0.51 percent in passenger-car mpg and 0.86 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 involve 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 40 percent of consumption in 2030 (EIA 2009a). This change is attributed in part to expected changes in the CAFE standards and to the increased use of biofuels. The steep decline in imports by 2030 is also driven by the surge in U.S. domestic crude-oil production in the decade before 2030. The 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 price maker 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 2030 (EIA 2009a).

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 2009 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 12 quadrillion British thermal units in 2030 (EIA 2009b). 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 2.21 quadrillion British thermal units by 2030.

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 0.51 percent in passenger-car mpg and 0.86 percent in light-truck mpg from 2020 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 0.51 percent in passenger-car mpg and 0.86 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 MY 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 162.8 billion gallons under the No Action Alternative. Consumption falls across the alternatives, from 140.7 billion gallons under Alternatives 3 and 4 to 131.3 billion gallons under Alternatives 8 and 9 representing a fuel savings of 21.8 to 31.5 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 91.2 billion gallons under the No Action Alternative. Consumption declines across the alternatives, from 80.1 billion gallons under Alternative 2 to 73.3 billion gallons under Alternative 8. This represents a fuel savings of 11.1 to 17.9 billion gallons in 2060.

Table 4.2.3-1

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	69.1	64.7	63.8	63.6	62.8	61.6	61.6	61.0	60.9
2030	94.5	82.6	82.2	82.3	80.7	78.3	78.2	76.8	76.8
2040	114.7	99.1	99.1	99.3	97.3	94.5	94.2	92.5	92.5
2050	136.7	118.1	118.2	118.4	116.0	112.6	112.4	110.3	110.3
2060	162.8	140.7	140.7	141.0	138.2	134.1	133.8	131.3	131.3
Fuel Savings Compared to No Action									
2020	--	4.4	5.3	5.6	6.3	7.5	7.5	8.1	8.2
2030	--	11.9	12.2	12.2	13.8	16.2	16.3	17.7	17.7
2040	--	15.6	15.5	15.4	17.3	20.2	20.4	22.2	22.2
2050	--	18.6	18.5	18.3	20.7	24.1	24.4	26.5	26.4
2060	--	22.1	22.1	21.8	24.6	28.7	29.0	31.5	31.5

Table 4.2.3-2

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

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Fuel Consumption									
2020	68.3	65.6	64.9	64.6	64.0	62.8	63.1	62.5	62.4
2030	62.8	56.8	56.5	56.3	55.0	53.3	53.4	52.5	52.6
2040	66.7	58.9	58.9	58.7	57.1	55.2	55.2	54.1	54.3
2050	77.1	67.8	67.8	67.6	65.7	63.4	63.4	62.1	62.4
2060	91.2	80.1	80.1	79.9	77.6	74.9	74.9	73.3	73.7
Fuel Savings Compared to No Action									
2020	--	2.7	3.4	3.7	4.4	5.6	5.3	5.8	5.9
2030	--	6.0	6.3	6.6	7.8	9.5	9.4	10.3	10.2
2040	--	7.7	7.8	8.0	9.5	11.5	11.5	12.6	12.3
2050	--	9.3	9.3	9.5	11.4	13.7	13.7	15.0	14.7
2060	--	11.1	11.1	11.3	13.6	16.3	16.3	17.9	17.5

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 2009 updated 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 MY 2030-MY 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 MY 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).[1] For comparison, the Chapter 3 analysis only examines the direct and indirect effects of the proposed MY 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

[1] 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.

4.3.3 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 MY 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. 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 equal to or greater than 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 in 2016; $PM_{2.5}$ under Alternative 3 in 2030 and 2050, Alternative 4 in 2020, 2030, and 2050, Alternative 5 in 2016 and 2020, Alternatives 6 and 7 in all years, and Alternative 9 in 2030 and 2050; SO_x under

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon monoxide (CO)									
2016	18,046,737	18,055,567	18,054,219	18,049,276	17,990,071	17,954,866	17,943,080	17,930,498	17,927,150
2020	15,999,485	16,036,418	16,026,843	16,014,641	15,855,097	15,734,079	15,680,630	15,645,538	15,633,337
2030	17,816,418	18,001,706	17,934,568	17,893,423	17,432,546	16,991,218	16,749,111	16,641,134	16,600,732
2050	24,155,097	24,530,976	24,385,367	24,315,810	23,541,753	22,770,712	22,314,840	22,130,779	22,061,720
Nitrogen oxides (NO_X)									
2016	2,043,669	2,040,386	2,038,801	2,038,077	2,035,890	2,033,211	2,033,658	2,032,473	2,031,999
2020	1,611,302	1,602,178	1,599,759	1,598,716	1,591,187	1,584,242	1,583,478	1,580,423	1,579,736
2030	1,460,039	1,441,960	1,438,364	1,437,032	1,410,643	1,385,381	1,374,322	1,365,493	1,363,497
2050	1,809,786	1,786,720	1,780,335	1,778,462	1,733,908	1,690,190	1,667,885	1,653,446	1,650,090
Particulate matter ($PM_{2.5}$)									
2016	63,686	63,201	63,010	62,991	63,145	63,149	63,315	63,249	63,205
2020	62,568	61,146	60,931	60,970	61,102	61,259	61,570	61,420	61,400
2030	75,214	71,757	71,840	72,092	71,975	72,220	72,570	72,232	72,245
2050	107,387	102,210	102,469	102,885	102,501	102,698	103,025	102,490	102,512
Sulfur oxides (SO_x)									
2016	164,406	161,493	160,246	159,818	160,089	159,031	159,855	159,312	159,006
2020	169,092	160,530	158,908	158,466	158,475	157,123	158,423	157,254	157,156
2030	193,480	171,806	171,744	171,993	171,402	169,671	171,512	169,231	169,555
2050	262,948	229,228	230,352	231,083	230,124	227,819	230,366	227,019	227,650
Volatile organic compounds (VOCs)									
2016	2,307,062	2,293,122	2,286,048	2,282,711	2,275,408	2,264,296	2,265,703	2,261,824	2,259,827
2020	1,940,313	1,900,024	1,889,242	1,884,635	1,867,354	1,845,387	1,842,769	1,834,396	1,832,809
2030	1,632,483	1,533,652	1,525,914	1,521,679	1,486,550	1,443,565	1,431,412	1,414,818	1,414,284
2050	1,803,222	1,652,075	1,645,210	1,640,518	1,587,401	1,522,744	1,501,494	1,476,771	1,476,595

Alternatives 3 in 2050, Alternative 4 in 2030 and 2050, Alternative 5 in 2016 and 2020, Alternative 7 in all years, and Alternative 9 in 2030 and 2050; and VOCs under Alternative 7 in 2016. 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.

Table 4.3.3-2 lists the net changes in nationwide cumulative emissions from passenger cars and light trucks for 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 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.

Table 4.3.3-2

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon monoxide (CO)									
2016	0	8,829	7,482	2,539	-56,666	-91,872	-103,657	-116,240	-119,587
2020	0	36,933	27,358	15,156	-144,388	-265,407	-318,855	-353,947	-366,148
2030	0	185,288	118,150	77,005	-383,872	-825,200	-1,067,306	-1,175,284	-1,215,686
2050	0	375,879	230,270	160,713	-613,344	-1,384,385	-1,840,257	-2,024,318	-2,093,377
Nitrogen oxides (NO_x)									
2016	0	-3,283	-4,868	-5,592	-7,779	-10,458	-10,011	-11,196	-11,670
2020	0	-9,124	-11,543	-12,586	-20,115	-27,061	-27,824	-30,879	-31,566
2030	0	-18,079	-21,675	-23,008	-49,396	-74,658	-85,717	-94,546	-96,543
2050	0	-23,066	-29,451	-31,324	-75,878	-119,596	-141,901	-156,340	-159,696
Particulate matter ($PM_{2.5}$)									
2016	0	-486	-677	-696	-541	-538	-371	-438	-482
2020	0	-1,422	-1,637	-1,598	-1,466	-1,308	-998	-1,148	-1,167
2030	0	-3,456	-3,373	-3,122	-3,239	-2,994	-2,644	-2,982	-2,969
2050	0	-5,177	-4,918	-4,502	-4,886	-4,689	-4,362	-4,897	-4,875
Sulfur oxides (SO_x)									
2016	0	-2,912	-4,160	-4,588	-4,316	-5,375	-4,551	-5,094	-5,400
2020	0	-8,562	-10,184	-10,626	-10,617	-11,969	-10,669	-11,838	-11,936
2030	0	-21,674	-21,735	-21,487	-22,078	-23,809	-21,968	-24,249	-23,925
2050	0	-33,720	-32,596	-31,865	-32,824	-35,129	-32,582	-35,928	-35,298
Volatile organic compounds (VOCs)									
2016	0	-13,941	-21,014	-24,352	-31,654	-42,766	-41,359	-45,238	-47,235
2020	0	-40,289	-51,071	-55,678	-72,959	-94,926	-97,544	-105,917	-107,504
2030	0	-98,830	-106,569	-110,804	-145,932	-188,917	-201,070	-217,665	-218,198
2050	0	-151,146	-158,012	-162,704	-215,820	-280,477	-301,727	-326,450	-326,627

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.

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, despite a growth in total VMT, as a result of the EPA emission standards. With current trends, emissions of diesel particulate matter (DPM) would increase in 2020, 2030, and 2050 over 2016 levels under the No Action Alternative. Alternative 1 (No Action) would result in no other increase or decrease in cumulative toxic air pollutant emissions in nonattainment and maintenance areas throughout the United States.

Table 4.3.3-3 summarizes the cumulative national toxic air pollutant emissions from passenger cars and light trucks under the No Action 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. As with criteria pollutants, emissions of most toxic air pollutants would increase from one alternative to the next more stringent alternative. The exceptions are acetaldehyde emissions, which would decrease under Alternative 3 in 2050, Alternative 4 in 2020, 2030 and 2050, and Alternative 6 in 2050; acrolein emissions, which would decrease under Alternative 9 in 2020, 2030 and 2050; benzene emissions, which would decrease under all alternatives and years except Alternative 2 in 2050; 1,3-butadiene emissions, which would decrease under Alternatives 3 through 9 in 2030 and 2050, Alternative 5 in 2020, and Alternative 7 in 2016 and 2020; DPM emissions, which would decrease under Alternatives 2, 5, 6, and 8 in all years, Alternative 3 in 2016, 2020, and 2030, Alternative 4 in 2016 and 2020, Alternative 7 in 2030 and 2050, and Alternative 9 in 2016 and 2020; and formaldehyde emissions, which would decrease under Alternative 2 in 2016 and 2020. The changes in toxic air pollutant emissions, positive or negative, would generally be small 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 2050; DPM emissions, which would decrease by more than 10 percent under all action alternatives in 2030 and 2050, and Alternative 9 in 2020; 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.

Cumulative emissions after 2016 would generally be greater 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 fuel economy in the cumulative analysis). The exceptions are acrolein under Alternative 9 in 2030 and 2050; benzene under all alternatives in 2020, and Alternatives 1 through 5 in 2030; DPM under all alternatives in 2020 and 2030; and formaldehyde under Alternatives 1 through 4 in 2020, and Alternative 1 in 2030.

Emissions changes with the cumulative analysis (compared to the No Action Alternative) would be greater than the corresponding emissions changes with the noncumulative analysis for most toxic air pollutants. The exceptions are acrolein under Alternative 9 in all years; benzene under Alternatives 6 through 9 in 2020, and Alternatives 3 through 9 in 2030; 1,3-butadiene under Alternatives 6 through 9 in 2020 and 2030, and formaldehyde under Alternatives 3 through 6 in 2016.

Table 4.3.3-3

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Acetaldehyde									
2016	10,039	10,041	10,045	10,047	10,071	10,087	10,090	10,097	10,100
2020	7,929	7,940	7,948	7,948	7,987	8,018	8,034	8,047	8,052
2030	6,644	6,700	6,705	6,696	6,727	6,740	6,752	6,768	6,770
2050	7,953	8,070	8,064	8,048	8,074	8,068	8,068	8,088	8,088
Acrolein									
2016	521	521	522	522	527	531	531	533	533
2020	410	411	412	413	423	432	435	438	432
2030	343	346	349	352	367	386	394	399	386
2050	411	418	422	426	449	478	490	498	478
Benzene									
2016	52,316	52,296	52,283	52,272	52,222	52,177	52,171	52,157	52,151
2020	39,689	39,643	39,619	39,598	39,464	39,338	39,301	39,264	39,254
2030	27,680	27,659	27,597	27,546	27,169	26,760	26,571	26,471	26,444
2050	28,048	28,111	27,984	27,901	27,253	26,534	26,164	25,993	25,945
1,3-Butadiene									
2016	5,704	5,706	5,707	5,708	5,709	5,711	5,711	5,712	5,712
2020	4,505	4,512	4,514	4,514	4,513	4,515	4,514	4,516	4,516
2030	3,618	3,652	3,650	3,648	3,625	3,607	3,594	3,592	3,589
2050	4,180	4,249	4,239	4,235	4,189	4,148	4,117	4,111	4,106
Diesel particulate matter (DPM)									
2010	86,700	85,133	84,397	84,123	83,788	82,953	83,249	82,892	82,695
2020	89,057	84,468	83,431	83,124	82,204	80,814	81,010	80,256	80,135
2030	101,834	90,261	89,882	89,885	88,037	85,824	85,767	84,330	84,393
2050	138,391	120,407	120,494	120,706	118,016	114,922	114,724	112,629	112,810
Formaldehyde									
2010	12,851	12,848	12,856	12,863	12,954	13,014	13,028	13,051	13,062
2020	10,202	10,195	10,218	10,225	10,398	10,539	10,608	10,656	10,673
2030	8,867	8,885	8,927	8,939	9,203	9,448	9,582	9,664	9,684
2050	10,901	10,966	11,022	11,036	11,416	11,775	11,970	12,092	12,118

Table 4.3.3-4 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.

Table 4.3.3-4

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/

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Acetaldehyde									
2016	0	3	7	8	32	48	51	58	61
2020	0	11	19	19	58	89	105	118	123
2030	0	57	61	53	84	97	109	125	127
2050	0	118	112	95	121	115	116	135	135
Acrolein									
2016	0	0	1	1	6	10	10	12	12
2020	0	1	2	3	13	22	25	28	22
2030	0	3	6	9	24	43	51	56	43
2050	0	7	11	15	38	67	79	87	67
Benzene									
2016	0	-19	-33	-43	-93	-139	-144	-159	-164
2020	0	-45	-70	-91	-225	-350	-388	-425	-435
2030	0	-21	-83	-134	-511	-920	-1,109	-1,209	-1,236
2050	0	62	-64	-147	-795	-1,514	-1,884	-2,055	-2,103
1,3-Butadiene									
2016	0	2	3	3	5	7	6	7	8
2020	0	7	9	10	8	10	10	11	11
2030	0	34	32	30	7	-11	-24	-26	-29
2050	0	69	58	54	8	-32	-64	-69	-75
Diesel particulate matter (DPM)									
2010	0	-1,567	-2,302	-2,577	-2,911	-3,747	-3,451	-3,807	-4,005
2020	0	-4,589	-5,626	-5,933	-6,853	-8,243	-8,047	-8,801	-8,922
2030	0	-11,572	-11,952	-11,949	-13,797	-16,010	-16,067	-17,504	-17,441
2050	0	-17,984	-17,897	-17,685	-20,375	-23,469	-23,667	-25,762	-25,581
Formaldehyde									
2010	0	-4	5	11	103	163	177	200	210
2020	0	-7	16	23	195	337	406	454	470
2030	0	18	61	72	336	581	715	797	817
2050	0	66	121	135	516	874	1,070	1,192	1,218

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.

4.3.3.2.3 Health Outcomes and Costs

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).

Table 4.3.3-5 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 3, with mixed results under Alternatives 4 through 7, and decreasing again under Alternatives 8 and 9.

Table 4.3.3-5

Cumulative Nationwide Changes in Health Outcomes (cases/year) from Criteria Air Pollutant Emissions 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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Mortality (ages 30 and older)									
Pope *et al.* 2002									
2016	0	-26	-36	-39	-36	-41	-34	-38	-41
2020	0	-77	-91	-92	-95	-101	-89	-100	-101
2030	0	-215	-216	-208	-239	-260	-252	-280	-280
2050	0	-364	-356	-339	-406	-453	-455	-504	-504
Laden *et al.* 2006									
2016	0	-66	-93	-99	-92	-106	-87	-98	-105
2020	0	-199	-234	-237	-245	-259	-229	-256	-260
2030	0	-551	-553	-532	-612	-665	-646	-717	-718
2050	0	-930	-911	-867	-1,037	-1,157	-1,162	-1,287	-1,288
Chronic Bronchitis									
2016	0	-17	-25	-26	-24	-28	-23	-26	-28
2020	0	-53	-63	-63	-66	-69	-61	-69	-70
2030	0	-141	-142	-136	-158	-172	-167	-186	-186
2050	0	-230	-226	-215	-259	-290	-292	-323	-323
Emergency Room Visits for Asthma									
2016	0	-24	-34	-37	-34	-39	-32	-37	-39
2020	0	-74	-87	-89	-90	-96	-84	-94	-96
2030	0	-197	-198	-191	-213	-230	-220	-245	-244
2050	0	-323	-315	-300	-347	-382	-377	-417	-416
Work Loss Days									
2010	0	-3,365	-4,776	-5,093	-4,713	-5,423	-4,444	-5,045	-5,390
2020	0	-9,983	-11,769	-11,896	-12,350	-13,073	-11,527	-12,916	-13,120
2030	0	-25,339	-25,475	-24,466	-28,335	-30,890	-30,088	-33,394	-33,445
2050	0	-39,749	-38,969	-37,043	-44,648	-49,958	-50,334	-55,754	-55,808

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.

In Table 4.3.3-5 the health impacts of each alternative are expressed 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 4.3.3-5, 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.

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 economic impacts 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 costs 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).

Table 4.3.3-6 lists the nationwide changes in health costs 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. Economic impacts follow the trends established with health outcomes above, generally decreasing (*i.e.*, benefits increasing) across more stringent alternatives through Alternative 3, with mixed results under Alternatives 4 through 7, and decreasing again under Alternatives 8 and 9.

Table 4.3.3-6

Cumulative Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
3-% Discount Rate									
Pope *et al.* 2002									
2016	0 a/	-215	-306	-326	-302	-348	-285	-324	-346
2020	0	-673	-794	-803	-830	-880	-775	-868	-882
2030	0	-1,913	-1,922	-1,848	-2,126	-2,313	-2,246	-2,492	-2,495
2050	0	-3,292	-3,225	-3,067	-3,672	-4,097	-4,116	-4,558	-4,560
Laden *et al.* 2006									
2016	0	-528	-749	-800	-739	-853	-699	-793	-847
2020	0	-1,649	-1,944	-1,967	-2,034	-2,155	-1,898	-2,126	-2,159
2030	0	-4,688	-4,711	-4,528	-5,209	-5,665	-5,501	-6,105	-6,110
2050	0	-8,069	-7,903	-7,518	-8,999	-10,040	-10,083	-11,167	-11,171

Table 4.3.3-6 (cont'd)

Cumulative Nationwide Changes in Health Costs (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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
7-% Discount Rate									
Pope *et al.* 2002									
2016	0	-196	-277	-296	-274	-316	-259	-294	-314
2020	0	-611	-720	-729	-753	-798	-703	-788	-800
2030	0	-1,735	-1,744	-1,676	-1,929	-2,098	-2,037	-2,261	-2,263
2050	0	-2,985	-2,924	-2,782	-3,331	-3,716	-3,733	-4,134	-4,136
Laden *et al.* 2006									
2010	0	-477	-677	-723	-668	-770	-631	-716	-765
2020	0	-1,490	-1,756	-1,777	-1,837	-1,947	-1,715	-1,921	-1,950
2030	0	-4,235	-4,255	-4,090	-4,705	-5,117	-4,969	-5,515	-5,519
2050	0	-7,287	-7,138	-6,790	-8,128	-9,068	-9,107	-10,087	-10,090

a/ Negative changes indicate economic benefit; positive emissions changes indicate economic costs.
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.

4.3.3.3 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 0.2 to 1.3 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.8 percent, SO_x emissions would be reduced 1.8 to 12.8 percent, and VOC emissions would be reduced 0.6 to 8.4 percent, compared to emissions projected under the No Action Alternative. There would be increases of CO emissions. CO emissions would increase 0.05 to 1.6 percent under Alternative 2, 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 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.

4.3.3.3.2 Toxic Air Pollutants

Under Alternative 2, cumulative emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde (in 2030) would be greater than noncumulative emissions for the same combinations of pollutant and year. Cumulative emissions of benzene, DPM, and formaldehyde (in 2020) would generally 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 benzene (except in 2050), DPM, and formaldehyde (in 2016 and 2020), and would increase emissions of acetaldehyde, acrolein, benzene (in 2050), 1,3-butadiene, and formaldehyde (in 2030 and 2050). Compared to Alternatives 3 through 9, Alternative 2 would result in lower emissions of acetaldehyde (except Alternative 4 in 2030, and Alternatives 3, 4, 6, and 7 in 2050), acrolein (in all years), 1,3-butadiene (in 2030 and 2050), DPM (under Alternatives 3 and 4 in 2050), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 2 cumulative analysis would be 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 2 would result in 364 fewer mortalities and 39,749 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 2 compared to the No Action Alternative. In 2050, Alternative 2 would reduce health costs by $3.3 billion annually using a 3-percent discount rate and estimates from Pope *et al.* (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less. Alternative 2 would result in less health and economic benefit than other more stringent alternatives.

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 1.6 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.6 percent, SO_x emissions would be reduced 2.5 to 12.4 percent, and VOC emissions would be reduced 0.9 to 8.8 percent, compared to emissions projected under the No Action Alternative. Except for emissions of $PM_{2.5}$ in 2030 and 2050, and SO_x in 2050, these emissions reductions are generally greater than would occur under Alternative 2. Except for emissions of $PM_{2.5}$ in all years and SO_x in 2030 and 2050, these emissions reductions are generally greater than would occur under Alternatives 4 through 9. There would be increases of CO emissions from 0.04 to 1.0 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 less than the corresponding emissions reductions under the Alternative 3 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs, except for NO_x in 2020, $PM_{2.5}$ and VOCs in 2020 and 2030, and SO_2 in all years. For CO, emissions increases under the Alternative 3 cumulative analysis would be greater than the corresponding emissions increases under the Alternative 3 noncumulative analysis. For CO, emissions reductions under the Alternative 3 cumulative analysis would be less than the corresponding emissions reductions under the Alternative 3 noncumulative analysis.

4.3.3.4.2 Toxic Air Pollutants

Under Alternative 3, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

Alternative 3 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 the No Action Alternative. Compared to Alternatives 4 through 9, Alternative 3 would result in higher emissions of benzene and DPM (except under Alternative 4 in 2030 and 2050), and lower emissions of acetaldehyde (except under Alternative 4 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 greater than the corresponding emissions changes under the Alternative 3 noncumulative analysis for all toxic air pollutants except benzene (in 2030) and formaldehyde (in 2016). For benzene (in 2030) and formaldehyde (in 2016), emissions changes 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.

4.3.3.4.3 Health Outcomes and Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 3 would result in 356 fewer mortalities and 38,969 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 3 compared to the No Action Alternative. In 2050, Alternative 3 would reduce health costs by $3.2 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 1.7 percent, $PM_{2.5}$ emissions would be reduced 1.1 to 4.2 percent, SO_x emissions would be reduced 2.8 to 12.1 percent, and VOC emissions would be reduced 1.1 to 9.0 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 $PM_{2.5}$ in 2020, 2030, and 2050, and SO_x in 2030 and 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 2016, 2020, and 2030, and SO_x in 2016 and 2020 (as compared to Alternative 5). There would be increases of CO emissions of 0.1 to 0.7 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 less than the corresponding emissions reductions under the Alternative 4 noncumulative analysis for NO_x, $PM_{2.5}$, SO_2, and VOCs. For CO, emissions increases under the Alternative 4 cumulative analysis would be greater than the corresponding emissions increases under the Alternative 4 noncumulative analysis.

4.3.3.5.2 Toxic Air Pollutants

Under Alternative 4, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

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 the No Action Alternative. Compared to Alternatives 5 through 9, Alternative 4 would result in higher emissions of benzene (in 2030 and 2050) and DPM, and lower emissions of acetaldehyde, 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 greater than the corresponding emissions changes under the Alternative 4 noncumulative analysis for all toxic air pollutants except benzene (in 2030) and formaldehyde (in 2016). For benzene (in 2030) and formaldehyde (in 2016), emissions changes under the Alternative 4 cumulative analysis would be less than the corresponding emissions changes under the Alternative 4 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 4 would result in 339 fewer mortalities and 37,043 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 4 compared to the No Action Alternative. In 2050, Alternative 4 would reduce health costs by $3.1 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 in 2016 and 2020), and less than under Alternative 6 through 9 (except for $PM_{2.5}$ for all years and alternatives but Alternatives 8 and 9 in 2050, and for SO_x for Alternative 7 in 2030 and 2050). Depending on the year, CO emissions would be reduced 0.3 to 2.5 percent, NO_x emissions would be reduced 0.4 to 4.2 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.6 percent, SO_x emissions would be reduced 2.6 to 12.5 percent, and VOC emissions would be reduced 1.4 to 12.0 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 greater 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 less 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 some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

Alternative 5 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 the No Action Alternative. Compared to Alternatives 6 through 9, Alternative 5 would result in higher emissions of benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and lower emissions of acetaldehyde, 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 greater than the corresponding emissions changes under the Alternative 4 noncumulative analysis for all toxic air pollutants except benzene (in 2030). For benzene (in 2030) emissions changes under the Alternative 5 cumulative analysis would be less than the corresponding emissions changes under the Alternative 5 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 5 would result in 406 fewer mortalities and 44,648 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 5 compared to the No Action Alternative. In 2050, Alternative 5 would reduce health costs by $3.7 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less.

Compared to Alternative 5, health and economic benefits would be greater under Alternatives 6, 8, and 9, and Alternative 7 in 2050, but less under Alternative 7 in 2016, 2020, and 2030.

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), less than under Alternative 7 (except in for NO_x and VOCs in 2016 and $PM_{2.5}$ and SO_x in all years), less than under Alternative 8 (except for $PM_{2.5}$ in 2016, 2020, and 2030 and SO_x in 2016 and 2020), and less than under Alternative 9 (except for $PM_{2.5}$ in 2016, 2020, and 2030 and SO_x in 2020). Depending on the year, CO emissions would be reduced 0.5 to 5.7 percent, NO_x emissions would be reduced 0.5 to 6.6 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.4 percent, SO_x emissions would be reduced 3.3 to 13.4 percent, and VOC emissions would be reduced 1.9 to 15.6 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 all pollutants.

4.3.3.7.2 Toxic Air Pollutants

Under Alternative 6, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year. Alternative 6 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative. Compared to Alternatives 7 through 9, Alternative 6 would result in higher emissions of benzene, 1,3-butadiene (in 2030 and 2050), and DPM (except under Alternative 7 in 2016 and 2020), and lower emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde.

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 benzene (in 2020 and 2030), 1,3-butadiene (in 2020 and 2030), and formaldehyde (in 2016). For benzene (in 2020 and 2030), 1,3-butadiene (in 2020 and 2030), and formaldehyde (in 2016) the emissions changes under the Alternative 6 cumulative analysis would be less than the corresponding emissions changes under the Alternative 6 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 6 would result in 453 fewer mortalities and 49,958 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 6 compared to the No Action Alternative. In 2050, Alternative 6 would reduce health costs by $4.1 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less.

Compared to Alternative 6, health and economic benefits would be greater under Alternatives 8 and 9, and Alternative 7 in 2050, but less under Alternative 7 in 2016, 2020, and 2030.

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 greater than under Alternative 6 (except for NO_x and VOCs in 2016, $PM_{2.5}$ and SO_x in all years) but less than under Alternatives 8 and 9. Depending on the year, CO emissions would be reduced 0.6 to 7.6 percent, NO_x emissions would be reduced 0.5 to 7.8 percent, $PM_{2.5}$ emissions would be reduced 0.6 to 4.1 percent, SO_x emissions would be reduced 2.8 to 12.4 percent, and VOC emissions would be reduced 1.8 to 16.7 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 greater than the corresponding emissions reductions under the Alternative 7 noncumulative analysis for all pollutants.

4.3.3.8.2 Toxic Air Pollutants

Under Alternative 7, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

Alternative 7 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde, acrolein, 1,3-butadiene (in 2016 and 2020), and formaldehyde compared to the No Action Alternative. Compared to Alternatives 8 and 9, Alternative 7 would result in higher emissions of acrolein (under

Alternative 9 in 2020, 2030, and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and lower emissions of acetaldehyde, acrolein (under Alternative 9 in 2016), 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 greater than the corresponding emissions changes under the Alternative 7 noncumulative analysis for all toxic air pollutants except benzene (in 2020 and 2030) and 1,3-butadiene (in 2020 and 2030). For benzene (in 2020 and 2030) and 1,3-butadiene (in 2020 and 2030) the emissions changes under the Alternative 7 cumulative analysis would be less than the corresponding emissions changes under the Alternative 7 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 7 would result in 455 fewer mortalities and 50,334 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 7 compared to the No Action Alternative. In 2050, Alternative 7 would reduce health costs by $4.1 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. With the Laden *et al*. method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 percent less.

Compared to Alternative 7, health and economic benefits would be greater under Alternatives 8 and 9.

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 but less than under Alternative 9 (except for $PM_{2.5}$ and SO_x in 2030 and 2050). Depending on the year, CO emissions would be reduced 0.6 to 8.4 percent, NO_x emissions would be reduced 0.5 to 8.6 percent, $PM_{2.5}$ emissions would be reduced 0.7 to 4.6 percent, SO_x emissions would be reduced 3.1 to 13.7 percent, and VOC emissions would be reduced 2.0 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 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 all pollutants.

4.3.3.9.2 Toxic Air Pollutants

Under Alternative 8, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

Alternative 8 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde, 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 higher emissions of acrolein (in 2020, 2030, and 2050), benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and lower emissions of acetaldehyde, acrolein (in 2016), 1,3-butadiene (in 2016 and 2020), and formaldehyde.

Emissions changes (compared to the No Action Alternative) under the Alternative 8 cumulative analysis would be greater than the corresponding emissions changes under the Alternative 8 noncumulative analysis for all toxic air pollutants except benzene (in 2020 and 2030) and 1,3-butadiene (in 2020 and 2030). For benzene (in 2020 and 2030) and 1,3-butadiene (in 2020 and 2030) the emissions changes under the Alternative 7 cumulative analysis would be less than the corresponding emissions changes under the Alternative 7 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 8 would result in 504 fewer mortalities and 55,754 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 8 compared to the No Action Alternative. In 2050, Alternative 8 would reduce health costs by $4.6 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 (except for $PM_{2.5}$ in all analysis years and SO_x in 2020, 2030, and 2050). Depending on the year, CO emissions would be reduced 0.7 to 8.7 percent, NO_x emissions would be reduced 0.6 to 8.8 percent, $PM_{2.5}$ emissions would be reduced 0.8 to 4.5 percent, SO_x emissions would be reduced 3.3 to 13.4 percent, and VOC emissions would be reduced 2.0 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 all pollutants.

4.3.3.10.2 Toxic Air Pollutants

Under Alternative 9, cumulative emissions would be less than noncumulative emissions for some combinations of pollutant and year and greater than noncumulative emissions for other combinations of pollutant and year.

Alternative 9 would reduce toxic air pollutant emissions compared to the No Action Alternative for benzene, 1,3-butadiene (in 2030 and 2050), and DPM, and would increase emissions of acetaldehyde, 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 greater than the corresponding emissions changes under the Alternative 9 noncumulative analysis for all toxic air pollutants except acrolein, benzene (in 2020 and 2030) and 1,3-butadiene (in 2020 and 2030). For acrolein, benzene (in 2020 and 2030), and 1,3-butadiene (in 2020 and

2030), the emissions changes under the Alternative 7 cumulative analysis would be less than the corresponding emissions changes under the Alternative 7 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 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 Costs

Compared to Alternative 1 (No Action), the cumulative impact of Alternative 9 would result in 504 fewer mortalities and 55,808 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 4.3.3-6 lists the corresponding reductions in health costs under Alternative 8 compared to the No Action Alternative. In 2050, Alternative 8 would reduce health costs by $4.6 billion annually, using a 3-percent discount rate and estimates from Pope *et al*. (2002). With the Laden *et al*. (2006) method, economic benefits would be 145 percent greater. Using a 7-percent discount rate, economic benefits would be 9.3 to 9.5 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 MY 2012-2016 standards together with those of reasonably foreseeable future actions, including the continuing increases in CAFE standards for MY 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 only minor modifications to reflect the slightly different scope (cumulative impacts versus the direct and indirect effects of the proposed action and alternatives).

4.4.1 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 its proposed Endangerment and Cause or Contribute Findings for GHGs under the Clean Air Act* – 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.

Global climate change refers to long-term trends in global terrestrial surface temperatures, precipitation, ice cover, sea levels, cloud cover, sea-surface temperatures and currents, and other climatic conditions. Scientific research has shown that, in the past century Earth's surface temperature and sea levels have risen, and most scientists attribute this to GHGs released by human activities, primarily the combustion of fossil fuels. Both EPA and IPCC have recently found that "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" (EPA 2009b, IPCC 2007b).

The primary GHGs – CO_2, methane (CH_4), and nitrous oxide (N_2O) – are created by both natural and human activities. 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. These accumulated gases trap heat in Earth's atmosphere, changing the climate, which then impacts resources such as ecosystems, water resources, agriculture, forests, and human health. As the world population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions and their concentrations in the atmosphere are expected to grow substantially over the next century. For a more in-depth discussion of the science of climate change, *see* Section 3.4.1.

4.4.1.1 Uncertainty within the IPCC Framework

IPCC reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This is briefly explained in the IPCC Fourth Assessment Synthesis Report and the IPCC Fourth Assessment Report Summary for Policy Makers (IPCC 2007c, IPCC 2007b). A more detailed discussion of the IPCC treatment of uncertainty can be found in the Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties (IPCC 2005). This EIS uses the IPCC uncertainty language (always noted in italics) when discussing qualitative environmental impacts on certain resources. Section 4.5.2.2 summarizes the IPCC treatment of uncertainty.

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 both the United States and the global environment. 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 3.4.1 for a discussion of this topic.

4.4.3 Methodology

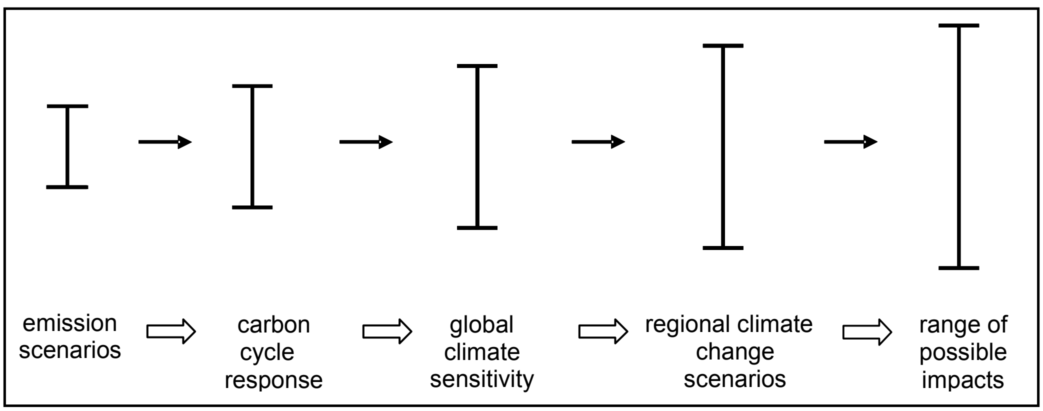
The methodology NHTSA used to characterize the effects of the proposed action and alternatives on climate has two key elements: (1) analyzing the effects of the proposed action and alternatives on GHG emissions and (2) analyzing how GHG emissions affect the climate system (climate effects).

This cumulative impacts analysis of each alternative includes the effects of the proposed CAFE standards for MY 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. 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; the sensitivity of climate to increased GHG concentrations; the rate of change in the climate system in response to changing GHG concentrations; the potential existence of thresholds in the climate system (which could be difficult to predict and simulate); 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 4.4.3-1). As shown in the figure, emissions estimates NHTSA used in this EIS are less uncertain than the global climate effects (as illustrated by the heights of the bars), which in turn are less uncertain than regional climate-change effects. The effects on climate are in turn less uncertain than the impacts of climate change on affected resources (terrestrial and coastal ecosystems, human health, and other resources, as discussed in Section 4.5).

Figure 4.4.3-1. 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

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)). The scientific understanding of the climate system is incomplete. Like any analysis of complex, long-term changes to support decisionmaking, the analysis described below involves many assumptions and uncertainties in the course of evaluating reasonably foreseeable significant adverse impacts on the human environment. This EIS uses methods and data that represent the best and most current information available on this topic, and that have been subjected to peer review and scrutiny. The information cited throughout this section that is extracted from 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 the Model for Assessment of Greenhouse Gas-Induced Climate Change (MAGICC) and the CCSP Final Report of SAP 2.1 (CCSP 2007), and Representative Concentration Pathway (RCP) emissions scenarios described below, are generally accepted in the scientific community.

The CCSP SAP 3.1 report on the strengths and limitations of climate models (CCSP 2008a) provides a thorough discussion of the methodological limitations regarding modeling. Readers interested in a detailed treatment of this topic might 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.

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 estimates include global CO_2, CH_4, and N_2O emissions resulting from direct fuel consumption and from the production and distribution of fuel ("upstream emissions"). The Volpe model also estimated the following non-GHGs, and accounted for in the climate modeling: SO_2, NO_x, CO, and VOCs.

Fuel savings from CAFE standards for MY 2012-2016 and other reasonably foreseeable actions result in lower emissions of CO_2, the primary GHG emitted as a result of refining, distribution, and use of transportation fuels.[1] 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 transportation-related CO_2 emissions is fuel combustion in internal combustion engines. NHTSA estimated reductions in CO_2 emissions resulting from fuel savings by assuming that the entire carbon content of gasoline, diesel, and other fuels is converted to CO_2 during the combustion process.[2] Specifically, NHTSA estimated 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 estimated 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 version 1.8b) model (Argonne 2002). The total reduction in CO_2 emissions from the improvement in fuel economy under each alternative CAFE standard and other reasonably foreseeable actions 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.

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.

[1] In estimating vehicular GHG emissions (*i.e.*, not including the full life-cycle emissions) for this rulemaking, NHTSA estimated CO_2, CH_4, and N_2O emissions, but not HFCs (hydrofluorocarbons). Of the total vehicular 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.)

[2] This assumption results in a slight overestimate of CO_2 emissions, because a small fraction of the carbon content of gasoline is emitted as carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimation is likely to be extremely small, and in any case, most of the carbon monoxide and unburned hydrocarbons are likely to be oxidized in the atmosphere to CO_2. This approach is consistent with the IPCC recommendation for "Tier 1" national GHG emissions inventories (IPCC 2006).

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 2007a) 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 follows:

- MAGICC has been used in the peer-reviewed literature to evaluate changes in global mean surface temperature and sea-level rise. In the IPCC Fourth Assessment Report for Working Group I (WGI) (IPCC 2007a), it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[3] 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.
- 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 NPRM between NHTSA and EPA.

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 modeling runs and sensitivity analysis are designed to use information on the alternatives, climate sensitivities, and CCSP SAP 2.1 emissions scenarios (Clarke *et al.* 2007) to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise likely to result under each alternative.

[3] For a discussion of AOGCMs, *see* Chapter 8 in IPCC (2007a).

The primary modeling runs are based on the results provided for the nine CAFE alternatives, a climate sensitivity of 3.0 °C for a doubling of CO_2 concentrations in the atmosphere, and the CCSP SAP 2.1 MiniCAM Level 3 scenario. These are referred to as the Reference Case results below, in contrast to various sensitivity runs that test high and low values for the climate sensitivity and the global emissions scenario.

The approach uses the following steps to estimate these changes:

1. NHTSA 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.
2. NHTSA assumed that global emissions for the action alternatives (Alternatives 2 through 9) 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 Aerosol Region 1 of MAGICC, which includes North America.
3. MAGICC 5.3.v2 was used 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 for a climate sensitivity of 3.0 °C.
4. The increase in global mean surface temperature was used along with factors that relate increase in global average precipitation to this increase in global mean surface temperature to estimate the increase in global averaged precipitation for each alternative for the CCSP SAP 2.1 MiniCAM Level 3 scenario.

Section 4.4.4 presents the results of the reference case modeling runs.

4.4.3.2.3 Sensitivity Analysis

The sensitivity analysis is based on the results provided for:

1. The No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 4). The sensitivity analysis was only performed for two CAFE alternatives because NHTSA deemed this sufficient to assess the effect of various climate sensitivities on the results.
2. Climate sensitivities, for a doubling of CO_2 concentrations in the atmosphere, of 2.0, 3.0, and 4.5 °C (3.6, 5.4, and 8.1 °F).[4]
3. 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). These global emissions scenarios represent various levels of implementation of global GHG emissions reduction policies.

[4] 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 (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.* 2007 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.* 2007).

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

The approach uses the following steps to estimate the sensitivity of the results to alternative estimates of the climate sensitivity and global emissions scenarios:

1. NHTSA assumed 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). These global emissions scenarios represent various levels of implementation of global GHG emissions reduction policies.
2. For each global emissions 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 under the Preferred Alternative (Alternative 4) are equal to the global emissions of each pollutant under the No Action Alternative (Alternative 1), minus emissions of each pollutant under the Preferred Alternative. All SO_2 reductions were applied to the Aerosol region 1 of MAGICC, which includes North America.
3. NHTSA assumed climate sensitivity values of 2.0, 3.0, and 4.5 °C (3.6, 5.4, and 8.1 °F), consistent with the *likely* range from the IPCC Fourth Assessment Report (IPCC 2007a).
4. 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 each global emissions scenario in Step 2, and climate sensitivity in Step 3.

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 to the IPCC *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) developed more than a decade ago.

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).

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. 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, perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These stabilization scenarios represent various levels of implementation of global GHG emissions reduction policies.

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.[5] 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 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 and 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.

United States: Regional Actions[6]

- **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, Department of Environmental Conservation, New York State 2009). 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.

[5] 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.

[6] Two of the three regional actions include Canadian provinces as participants and observers.

- **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 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 MY 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).
- **H.R. 2454: American Clean Energy and Security Act ("Waxman-Markey Bill") (Congressional Research Service 2009).** The bill, as introduced on May 15, 2009, would amend the Clean Air Act to require the EPA Administrator to promulgate regulations to (1) cap and reduce GHG emissions, annually, so that GHG emissions from capped sources would be reduced to 97 percent of 2005 levels by 2012, 83 percent by 2020, 58 percent by 2030, and 17 percent by 2050; and (2) establish a federal GHG registry. The bill designates CO_2, CH_4,

N_2O, SF_6, PFCs, and nitrogen trifluoride (NF_3) as GHGs and establishes a CO_2 equivalent value for each gas. The release of these gases would be regulated for sources including electricity sources, fuel producers and importers, industrial gas producers and importers, geological sequestration sites, industrial stationary sources, industrial fossil fuel-fired combustion devices, natural gas local distribution companies, NF_3 sources, algae-based fuels, and fugitive emissions. In addition, the bill would establish a combined efficiency and renewable electricity standard that requires utilities to supply an increasing percentage of their demand from a combination of energy efficiency savings and renewable energy (6 percent in 2012, 9.5 percent in 2014, 13 percent in 2016, 16.5 percent in 2018, and 20 percent in 2021 through 2039). The bill has passed in the House of Representatives, and at this writing is under consideration in the Senate.

- **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 2009e), 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).

International Actions

- **United Nation's Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol, and upcoming Conference of the Parties (COP)-15 in Copenhagen, Denmark.** UNFCCC is an international treaty signed by many countries around the world (including the United States[7]), 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). It was recognized in December of 2007 at the COP-13 meeting in Bali, Indonesia, that the upcoming December 2009 COP-15 meeting in Copenhagen represents more or less the last chance to achieve an agreement under the UNFCCC, if this agreement is to be approved and ratified in time for it to come into force immediately after the Kyoto Protocol expires in 2012 (United Nations Climate Change Conference 2008).
- **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

[7] 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).

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 (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).

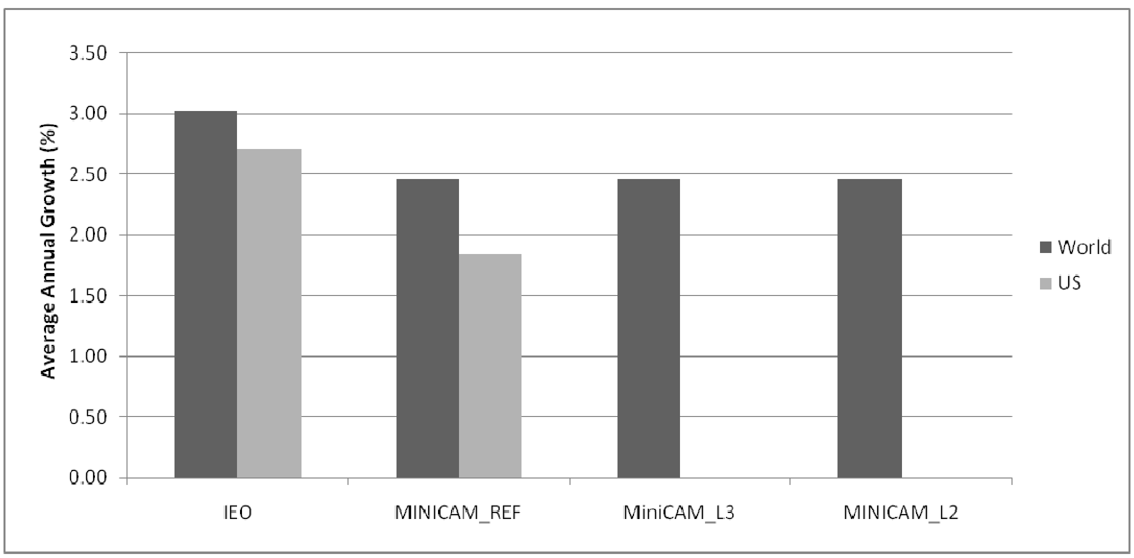
The SAP 2.1 MiniCAM Level 3 scenario provides a global context for emissions of a full suite of GHGs and ozone precursors for a Reference Case harmonious with implementation of the above policies and initiatives. There are some inconsistencies between the overall assumptions used by CCSP in SAP 2.1 (Clarke *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 1,660million metric tons of CO_2 ($MMTCO_2$); emissions in 2020 under the Preferred Alternative (Alternative 4) are 1,550 $MMTCO_2$ (*see* Table 4.4.4-2). The difference of 110 $MMTCO_2$ 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 110 $MMTCO_2$ less than this reference level, or 33,950 $MMTCO_2$ 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 AEO 2009 (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 4.4.3-2 through 4.4.3-6 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 scenarios.[8,9] The IEO forecast is for a reference case, while the SAP 2.1 forecasts are for a reference case and two climate policy cases.

Figure 4.4.3-2. 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

[8] 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.

[9] 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. All IEO energy-use estimates were converted to exajoules.

Figure 4.4.3-3. Global Annual CO_2 Emissions from Fossil Fuel Use

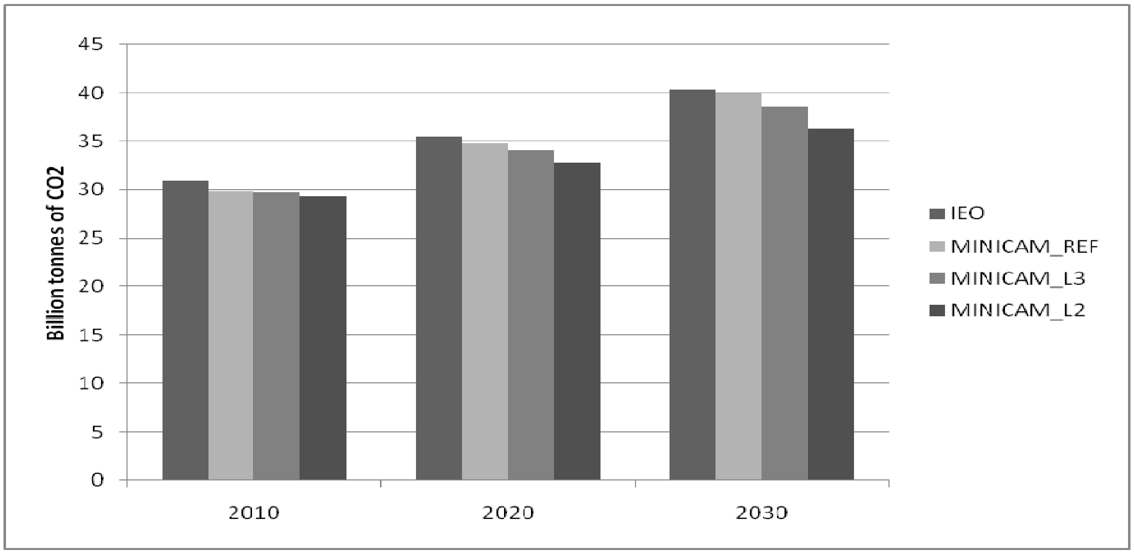


Figure 4.4.3-4. U.S. Annual CO_2 Emissions from Fossil Fuel Use

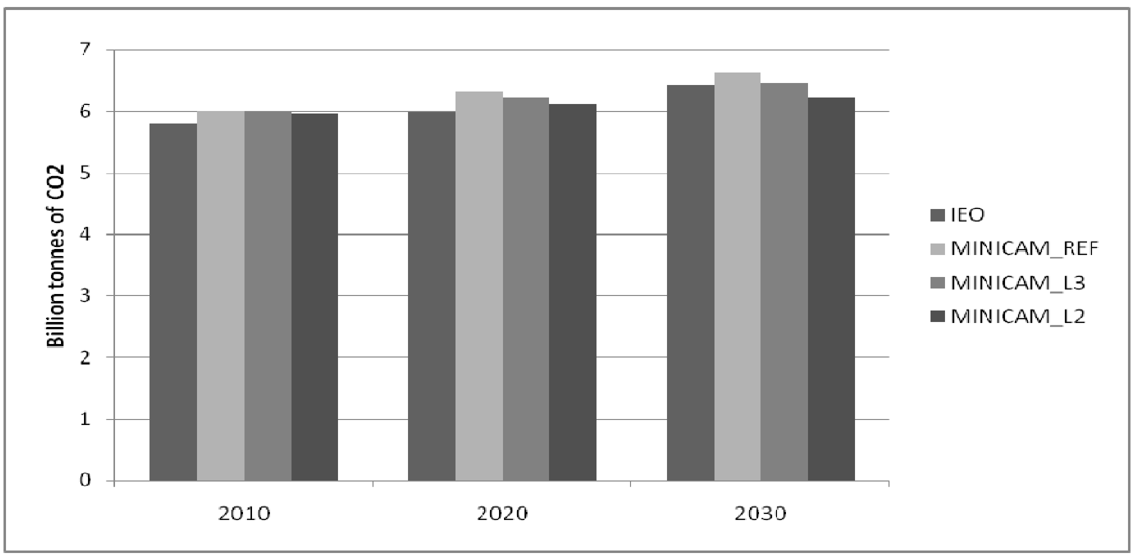


Figure 4.4.3-5. World Primary Energy Use Forecast

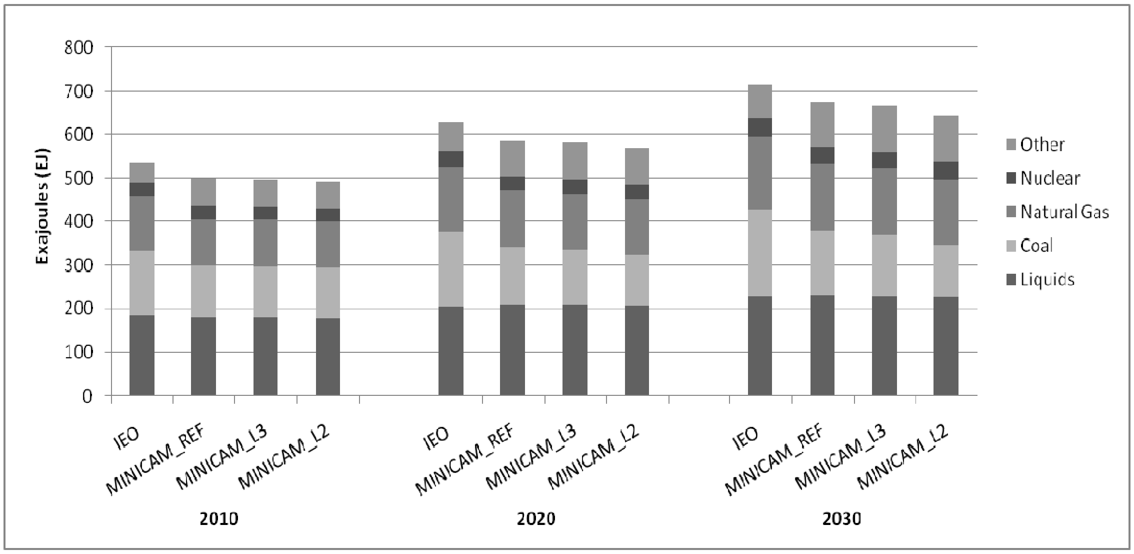
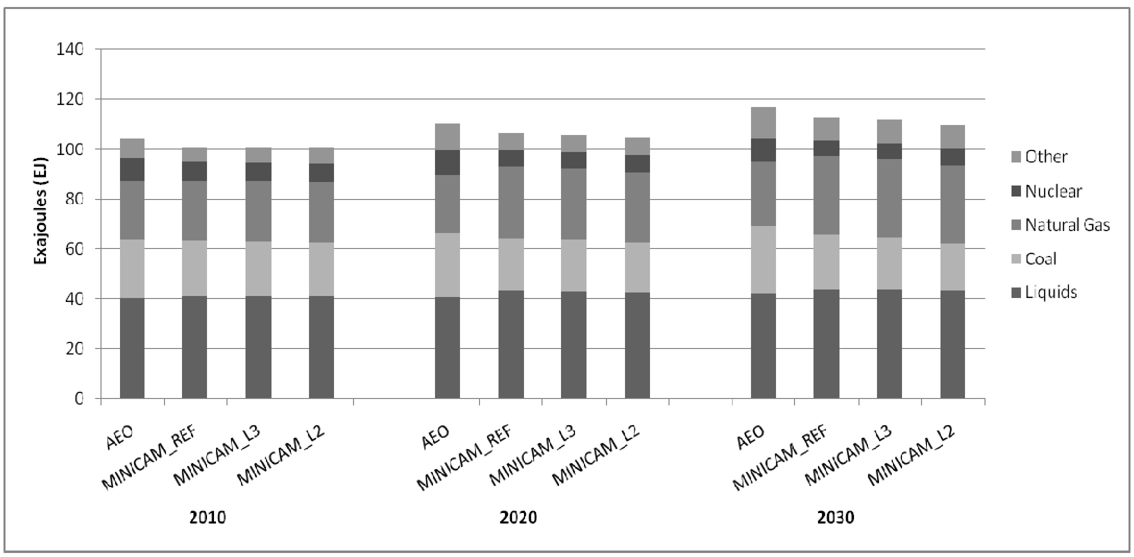


Figure 4.4.3-6. U.S. Primary Energy Use Forecast



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 4.4.3-2).

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 4.4.3-5. 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 that result in higher CO_2 emissions, as shown in Figure 4.4.3-3. 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 2009 (EIA 2009a)[10] projection shows an increase in total primary energy use in the United States, but much of the increase is from the use of coal. On the other hand, the SAP MiniCAM scenarios have a higher share of natural gas (Figure 4.4.3-6). However, the AEO reference scenario has a larger share of other fuels[11] than the SAP MiniCAM scenarios, resulting in lower CO_2 emissions (Figure 4.4.3-4).

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.

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

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,[12] 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" (National Research Council 2002 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 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.* 2007), and CCSP SAP 3.4: *Abrupt Climate*

[10] AEO 2009 revised estimates were used for U.S. primary energy consumption and form the basis for the IEO 2009 forecast.
[11] For the AEO reference scenario, "other" includes biomass, hydropower, and other renewable fuels.
[12] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

Change (CCSP 2008c) – 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 survey of the current state of climate science on tipping points and abrupt climate change and provides a summary of existing credible scientific evidence.

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 global climate change consequences.

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.[13]

NHTSA considers the following measures of the cumulative impact of alternative CAFE standards for MY 2012-2016 *and* other reasonably foreseeable actions affecting CO_2 emissions:

- CO_2 emissions from MY 2012-2016 passenger cars and light trucks, which are directly affected by the new CAFE standards;
- CO_2 emissions from MY 2017-2030 passenger cars and light trucks, assuming annual average percentage gains in mpg consistent with the AEO 2009 updated Reference Case projections, with all action alternatives exceeding the combined EISA target of 35 mpg in 2020 (*see* Section 4.1.3);
- CO_2 emissions from MY 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,[14] and older vehicles leave the fleet; and

[13] Although this section includes only a discussion of CO_2 emissions, 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.
[14] 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.

- CO_2 emissions from MY 2061-2100 passenger cars and light trucks, for which emissions are held constant.[15]

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 MY 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 the 2012 to 2100 period due to the MY 2012-2016 CAFE standards and other reasonably foreseeable future actions ranged from 27,300 to 39,100 $MMTCO_2$. Compared to cumulative global emissions of 3,919,462 $MMTCO_2$ over this period (projected by the 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 0.7 to 1.0 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

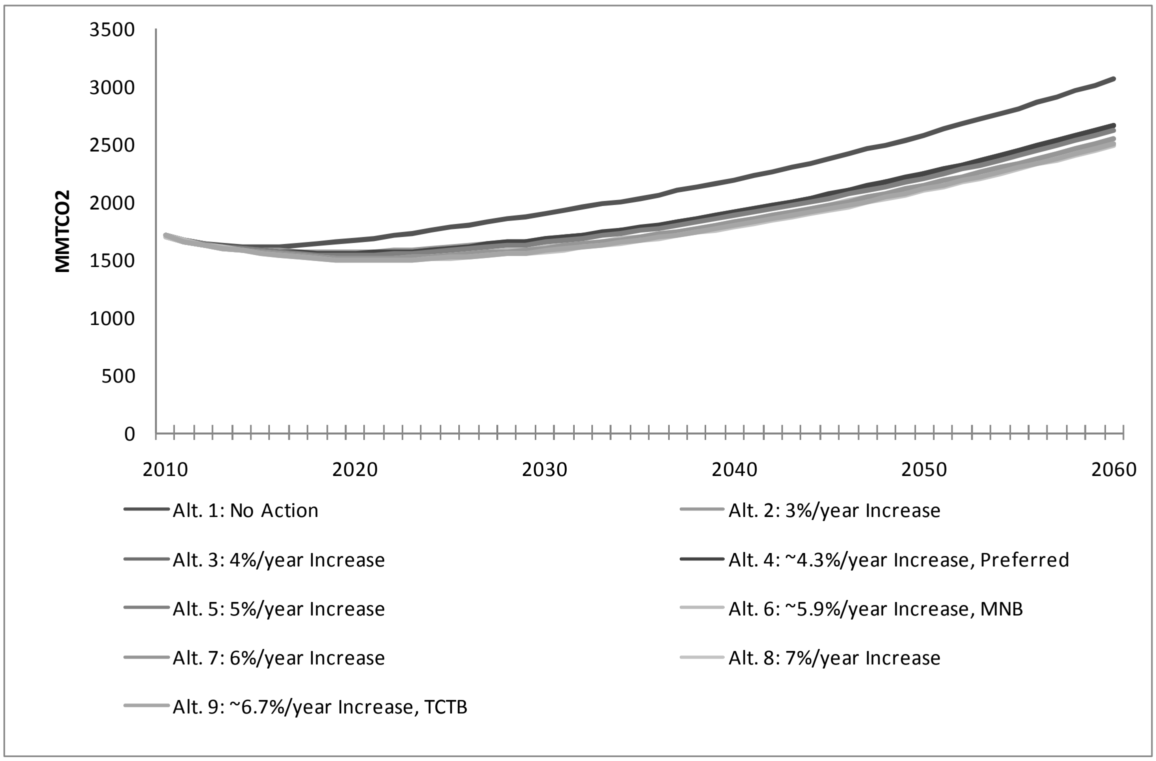
Alternative	Emissions	Emissions Reductions Compared to No Action Alternative
1 No Action	227,600	0
2 3%/year Increase	200,300	27,300
3 4%/year Increase	200,200	27,300
4 ~4.3%/year Increase, Preferred	200,300	27,300
5 5%/year Increase	196,700	30,900
6 ~5.9%/year Increase, MNB	191,600	36,000
7 6%/year Increase	191,800	35,800
8 7%/year Increase	188,500	39,100
9 ~6.7%/year Increase, TCTB	188,790	38,791

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

[15] 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.

designed to reduce CO_2 emissions. As mentioned earlier, U.S. passenger cars and light trucks currently account for approximately 21.7 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 11.2 to 16.0 percent, 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 5.1 to 7.2 percent in 2100. Figure 4.4.4-1 shows projected annual emissions from passenger cars and light trucks under MY 2012-2016 standards and other reasonably foreseeable future actions.

Figure 4.4.4-1. Cumulative Annual Emissions Under the MY 2012-2016 Standards and Other Reasonably Foreseeable Future Actions ($MMTCO_2$)



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 MY 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.

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 ~5.9%/year Increase MNB	Alt. 7 6%/year Increase	Alt. 8 7%/year Increase	Alt. 9 ~6.7%/year Increase TCTB
Carbon dioxide (CO_2)									
2010	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
2020	1,660	1,570	1,550	1,550	1,530	1,500	1,510	1,500	1,500
2030	1,900	1,680	1,670	1,670	1,640	1,600	1,600	1,580	1,580
2040	2,190	1,900	1,900	1,910	1,870	1,820	1,820	1,790	1,790
2050	2,580	2,240	2,240	2,250	2,200	2,140	2,140	2,100	2,110
2060	3,060	2,660	2,660	2,670	2,610	2,540	2,540	2,500	2,500
Methane (CH_4)									
2010	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2020	1.93	1.84	1.81	1.81	1.79	1.76	1.76	1.75	1.74
2030	2.22	1.97	1.96	1.96	1.92	1.87	1.87	1.84	1.84
2040	2.56	2.24	2.24	2.24	2.19	2.13	2.13	2.09	2.09
2050	3.01	2.63	2.63	2.63	2.58	2.50	2.50	2.46	2.46
2060	3.58	3.12	3.13	3.13	3.06	2.97	2.97	2.92	2.92
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	0.03	0.03	0.03
2030	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
2040	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2050	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04
2060	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05

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 shown in Figure 4.4.4-1, despite increases in fuel economy, total fuel consumption by U.S. passenger cars and light trucks is projected to increase over most of the period shown in the table under each of the action alternatives. 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 3.7 percent of total global emissions of CO_2 in 2005 (EPA 2009a, WRI 2009).[16] 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.

In its updated *AEO* 2009, EIA projects U.S. transportation-derived CO_2 emissions will increase from 1,905 $MMTCO_2$ in 2010 to 2,045 $MMTCO_2$ in 2030, with cumulative emissions from transportation over this period reaching 41,093 $MMTCO_2$ (EIA 2009a). Over this same period, the cumulative emissions reductions from this rulemaking and other reasonably foreseeable actions are projected to be 1,950 to 3,260 $MMTCO_2$ compared to emissions projected under the No Action Alternative, which would yield a 5- to 8-percent reduction in CO_2 emissions from the transportation sector. The emissions reductions as a result of increasing fuel economy of new passenger cars and light trucks would be expected to increase further as new vehicles, meeting the higher CAFE standards that each action alternative would establish, enter the fleet and older vehicles are retired. For example, in 2030, projected emissions reductions would be 220to 320 $MMTCO_2$ depending on the alternative, a 11- to 16-percent decrease from projected U.S. transportation emissions of 2,045 $MMTCO_2$ in 2030 (*i.e.*, under the No Action Alternative).

As another measure of the relative environmental impact of this rulemaking, these emissions reductions can 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 2007a).[17] If this goal is achieved, emissions levels in 2020 would be 33-percent less than the future baseline (the No Action Alternative), and 15-percent lower than those at the beginning of the WCI action (WCI 2007b). By comparison, this rulemaking is expected to reduce CO_2 emissions by 310 to 680 $MMTCO_2$ over the same period, with emissions levels in 2020 representing a 5- to 10-percent reduction from the future baseline emissions for passenger cars and light trucks.

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).[18] This represents a 23-percent reduction from the

[16] Includes land-use change and forestry, and excludes international bunker fuels.
[17] Since this goal was stated, Montana, Quebec, and Ontario joined the WCI. Thus, the total emissions reduction is likely to be more than 350 $MMTCO_2$. A revised estimate was not available as of July 14, 2009.
[18] 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.

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 this rulemaking will reduce CO_2 emissions by 810 to 1,530 $MMTCO_2$ over this period, with emissions levels in 2024 representing an 8- to 13-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 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)). In 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.

4.4.4.2 Cumulative Effects on Climate Change

The approach to estimating the cumulative effects of climate change from the MY 2012-2016 CAFE standards combined with other reasonably foreseeable future actions mirrors that used to estimate the direct and indirect effects of the MY 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, MY 2017-2020 CAFE standards are reasonably foreseeable and must be accounted for when analyzing the cumulative impacts of the MY 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 and Alternative 3), 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 2009 updated 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 MY 2012-2016 CAFE standards have a small impact on climate change. The emissions reductions and resulting climate impacts for the MY 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.[19] 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.

Table 4.4.4-3

Comparison of MAGICC Results and Reported IPCC Results (IPCC 2007a)

	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	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.

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.

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.[20] 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).

[19] NHTSA used the default climate sensitivity in MAGICC of 3.0 °C (5.4 °F)

[20] 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.

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 654.0 ppm under the TCTB Alternative (Alternative 9) to 657.5 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 above 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 2.60 to 2.61 °C (4.68 to 4.70 °F) as of 2100.[21] 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.

Table 4.4.4-5 summarizes the regional changes to warming and seasonal temperatures from the IPCC Fourth Assessment Report. 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.

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, which means they cannot be specified separately in the model.[22] The radiative forcing of black carbon is difficult to quantify accurately because it is a function of microphysical properties, the geographic and vertical placement, and lifetime of the aerosol. However, black carbon clearly contributes substantially to global warming (Jacobson 2001). Total global black carbon emissions are estimated to be approximately 8 teragrams (10^{12} grams) of carbon per year (Bond *et al.* 2004 in Forster *et al.* 2007), with estimates of fossil fuel contributions ranging from 2.8 teragrams of carbon per year (Ito and Penner 2005 in Forster *et al.* 2007) to 8.0 teragrams of carbon per year (Haywood and Boucher 2000 in Forster *et al.* 2007). In summary, climate modeling does account for the effects of black carbon on climate variables.

[21] 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.
[22] 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 PM mass that is then incorporated into the Volpe model. This PM is based on tailpipe emissions and therefore includes carbon emissions from the combustion process. Because the carbon emissions are lumped into the PM and not treated independently, the Volpe model does not provide direct results of the impact of the carbon emissions.

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	657.5	0.805	1.327	2.611	7.83	13.67	32.84
2 3%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
3 4%/year Increase	438.5	497.3	655.1	0.805	1.323	2.600	7.83	13.65	32.75
4 ~4.3%/year Increase, Preferred	438.5	497.3	655.1	0.804	1.323	2.600	7.83	13.65	32.75
5 5%/year Increase	438.4	497.2	654.7	0.804	1.323	2.599	7.83	13.65	32.73
6 ~5.9%/year Increase, MNB	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
7 6%/year Increase	438.4	497.0	654.3	0.804	1.322	2.596	7.83	13.64	32.71
8 7%/year Increase	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70
9 ~6.7%/year Increase, TCTB	438.4	496.9	654.0	0.804	1.321	2.595	7.83	13.64	32.70
Reductions Under Alternative CAFE Standards									
2 3%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
3 4%/year Increase	0.2	0.7	2.4	0.001	0.003	0.011	0.00	0.02	0.09
4 ~4.3%/year Increase, Preferred	0.2	0.7	2.4	0.001	0.004	0.011	0.00	0.02	0.09
5 5%/year Increase	0.3	0.8	2.8	0.001	0.004	0.012	0.00	0.02	0.11
6 ~5.9%/year Increase, MNB	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
7 6%/year Increase	0.3	1.0	3.2	0.001	0.005	0.015	0.00	0.03	0.13
8 7%/year Increase	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14
9 ~6.7%/year Increase, TCTB	0.3	1.1	3.5	0.002	0.005	0.016	0.00	0.03	0.14

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

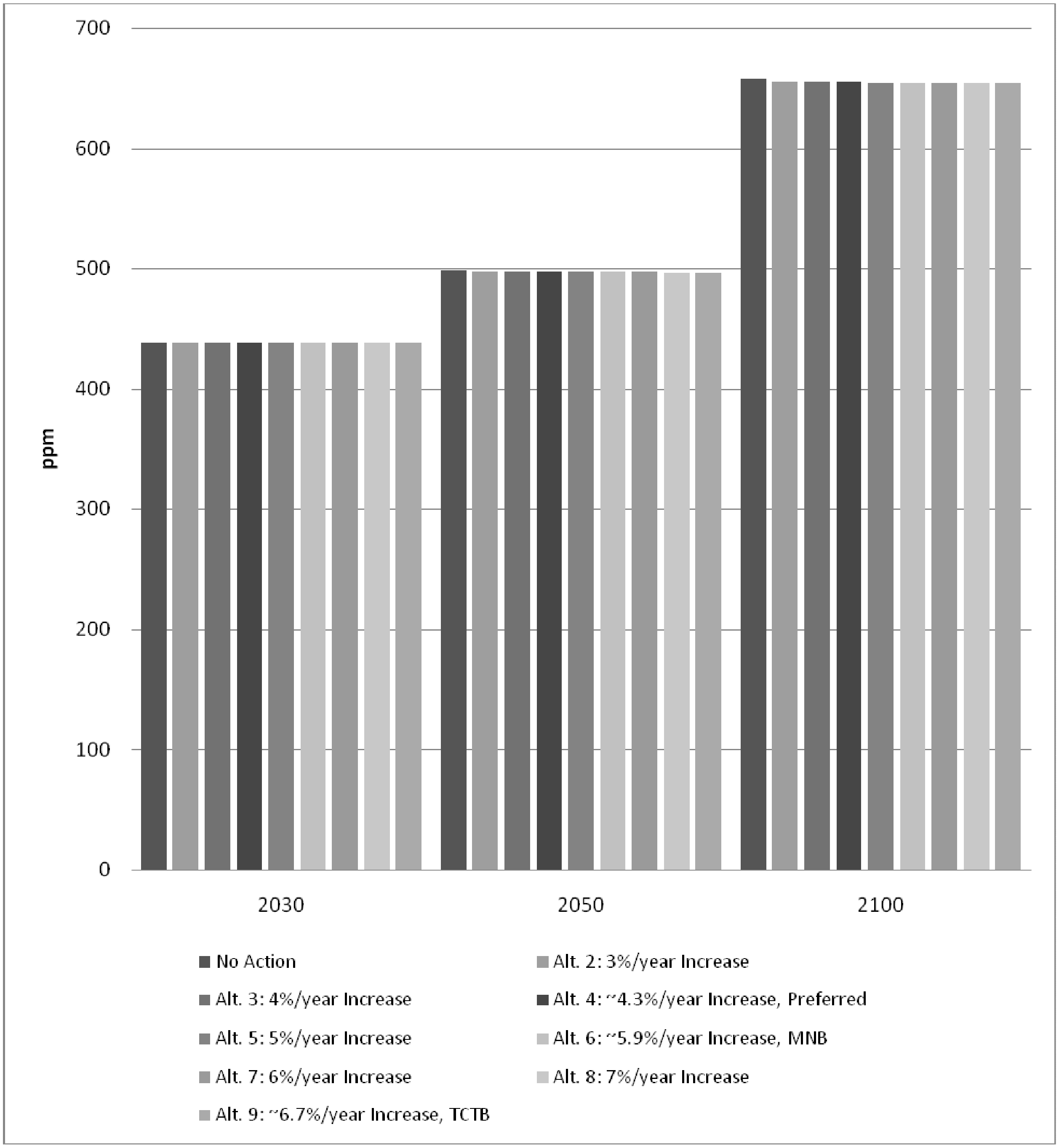


Figure 4.4.4-3. Cumulative Effects on Global Mean Surface Temperature Increase

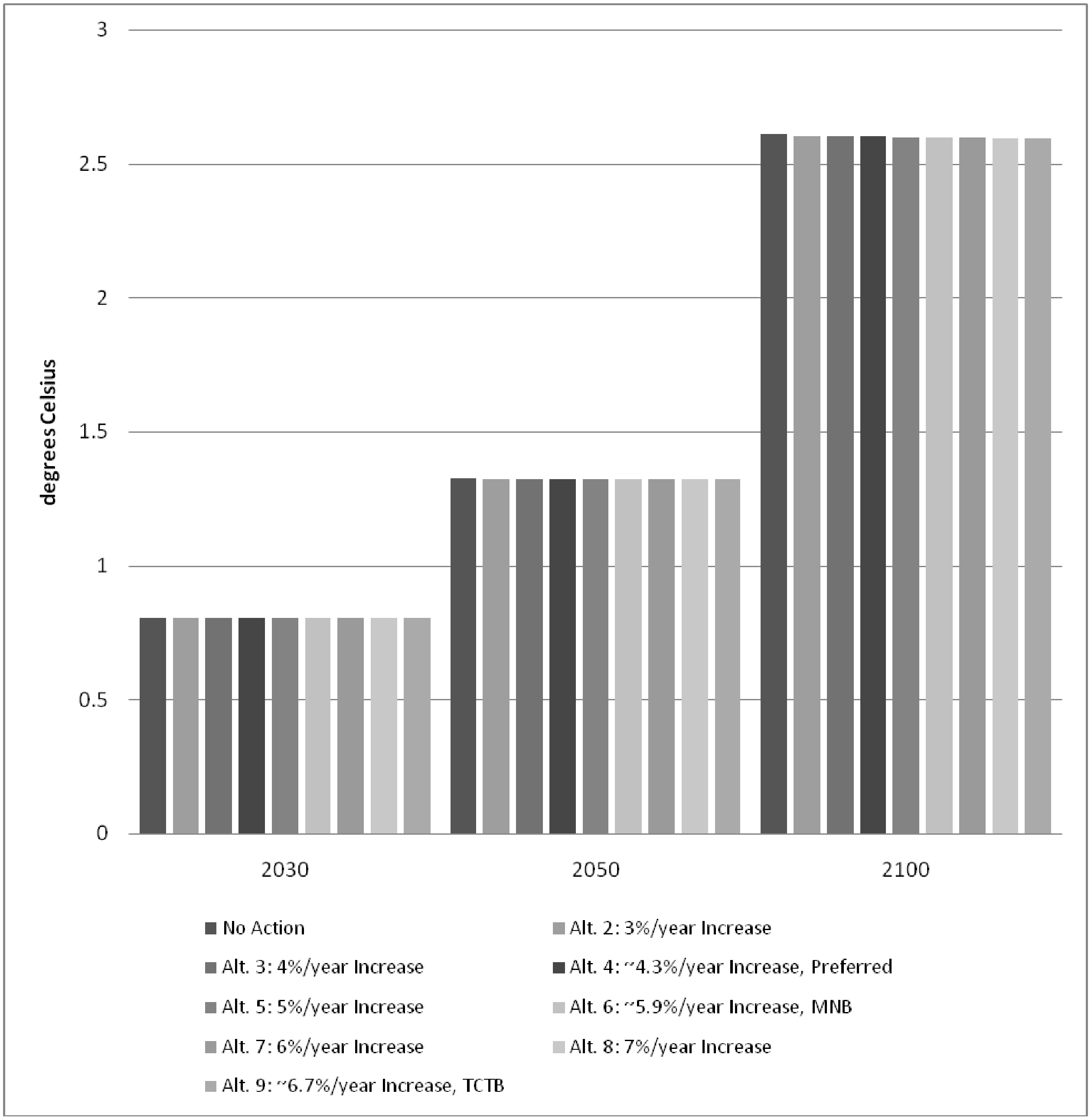


Figure 4.4.4-4. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

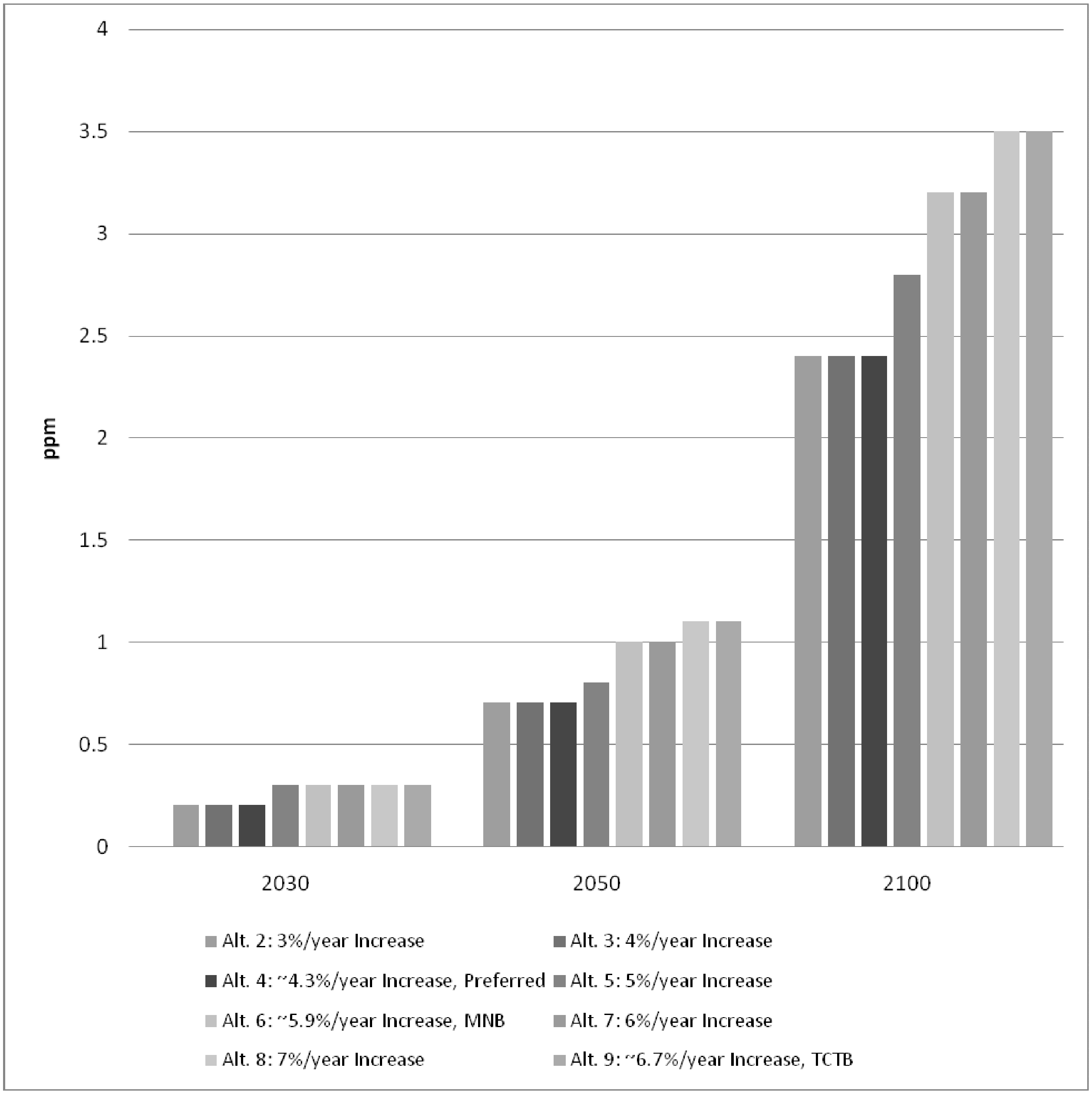


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Figure 4.4.4-5. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)

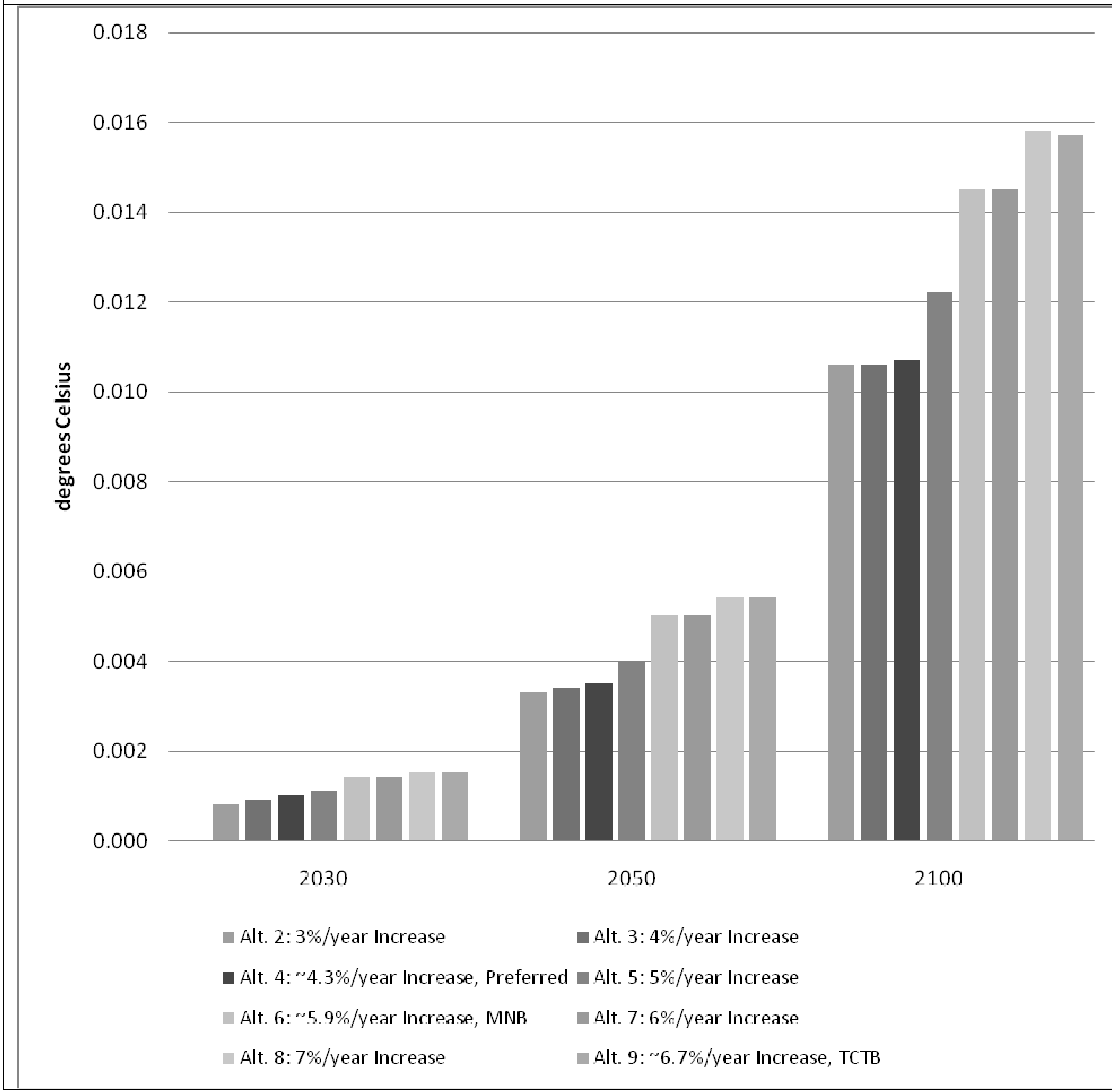


Table 4.4.4-5

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	
	Southern and Central Europe		Maximum Summer Temperatures *likely* to increase more than average
	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 of longer duration, 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 *likely* to be largest in winter Minimum winter temperatures *likely* to increase more than the average
	Southwest		Warming *likely* to be largest in summer Maximum summer temperatures *likely* to increase more than the average
	Northeast USA		
	Southern Canada		
	Canada		
	Northernmost part of Canada		
Central and South America	Southern South America	*Likely* to be similar to the global mean	
	Central America	*Likely* to be larger than global mean	
	Southern Andes		
	Tierra del Fuego		
	Southeastern South America		
	Northern South America		

Table 4.4.4-5 (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
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 a decrease in the frequency of cold extremes *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 largest in winter and smallest in summer
	Antarctic	*Likely* to warm	
Small Islands		*Likely* to be smaller than the global annual mean	

4.4.4.2.3 Precipitation

In some areas, higher temperatures can increase precipitation. Increases in precipitation are a result of higher temperatures causing more 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.* 2007), 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 CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). In this case, the IPCC (Meehl *et al.* 2007) summary of precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in precipitation in proportion to their 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.* 2007) is given as the scaled change in precipitation (as a percentage change from 1980 through 1999 averages) divided by the increase in global mean surface warming for the same period (per °C), as shown in Table 4.4.4-6. IPCC provided scaling factors in the year ranges 2011 through 2030, 2046 through 2065, 2080 through 2099, and 2180 through 2199. NHTSA used the scaling factors for the A1B (medium) scenario in this EIS analysis because MAGICC does not directly estimate changes in global mean precipitation.

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 4.4.4-7 (again, based on the A1B [medium] scenario).

Table 4.4.4-6

Global Mean Precipitation Change (scaled, % per °C) (Meehl *et al.* 2007) a/

Scenario	2011-2030	2046-2065	2080-2099	2180-2199
A2	1.38	1.33	1.45	NA
A1B	1.45	1.51	1.63	1.68
B1	1.62	1.65	1.88	1.89

a/ These years do not correspond exactly to the years for which results are being reported.

Table 4.4.4-7

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	2.406
3 4%/year Increase	0.586	1.462	2.406
4 ~4.3%/year Increase, Preferred	0.586	1.462	2.406
5 5%/year Increase	0.586	1.461	2.405
6 ~5.9%/year Increase, MNB	0.586	1.460	2.403
7 6%/year Increase	0.586	1.460	2.403
8 7%/year Increase	0.586	1.459	2.401
9 ~6.7%/year Increase, TCTB	0.586	1.459	2.402
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	0.009
3 4%/year Increase	0.000	0.004	0.009
4 ~4.3%/year Increase, Preferred	0.000	0.004	0.009
5 5%/year Increase	0.000	0.005	0.011
6 ~5.9%/year Increase, MNB	0.000	0.006	0.013
7 6%/year Increase	0.000	0.006	0.013
8 7%/year Increase	0.000	0.006	0.014
9 ~6.7%/year Increase, TCTB	0.000	0.006	0.014
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 ~5.9%/year Increase, MNB	0.85%	2.20%	3.92%
7 6%/year Increase	0.85%	2.20%	3.92%
8 7%/year Increase	0.85%	2.20%	3.91%
9 ~6.7%/year Increase, TCTB	0.85%	2.20%	3.91%

Table 4.4.4-7 (cont'd)

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
Reduction in Global Mean Precipitation Change for Alternative CAFE Standards (% Compared to No Action Alternative)			
2 3%/year Increase	0.00%	0.01%	0.01%
3 4%/year Increase	0.00%	0.01%	0.01%
4 ~4.3%/year Increase, Preferred	0.00%	0.01%	0.02%
5 5%/year Increase	0.00%	0.01%	0.02%
6 ~5.9%/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%	0.02%
9 ~6.7%/year Increase, TCTB	0.00%	0.01%	0.02%

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.

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation, as described in Meehl *et al.* (2007, page 750):

> 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.

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.

Table 4.4.4-8 summarizes the regional changes to precipitation from the IPCC Fourth Assessment Report. 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.[23]

[23] *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).

Table 4.4.4-8

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (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	Annual mean precipitation *likely* to increase	
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 *very likely* to decrease	
Asia	Central Asia	Precipitation in summer *likely* to decrease	
	Tibetan Plateau	Precipitation in boreal winter *very likely* to increase	
	Northern Asia	Precipitation in boreal winter *very likely* to increase Precipitation in summer *likely* to increase	
	Eastern Asia	Precipitation in boreal winter *likely* to increase Precipitation in summer *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme precipitation and winds associated with tropical cyclones *likely* to increase	
	South Asia	Precipitation in summer *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme precipitation and winds associated with tropical cyclones *likely* to increase	
	Southeast Asia	Precipitation in boreal winter *likely* to increase in southern parts Precipitation in summer *likely* to increase in most parts of southeast Asia Extreme precipitation and winds associated with tropical cyclones *likely* to increase	

Table 4.4.4-8 (cont'd)

Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (Christensen *et al*. 2007)

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
North America	Northern regions/Northern North America		Snow season length and snow depth *very likely* to decrease
	Southwest	Annual mean precipitation is *likely* to decrease	
	Northeast USA	Annual mean precipitation *very likely* to increase	
	Southern Canada		
	Canada	Annual mean precipitation *very likely* to increase	
	Northernmost part of Canada		Snow season length and snow depth *likely* to increase
Central and South America	Southern South America		
	Central America	Annual precipitation *likely* to decrease	
	Southern Andes	Annual precipitation *likely* to decrease	
	Tierra del Fuego	Winter precipitation *likely* to increase	
	Southeastern South America	Summer precipitation *likely* to increase	
	Northern South America	Uncertain how precipitation will change	
Australia and New Zealand	Southern Australia	Precipitation *likely* to decrease in winter and spring	
	Southwestern Australia	Precipitation *very likely* to decrease in winter	
	Rest of Australia		
	New Zealand, South Island	Precipitation *likely* to increase in the west	
	Rest of New Zealand		
Polar Regions	Arctic	Annual precipitation *very likely* to increase; *Very likely* that the relative precipitation increase will be largest in winter and smallest in summer	
	Antarctic	Precipitation *likely* to increase	
Small Islands		Mixed, depending on the region	

4.4.4.2.4 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) and 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).

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). This projection does not include all changes in ice-sheet flow or the potential for rapid acceleration in ice loss (Alley *et al.* 2005, Gregory and Huybrechts 2006, and Hansen 2005, all in Pew 2007). 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 by 2100 for strong warming scenarios cannot be ruled out." Section 4.5.5.1 discusses sea-level rise in more detail.

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 32.70 centimeters (12.87 inches) under the TCTB Alternative (Alternative 9), for a maximum reduction of 0.14 centimeter (0.06 inch) by 2100 under the No Action Alternative.

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.[24] 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.

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 4.4.4-9 presents the results from the sensitivity analysis.

[24] 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 4.4.4-9

Cumulative Effects on CO_2 concentration, Temperature, 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	483.0	551.3	0.612	0.986	1.546	22.32
		3.0	435.7	486.5	563.5	0.812	1.324	2.177	29.92
		4.5	437.4	490.5	578.8	1.034	1.705	2.948	38.76
	Reduction compared to No Action								
		2.0	0.2	0.8	2.2	0.001	0.003	0.009	0.08
		3.0	0.3	0.8	2.4	0.001	0.004	0.012	0.11
		4.5	0.2	0.8	2.5	0.001	0.004	0.015	0.12
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	493.8	641.0	0.606	0.987	1.880	24.60
		3.0	438.5	497.3	655.1	0.804	1.323	2.600	32.75
		4.5	440.1	501.3	672.6	1.023	1.702	3.461	42.12
	Reduction compared to No Action								
		2.0	0.3	0.7	2.4	0.001	0.003	0.008	0.08
		3.0	0.2	0.7	2.4	0.001	0.004	0.011	0.09
		4.5	0.2	0.7	2.6	0.001	0.004	0.014	0.12
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	510.0	762.6	0.699	1.166	2.285	28.61
		3.0	441.5	514.1	780.4	0.922	1.553	3.126	37.91
		4.5	443.3	518.8	802.6	1.166	1.987	4.120	48.55
	Reduction compared to No Action								
		2.0	0.3	0.7	2.5	0.001	0.003	0.007	0.07
		3.0	0.3	0.7	2.6	0.001	0.003	0.010	0.09
		4.5	0.3	0.8	2.7	0.001	0.004	0.012	0.12

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.

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 4.4.4-9, 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 2.2 to 2.7 ppm. The Reference Case using the MiniCAM Level 3 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of 2.4 ppm.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, as shown in Table 4.4.4-9. 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 consistently 0.001 °C (0.002 °F) for 2.0 °C (3.6 °F) climate sensitivity to the 4.5 °C (8.1 °F) climate sensitivity across each of the global emissions scenarios, as shown 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 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 4.4.4-9. 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.

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 – a few ppm of CO_2, a hundredth 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.[1]

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 its proposed Endangerment and Cause or Contribute Findings for GHGs under 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. GHG emissions from other sources (such as power plants, natural gas use, and agricultural production)

[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).

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.

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

4.5.3 Freshwater Resources

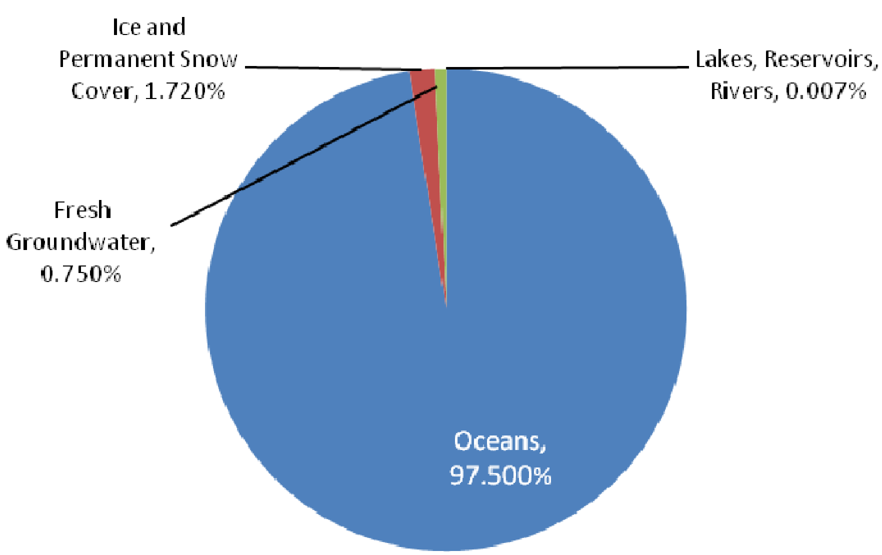
In 2008, IPCC concluded that "Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems" (Bates *et al.* 2008). In 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.* 2008a). 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 55m (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 20th 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). 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.* 2008a) 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). Glaciers throughout the Arctic are melting, with a particularly rapid retreat of Alaska's glaciers, representing about half of the loss of glacial mass worldwide (ACIA 2004).

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.* (2006). 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, DFID 2004);
- Overloading the capacity of water and wastewater treatment plants during extreme rainfall (Environment Canada 2001); 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).

<u>Precipitation</u>

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 Mexico (D’Antonio 2006), New Jersey (EPA 1997), and the West (Saunders *et al.* 2008). “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 2006b 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 2008b 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 *et al*. 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).

Restoration of beneficial uses (to address habitat loss, eutrophication, beach closures) under the Great Lakes Water Quality Agreement will likely be vulnerable to declines in water levels, warmer water temperatures, and more intense precipitation (Mortsch *et al.* 2003). 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).
- Restoration of beneficial uses (to address habitat loss, eutrophication, beach closures) under the Great Lakes Water Quality Agreement will *likely* be vulnerable to declines in water levels, warmer water temperatures, and more intense precipitation (Mortsch *et al.* 2003).
- 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 in Kundzewicz et al 2007, 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.* (2006).

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, DFID 2004);

- Overloading the capacity of water and wastewater treatment plants during extreme rainfall (Environment Canada 2001); 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.

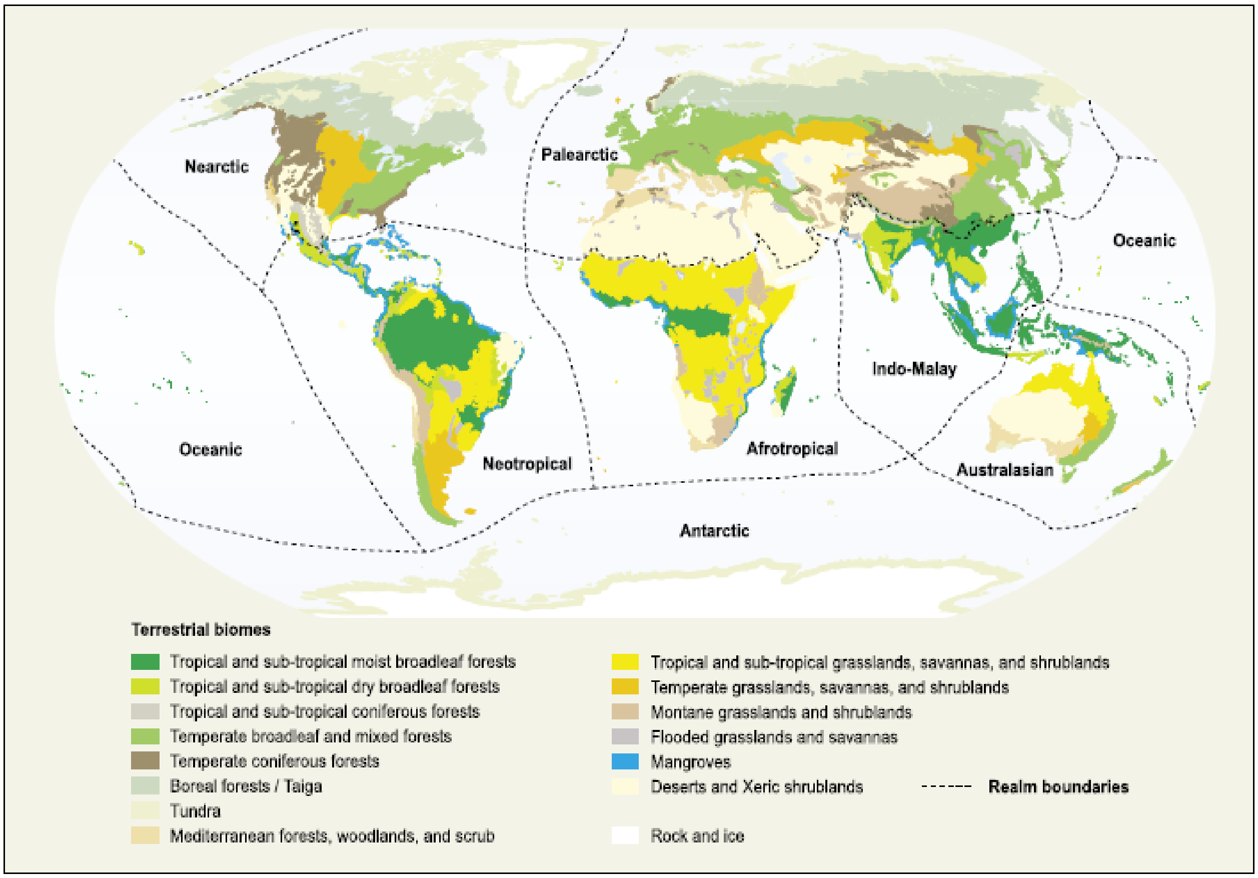
Ecosystems addressed in this section include (EPA 2009b, EPA 2001)terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra; aquatic communities, such as rivers, lakes, and ponds; and freshwater wetlands, such as marshes, swamps, and bogs.

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.

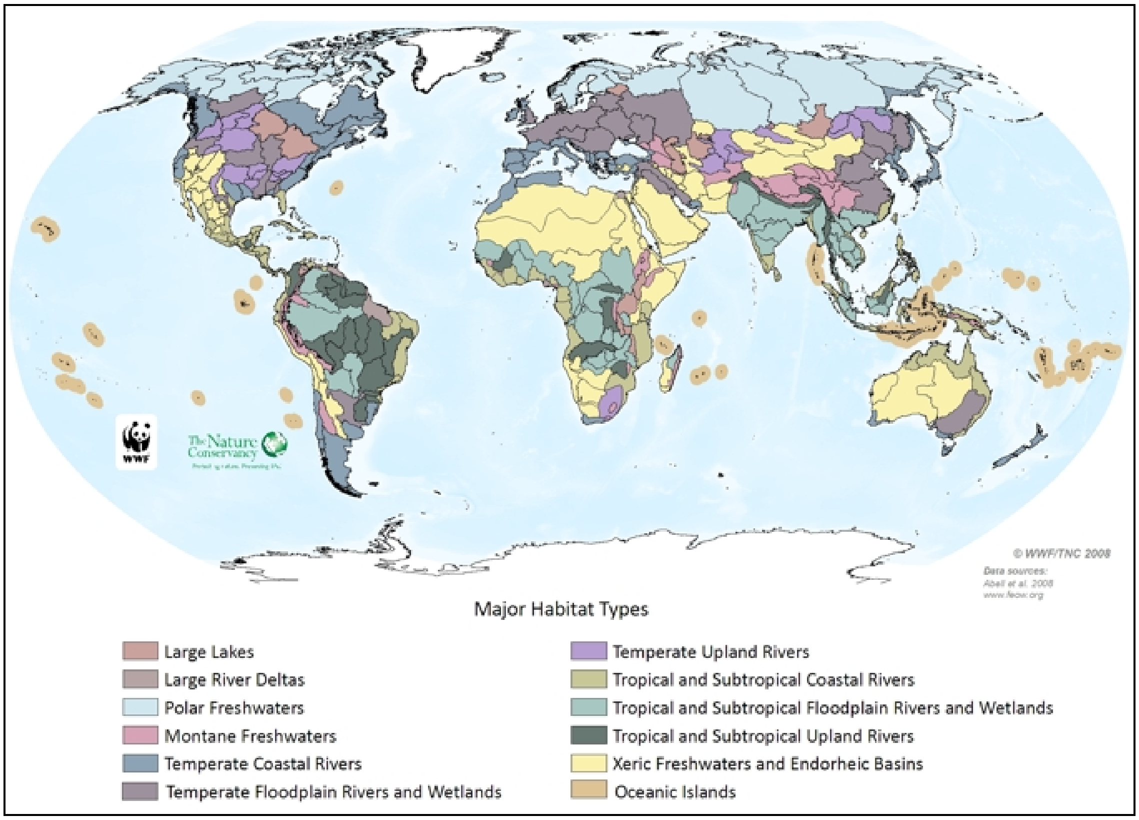
- *Mangroves* occur in the waterlogged, salty soils of sheltered tropical and subtropical shores, where they stretch from the intertidal zone to the high tide mark. Associated with these tree species is a whole host of aquatic and salt-tolerant plants. Mangroves provide important nursery habitats for 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.

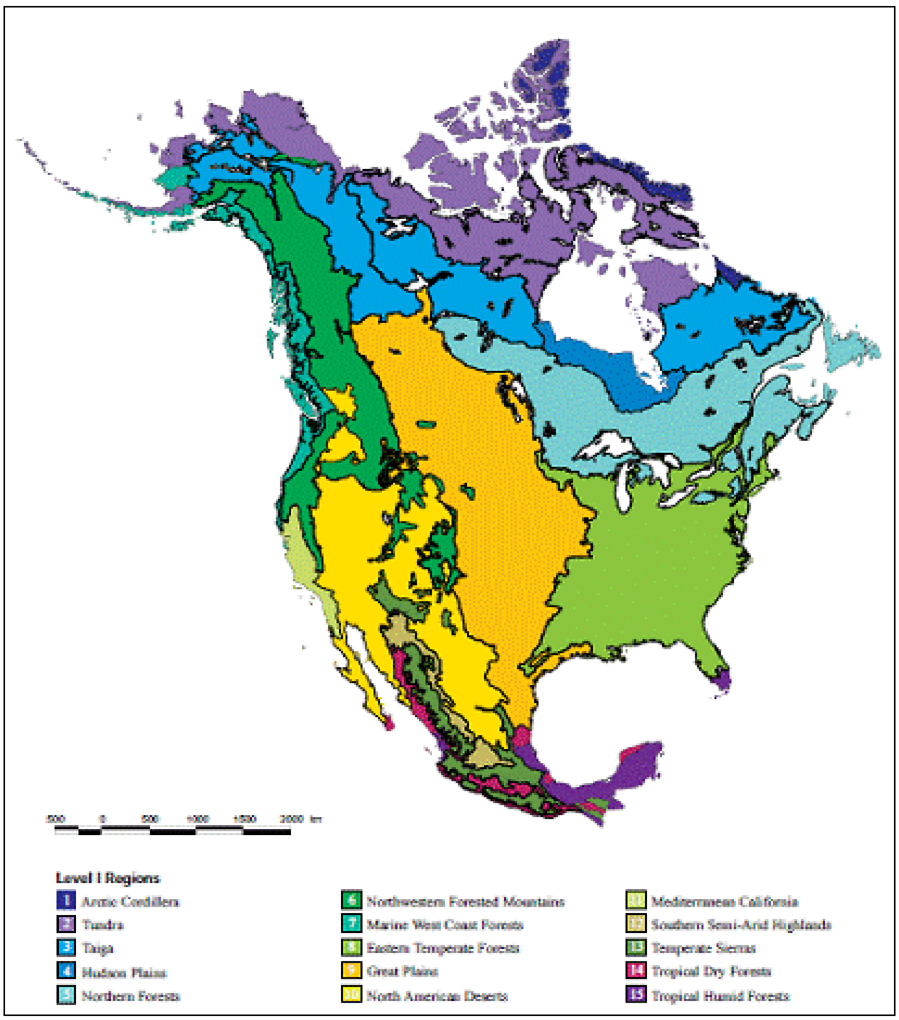
  - *Riparian forested wetlands (swamps)* are linear systems formed along rivers and lakes. They are typically saturated during the winter while plants are dormant and evapotranspiration is low. During the summer, they are usually dry, except during periods of flooding. The pH and nutrient load of riparian 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 *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 (EPA 2009b, 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 6.5 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).
- Several frog species now initiate breeding calls 10 to 13 days earlier than a century ago (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, and Parmesan and

Galbraith 2004). Forty percent of the populations below 2,400 feet elevation are now extinct (GCRP *et al*. 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.* 2006 as cited in CCSP 2008b).
- 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 *et al*. 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 *et al*. 2009).
- In the past decade, the percentage of Rocky Mountain wildflower buds that are exposed to frost has doubled, hindering their reproductive ability (GCRP *et al*. 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 and ACIA 2005b, both 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 *et al*. 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 is expected to experience a rise in sea level that is 0.3 to 0.51 meter (1.0 to 1.6 feet) 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). As the climate warms and sea ice melts, the polar bear loses much of its natural habitat. If current trends in sea-ice loss continue, the polar bear could become extirpated from most of its range within 100 years (IUCN 2008). Two thirds of polar bears could be gone from Alaska by the middle of this century (GCRP *et al*. 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*. 2006). In the southwestern United States, high temperatures, drought, and the piñon ips bark beetle have had the cumulative effect of causing a mass die-back of piñon trees. From 2002 to 2003 alone, piñon mortality in Mesa Verde National Park in Colorado and Bandelier National Monument in New Mexico exceeded 90 percent. Researchers determined that climate factors drove the die-off (Saunders *et al.* 2008). 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).

Stefan *et al*. (2001) in Kling *et al.* 2003 simulated the effects of a doubling of CO_2 on U.S. lakes and projected that suitable habitat for coldwater and cool water fishes would decline by 45 and 30 percent, respectively. 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). In the desert Southwest and the southern Great Plains, where rivers drain to the east and west, fish species will have no opportunity for northward migration, and it is expected that many native fish species in these regions could become extinct with only a few degrees of warming (Poff *et al*. 2002). 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. Species vulnerable to declines include arctic char, broad whitefish, and Arctic cisco, which are important components of the diets of indigenous peoples (ACIA 2004).

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).
- CO_2 levels are projected to be much higher than any in the past 650,000 years, and temperatures are projected to be as high as any in the past 740,000 years. Both increases are very likely to impact ecosystems (*very likely*) (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 (EPA 2009b, GCRP *et al*. 2009).
- Thirty-five percent of known bird species (3,438 of 9,856) are potentially susceptible to climate change, as are 52 percent of global amphibian species. Seventy to 80 percent of birds that are already considered threatened are also climate-change susceptible (IUCN 2008).
- 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. Coldwater fishes, aquatic invertebrates, and waterfowl are among the species groups expected to move north as the climate warms (Poff *et al*. 2002; 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.

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.* 2004), 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.* 2004). Coastal zones have also been found to support a much higher percentage of the world's threatened and endangered species.

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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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.

a/ EPA (2006)

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.* 2004). 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 through the effects of higher sea levels, warmer seawater, altered ocean circulation patterns, increased and extreme storm events, and increased carbon dioxide concentrations (UNESCO and WWAP 2006, Burke *et al.* 2001).

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 East 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.* 2004). 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).

A number of marine wildlife species have been or could be adversely affected by environmental changes in temperature, availability of water and nutrients, runoff from land, wind patterns, and storminess that are associated with climate change (Kennedy *et al.* 2002). Burke *et al.* (2001) found the following trends in 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.

Marshes and mangroves are particularly susceptible to sea-level rise affecting the feeding or nesting grounds of black rail, clapper rail, some terns, and plovers (Kennedy *et al.* 2002). Over the short term, however, shrimp, menhaden, dabbling ducks, and some shorebirds would benefit from the release of nutrients from the breakup of marshes (Kennedy *et al.* 2002).

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) 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 2006), 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 the beginning of the 20th Century 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 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 2009). 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 (EPA 2009b).

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). 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 2006). Santa Cruz is 20 feet above sea level and has levees built to contain the 100-year flood. If sea levels were to increase above 12 inches as projected for the medium warming range of temperatures, a flood associated with a storm surge event at the 100-year level might happen once every 10 years (California Energy Commission 2006a). 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). Some societal effects include (*see* Section 4.5.7 for more information on societal effects):

- Infrastructure such as bulkheads, dams, and levees could be damaged by flooding and strong storms (Nicholls *et al.* 2007a in National Science and Technology Council 2008).
- Coastal ports, roads, railways, and airports are at risk of disruption due to power outages, flooded routes, and poor travel conditions (Nicholls *et al.* 2007a in National Science and Technology Council 2008).
- Industries that rely on coastal stability, such as travel and recreation, fishing and hunting, and trade, are expected to become increasingly sensitive to these temperature and precipitation changes in the coming decades (Nicholls *et al.* 2007a in National Science and Technology Council 2008).
- The most at-risk state in the United States is expected to be Alaska because the indigenous communities depend on wildlife for hunting and fishing practices, reside within floodplains, and currently face water shortages (Field *et al.* 2007b 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. With a 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 2005a). 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).

<u>Sea-level Rise</u>

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 (2007) and EPA (2009b) state that sea level *will likely* rise 0.19 to 0.58 meter (0.6 to 1.9 feet) by 2100. 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 melt sea ice and create more open water, wind and waves thereby increasing shoreline erosion. 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 (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 2008c). 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 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). 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 as cited in CCSP 2008b).

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 2006).

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 2008c). 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 2008c). 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 2008c). 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 2008c). 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.* 2006 as cited in CCSP 2008b).

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 2008c). 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 2008c).

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 (2009) 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). 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).

In the western United States, particularly in Colorado, a recent measurable decline in aspen trees has been linked to global warming. Unlike earlier episodes of aspen tree dieback, the current decline is occurring more rapidly and over larger areas. The dieback is caused by bark beetles that were not known to have existed in the area (Saunders *et al.* 2008). In effect, "the hotter, drier conditions recently present in Colorado's mountains have enabled these unexpected agents to so quickly kill so many aspen" (Saunders *et al.* 2008). The forest disturbances such as insect outbreaks "are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons" (Field *et al.* 2007c in Saunders *et al.* 2008). 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. 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 2008c). 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).

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 in California, are expected to decrease in yield or quality based on moderate climate-change scenarios (EPA 2009b). 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 2008c). 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 2008c). 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 2008c). The mortality rate continued to increase even though growth at the forest tree line had been increasing previously (Swetnam and Betancourt 1998 in CCSP 2008c). Forest productivity has decreased from climate change-induced warming in drought-prone regions (McKenzie *et al.* 2001 in CCSP 2008c) and in subalpine regions (Monson *et al.* 2005, Sacks *et al.* 2007, both in CCSP 2008c). 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).

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 2008c). 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 2008c). 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 2008c).

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).

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 2008c).

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). In Alaska, the spawning and migration behaviors of commercially fished species could be affected and increasing temperatures might cause an increase in the cooling needs for storage and processing of catch (CIER 2007).

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.* 2006). 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.* 2006). On the other hand, during droughts, certain fungi, such as *Aspergillus flavus*, are stimulated and will feed on drought-weakened crops (Epstein *et al.* 2006).

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.* 2006). 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.* 2006). Overall, the "effects of future drought and decreased soil moisture on agriculture and natural vegetation (such as forests) are uncertain and may, at least in part, be temporarily offset by fertilization effects of higher atmospheric concentrations of CO_2" (Triggs *et al.* 2004 in CIER 2007). These extreme weather events, 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 2008c).

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 2008c). Specifically, regional climate change could most affect species such as tuna and Peruvian anchovy (Barber 2001, Lehodey *et al.* 2003a, both in CCSP 2008c).

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 21st 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. Because the developing countries and poorer populations tend to have weaker infrastructure in place to begin with, their vulnerability to climate-change impacts is expected to be higher and their capacity to cope or adapt are expected to be lower than developed countries and 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 high frequency of hurricanes, its loss of natural protection (*e.g.*, barrier islands and wetlands), and the fact 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 respiratory and cardiovascular problems (Patz and Baldus 2001 in National Research Council 2002a).
- Changes in mortality rates caused by temperature extremes (Rozenzweig and Solecki 2001 in CCSP 2008d).
- 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).

As a specific example regarding urban infrastructure, the New York City Department of Environmental Protection assessed potential climate-change impacts on the City's drainage and wastewater collection systems, noting that if rainfall becomes more intense, sewer-system capacities could be exceeded, leading to street and basement flooding (NY City DEP 2008). Additionally, extreme precipitation events could lead to an inundation of the Water Pollution Control Plants' influent wells. Sea-level rise could threaten hydraulic capacity of Water Pollution Control Plants' outfalls by making peak flow discharges more difficult and increase the salinity of influent to the Water Pollution Control Plant, which would upset biological treatment processes and lead to corrosion of equipment (NY City DEP 2008).

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. After Hurricane Katrina struck, a total of 90,000 square miles was declared a federal disaster area, 80 percent of New Orleans was flooded, more than 1,700 lives were lost, 850,791 housing units were damaged, and 2,100 oil platforms and more than 15,000 miles of pipeline were damaged (Petterson *et al.* 2006 in CIER 2007).

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). Land-use choices, specifically the discouragement of housing development in flood-prone areas, including areas below sea level and in deep flow plains, can help protect human settlements and preserve management flexibility for these areas (Isenberg *et al.* 2008). 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. If increasing trends of adverse weather events continue, claims made to private and public insurers are expected to climb (NAST 2001 in CIER 2007). Overall risk exposure of insurers' has grown considerably (*e.g.*, the National Flood Insurance Program's exposure increased four-fold since 1980 to $1 trillion in 2005 and the Federal Crop Insurance Corporation's exposure grew up to $44 billion) (U.S. GAO 2007 in CIER 2007). In the United States, of the $19 trillion in insured commercial and residential properties, 41 percent are in coastal communities. 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. This could have a particular effect on the Midwest, which is a heavy domestic freight and shipping route area. Approximately "$3.4 billion and 60,000 jobs rely on the movement of goods within the Great Lakes-St. Lawrence shipping route annually" (Easterling and Karl 2001 in CIER 2007). 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). In fact, "system connectivity is predicted to be come 25 percent impaired causing a loss of $850 million annually" (Easterling and Karl 2001 in CIER 2007). Dredging 7.5 to 12.5 million cubic yards, which would cost $85 to $142 million, might be the only alternative to salvage this system if water levels decline substantially (Great Lakes Regional Assessment Group 2000 in CIER 2007).

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. According to a recent study by UNESCO, "The adverse impacts of climate change will have consequences for humanity as a whole including the products of human creativity...these consequences will be manifest in at least two principal ways: (1) the direct physical effects on the buildings or structures and (2) the effects on social structures and habitats" (Colette *et al.* 2007).

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).

In discussing the impacts of climate change on historic cities and settlements around the world, Colette *et al.* 2007 lists the following potential threats associated with climate change:

- Increased salt mobilization with resulting damage to surfaces and decoration as a result of increasing rate of heavy rainfall.
- Changes in the amplitude of temperature and humidity can cause splitting, cracking, flaking and other damage to exposed surfaces.
- Organic building materials such as wood could be subject to increase infestation as a result of migration of pests.
- An increase in flooding can directly damage structures and promote growth of damaging micro-organisms such as molds and fungi.
- In arid regions, desertification, salt weathering and erosion could threaten cultural and historic sites.

Climate change could also create pressures that result in migration of populations, which in turn could result in the breakdown of communities and the loss of "rituals and cultural memory" (Colette *et al.* 2007).

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 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 the United Kingdom and Norway can cope with most kinds of gradual climate change, but localized differences can show considerable variability in stresses and capacities to adapt (Environment Canada 1997, Kates and Wilbanks 2003 in National Science and Technology Council 2008, London Climate Change Partnership 2004, 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 0.93 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 developing 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, developing 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 industrialized 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.* 2006), due in part to disproportionate warming at night (Easterling *et al.*1997 in Epstein *et al.* 2006). Heat waves can trigger poor air quality and forest fires, leading to further increases in human mortality and morbidity (Bates *et al.* 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.* 2006). 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 2009a).

The urban heat island effect could increase temperatures experienced in cities by 2 to 10 ºF compared to neighboring rural and suburban areas (EPA 2005 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 2005, 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[2] 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

[2] 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). Globally, if 40 percent of the increase in number of weather-related disasters from 1980 to present is attributed to climate change and a "4 percent proportion of the total seriously affected by environmental degradation based on negative health outcomes," it can be estimated that 325 million people are seriously affected annually by climate change (GHF 2009).

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.* 2006), 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.* 2006). 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.[3] 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 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*

[3] 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.

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 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).

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.* 2006). 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.* 2006). 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.* 2006).

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.* 2006); toxins associated with red tide directly affect the nervous system (Epstein *et al.* 2006).

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.* 2006). Changes in seasonal duration and increases in weather variability reduce or eliminate these constraints (Epstein *et al.* 2006). 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.* 2006). 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.* 2006). 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 (EPA 2009b). 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, Thomson *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.* 2006).

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.* 2004, 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.* 2004, 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.* 2006).

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,[4] 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" (National Research Council 2002b 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).

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.[5] 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

[4] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.
[5] For example, climate-related thresholds for ecosystems are discussed in CCSP SAP 4.2.

- 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 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[6] 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).

[6] 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/.

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 changes cannot be predicted with confidence" because of the insufficiencies of current climate models, which reflect the limits of current understanding.[7] However, the CCSP report does reiterate the conclusions of the Committee on Abrupt Climate Change (National Research Council 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.[8] These reasons for concern include the risks of large-scale discontinuities (also referred to as singularities or tipping points).[9] 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

[7] *See* CCSP 2008d.
[8] The "reasons for concern" were originally introduced and discussed in the IPCC Third Assessment Report.
[9] 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.

time scales,"[10] 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."

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*[11] (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 (National Research Council 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;

[10] 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.

[11] 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)

- 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 [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,[12] 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.

[12] 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.

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.

In a study utilizing model simulations and paleoclimatic data,[13] 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

[13] 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.

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).

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 "dramatic" release of CH_4 to the atmosphere from clathrate hydrates[14] 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).

[14] 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).[15] 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).[16]

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[17]). Lenton *et al.* (2008) determined that several other systems (loss of Arctic sea ice, Indian summer monsoon disruption,

[15] 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.

[16] 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.).

[17] *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. 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.[1]

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

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[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).

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. 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 2009a, 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.

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, Black 2008); 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.[1]

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, Raven *et al.* 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 (Raven *et al*. 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). 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 (Raven et al., 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 (Caldeira and Wickett 2005). 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 of CO_2, the greatest pH decline in relation to the global average will occur in polar and subpolar regions.

[1] *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).

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). 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, Raven *et al*. 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). 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. 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, CO_2 levels were artificially elevated in a forest for the purpose of studying the effect of atmospheric CO_2 on soil communities. An *indirect* impact of the increased CO_2 was that distinct changes in the composition of soil microbe communities occurred as a result of increased plant detritus (BNL 2007, Science Daily 2007). In another 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. Upon reaching a certain level of CO_2 in the atmosphere, carbon sinks in soils could become net carbon emitters (Heath *et al.* 2005, Black 2008). 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) implicitly 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 into the selected alternative. 40 CFR § 1505.2(c).

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 (MY) 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 MY 2012-2016 and for MY 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 MY 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) would result in a decrease in energy consumption, carbon dioxide (CO_2) emissions, and associated climate-change effects.

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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 MY 2017 and beyond in a future rulemaking, this NEPA analysis makes assumptions about the MY 2017-2030 standards based on the MY 2012-2016 standards, the EISA requirements, and the Annual Energy Outlook 2009 assumptions regarding projected vehicle fuel economy increases.

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 demonstrate declines compared to the No Action Alternative (Alternative 1). Health costs and impacts are estimated to be reduced under all alternatives.

Nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$), sulfur oxides (SO_x), volatile organic compounds (VOCs), acetaldehyde, benzene, diesel particulate matter (DPM), and formaldehyde 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), acrolein, and 1,3-butadiene 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, the increases are approximately 1.5 percent or less for CO and 0.02 percent for 1,3-butadiene, compared to those under the No Action Alternative (Alternative 1).

5.2 MITIGATION MEASURES

As noted above, NEPA does not obligate an agency to adopt a mitigation plan. Rather, NEPA merely 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 the proposed CAFE standards in conjunction with these actions would mitigate the environmental impacts and provide even greater environmental benefits.

Generally emissions from criteria pollutants and MSATs are anticipated to decline, although emissions of CO, acrolein, and 1,3-butadiene could increase under certain alternatives and analysis years, compared to the No Action Alternative (Alternative 1). NHTSA notes that the analysis for acrolein emissions is incomplete because upstream emissions factors are not available. Upstream emissions decrease due to fuel savings and reduced emissions from fuel refining and transportation. If upstream emissions of acrolein were included in the analysis, total acrolein emissions would show smaller increases or might decrease. Thus, the acrolein emissions reported in this EIS represent an upper bound.

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 choices regarding which technologies to use have 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, acrolein, and 1,3-butadiene (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 call attention to 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. The programs are also indicative of the types of programs that might be available in the future at all government levels for even further mitigation.

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). 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

[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).

climate change. Specifically, DOT has a Secretarial goal to lower the number of vehicle miles travelled (VMT). In support of this goal, Secretary 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). The livability principles are an extension of ongoing national awareness and interest in Smart Growth. 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.[7]

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.

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).

[7] *See* http://www.epa.gov/smartgrowth/index.htm (last accessed Jul. 27, 2009).

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7.4.8 Unavoidable Impacts and Irreversible and Irretrievable Resource References

No citations appear in Section 4.8.

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Chapter 8 Distribution List

The Council on Environmental Quality (CEQ) regulation 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, 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 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 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. Department. of State, Bureau of Oceans and International Environmental and Scientific Affairs
- 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
- Vermont Attorney General, Environmental Division
- Georgia Environmental Protection Division
- Massachusetts Attorney General's Office
- 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
- 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 Janet Napolitano, 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 Ruth Ann Minner, 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 Kathleen Sebelius, Governor of Kansas
- The Honorable Steve 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 Jon S. Corzine, 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 Jon Huntsman, Jr., Governor of Utah
- The Honorable Jim Douglas, Governor of Vermont
- The Honorable Timothy M. Kaine, 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
- 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
- Nissan North America, Inc.
- Northeast States for Coordinated Air Use Management
- Presbyterian Church (USA)
- Public Citizen
- Sierra Club
- Sierra Club Global Warming and Energy Program
- Sierra Club Legislative Office
- Stratacomm on behalf of Aluminum Association Auto & Light Truck Group
- The American Council for an Energy-Efficient Economy (ACEEE)
- The Consumer Alliance
- The Episcopal Church
- 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