Medium- and Heavy-Duty Fuel Efficiency Improvement Program

Draft Environmental Impact Statement

October 2010

NHTSA

www.nhtsa.gov

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Administrator

1200 New Jersey Avenue, SE
Washington, DC 20590

October 25, 2010

In Reply Refer To:
Draft Environmental Impact Statement for
New Medium- and Heavy-Duty Fuel
Efficiency Improvement Program
Docket No. NHTSA-2010-0079

To Interested Parties:

I am pleased to enclose a copy of the National Highway Traffic Safety Administration's (NHTSA) Draft Environmental Impact Statement (DEIS), which analyzes the potential environmental impacts of the agency's newly proposed Fuel Efficiency Improvement Program for commercial medium- and heavy-duty on-highway vehicles and work trucks ("HD vehicles").

Concurrent with this DEIS, NHTSA and the U.S. Environmental Protection Agency (EPA) are announcing a joint proposed rulemaking that would reduce greenhouse gas (GHG) emissions from and increase the fuel efficiency of HD vehicles. NHTSA is proposing fuel consumption standards under the Energy Independence and Security Act of 2007 (EISA), and EPA is proposing GHG emissions standards under the Clean Air Act. These proposed standards would be tailored to each of three regulatory categories of HD vehicles: Combination Tractors; Pick-up Trucks and Vans; and Vocational Trucks, as well as gasoline and diesel HD vehicle engines. EPA's proposed GHG emissions standards would begin with model year (MY) 2014. NHTSA's proposed fuel consumption standards would be optional in MYs 2014 and 2015, becoming mandatory beginning in MY 2016 for most regulatory categories. The joint proposed rulemaking is consistent with President Obama's May 21, 2010 directive to improve the fuel efficiency of and reduce GHG pollution from HD vehicles through coordinated Federal standards.

NHTSA prepared the enclosed DEIS, which analyzes the environmental impacts of the proposed fuel consumption standards for MYs 2014-2018. EPA and the Federal Motor Carrier Safety Administration (FMCSA) served as cooperating agencies in the preparation of this DEIS. EPA has special expertise in the areas of climate change and air quality and FMCSA has special expertise in HD vehicles.

The DEIS compares the environmental impacts of the proposed standards and reasonable alternatives, including a "No Action" Alternative, pursuant to the National Environmental Policy Act (NEPA), 42 U.S.C. §§ 4321-4347, and implementing regulations issued by the Council on Environmental Quality and the U.S. Department of Transportation. The DEIS considers the direct, indirect, and cumulative impacts of the proposed standards and reasonable alternatives and describes these impacts to inform decisionmakers and the public of the environmental impacts of the various alternatives.

Among other potential impacts, NHTSA has analyzed 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. In developing the proposed standards and possible alternatives, NHTSA was guided by EISA, which requires that the HD Fuel Efficiency Improvement Program established by NHTSA be "designed to achieve the maximum feasible improvement," and that the various required aspects of the program be "appropriate, cost-effective, and technologically feasible" for HD vehicles. 49 U.S.C. § 32902(k)(2). NHTSA also considered relevant environmental and safety considerations. NHTSA estimates that the proposed fuel consumption standards would result in an annual fuel savings of 8.94 billion gallons by 2050.

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

Invitation to Comment

I invite you or your organization to submit written comments on this DEIS. In accordance with required NEPA procedures, EPA will publish a Notice of Availability of this DEIS in the Federal Register. The public comment period will end on January 3, 2011.

To ensure consideration, it is important that NHTSA receives your comments on or before the closing date. All comments and 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-2010-0079.**

- **Mail your comments so that they will be received in Washington, DC on or before the comment closing date of January 3, 2011.**

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 on or before the comment closing date of January 3, 2011.**

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

After the comments are reviewed, any significant new issues are investigated, and appropriate modifications are made to the DEIS, NHTSA will issue a Final EIS. The Final EIS will address timely comments received on the DEIS. Notices in the Federal Register will announce the availability of NHTSA's FEIS for the proposed fuel consumption standards for HD vehicles. NHTSA also plans to continue to post information about its environmental review on its fuel economy website (http://www.nhtsa.gov/fuel-economy).

This DEIS is available for public viewing on the fuel economy website at http://www.nhtsa.gov/fuel-economy and also in the public docket at http://www.regulations.gov (Docket No. NHTSA-2010-0079). Copies of the DEIS have been mailed to parties on NHTSA's HD Fuel Efficiency Improvement Program 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 DEIS or provided comments during scoping. The DEIS is also available for public inspection at:

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

Additional information about the project is available by contacting Angel Jackson with NHTSA's Fuel Economy Division, Office of International Policy, Fuel Economy and Consumer Programs, at 202-366-0154, or by visiting the NHTSA fuel economy website identified above. For assistance, please contact NHTSA toll free at 1-888-327-4236 (for TTY, contact 1-800-424-9153). The NHTSA fuel economy website also provides access to the texts of formal NHTSA documents, such as orders, notices, and rulemakings.

Sincerely yours,

David L. Strickland

Enclosure

DRAFT ENVIRONMENTAL IMPACT STATEMENT

MEDIUM- AND HEAVY-DUTY FUEL EFFICIENCY IMPROVEMENT PROGRAM

OCTOBER 2010

LEAD AGENCY:
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

COOPERATING AGENCIES:
U.S. ENVIRONMENTAL PROTECTION AGENCY
FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

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+/−	plus or minus
°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
4wd	four-wheel drive
ABT	averaging, banking, and trading
AEO	Annual Energy Outlook
AER	Annual Energy Review
AMO	Atlantic Multidecadal Oscillation
AMOC	Atlantic Meridional Overturning Circulation
AOGCM	atmospheric-ocean general circulation model
APU	auxiliary power unit
BACT	Best Available Control Technology
bhp-hr	brake-horsepower-hour
BTU	British thermal unit
CAA	Clean Air Act
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAFE	Corporate Average Fuel Economy
CBD	Center for Biological Diversity
CCSP	U.S. Climate Change Science Program
CDC	Centers for Disease Control and Prevention
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CMAQ	Congestion Mitigation and Air Quality Improvement
CMV	commercial motor vehicle
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of the Parties
CSI	Cambridge Systematics, Inc.
CT DEP	Connecticut Department of Environmental Protection
CT DOT	Connecticut Department of Transportation
DEIS	Draft Environmental Impact Statement
DHHS	U.S. Department of Health and Human Services
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPM	diesel particulate matter
E10	gasoline blend, 10% ethanol and 90% gasoline
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
EPRI	Electric Power Research Institute
ESS	energy storage system
EU	European Union

EU ETS	European Union (Greenhouse Gas) Emission Trading System
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FR	Federal Register
FTA	Federal Transit Administration
FTP	Federal Test Procedure
g/bhp-hr	gram per brake-horsepower-hour
g/mi	gram per mile
GCAM	Global Change Assessment Model
GCM	general circulation model
GCRP	U.S. Global Change Research Program
GCWR	gross combined weight rating
GDP	gross domestic product
Gt	gigatons (1,000,000,000 tons)
GHG	greenhouse gas
GIS	geographic information system
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GVWR	gross vehicle weight rating
GWP	global warming potential
H_2CO_3	carbonic acid
HD	heavy-duty; medium- and heavy-duty
HDD	heavy duty diesel
HHDD	heavy heavy duty diesel
HFET	Highway Fuel Economy Test
HEV	hybrid electric vehicle
HFC	hydrofluorocarbon
hp	horsepower
HUD	U.S. Department of Housing and Urban Development
IARC	International Agency for Research on Cancer
IEO	International Energy Outlook
IGSM	Integrated Global System Model
OOIDA	Owner-Operator Independent Drivers Association, Inc.
IPCC	Intergovernmental Panel on Climate Change
IRIS	Integrated Risk Information System
JIT	Just in Time
km/hr	kilometer per hour
kW	kilowatt
LHDD	light heavy duty diesel
LT	light trucks
MAGICC	Model for Assessment of Greenhouse Gas-induced Climate Change
MERGE	Model for Evaluating Regional and Global Effects
MARAD	Maritime Administration
MD	medium-duty
MDPV	medium-duty passenger vehicles
mg/L	milligram per liter
mg/m^3	milligram per cubic meter
MHDD	medium heavy duty diesel
mm	millimeter
$MMTCO_2$	million metric tons of carbon dioxide
MOC	Meridional Overturning Circulation
MOVES	Motor Vehicle Emission Simulator (EPA)
MOVES2010	2010 Motor Vehicle Emission Simulator (EPA)
mpg	mile per gallon
mph	mile per hour

MSAT	mobile source air toxic
MTBE	methyl tertiary butyl ether
MY	model year
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NATA	National-scale Air Toxics Assessment
NCI	National Cancer Institute
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHTSA	National Highway Traffic Safety Administration
NO	nitric oxide
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_x	nitrogen oxides
Non-EGU	sources other than electric generating units (power plants).
NPP	net primary productivity
NPRM	Notice of Proposed Rulemaking
NRC	National Research Council
PAH	polycyclic aromatic hydrocarbon
PETM	Paleocene-Eocene thermal maximum
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
PSD	Prevention of Significant Deterioration
RCP	Representative Concentration Pathway
RFS	Renewable Fuel Standard
RFS2	Renewable Fuel Standard 2
RGGI	Regional Greenhouse Gas Initiative
RIA	Regulatory Impact Analysis
SAP	Synthesis and Assessment Product
SAB	Science Advisory Board
SBA	Small Business Administration
SET	Supplemental Engine Test
SC DOT	South Carolina Department of Transportation
SCC	social cost of carbon
SF_6	sulfur hexafluoride
SIP	State Implementation Plan
SO_x	sulfur oxides
SO_2	sulfur dioxide
SRES	Special Report on Emission Scenarios
TS&D	Transportation, Storage, and Distribution
Tg	teragram (1,000,000,000,000 grams)
THC	thermohaline circulation
TN DOT	Tennessee Department of Transportation
tpy	ton per year
TSD	Technical Support Document
U.S.C.	United States Code

USCAR	United States Council for Automotive Research
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VMT	vehicle-miles traveled
VOC	volatile organic compound
VSL	value of statistical life
W/m^2	watts per square meter
WCI	Western Climate Initiative
WGI	Work Group I, IPCC
WMO	World Meteorological Organization
WV DOT	West Virginia Department of Transportation

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.
Albedo	Surfaces on Earth reflect solar radiation back to space. The 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.
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.
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.
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.
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.

Term	Definition
Ocean acidification	A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.
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.
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).
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.
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.
Transpiration	Water loss from plant leaves.
Turbidity	A decrease in the clarity of water due to the presence of suspended sediment.
Vehicle miles traveled	Total number of miles driven.

FOREWORD

The National Highway Traffic Safety Administration (NHTSA) prepared this Environmental Impact Statement (EIS) to analyze and disclose the potential environmental impacts of and reasonable alternatives for the proposed Fuel Efficiency Improvement Program for the total fleet of commercial medium- and heavy-duty vehicles 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. This EIS compares the potential environmental impacts of ten alternative approaches that NHTSA is considering, including the Preferred Alternative and the No Action Alternative. It also analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance. Note that footnotes and supporting citations are not included in this summary section. Consult the relevant chapters of this EIS for that information.

BACKGROUND

The Energy Policy and Conservation Act of 1975 (EPCA) mandated that NHTSA establish and implement a regulatory program for motor vehicle fuel economy. As codified in Chapter 329 of Title 49 of the U.S. Code, and as amended by the Energy Independence and Security Act of 2007 (EISA), EPCA sets forth extensive requirements concerning the establishment of average fuel economy standards for passenger automobiles and non-passenger automobiles, which are motor vehicles that weigh less than 10,000 pounds. This regulatory program, known as the Corporate Average Fuel Economy Program (CAFE), was established to reduce national energy consumption by increasing the fuel economy of these vehicles.

EISA was enacted in December 2007, providing the U.S. Department of Transportation (DOT) U.S. DOT (and by delegation, NHTSA) new authority to implement, via rulemaking and regulations, "a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program," to regulate the fuel consumption of motor vehicles weighing more than 10,000 pounds. This provision also directs NHTSA to "adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible for commercial medium- and heavy-duty on-highway vehicles and work trucks." This new authority permits NHTSA to set "separate standards for different classes of vehicles." The commercial medium- and heavy-duty on-highway vehicles and work trucks are hereinafter referred to collectively as HD vehicles. Pursuant to EISA, the HD Fuel Efficiency Improvement Program NHTSA adopts must provide not less than four full model years of regulatory lead time and three full model years of regulatory stability.

Consistent with these requirements, NHTSA is proposing that mandatory standards begin in model year (MY) 2016 and that the standards remain stable for three model years. Although EISA prevents NHTSA from enacting mandatory standards before MY 2016, NHTSA is proposing optional voluntary compliance standards for MYs 2014–2015 prior to mandatory regulation in MY 2016. As directed by EISA, this rulemaking is being conducted in consultation with the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE).

In summary, the EISA directives at 49 U.S.C. § 32902(k)(2) and (k)(3) contain the following requirements specific to the HD Fuel Efficiency Improvement Program: (1) the program must be "designed to achieve the

maximum feasible improvement;" (2) the various required aspects of the program must be appropriate, cost effective, and technologically feasible for HD vehicles; and (3) the standards adopted under the program must provide not less than four model years of regulatory lead time and three model years of regulatory stability. In considering these requirements, NHTSA will also account for relevant environmental and safety considerations.

Further guiding the establishment of NHTSA's HD Fuel Efficiency Improvement Program, on May 21, 2010 President Obama issued a memorandum entitled "Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks" to the Secretary of Transportation, the Administrator of NHTSA, the Administrator of EPA, and the Secretary of Energy. The memorandum requested that the Administrators of EPA and NHTSA begin work on a Joint Rulemaking under EISA and the Clean Air Act and to establish fuel efficiency and greenhouse gas (GHG) emissions standards for commercial medium- and heavy-duty vehicles beginning with MY 2014, with the aim of issuing a Final Rule by July 30, 2011. The proposed NHTSA HD Fuel Efficiency Improvement Program and this EIS are consistent with this directive.

The President requested that, before promulgating a final rule, the Administrators of EPA and NHTSA: "Propose and take comment on strategies, including those designed to increase the use of existing technologies, to achieve substantial annual progress in reducing transportation sector emissions and fossil fuel consumption …" The President also requested that NHTSA implement fuel efficiency standards and EPA implement GHG emissions standards that take into account the market structure of the trucking industry and the unique demands of HD vehicle applications; seek harmonization with applicable State standards; consider the findings and recommendations published in the National Academy of Sciences report on HD truck regulation; strengthen the industry and enhance job creation in the United States; and seek input from all stakeholders, while recognizing the continued leadership role of California and other States.

Under NEPA, a Federal agency must analyze environmental impacts if the agency implements a proposed major Federal action, provides funding for that 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). To inform its development of the HD Fuel Efficiency Improvement Program required under EISA, NHTSA prepared this Draft EIS (DEIS) to analyze and disclose the potential environmental impacts of a proposed preferred alternative and other proposed alternative actions pursuant to CEQ NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations. This EIS compares the potential environmental impacts among alternatives, including a No Action Alternative. It also analyzes the potential direct, indirect, and cumulative impacts of the alternatives, and discusses impacts in proportion to their significance.

On May 25, 2010, NHTSA invited EPA and the Federal Motor Carrier Safety Administration (FMCSA) to become cooperating agencies with NHTSA in the development of the EIS for the HD rulemaking. Under 40 CFR § 1501.6, a Federal agency that has special expertise with respect to any environmental issue that should be addressed in the EIS may be a cooperating agency upon request of the lead agency. EPA has special expertise in the areas of climate change and air quality and FMCSA has special expertise in HD vehicles. EPA and FMCSA accepted NHTSA's invitation and agreed to become cooperating agencies. The staff of both agencies participated in technical discussions and reviewed and commented on draft sections and the draft final version of the DEIS.

PURPOSE AND NEED FOR THE PROPOSED ACTION

For this EIS, NHTSA's proposed action is to set HD vehicle fuel consumption standards, in accordance with the EISA mandate to "implement a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program." NHTSA and EPA are proposing coordinated and harmonized fuel consumption and GHG emissions standards for HD vehicles built in MYs 2014–2018. NHTSA is proposing standards for HD vehicles beginning in MY 2016, and voluntary compliance standards for MYs 2014–2015 HD vehicles.

NEPA requires that proposed alternatives be developed based on the action's purpose and need. The purpose and need statement explains why the action is needed, describes the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the NEPA analysis. As noted above, in accordance with EISA, NHTSA must establish a fuel efficiency improvement program for HD vehicles "designed to achieve the maximum feasible improvement, and [must] adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible for commercial medium- and heavy-duty on-highway vehicles and work trucks." The standards adopted under NHTSA's fuel efficiency improvement program must provide not less than four model years of regulatory lead time and three model years of regulatory stability. In considering these various requirements, NHTSA will also account for relevant environmental and safety requirements.

ALTERNATIVES

NHTSA and EPA are proposing standards for each of the following categories, which together comprise all HD vehicles and all engines used in such vehicles:

- Class 2b and 3 HD Pickups and Vans
- Class 2b through 8 Vocational Vehicles
- Class 7 and 8 Combination Tractors

Table S-1 and Figure S-1 show the vehicle classifications. For more details about these vehicle categories *see* Section 2.3.

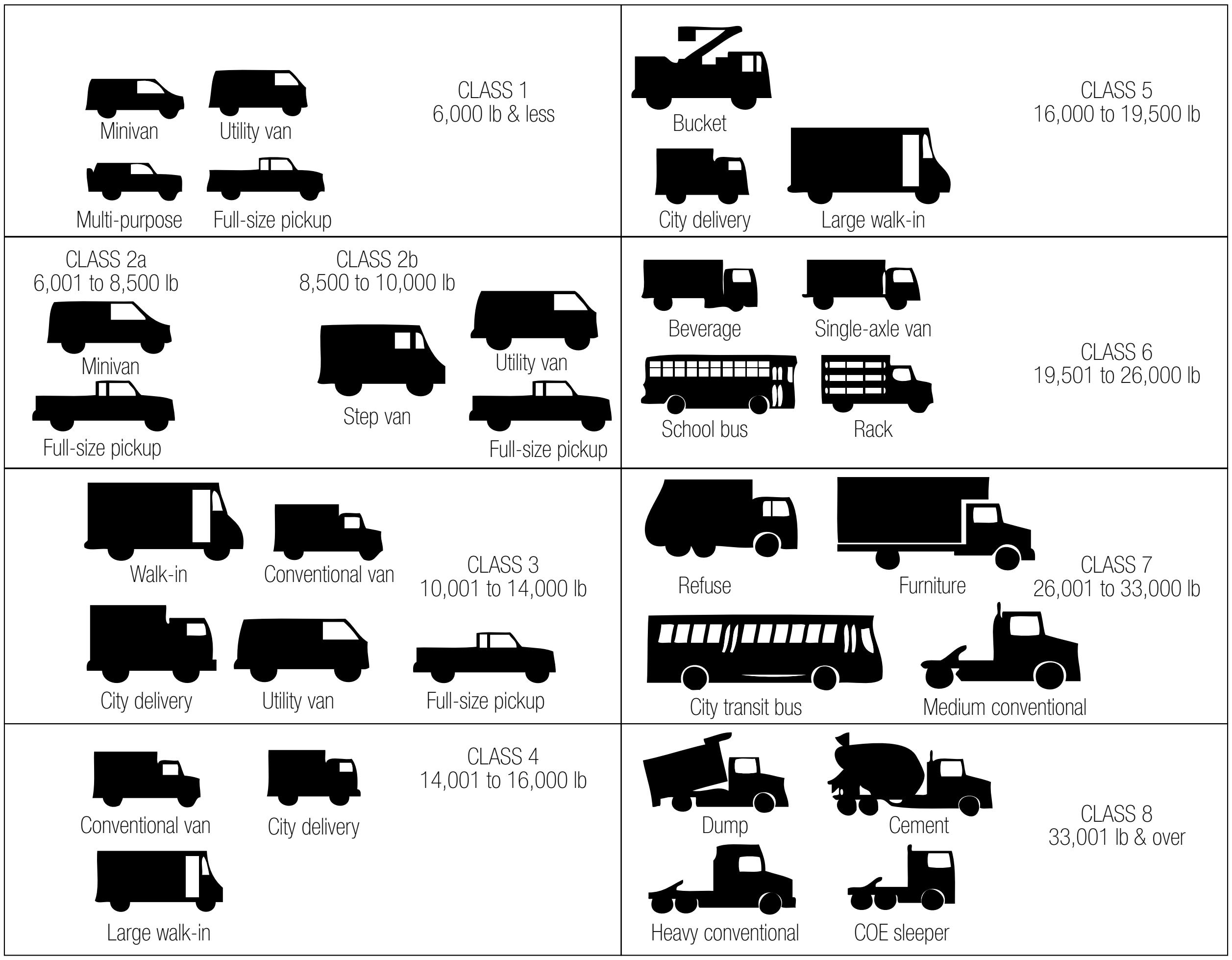
In developing a reasonable range of alternatives for this EIS, NHTSA was guided by the requirements of EISA described above. The NEPA analysis presented in this EIS informs the agency's action in setting HD vehicle fuel consumption standards.

The specific alternatives selected for evaluation by NHTSA encompass a reasonable range to evaluate the potential environmental impacts of the proposed HD Fuel Efficiency Improvement Program and alternatives under NEPA. At one end of this range is the No Action Alternative (Alternative 1), which assumes

Table S-1. HD Vehicle Categories by Gross Vehicle Class Weight Rating (pounds)

Class 2b	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
8,501-10,000 lbs	10,001-14,000 lbs	14,001-16,000 lbs	16,001-19,500 lbs	19,501-26,000 lbs	26,001-33,000 lbs	> 33,001 lbs
HD Pickups and Vans (Work Trucks)						
Vocational Vehicles (*e.g.,* van trucks, utility "bucket" trucks, tank trucks, refuse trucks, buses, fire trucks, flat-bed trucks, and dump trucks)						
					Tractors (for Combination Tractor-Trailers)	

Figure S-1. HD Vehicle Categories



no action would occur under the HD National Program. Under this alternative, neither NHTSA nor EPA would issue a rule regarding the HD fuel consumption standards or GHG emissions. The No Action Alternative assumes that average fuel efficiency levels in the absence of an HD Fuel Efficiency Improvement Program would equal the agencies' collective market forecast – the level of fuel efficiency and GHG performance NHTSA believes manufacturers would continue to achieve, without regulation. 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. Similarly, the No Action Alternative would yield no additional environmental improvement other than might occur from market forces.

NHTSA has also examined nine action alternatives, each of which would regulate the HD vehicle fleet (or portions of that fleet) in a different way. The analysis of action alternatives examines the environmental impacts associated with applying specific fuel consumption standards to HD engines and one or more of the following vehicle categories: HD pickups and vans, vocational vehicles, and combination tractors. This analytical approach was selected in view of the complexity of the HD vehicle fleet, the applicability of differing fuel-savings technologies to different portions of that fleet, and the relative degree of homogeneity among vehicles within broad categories (HD pickups and vans, vocational vehicles, and combination tractors).

Below is a brief description of the nine action alternatives. NHTSA added five alternatives to those first proposed in the Notice of Intent, Alternatives 4, 5, 6A, 6B, and 8. Alternative 6 is the agency's Preferred Alternative. For a detailed explanation of the alternatives, *see* Section 2.3 of this EIS.

- **Alternative 1** specifies no fuel consumption standards (No Action).
- **Alternative 2** specifies standards for all HD engines used in Classes 2b through 8 vehicles (in gallons per 100 brake-horsepower-hour [gal/100 bhp-hr]).
- **Alternative 3** specifies standards for each of the following:
  - Class 8 tractors (in gallons per 1,000 ton-miles [gal/1,000 ton-miles])
  - Engines used in Class 8 tractors (in gal/100 bhp-hr).
- **Alternative 4** specifies standards for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr).
- **Alternative 5** specifies standards for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gallons per 100 miles [gal/100 miles]).
- **Alternative 6**, the Preferred Alternative, specifies standards for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles).
- **Alternative 6A** specifies standards 15 percent less stringent than the Preferred Alternative, Alternative 6, for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles).
- **Alternative 6B** specifies standards 20 percent more stringent than the Preferred Alternative, Alternative 6, for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles).
- **Alternative 7** specifies standards for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles)
  - Trailers pulled by Classes 7 and 8 tractors (reducing gal/1,000 ton-miles standard for combination tractor-trailers).

- **Alternative 8** specifies standards for each of the following:
  - Classes 7 and 8 tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles)
  - Trailers pulled by Classes 7 and 8 tractors, with more stringent standards specified for HD pickups and vans and vocational vehicles, associated with accelerated adoption of hybrid engine technology (reducing gal/100 miles standard for HD pickups and vans and reducing gal/1,000 ton-miles standard for tractor-trailers and vocational vehicles).

POTENTIAL ENVIRONMENTAL CONSEQUENCES

This section describes how the proposed action and alternatives could affect energy use, air quality, and climate, which are the resources for which NHTSA performed a quantitative assessment.

This EIS also describes potential additional impacts on water resources, biological resources, safety, hazardous materials and regulated wastes, noise, and environmental justice. NHTSA assesses those resource areas qualitatively.

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

When comparing direct and indirect effects with cumulative effects, it is important to understand that the methodology for evaluating direct effects analyzes the direct impacts of fuel efficiency requirements for MYs 2014–2018 under each action alternative, assuming no further increases in average new HD vehicle fuel efficiency after 2018. The cumulative analysis includes, as a reasonably foreseeable action, increases in fuel efficiency of the HD vehicle fleet beyond 2018 based on Annual Energy Outlook (AEO) projections until 2050. The cumulative impacts analysis considers both national and global potential impacts.

The alternatives in the tables and figures that follow are arranged in ascending order of fuel savings, to aid in the environmental analysis and the comparison of alternatives. Consequently, the alternatives appear out of numerical sequence.

Energy Use

Energy intensity in the United States (energy use per dollar of gross domestic product) is expected to decline by an average of 1.9 percent per year from 2008 to 2035. Despite this continuing improvement in economy-wide energy efficiency, transportation fuel consumption has grown steadily through annual increases, and now represents the major use of petroleum in the U.S. economy.

The transportation sector is the second largest consumer of energy in the United States (after the industrial sector) and, as shown in Figure S-2, represents 28 percent of U.S. total energy use. According to the EIA, more than half of U.S. energy consumption in the transportation sector – ranging from 60 percent in 2008 to 50 percent by 2035–can be attributed to gasoline consumption from light vehicles. Diesel consumption from heavy-duty vehicles made up 17 percent of energy consumption in the U.S. transportation sector in 2008, and is projected to increase to 20 percent of energy consumption in the U.S. transportation sector in 2035. Going forward in time, the transportation sector will continue to be the largest component of total U.S. energy consumption after the industrial sector.

As shown in Figure S-3, about 70 percent of the petroleum used in the United States is consumed by the transportation sector. NHTSA's analysis of fuel consumption in this EIS assumes that fuel consumed by HD vehicles will consist predominantly of diesel and gasoline fuel derived from petroleum for the foreseeable future. Petroleum consumption by HD vehicles will continue to grow. In 2008, the proportion of petroleum consumption by HD vehicles out of all highway modes of transportation (*e.g.* light-duty vehicles, commercial light trucks – 8,500 to 10,000 pounds, and HD vehicles) was approximately 19 percent. The EIA projects that this proportion will drop by 1 to 2 percent, along with total energy consumption in the transportation sector, due to onset of the economic recession that began during the latter half of 2008. However, it is expected to recover by 2013, and is expected to reach 23 percent by 2035.

Key Findings for Energy Use

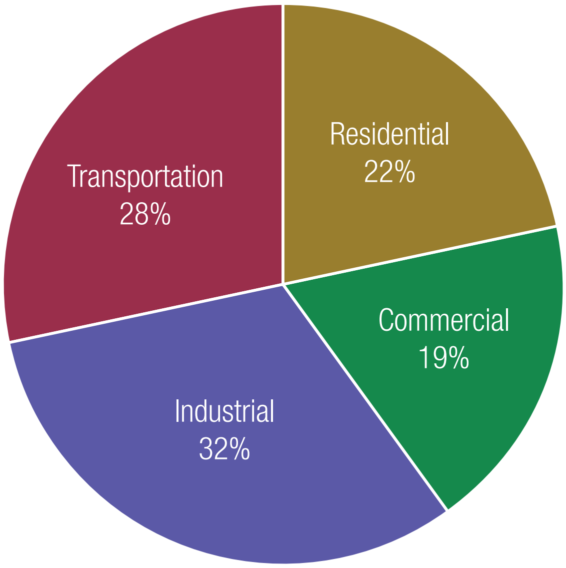
To calculate fuel savings for each proposed alternative, NHTSA subtracted fuel consumption under each alternative from the No Action Alternative level. The fuel consumption and savings figures presented below are for 2050, when nearly the entire U.S. fleet will likely be composed of MY 2014-2018 and later vehicles.

Direct and Indirect Effects

HD Pickups and Vans:

- Total annual fuel savings in 2050 ranges from 0.72 billion gallons for Alternative 2 (Engine Only) to 2.65 billion gallons for Alternative 8 (Accelerated Hybrid Adoption) when compared to the No Action Alternative (Alternative 1). *See* Figure S-4.

Figure S-2. U.S. Energy Consumption by Sector, 2008



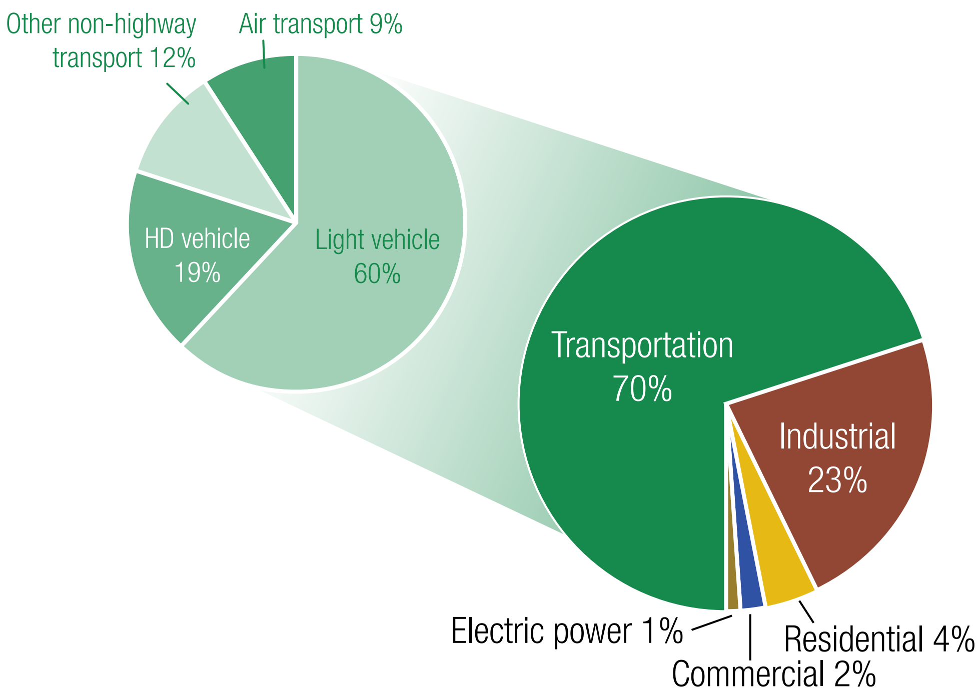
Source: EIA (Energy Information Administration). 2009. Table 2.1a – Energy Consumption by Sector, 1949-2009. Annual Energy Review 2009. DOE/EIA-0384(2009). U.S. Department of Energy. Washington, D.C. *Available at:* <http://www.eia.doe.gov/emeu/aer/pdf/aer.pdf>. (Accessed: October 15, 2010).

- Fuel consumption under the No Action Alternative and Alternative 3 is 11.64 billion gallons in 2050. Alternative 3 does not regulate HD pickups and vans. Consumption under the other alternatives ranges from 10.92 billion gallons for Alternative 2 (Engine Only) to 8.99 for Alternative 8 (Accelerated Hybrid Adoption).
- Fuel consumption under the Preferred Alternative (Alternative 6) is 10.27 billion gallons in 2050, representing a savings of 1.37 billion gallons compared with fuel consumption under the No Action Alternative.

Vocational Vehicles:

- Total annual fuel savings in 2050 ranges from 1.18 billion gallons for Alternative 2 (Engine Only) to 5.22 billion gallons for Alternative 8 (Accelerated Hybrid Adoption) when compared to the No Action Alternative (Alternative 1). *See* Figure S-5.

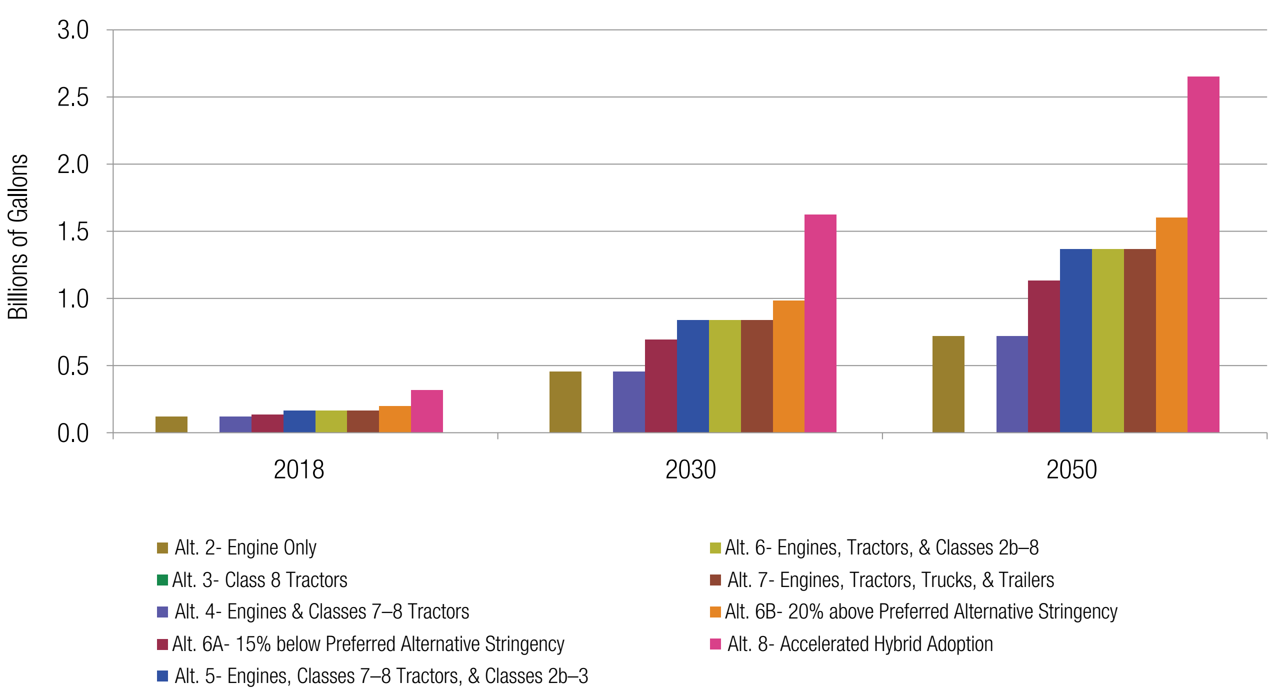
Figure S-3. U.S. Petroleum Consumption by Sector, 2008



Source: EIA. 2010. Table 7 – Transportation Sector Key Indicators and Delivered Energy Consumption, 2007-2035. Annual Energy Outlook 2010. DOE/EIA-0383(2010). April. U.S. Department of Energy. Washington, D.C. *Available at:* <http://www.eia.doe.gov/oiaf/aeo/>. (Accessed: August 4, 2010).

Source: EIA. 2009. Table 5.13a – Estimated Petroleum Consumption: Residential and Commercial Sectors; Table 5.13b – Estimated Petroleum Consumption: Industrial Sector; Table 5.13c – Estimated Petroleum Consumption: Transportation Sector; Table 5.13d – Estimated Petroleum Consumption: Electric Power Sector. Annual Energy Review 2009. DOE/EIA-0384(2009). U.S. Department of Energy. Washington, D.C. *Available at:* <http://www.eia.doe.gov/emeu/aer/pdf/aer.pdf>. (Accessed: October 15, 2010).

Figure S-4. HD Pickup and Van Annual Fuel Savings by Alternative



- Fuel consumption under the No Action Alternative and Alternative 3 is 25.10 billion gallons in 2050. Alternative 3 does not regulate vocational vehicles. Consumption under the other alternatives ranges from 23.92 billion gallons for Alternative 2 (Engine Only) to 19.88 billion gallons for Alternative 8 (Accelerated Hybrid Adoption).
- Fuel consumption under the Preferred Alternative (Alternative 6) is 23.11 billion gallons, representing a savings of 1.99 billion gallons compared with fuel consumption under the No Action Alternative.

Combination Tractors:

- Total annual fuel savings in 2050 ranges from 2.61 billion gallons for Alternative 2 (Engine Only) to 6.39 billion gallons for Alternative 6B (20% above Preferred Alternative Stringency) when compared to the No Action Alternative (Alternative 1). *See* Figure S-6.
- Fuel consumption under the No Action Alternative is 51.65 billion gallons in 2050. Consumption under the other alternatives ranges from 49.04 billion gallons for Alternative 2 (Engine Only) to 45.27 billion gallons for Alternative 6B (20% above Preferred Alternative Stringency).
- Fuel consumption under the Preferred Alternative (Alternative 6) is 46.07 billion gallons in 2050, representing a savings of 5.58 billion gallons compared with fuel consumption under the No Action Alternative.

All HD Vehicles (Pickups and Vans, Vocational Vehicles, and Combination Tractors):

- Total annual fuel savings in 2050 ranges from 4.51 billion gallons for Alternative 2 (Engine Only) to 13.93 billion gallons for Alternative 8 (Accelerated Hybrid Adoption) when compared to the No Action Alternative (Alternative 1). *See* Figure S-7.
- Fuel consumption under the No Action Alternative is 88.39 billion gallons in 2050. Consumption under the other alternatives ranges from 83.88 billion gallons for Alternative 2 (Engine Only) to 74.47 for Alternative 8 (Accelerated Hybrid Adoption).
- Fuel consumption under the Preferred Alternative (Alternative 6) is 79.45 billion gallons in 2050, representing a savings of 8.94 billion gallons compared with fuel consumption under the No Action Alternative.

Cumulative Effects

- Total annual fuel savings in 2050 range from 4.11 billion gallons for Alternative 2 (Engine Only) to 12.68 billion gallons for Alternative 8 (Accelerated Hybrid Adoption) when compared to the No Action Alternative (Alternative 1). *See* Figure S-8.
- Fuel consumption under the No Action Alternative is 80.88 billion gallons in 2050. Consumption under the other alternatives ranges from 76.76 billion gallons for Alternative 2 (Engine Only) to 68.19 billion gallons for Alternative 8 (Accelerated Hybrid Adoption).
- Fuel consumption under the Preferred Alternative (Alternative 6) is 72.71 billion gallons in 2050, representing a savings of 8.16 billion gallons compared with fuel consumption under the No Action Alternative.

For readers interested in additional details about the direct and indirect effects of the alternatives on annual fuel consumption, *see* Section 3.2 of this EIS. For readers interested in additional details about the cumulative effects of each alternative on annual fuel consumption, *see* Section 4.2 of this EIS.

Figure S-5. Vocational Vehicles Annual Fuel Savings by Alternative

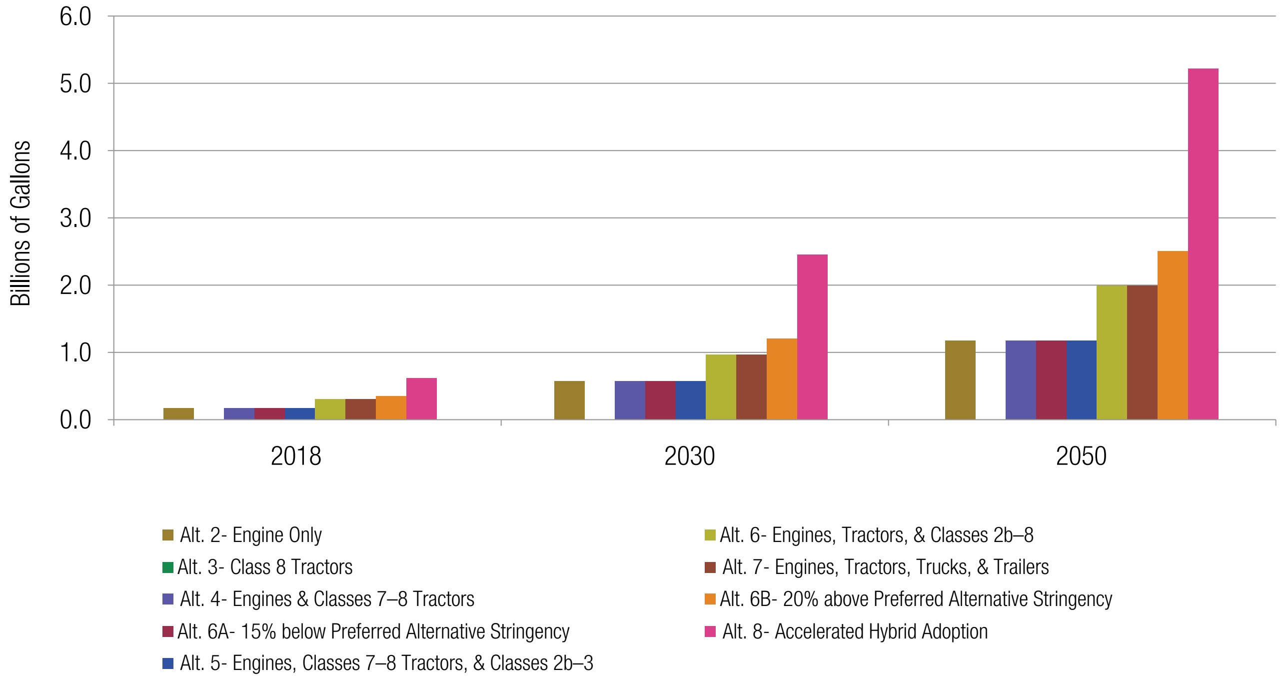


Figure S-6. Combination Tractor Annual Fuel Savings by Alternative

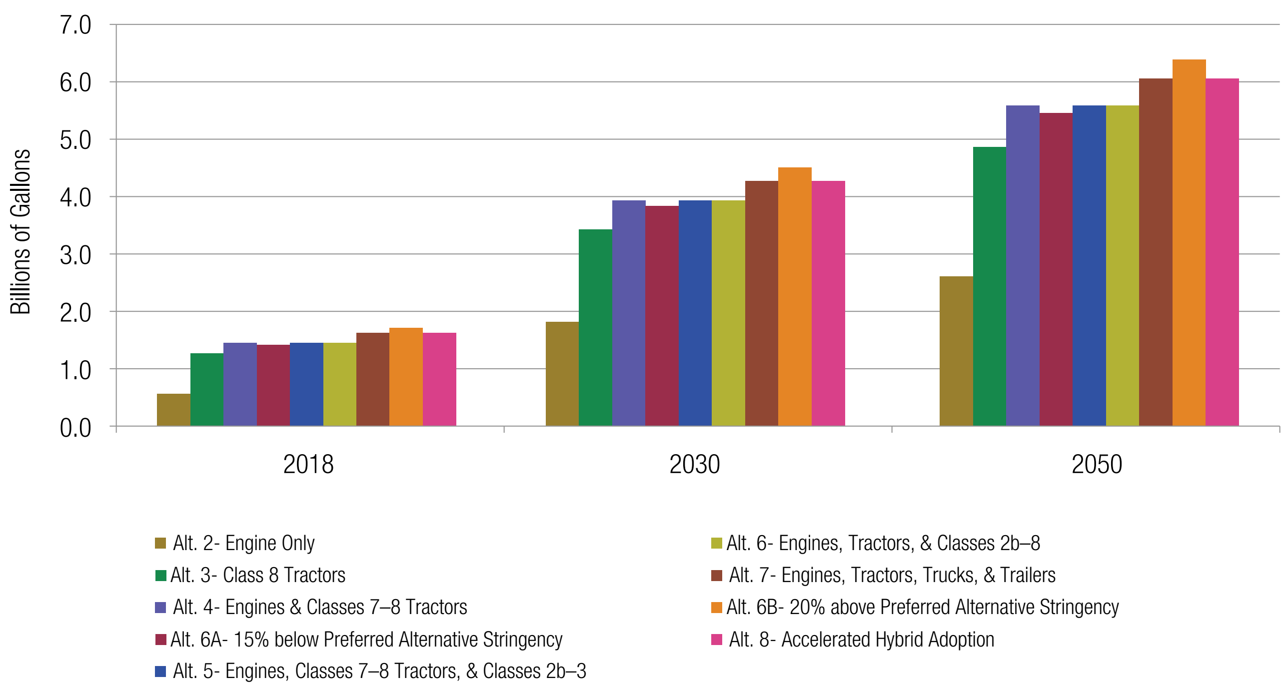


Figure S-7. All HD Vehicles Annual Fuel Savings by Alternative

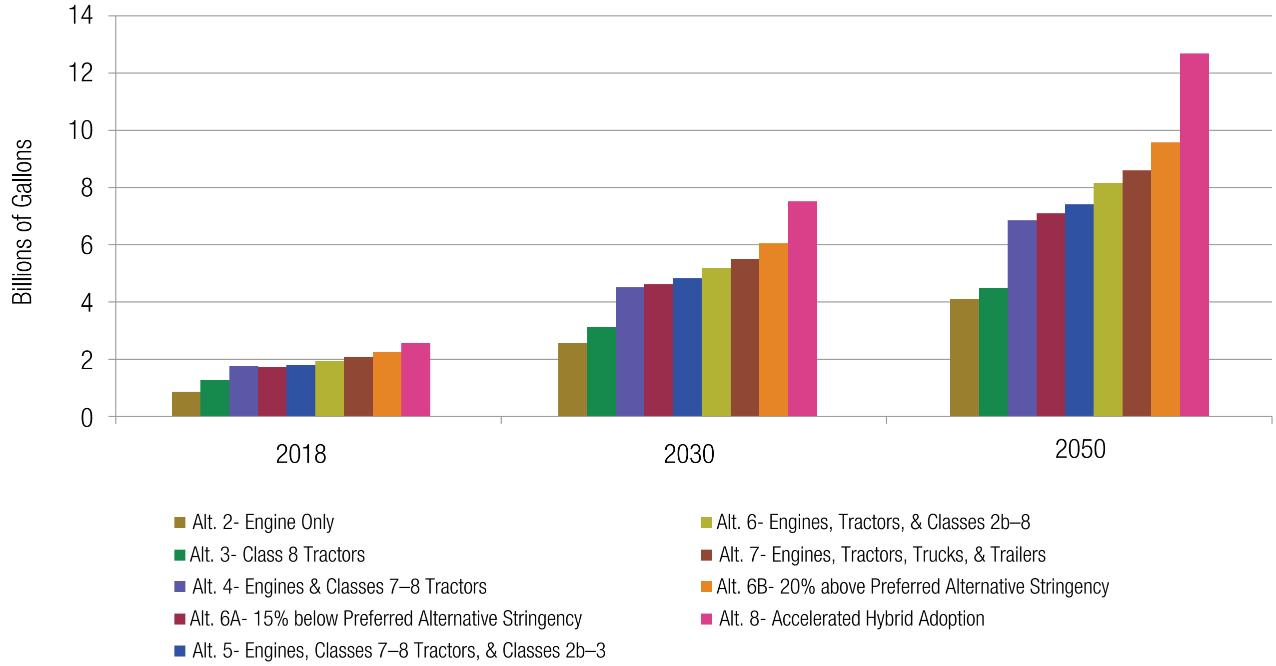
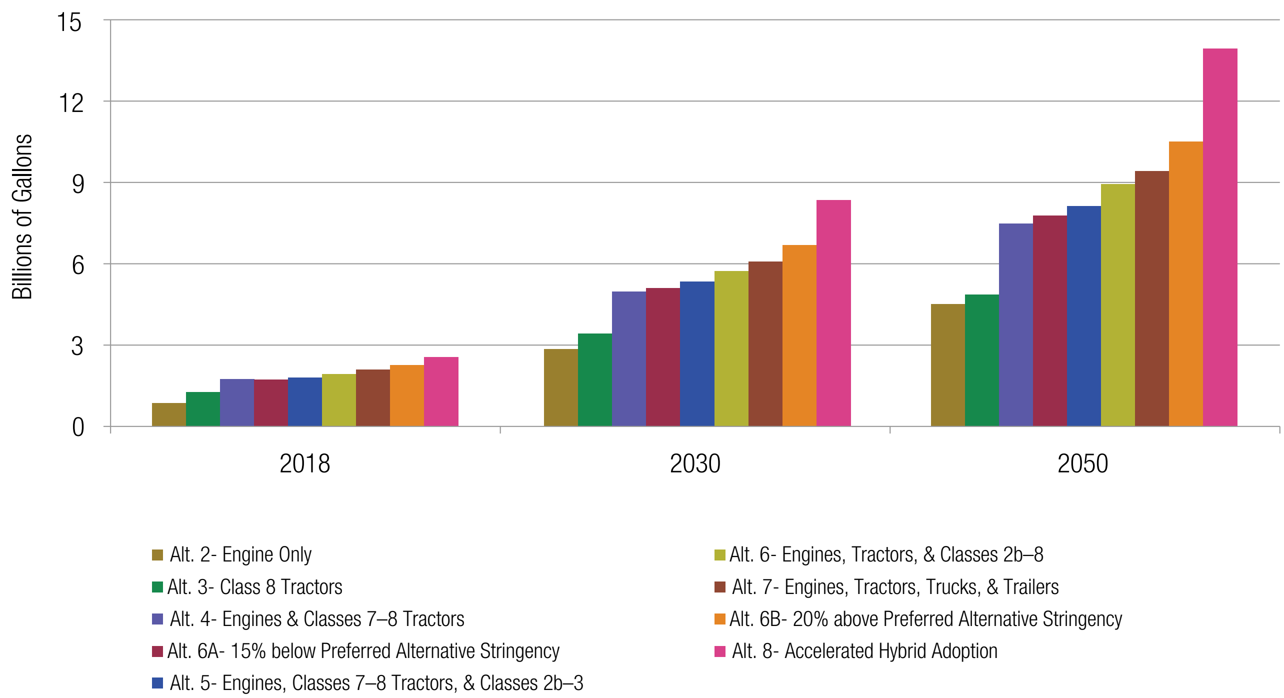


Figure S-8. Cumulative HD Vehicle Annual Fuel Savings by Alternative



Air Quality

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

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

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

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

Health Effects of the Pollutants

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

- Damage to lung tissue;
- Reduced lung function;
- Exacerbation of existing respiratory and cardiovascular diseases;
- Difficulty breathing;
- Irritation of the upper respiratory tract;
- Bronchitis and pneumonia;
- Reduced resistance to respiratory infections;
- Alterations to the body's defense systems against foreign materials;
- Reduced delivery of oxygen to the body's organs and tissues;
- Impairment of the brain's ability to function properly; and
- Cancer and premature death.

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

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

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

Highway vehicles (including HD vehicles) remain responsible for about 50 percent of total U.S. emissions of carbon monoxide, 4 percent of $PM_{2.5}$ emissions, and 1 percent of PM_{10} emissions. HD vehicles contribute 6 percent of U.S. highway emissions of CO, 66 percent of highway emissions of $PM_{2.5}$, and 55 percent of highway emissions of PM_{10}. Highway vehicles also contribute about 21 percent of total nationwide emissions of VOCs and 32 percent of NO_x, both of which are chemical precursors of ozone. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors. HD vehicles contribute 8 percent of U.S. highway emissions of VOC and 50 percent of NO_x. Highway vehicles contribute less than 1 percent of SO_2, but SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere. With the elimination of lead in automotive gasoline, lead is no longer emitted from motor vehicles in more than negligible quantities, and thus is not assessed in this analysis.

Key Findings for Air Quality

The findings for direct and indirect effects are shown for 2030 which represents a mid-term forecast year when a large proportion of HD vehicles would at least meet the MYs 2014-2018 standards. Findings for cumulative effects are shown for 2050. By 2050, almost all HD vehicles in operation would meet the MYs 2014–2018 standards, and the impact of these standards would be determined primarily by VMT growth rather than further tightening of the standards. The No Action Alternative results in the highest emissions of most criteria pollutants, although some of the action alternatives result in slightly higher emissions of some criteria pollutants. For MSATs, some of the alternatives result in slightly higher emissions of some hazardous air pollutants, when compared with emission levels under the No Action Alternative.

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

EPA used the value of statistical life (VSL) metric to calculate the economic benefits associated with reducing the risk of premature mortality. The VSL refers to the aggregate estimated value of reducing small risks across a large number of people. It is based on how people themselves would value reducing these risks, *i.e.,* their “willingness to pay.” An estimated VSL of $6.3 million (in 2000 dollars), as established by EPA in 2009, was used for the EIS. For other health-related effects, EPA used willingness-to-pay estimates derived from the valuation literature, estimated healthcare expenses, and lost wages in the valuation of economic benefits.

Direct and Indirect Effects

Criteria Pollutants

- Emissions of criteria pollutants are generally highest under the No Action Alternative (Alternative 1) and generally decline as fuel consumption decreases across the alternatives.

- Emissions of CO and NO_x are slightly higher under Alternatives 2 (Engine Only) than under the No Action Alternative, but decline below the No Action Alternative emissions levels as fuel consumption decreases under Alternatives 3 through 8.
- Emissions of $PM_{2.5}$ are slightly higher under Alternatives 3 through 7 than under the No Action Alternative, but generally decline as fuel consumption decreases under Alternatives 3 through 8. This is due to the assumption that sleeper cab tractor trucks would use the auxillary power units instead of idling for long time periods.
- Emissions of NO_x, SO_2, and VOCs are lowest under Alternative 8 (Accelerated Hybrid Option), emissions of CO are lowest under Alternative 3, and emissions of $PM_{2.5}$ are generally lowest under Alternative 2 (Engine Only).
- Under Alternative 6 (the Preferred Alternative) emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative. Emissions under the Preferred Alternative generally would be lower than under Alternatives 1 through 5 and 6A, but higher than under Alternatives 6B, 7, and 8. Under the Preferred Alternative emissions of $PM_{2.5}$ would be lower than under Alternatives 3 through 5 and 6A, but higher than under Alternatives 1, 2, 6B, 7, and 8.

Hazardous Air Pollutants

- Toxic air pollutant emissions show both increases and decreases depending on the pollutant and alternative analyzed. Where there are increases in toxic air pollutant emissions, they are generally small in relation to emission levels under the No Action Alternative. Where there are decreases in toxic air pollutants, they are generally greater in magnitude than the increases.
- Emissions of acetaldehyde, acrolein, benzene, and formaldehyde generally increase from the No Action Alternative to Alternative 2 (Engine Only), and then generally decrease or are the same with each successive alternative from Alternative 2 to Alternative 8 (Accelerated Hybrid Option). Emissions of these pollutants are highest under Alternative 2 and lowest under Alternative 8.
- Emissions of 1,3-butadiene are highest under Alternative 2, lowest under Alternative 3, and approximately the same from Alternatives 4 through 8.
- Emissions of DPM are lowest under Alternative 2 (Engine Only) or Alternative 8 (Accelerated Hybrid Option) depending on the year, are highest under Alternative 3, and decline under each successive alternative from Alternative 3 to 8.
- Under Alternative 6 (the Preferred Alternative) emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde would be reduced or approximately equivalent compared to the Alternatives 1 through 5 and 6A. DPM emissions under the Preferred Alternative would be slightly higher in 2030 and 2050 compared to the Alternatives 1 and 2, but lower than under Alternatives 3 through 5 and 6A. Under the Preferred Alternative toxic air pollutant emissions would be slightly higher than or approximately equivalent to emissions under Alternatives 6B, 7, and 8.

Health and Health Benefits

- Alternatives 2 through 8 would reduce adverse health effects nationwide compared with the No Action Alternative (Alternative 1). Reductions generally increase as fuel consumption decreases across alternatives.
- The monetized benefits follow the same patterns as reductions in adverse health effects. When estimating quantified and monetized health impacts, EPA relies on results from two $PM_{2.5}$-related premature mortality studies it considers equivalent (Pope *et al.* 2002 and

Laden *et al.* 2006). EPA recommends that monetized benefits be shown using incidence estimates derived from each of these studies and valued using both a 3-percent and 7-percent discount rate to account for an assumed lag in the occurrence of mortality after exposure (EPA assumes a 20-year distributed "cessation lag"), for a total of four separate calculations of monetized health benefits. *See* Sections 3.3.2.4.2 and 3.3.3.3.3 in Section 3.3 of this EIS. Estimated benefits in annual health costs range from $224 million for Alternative 2 (Engine Only) (the lowest of the four calculations) to $4.6 billion for Alternative 8 (Accelerated Hybrid Option) (the highest of the four calculations).

- Under the Preferred Alternative, health outcomes would be fewer and monetized health benefits would be greater than under Alternatives 2 through 5 and 6A. Health outcomes would be greater and monetized health benefits would be less than under Alternatives 6B, 7, and 8.

Cumulative Effects

Criteria Pollutants

- Emissions of criteria pollutants are generally highest under the No Action Alternative, and generally decline as fuel consumption decreases across the alternatives, with the exceptions noted below.
- Emissions of CO and NO_x are slightly higher under Alternative 2 (Engine Only) than under the No Action Alternative, but decline below the No Action Alternative emissions levels as fuel consumption decreases under Alternatives 3 through 8.
- Emissions of $PM_{2.5}$ are slightly higher under Alternatives 3 through 7 than under the No Action Alternative, but generally decline as fuel consumption decreases under Alternatives 3 through 8.
- Emissions of SO_2 and VOCs are highest under the No Action Alternative, and decline consistently under Alternatives 2 through 8 in all analysis years.
- Emissions of NOx, SO_2, and VOCs are generally lowest under Alternative 8 (Accelerated Hybrid Adoption), emissions of CO are lowest under Alternative 3 (Class 8 Tractors), and emissions of PM2.5 in 2050 are lowest under Alternative 2 (Engine Only).
- Under Alternative 6 (the Preferred Alternative) cumulative emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative. Emissions under the Preferred Alternative generally would be lower than under Alternatives 1 through 5 and 6A, but higher than under Alternatives 6B, 7, and 8. Under the Preferred Alternative cumulative emissions of $PM_{2.5}$ would be lower than under Alternatives 3 through 5 and 6A, but higher than under Alternatives 1, 2, 6B, 7, and 8.

Hazardous Air Pollutants

- Toxic air pollutant emissions show both increases and decreases depending on the pollutant and alternative. Where there are increases in toxic air pollutant emissions, they are generally small in relation to emission levels under the No Action Alternative. Where there are decreases in toxic air pollutant emissions, they are generally greater in magnitude than the increases.
- Emissions of acetaldehyde, acrolein, benzene, and formaldehyde generally increase from the No Action Alternative to Alternative 2 (Engine Only), and then generally decrease or are equivalent across the alternatives from Alternative 2 to Alternative 8. Emissions of these pollutants in 2050 are highest under Alternative 2 (Engine Only) and lowest under Alternative 8 (Accelerated Hybrid Adoption).

- Emissions of acetaldehyde, acrolein, benzene, and formaldehyde generally increase from the No Action Alternative to Alternative 2 (Engine Only), and then generally decrease or are equivalent from Alternative 2 to Alternative 8. Emissions of these pollutants in 2050 are highest under Alternative 2 (Engine Only) and lowest under Alternative 8 (Accelerated Hybrid Adoption).
- Emissions of 1,3-butadiene are nearly the same under all alternatives. Emissions of 1,3 butadiene in 2050 are highest under the No Action Alternative and Alternative 2 (Engine Only), and lowest under Alternative 3 (Class 8 Tractors).
- Emissions of DPM are lowest under Alternative 2 (Engine Only) or 8 (Accelerated Hybrid Adoption) depending on the year, are highest in Alternative 3 (Class 8 Tractors), and generally decline from Alternative 3 to 8.
- Under Alternative 6 (the Preferred Alternative) emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde would be reduced or approximately equivalent compared to the Alternatives 1 through 5 and 6A. DPM emissions under the Preferred Alternative would be slightly higher in 2030 and 2050 compared to the Alternatives 1 and 2, but lower than under Alternatives 3 through 5 and 6A. Under the Preferred Alternative toxic air pollutant emissions would be slightly higher than or approximately equivalent to emissions under Alternatives 6B, 7, and 8.

Health and Health Benefits

- Alternatives 2 through 8 would reduce adverse health effects nationwide compared with the No Action Alternative. Reductions generally increase as fuel consumption decreases across alternatives.
- The monetized benefits also follow the same patterns as reductions in adverse health effects. Estimated annual monetized health benefits in 2050 range from $362 million for Alternative 2 (lowest of the four calculations) to $7.5 billion for Alternative 8 (highest of the four calculations).
- Under the Preferred Alternative, cumulative health outcomes would be fewer and monetized health benefits would be greater than under Alternatives 2 through 5 and 6A. Cumulative health outcomes would be greater and monetized health benefits would be less than under Alternatives 6B, 7, and 8.

For readers interested in additional detail, Tables 3.3.3-1 through 3.3.3-10 in Section 3 of this EIS provide data on the direct effects of criteria pollutant and hazardous air pollutant emissions, as well as monetized health benefits for the alternatives. Tables 4.3.3-1 through 4.3.3-4 in Section 4 of this EIS provide cumulative effects data on criteria pollutant and hazardous air pollutant emissions. Table 4.3.3 9 in Section 4 of this EIS provides cumulative effects data on monetized health benefits for the alternatives.

Climate

Earth's natural greenhouse effect makes the planet habitable for life (*see* Figure S-9). CO_2 and other GHGs trap heat in the troposphere (the layer of the atmosphere that extends from Earth's surface up to about 8 miles), absorb heat energy emitted by Earth's surface and its lower atmosphere, and re radiate much of it back to the surface. Without GHGs in the atmosphere, most of this heat energy would escape back to space.

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

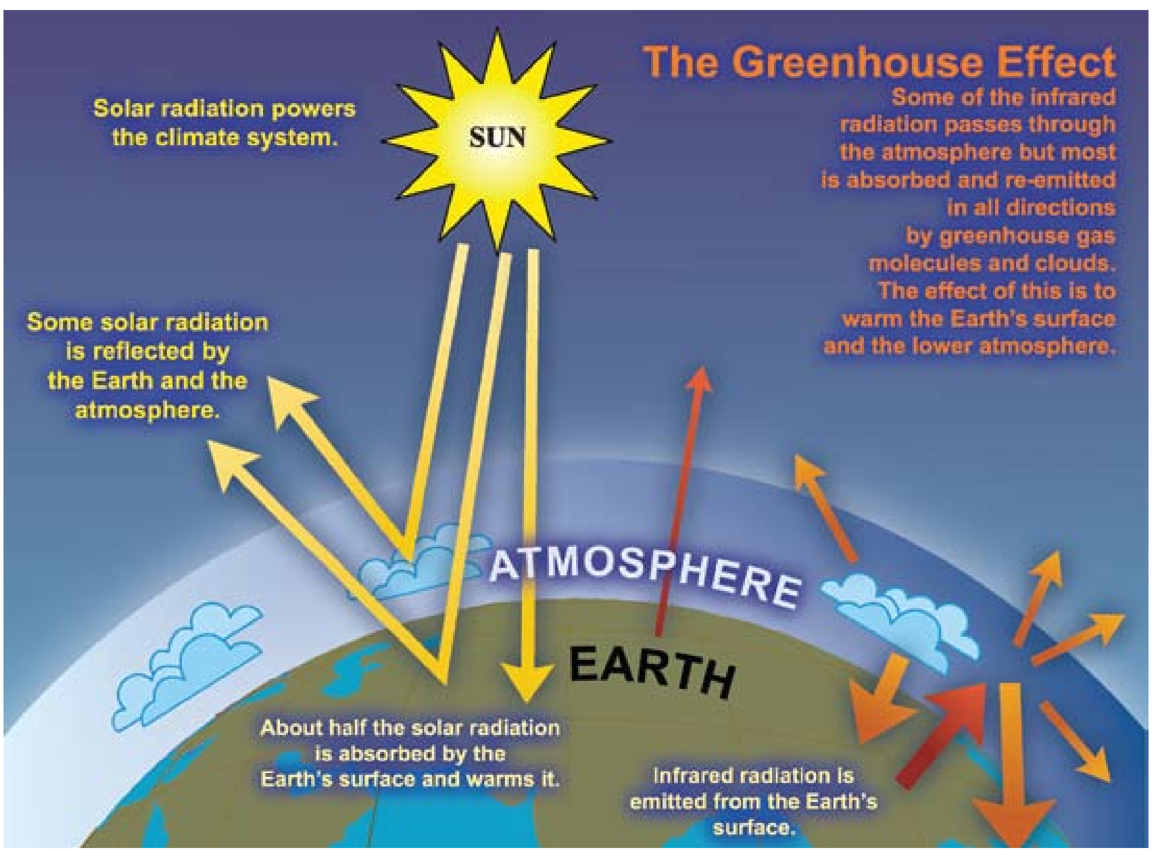
Since the industrial revolution, when fossil fuels began to be burned in increasing quantities, concentrations of GHGs in the atmosphere have increased. CO_2 has increased by more than 38 percent since pre-industrial times, while methane's concentration is now 149 percent above pre-industrial levels.

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

During the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) or 0.74 degrees Celsius (°C), 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.

As stated in a recent NRC report, "There is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing, and these changes are in large part caused by human activities" (NRC 2010). These activities--such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees--contribute to increased concentrations of GHGs in the atmosphere, which in turn trap increasing amounts of heat, altering the earth's energy balance.

Figure S-9. The Greenhouse Effect



Source: IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 996 pgs.

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), the National Research Council (NRC), the U.S. Global Change Research Program (GCRP), and EPA. Our discussion focuses heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and U.S. climate change: the IPCC Fourth Assessment Report (Climate Change 2007), the EPA Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act and the accompanying Technical Support Document (TSD), and CCSP, GCRP, NRC, and National Science and Technology Council reports that include Synthesis and Assessment Products, Global Climate Change Impacts in the United States, America's Climate Choices, and Scientific Assessment of the Effects of Global Change on the United States. This EIS frequently cites these sources and the studies they review.

Impacts of Climate Change

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

- Impacts on freshwater resources could include changes in precipitation patterns; decreasing aquifer recharge in some locations; changes in snowpack and timing of snowmelt; saltwater intrusion from sea-level changes; changes in weather patterns resulting in flooding or drought in certain regions; increased water temperature; and numerous other changes to freshwater systems that disrupt human use and natural aquatic habitats.
- Impacts on terrestrial ecosystems could include shifts in species range and migration patterns, potential extinctions of sensitive species unable to adapt to changing conditions, increases in the occurrence of forest fires and pest infestation, and changes in habitat productivity due to increased atmospheric concentrations of CO_2.
- Impacts on coastal ecosystems could include the loss of coastal areas due to submersion and erosion, additional impacts from severe weather and storm surges, and increased salinization of estuaries and freshwater aquifers.
- Impacts on land use could include flooding and severe-weather impacts on 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 on 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 in the seasonal patterns of vector-borne diseases, and increases in malnutrition.

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

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

Contribution of U.S. Transportation Sector to Climate Change

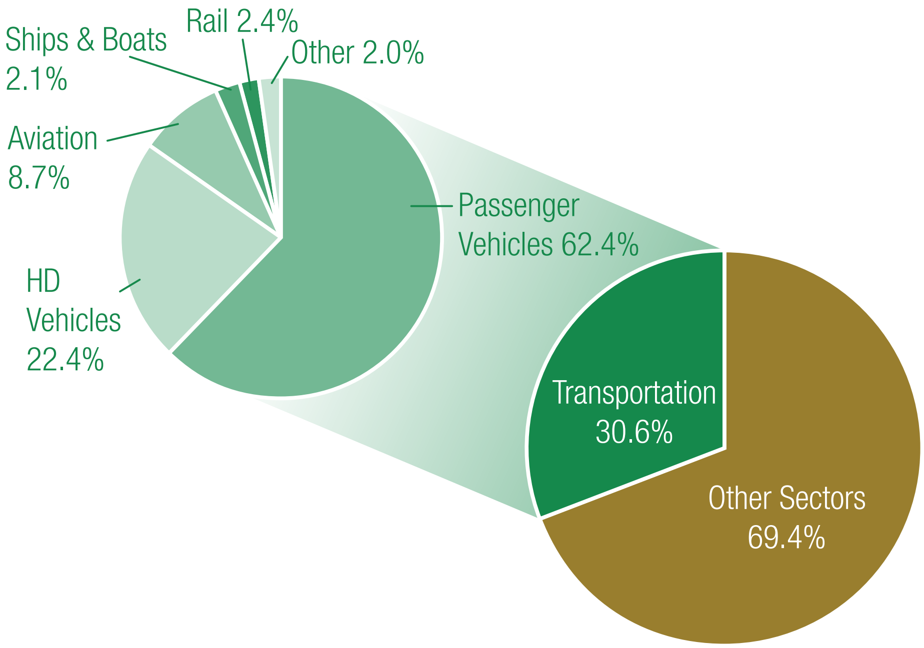
Contributions to the buildup of GHGs in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity. Emissions from the United States account for about 17.4 percent of total global CO_2 emissions. As shown in Figure S-10, the U.S. transportation sector contributed 30.6 percent of total U.S. CO_2 emissions in 2008, with HD vehicles accounting for 22.4 percent of total U.S. CO_2 emissions from transportation. Thus, 6.9 percent of total U.S. CO_2 emissions come from HD vehicles. From a global perspective, HD vehicles in the United States account for roughly 1.2 percent of total global CO_2 emissions, as compared to 3.3 percent for U.S. light-duty vehicles.

Key Findings for Climate

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

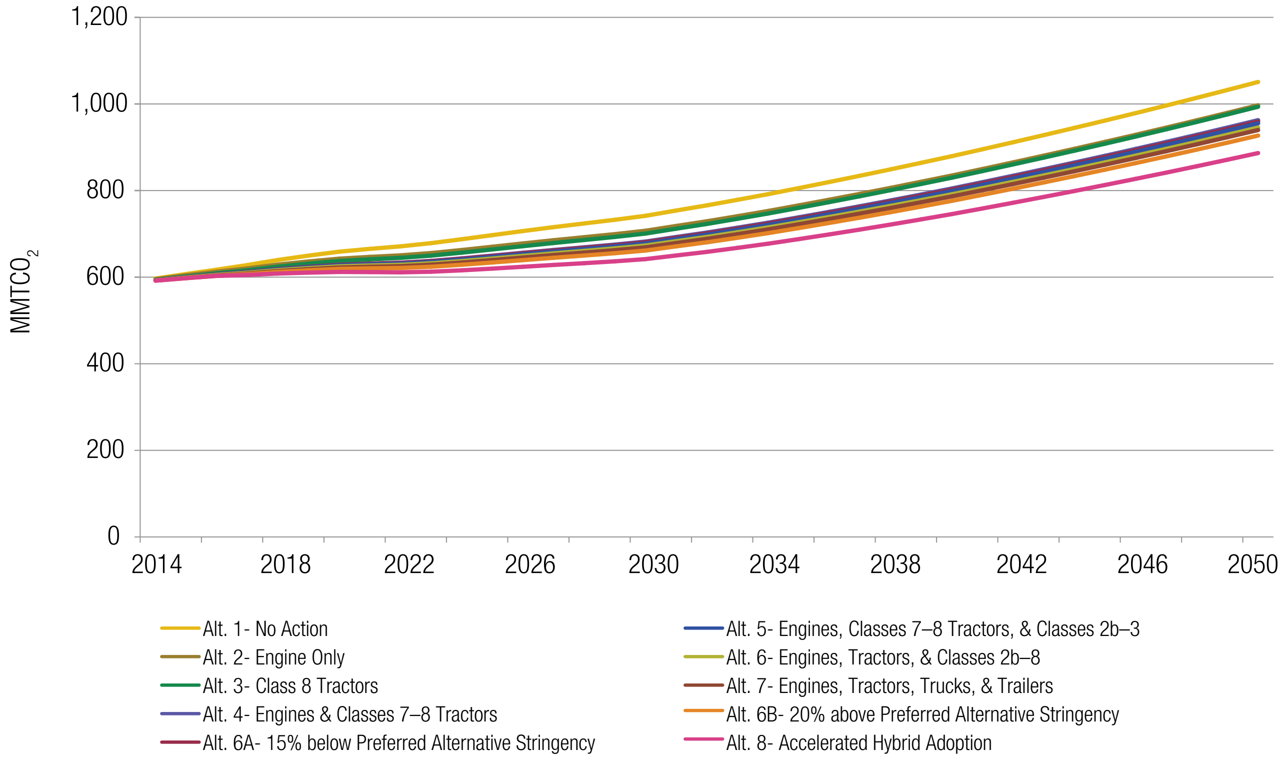
Note that under all alternatives analyzed in this EIS, growth in the number of HD vehicles in use throughout the United States, combined with assumed increases in their average use (annual VMT per vehicle), is projected to result in growth in total HD vehicle travel. This growth in travel outpaces improvements in fuel efficiency for each of the action alternatives, resulting in projected increases in total fuel consumption by HD vehicles in the United States (*see* Figure S-11).

Figure S-10. U.S. Transportation Sector's Contribution to U.S. CO_2 Emissions



Source: EPA (U.S. Environmental Protection Agency). 2010. Inventory of U.S. Greenhouse Gas Emissions and Sinks. Washington, D.C. EPA 430-R-10-006. 441 pgs. Last Revised: April 15, 2010. *Available at:* <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>. (Accessed: August 9, 2010).

Figure S-11. Projected Annual Greenhouse Gas Emissions (million metric tons) from HD Vehicles by Alternative, Direct and Indirect Impacts



Because CO_2 emissions are a direct consequence of fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles. NHTSA estimates that the proposed HD Fuel Efficiency Improvement Program will reduce fuel consumption and CO_2 emissions from what they otherwise are estimated to be in the absence of the program (*i.e.,* fuel consumption and CO_2 emissions under the No Action Alternative).

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

Below, estimates of GHG emissions and reductions (both direct and indirect effects and cumulative effects) are summed for the period 2014 through 2100 under each of the ten alternatives. Climate effects such as mean global increase in surface temperature and sea level rise are typically modeled to 2100 or longer due to the amount of time required for the climate system to show the effects of the greenhouse gas emissions (or in this case emission reductions). This inertia primarily reflects the amount of time required for the ocean to warm in response to the increased radiative forcing.

Direct and Indirect Effects

Greenhouse Gas Emissions

- Compared with total projected U.S. CO_2 emissions in 2100 of 7,193 million metric tons of carbon dioxide equivalent ($MMTCO_2$), the action alternatives would reduce total U.S. CO_2 emissions by 0.7 to 2.1 percent in 2100. Figure S-11 shows projected annual GHG emissions and reductions from HD vehicles by alternative.
- Compared with cumulative global emissions of 5,204,115 $MMTCO_2$ over this period, the action alternatives are expected to reduce annual global CO_2 emissions by between 0.1 percent (Alternative 2, Engine Only) and 0.2 percent (Alternative 8, Accelerated Hybrid Adoption).
- Average annual CO_2 emission reductions from the alternatives range from 44 to 134 $MMTCO_2$ over 2014–2100, equivalent to the annual CO_2 emissions of 11 to 35 coal-fired power plants.
- The emission reductions from the alternatives are equivalent to the annual emissions of between 0.54 million HD vehicles (Alternative 2) and 1.60 million HD vehicles (Alternative 8) in 2018, compared with the No Action Alternative. Emission reductions in 2018 from the Preferred Alternative (Alternative 6) are equivalent to the annual emissions of 1.20 million HD vehicles.

In January 2010, President Obama submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020, in association with the Copenhagen Accord, and in conformity with anticipated U.S. energy and climate legislation. Although this rulemaking contributes to meeting that goal, the alternatives would result in projected CO_2 emissions from the HD vehicle sector in 2020 in the range of 8.2 to 13.6 percent above 2005 levels. Thus, no alternative would reduce 2020 emissions from HD vehicles to 17 percent below 2005 levels, due to the fact that total VMT increases under all scenarios. *See* Figure S-12.

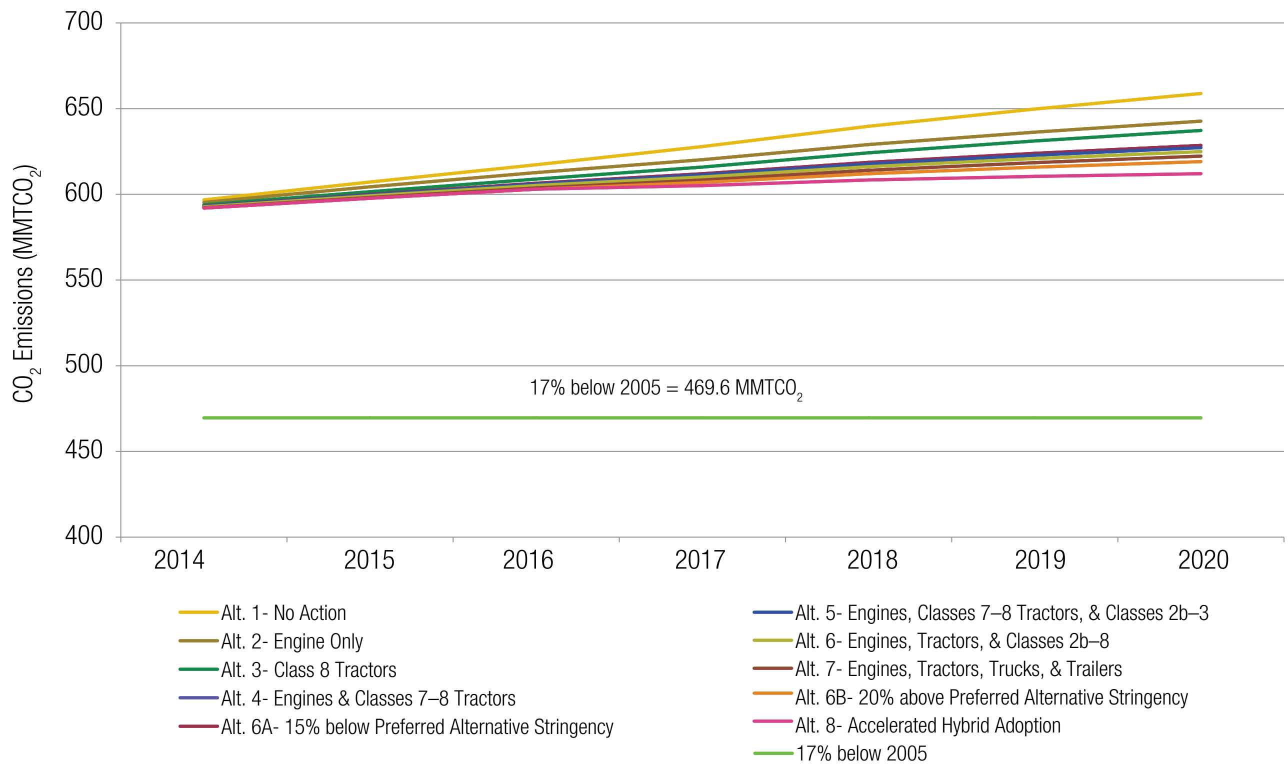
The President's stated policy goal outlined above does not specify that every emitting sector of the economy must contribute equally proportional emission reductions. Significantly, the action of setting standards under the HD Fuel Efficiency Improvement Program does not directly regulate total emissions from HD vehicles. *See* Section 3.4.4.1 of this EIS for additional discussion relating NHTSA's action to this policy goal.

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

CO_2 emissions affect the concentration of CO_2 in the atmosphere, which in turn affects global temperature, sea level, and precipitation patterns. For the analysis of direct and indirect effects, NHTSA used the GCAM reference scenario to represent the reference case emissions scenario; that is, future global emissions assuming no additional climate policy. The impacts of the proposed action and alternatives on temperature, precipitation, or sea-level rise are small in absolute terms, because the action alternatives result in a small proportional change to the emissions trajectories in the Reference Case scenario to which the alternatives were compared. Although these effects are small, they occur on a global scale and are long-lived.

- Estimated CO_2 concentrations in the atmosphere for 2100 range from 783.8 parts per million (ppm) under Alternative 8 (Accelerated Hybrid Option) to 784.9 ppm under the No Action Alternative (Alternative 1).
- For 2100, the reduction in temperature for the action alternatives, as compared to the No Action Alternative, ranges from 0.002 °F (0.001 °C) to 0.007 °F (0.004 °C). *See* Figure S-13.

Figure S-12. Projected Annual CO_2 Emissions from HD Vehicles by Alternative Compared with 17 Percent below 2005 Levels, Direct and Indirect Impacts



Note: CO_2 emissions for HD vehicles in 2005 are 565.8 $MMTCO_2$.

Figure S-13. Reduction in Global Mean Temperature Compared with the No Action Alternative, Direct and Indirect Impacts

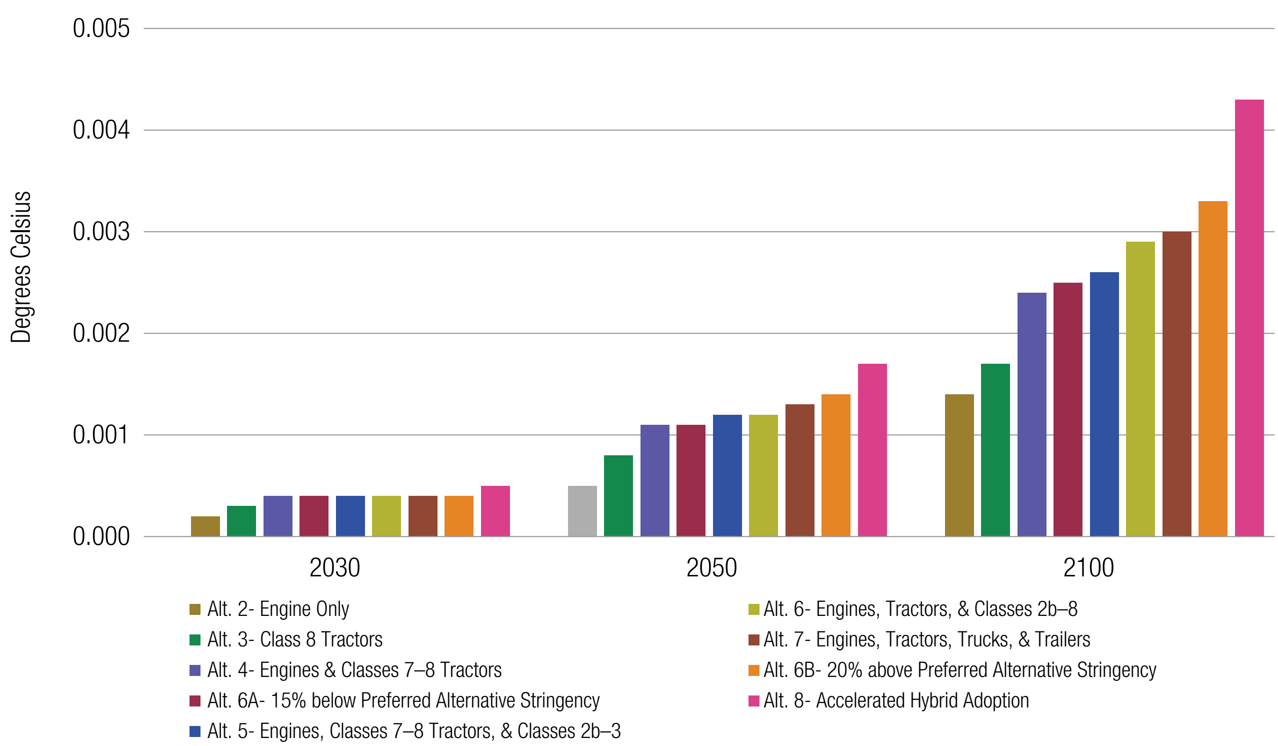
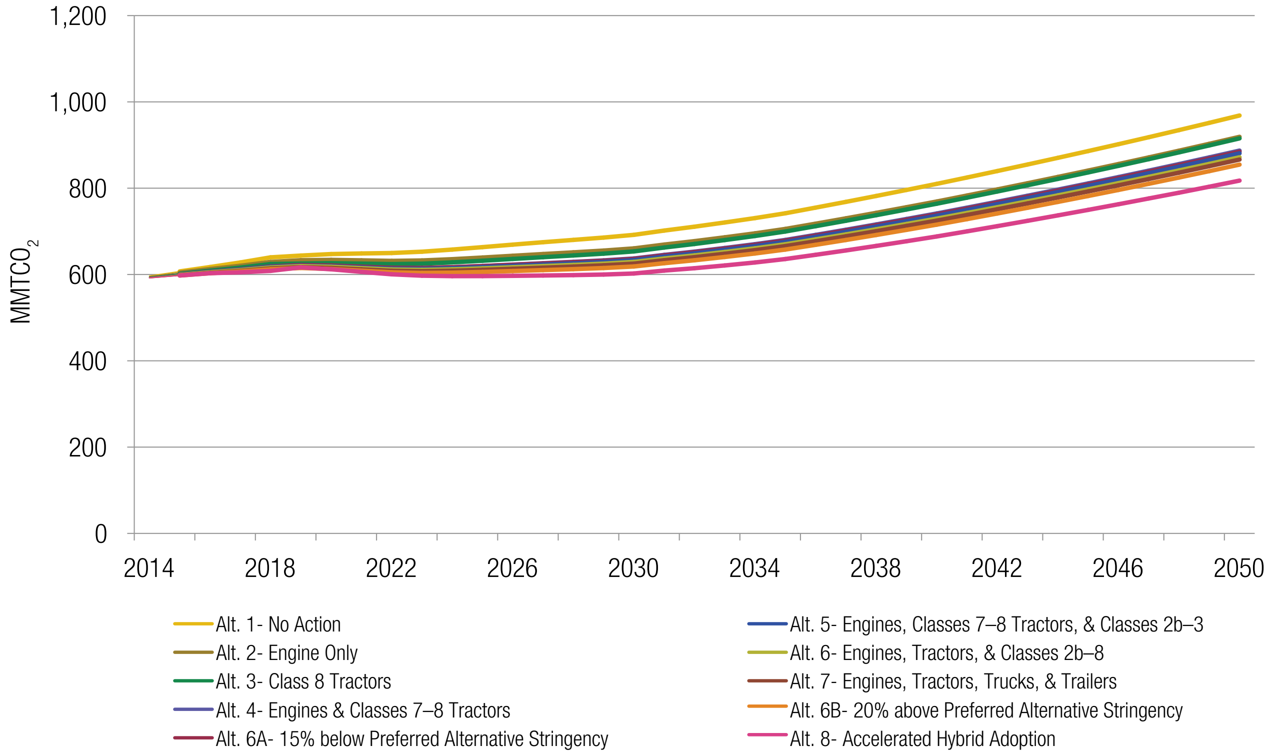


Figure S-14. Projected Greenhouse Gas Emissions from HD Vehicles by Alternative, Cumulative Impacts



- Projected sea-level rise in 2100 ranges from 14.72 inches (37.40 centimeters) under the No Action Alternative to 14.71 inches (37.36 centimeters) under Alternative 8. Thus, the action alternatives will result in a maximum reduction of sea-level rise equal to 0.016 inch (0.04 centimeter) by 2100 from the level projected under the No Action Alternative.
- For 2090, the reduction in global mean precipitation (percent change) for the action alternatives, as compared to the No Action Alternative, ranges from 0.00% to 0.01%.

Cumulative Effects

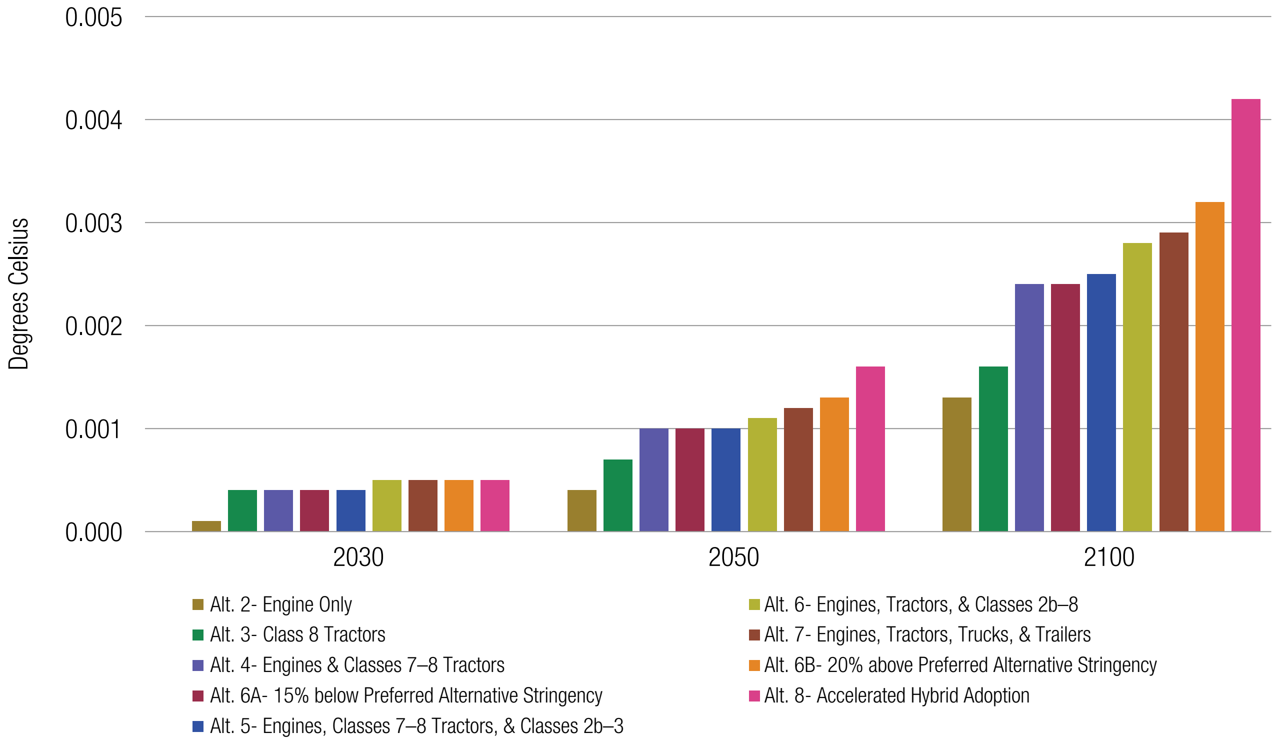
Greenhouse Gas Emissions

- Compared with projected global emissions of 4,294,482 $MMTCO_2$ from 2014 through 2100, the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.1 to 0.2 percent from their projected levels under the No Action Alternative. *See* Figure S-14.
- Projections of total emission reductions over the 2014 through 2100 period due to the HD standards and other reasonably foreseeable future actions (*i.e.,* forecasted fuel efficiency increases resulting from market-driven demand) range from 3,500 to 10,600 $MMTCO_2$.

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

- Estimated CO_2 concentrations in the atmosphere for 2100 range from 676.8 ppm under Alternative 8 (Accelerated Hybrid Option) to 677.8 ppm under the No Action Alternative.
- For 2100, the reduction in temperature increase for the action alternatives in relation to the No Action Alternative is about 0.002 to 0.007 ° F (0.001 to 0.004 °C). *See* Figure S-15.

Figure S-15. Reduction in Global Mean Temperature Compared with the No Action Alternative, Cumulative Impacts



- Projected sea-level rise in 2100 ranges from 13.16 inches (33.42 centimeters) under the No Action Alternative to 13.15 inches (33.39 centimeters) under Alternative 8. Thus, the action alternatives will result in a maximum reduction of sea-level rise equal to 0.01 inch (0.03 centimeter) by 2100 from the level that could occur under the No Action Alternative.

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

Health, Societal, and Environmental Impacts of Climate Change

The magnitude of the changes in climate effects that would be produced by the most stringent alternative is 1 ppm less of CO_2, less than one hundredth of a degree difference in temperature, one hundredth of one percent change in the rate of precipitation increase, and less than one-half millimeter of sea-level rise. These changes are too small to address quantitatively in terms of their impacts on health, society, and the environment. Given the enormous resource values at stake, these distinctions could be important, but they are too small for current quantitative techniques to resolve. For detailed discussion of the impacts of climate change on various resource sectors, *see* Section 4.5 of this EIS.

The changes in non-climate impacts (such as ocean acidification by CO_2) associated with the alternatives have also been assessed qualitatively. A reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce the ocean acidification effect and the CO_2 fertilization effect. For additional discussion of non-climate environmental impacts, *see* Section 3.5 of this EIS.

Chapter 1 Purpose and Need for the Proposed Action

1.1 INTRODUCTION

The Energy Policy and Conservation Act of 1975 (EPCA)[1] mandated that the National Highway Traffic Safety Administration (NHTSA) establish and implement a regulatory program for motor vehicle fuel economy.[2] As codified in Chapter 329 of Title 49 of the U.S. Code, and as amended by the Energy Independence and Security Act of 2007 (EISA),[3] EPCA sets forth extensive requirements concerning the establishment of average fuel economy standards for passenger automobiles and non-passenger automobiles, which are motor vehicles that weigh less than 10,000 pounds.[4] This regulatory program, known as the Corporate Average Fuel Economy Program (CAFE), was established to reduce national energy consumption by increasing the fuel economy of these automobiles.

EISA was enacted in December 2007, providing the U.S. Department of Transportation (DOT) (and by delegation, NHTSA) new authority to implement, via rulemaking and regulations, "a commercial medium- and heavy-duty on-highway vehicle[5] and work truck[6] fuel efficiency improvement program designed to achieve the maximum feasible improvement" for motor vehicles weighing more than 10,000 pounds.[7] This provision also directs NHTSA to "adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible for commercial medium- and heavy-duty on-highway vehicles and work trucks."[8] This new authority permits NHTSA to set "separate standards for different classes of vehicles."[9] The commercial medium-duty and heavy-duty (HD) on-highway vehicles and work trucks are hereinafter referred to collectively as HD vehicles.[10] EISA also provides for

[1] EPCA was enacted to serve the Nation's energy demands and promote energy conservation when feasibly obtainable. EPCA is codified at 49 U.S.C. § 32901 *et seq.*

[2] EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States. The Secretary delegated responsibility for implementing EPCA fuel economy requirements to NHTSA. 49 CFR §§ 1.50, 501.2(a)(8).

[3] Pub. L. No. 110-140, 121 Stat. 1492 (Dec. 19, 2007) (codified in scattered sections of the U.S. Code). EISA amends and builds on EPCA by setting out a comprehensive energy strategy for the 21st Century addressing renewable fuels and the reduction of fuel consumption from all motor vehicle sectors.

[4] 49 U.S.C. §§ 32901(a)(3), (a)(17)-(18).

[5] EISA added the following definition to the automobile fuel economy chapter of the U.S. Code: "commercial medium- and heavy-duty on-highway vehicle" means an on-highway vehicle with a gross vehicle weight rating of 10,000 pounds or more. 49 U.S.C. § 32901(a)(7).

[6] EISA added the following definition to the automobile fuel economy chapter of the U.S. Code: "work truck" means a vehicle that – (A) is rated at between 8,500 and 10,000 pounds gross vehicle weight; and (B) is not a medium-duty passenger vehicle (as defined in section 86.1803–01 of title 40, Code of Federal Regulations, as in effect on the date of the enactment of [EISA]). 49 U.S.C. § 32901(a)(19).

[7] 49 U.S.C. § 32902(k)(2).

[8] *Id.*

[9] *Id.*

[10] For purposes of this EIS, the term "heavy-duty" or "HD" applies to all highway vehicles and engines that are not within the range of light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles (MDPV) covered by the greenhouse gas and CAFE standards issued for model years (MY) 2012–2016. The term does not include motorcycles. In addition, for the purpose of this EIS, the term also does not include recreational vehicles. Under EISA, NHTSA is required to set standards for "commercial medium- and heavy-duty on-highway vehicles and work trucks." NHTSA interprets this requirement to include all categories of the heavy-duty vehicle categories described above, except for recreational vehicles, such as motor homes, because recreational vehicles are not commercial. For background on the HD vehicle segment, and fuel efficiency improvement technologies available for those vehicles, *see* the report recently issued by the National Academy of Sciences (NAS 2010), Transportation Research Board, National Research Council, Committee to Assess Fuel Economy Technologies for Medium-and Heavy-Duty Vehicles, "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles."

regulatory lead time and regulatory stability. The HD Fuel Efficiency Improvement Program NHTSA adopts pursuant to EISA must provide not fewer than four full model years of regulatory lead time and three full model years of regulatory stability.[11] Consistent with these requirements, NHTSA is proposing mandatory standards to begin in model year (MY) 2016 and to remain stable for three model years. Although EISA prevents NHTSA from enacting mandatory standards before MY 2016, NHTSA is proposing optional voluntary compliance standards for MYs 2014–2015 prior to mandatory regulation in MY 2016. As directed by EISA, this HD vehicle rulemaking is being conducted in consultation with the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE).[12]

In summary, the EISA directives at 49 U.S.C. § 32902(k)(2) and (k)(3) contain the following requirements specific to the HD Fuel Efficiency Improvement Program: (1) the program must be "designed to achieve the maximum feasible improvement;" (2) the various required aspects of the program must be appropriate, cost effective, and technologically feasible for HD vehicles; and (3) the standards adopted under the program must provide no fewer than four model years of regulatory lead time and three model years of regulatory stability. In considering these requirements, NHTSA will also account for relevant environmental and safety considerations.

Further guiding the establishment of NHTSA's HD Fuel Efficiency Improvement Program, President Obama issued a memorandum on May 21, 2010 entitled "Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks" to the Secretary of Transportation, the Administrator of NHTSA, the Administrator of EPA, and the Secretary of Energy. [13] The memorandum requested that the Administrators of EPA and NHTSA begin work on a Joint Rulemaking under EISA and the Clean Air Act (CAA) and establish fuel efficiency and greenhouse gas (GHG) emission standards for commercial medium- and heavy-duty vehicles beginning with MY 2014, with the aim of issuing a Final Rule by July 30, 2011. The Notice of Proposed Rulemaking (NPRM) for NHTSA's HD Fuel Efficiency Improvement Program and this accompanying environmental impact statement (EIS) are consistent with this directive.

The President requested that, before promulgating a final rule, the Administrators of EPA and NHTSA "Propose and take comment on strategies, including those designed to increase the use of existing technologies, to achieve substantial annual progress in reducing transportation sector emissions and fossil fuel consumption …" The President also requested that NHTSA implement fuel efficiency standards and EPA implement GHG emission standards that take into account the market structure of the trucking industry and the unique demands of heavy-duty vehicle applications; seek harmonization with applicable State standards; consider the findings and recommendations published in the National Academy of Sciences (NAS) report on medium- and heavy-duty truck regulation; strengthen the industry and enhance job creation in the United States; and seek input from all stakeholders, while recognizing the continued leadership role of California and other States.

1.2 JOINT RULEMAKING AND NATIONAL ENVIRONMENTAL POLICY ACT PROCESS

NHTSA and EPA are proposing rules under each agency's respective statutory authorities that together comprise a coordinated and comprehensive HD National Program. The proposed rules would result in substantial improvements in fuel efficiency and reductions in GHG emissions from HD vehicles,

[11] 49 U.S.C. § 32902(k)(3).
[12] 49 U.S.C. § 32902(k)(2).
[13] The White House, Office of the Press Secretary, *Presidential Memorandum Regarding Fuel Efficiency Standards* (May 21, 2010) (White House 2010a); The White House, Office of the Press Secretary, *President Obama Directs Administration to Create First-Ever National Efficiency and Emissions Standards for Medium- and Heavy-Duty Trucks* (May 21, 2010) (White House 2010b).

based on technology that is, for the most part, already being commercially applied and can be incorporated at a reasonable cost.

The HD Fuel Efficiency Improvement Program promises to deliver additional environmental and energy benefits, cost savings, and administrative efficiencies on a nationwide basis that might not be available under a less coordinated approach. It also offers the prospect of regulatory convergence by making it possible for the programs of two Federal agencies to act together in providing these benefits. Thus, the program might also help to mitigate the additional costs that manufacturers would otherwise face by having to comply with multiple Federal programs.

Under the National Environmental Policy Act (NEPA),[14] a Federal agency must analyze environmental impacts if the agency implements a proposed major Federal action, provides funding for that 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).[15] To inform its development of the HD Fuel Efficiency Improvement Program required under EISA, NHTSA prepared this EIS to analyze and disclose the potential environmental impacts of a proposed preferred alternative and other proposed alternative actions pursuant to Council on Environmental Quality (CEQ) NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.[16] This EIS compares the potential environmental impacts among alternatives, including a No Action Alternative. It also analyzes the potential direct, indirect, and cumulative impacts of the alternatives and discusses impacts in proportion to their significance.

1.2.1 Building Blocks of the HD National Program

The standards that are being proposed represent the first time that NHTSA and EPA would regulate the HD vehicle sector for fuel consumption and GHG emissions. NHTSA and EPA are proposing standards for HD vehicles and engines that are rooted in EPA’s prior regulatory and voluntary program history, the recent National Program regulating fuel economy and GHG emissions for light-duty vehicles, and extensive technical and engineering analyses conducted at the Federal level. This section summarizes some of the most important precursors and foundations for this HD National Program.

1.2.1.1 EPA’s Regulatory and Voluntary Program History

Since the 1980s, EPA has acted several times to address tailpipe emissions of criteria pollutants and air toxics from HD vehicles and engines. During the past 18 years, these programs have primarily addressed emissions of ozone precursors (hydrocarbons and nitrogen oxides [NO_x] and particulate matter [PM]). These programs have successfully achieved significant and cost-effective reductions in emissions and associated health and welfare benefits for the Nation. The programs have been structured to account for the varying circumstances of the engine and truck industries: They have regulated various classes of HD vehicles differently to account for the various sizes and work requirements that characterize HD vehicles and their engines. As required by the CAA, the emission standards implemented by these programs include standards that apply at the time the vehicle or engine is sold and that apply in actual use. As a result of these programs, new vehicles meeting current emission standards will emit 98 percent less

[14] 42 U.S.C. §§ 4321–4347.
[15] 42 U.S.C. § 4332.
[16] NEPA is codified at 42 U.S.C. §§ 4321–4347. The CEQ NEPA implementing regulations are codified at 40 CFR Parts 1500–1508, and the NHTSA NEPA implementing regulations are codified at 49 CFR Part 520.

NO_x and 99 percent less PM than similar vehicles did 20 years ago.[17] The most recent EPA regulations, which were fully phased in during MY 2010, are projected to provide more than $70 billion in health and welfare benefits annually in 2030 alone.[18]

EPA's overall program goal has always been to achieve emission reductions from the complete suite of vehicles that operate on our highways. The agency often has accomplished this goal for many HD vehicle categories by regulating engine emissions. A key part of this success has been the development over many years of a well-established, representative, and robust set of engine test procedures that industry and EPA now routinely use to measure emissions and determine compliance with emission standards. These test procedures, in turn, serve the overall compliance program that EPA implements to help ensure that emission reductions are being achieved. By isolating the engine from the many variables involved when the engine is installed and operated in an HD vehicle, EPA has been able to accurately address the contribution of the engine alone to overall emissions. This EIS discusses how the proposed program incorporates the existing engine-based approach, as well as new vehicle-based approaches.

EPA's voluntary SmartWay Transport Partnership program encourages shipping and trucking companies to take actions that reduce fuel consumption, carbon dioxide (CO_2) emissions, and criteria pollutant emissions, by working with the freight sector to identify low-carbon strategies and technologies and by providing technical information, financial incentives, and partner recognition to accelerate the adoption of these strategies (EPA 2010a). Through the SmartWay program, EPA has worked closely with truck manufacturers and truck fleets to develop test procedures for evaluating vehicle and component performance in reducing fuel consumption and has conducted testing and established test programs to verify technologies that can achieve such reductions. Over the past six years, EPA has developed hands-on experience testing the largest heavy-duty trucks and evaluating improvements in tire and vehicle aerodynamic performance. In 2010, according to vehicle manufacturers, approximately 5 percent of new combination heavy-duty trucks will meet the SmartWay performance criteria, demonstrating that they represent the pinnacle of current heavy-duty truck reductions in fuel consumption.

The SmartWay program includes operational approaches that both truck fleet owners and individual drivers can incorporate which NHTSA and EPA believe will reinforce the proposed standards. These include such approaches as improved logistics and driver training. These complementary SmartWay mechanisms can also provide benefits for the existing truck fleet, furthering the public policy objectives of addressing energy security and climate change.

1.2.1.2 The Recent NHTSA and EPA Light-Duty National GHG Program

On April 1, 2010, EPA and NHTSA finalized the first-ever National Program for light-duty cars and trucks, which set GHG and fuel economy standards for MYs 2012-2016.[19] In certain respects, the agencies have used the Light-Duty National Program as a model for this proposed HD National Program. This is most apparent in the case of medium-duty pickups and vans, which are very similar to the light-duty trucks addressed in the Light-Duty National Program both technologically and in terms of how they are manufactured (*i.e.,* the same company often makes both the vehicle and the engine). For these vehicles, there are close parallels to the light-duty program in how the agencies have developed respective

[17] MY 1984 heavy-duty engines met standards of 10.7 grams per brake-horsepower-hour (g/bhp-hr) NO_x and 0.6 g/bhp-hr PM; MY 2007 and later heavy-duty engines meet standards of 0.2 g/bhp-hr NO_x and 0.01 g/bhp-hr PM.
[18] 66 *FR* 5106 (Jan. 18, 2001).
[19] *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule*, 75 *FR* 25324 (May 7, 2010).

proposed standards and compliance structures, although for this current Rule each agency is proposing standards based on attributes other than vehicle footprint, as discussed below.

Due to the diversity of the remaining HD vehicles, there are fewer parallels with the structure of the light-duty program; the agencies, however, have maintained the same collaboration and coordination that characterized the development of the light-duty program. Most notably, as with the light-duty program, manufacturers will be able to design and build to meet the requirements of a closely coordinated Federal program and avoid unnecessarily duplicative testing and compliance burdens.

1.2.1.3 National Academy of Sciences Report

As mandated by Congress in EISA, the National Research Council (NRC) of NAS recently issued a report to NHTSA and Congress that evaluates medium-duty and heavy-duty truck fuel efficiency improvement opportunities, titled "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-duty Vehicles" (NAS 2010). This study covers the same universe of HD vehicles that is the focus of this proposed rulemaking – all highway vehicles that are not light-duty, medium-duty passenger vehicles (MDPVs), or motorcycles. The agencies have carefully evaluated the research supporting this report and its conclusions and have taken them into consideration in the development of this rulemaking.

1.3 PROPOSED ACTION

For this EIS, NHTSA's proposed action is to set HD vehicle fuel consumption standards, in accordance with the EISA mandate to "implement a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program."[20] NHTSA and EPA are proposing coordinated and harmonized fuel consumption[21] and GHG emission standards for HD vehicles to be built in MYs 2014–2018. NHTSA is proposing mandatory standards for HD vehicles beginning in MY 2016 and voluntary compliance standards for HD vehicles for MYs 2014–2015.

Reducing HD fuel consumption and GHG emissions requires increasing the inherent efficiency of the engine and reducing the work that needs to be done per mile traveled. This objective requires a focus on the entire vehicle. For example, in addition to the basic emissions and fuel consumption levels of the engine, the aerodynamics of the vehicle can have a major impact on the amount of work that must be performed to transport freight. NAS recommended this focus on both the engine and the rest of the vehicle in its March 2010 report referenced above. The proposed standards that make up the HD National Program aim to address the complete vehicle, to the extent practicable and appropriate under the agencies' respective statutory authorities, through complementary engine and vehicle standards.

1.3.1 HD Vehicle Categories Covered by the Proposed Standards

NHTSA and EPA are proposing standards applicable to all highway vehicles and engines that are not regulated by the light-duty vehicle, light-duty truck, and medium-duty passenger vehicle greenhouse

[20] 49 U.S.C. § 32902(k)(2).

[21] NHTSA's proposed action will be to set fuel consumption standards, as opposed to the fuel economy standards that the agency sets under the CAFE program for light-duty vehicles. Whereas fuel economy measures the distance a vehicle can travel with a gallon of fuel, and is expressed in miles per gallon (mpg), fuel consumption is the inverse metric – the amount of fuel consumed in driving a given distance. (NAS 2010). Fuel consumption is a useful measurement because it is directly related to the goal of decreasing the amount of fuel necessary for an HD vehicle to travel a given distance. Fuel consumption standards satisfy EISA's directive that NHTSA implement a fuel efficiency improvement program because the more efficient an HD vehicle is in completing its work, the less fuel it will consume to move cargo a given distance.

gas and CAFE standards issued for MYs 2012–2016. Thus, in the agencies' proposed rule and in the EIS, unless specified otherwise, the covered vehicle classes include all vehicles rated at a gross vehicle weight rating (GVWR) greater than 8,500 pounds (except for MDPVs) and the engines that power these vehicles. EISA Section 103(a)(3) defines a 'commercial medium- and heavy-duty on-highway vehicle' as an on-highway vehicle with a GVWR of 10,000 pounds or more.[22] EISA Section 103(a)(6) defines a "work truck" as a vehicle that is rated at between 8,500 and 10,000 pounds gross vehicle weight and is not a medium-duty passenger vehicle.[23] Therefore, in this EIS, the term "HD vehicles" refers to both work trucks and commercial medium- and heavy-duty on-highway vehicles, as defined by EISA. For the purpose of this EIS only, this term does not include recreational vehicles. Under EISA, NHTSA is required to set standards for "commercial medium- and heavy-duty on-highway vehicles and work trucks." NHTSA interprets this requirement to include all categories of the heavy-duty category described above, except for recreational vehicles, such as motor homes, because recreational vehicles are not commercial.

HD engines affected by the proposed standards are generally those installed in commercial medium- and heavy-duty trucks. This term excludes engines installed in vehicles certified to a complete vehicle emission standard based on a chassis test, because these are addressed as a part of those complete vehicles. It also excludes engines used exclusively for stationary power when the vehicle is parked.

EPA and NHTSA are proposing to defer the proposed greenhouse gas emission and fuel consumption standards temporarily for any manufacturers of HD engines, combination tractors, and vocational vehicles that meet the "small business" size criteria set by the Small Business Administration (SBA). The agencies are not aware of any manufacturers of HD pickups and vans that meet these criteria. For each of the other categories and for engines, NHTSA and EPA have identified a small number of manufacturers that appear to meet the SBA criteria. The production of these companies is small, and the agencies believe that deferring the standards for these companies at this time would have a negligible impact on the GHG emission reductions and fuel consumption reductions that the program would otherwise achieve. The specific deferral provisions are discussed in detail in Section III of the NPRM.

NHTSA and EPA are proposing standards for each of the following categories, which together comprise all HD vehicles and all engines used in such vehicles:

- **Combination Tractors (Classes 7 and 8)**

  Heavy-duty combination trucks are built to move freight. The ability of a truck to meet a customer's freight transportation requirements depends on three major characteristics of the tractor: the GVWR (which along with gross combined weight rating [GCWR] establishes the maximum carrying capacity of the tractor and trailer), cab type (sleeper cabs provide overnight accommodations for drivers), and the tractor roof height (to mate tractors to trailers for the most fuel-efficient configuration). Each of these attributes impacts the baseline fuel consumption and GHG emissions, as well as the effectiveness of possible technologies like aerodynamics, and is discussed in more detail in Section III.B of the NPRM. Class 7 trucks, which have a GVWR of 26,000 to 33,000 pounds and a typical GCWR of 65,000 pounds,

[22] *Codified at* 49 U.S.C. § 32901(a)(7).

[23] EISA Section 103(a)(6) is codified at 49 U.S.C. § 32901(a)(19). EPA defines medium-duty passenger vehicles as any complete vehicle between 8,500 and 10,000 pounds GVWR designed primarily for the transportation of persons that meet the criteria outlined in 40 CFR § 86.1803-01. The definition specifically excludes any vehicle that (1) has a capacity of more than 12 persons total or (2) is designed to accommodate more than 9 persons in seating rearward of the driver's seat or (3) has a cargo box (*e.g.*, pickup box or bed) of 6 feet or more in interior length. (*See* the Tier 2 final rulemaking, 65 *FR* 6698 [Feb. 10, 2000]).

have a lesser payload capacity[24] than Class 8 trucks. Class 8 trucks have a GVWR of greater than 33,000 pounds and a typical GCWR of 80,000 pounds. As discussed in Section IX of the NPRM, under the Preferred Alternative the agencies would not regulate GHG emission and fuel consumption standards for trailers at this time.

- **HD Pickup Trucks and Vans (Classes 2b and 3)**

  HD vehicles with a GVWR of 8,501 to 10,000 pounds are classified in the industry as Class 2b motor vehicles. As discussed above, Class 2b includes MDPVs that the agencies regulate under the light-duty vehicle program, and the agencies are not considering additional requirements for MDPVs in this rulemaking. HD vehicles with GVWR of 10,001 to 14,000 pounds are classified as Class 3 motor vehicles. NHTSA and EPA are proposing to regulate Class 2b and Class 3 HD vehicles (referred to in the EIS as "HD pickups and vans") together using an approach similar to that used in the current CAFE program and EPA's GHG emission standards for light-duty vehicles.

- **Vocational Vehicles (Classes 2b through 8)**

  Classes 2b–8 vocational trucks (*i.e.,* vehicles) consist of a very wide variety of configurations including delivery, refuse, utility, dump, tow, and cement trucks; transit, shuttle, and school buses, emergency vehicles; and motor homes, among others. The agencies are defining Classes 2b–8 vocational vehicles as all HD vehicles not included in the HD pickup and van or Class 7 and 8 tractor segments. As noted above, this also does not include vehicles for which the agencies are proposing to defer the setting of standards, such as small business manufacturers. In addition, in accordance with the agencies' respective statutory authorities, recreational vehicles are included under EPA's proposed standards but are not included under NHTSA's proposed standards.

The agencies' scope is the same with the exception of recreational vehicles (or motor homes). As noted above, EISA requires NHTSA to set standards for "commercial medium- and heavy-duty on-highway vehicles and work trucks."[25] NHTSA interprets this requirement as pertaining to all categories of the HD vehicle sector described above, except for recreational vehicles, such as motor homes because recreational vehicles are not commercial vehicles. EPA is proposing to include recreational on-highway vehicles within its rulemaking, while NHTSA is limiting the scope of its proposed action to commercial vehicles, which would exclude recreational vehicles.

1.3.2 Program Flexibilities for Achieving Compliance

The HD National Program is intended to provide compliance flexibility to manufacturers. NHTSA and EPA believe that incorporating carefully structured regulatory flexibility provisions into the overall program is an important way to achieve each agency's goals for the program. This flexibility would allow sufficient lead time for technological improvements and additions to be made while reducing the cost of the program without compromising overall environmental and fuel efficiency objectives. The proposed flexibility provisions enable the agencies to consider more stringent overall standards that would become effective sooner than if the agencies were to implement a more rigid program in which all of a manufacturer's similar vehicles or engines would be required to achieve the same emission or fuel consumption levels, and at the same time.

[24] Payload is determined by a tractor's GVWR and GCWR relative to the weight of the tractor, trailer, fuel, driver, and equipment.
[25] 49 U.S.C. § 32902(k)(2).

NHTSA's and EPA's proposed flexibility provisions are essentially identical in structure and function. As described below, the proposed standards include flexibility provisions that separately apply to each HD vehicle type.

For HD pickups and vans, the agencies are proposing a fleet averaging system, without restriction, that is very similar to the light-duty GHG and CAFE fleet averaging system.

For Classes 7 and 8 combination tractor and Classes 2b–8 vocational vehicle categories and for HD engines, the agencies are proposing two primary types of flexibility – averaging, banking, and trading (ABT) provisions and innovative technology credit provisions.

The proposed ABT provisions are patterned on existing EPA ABT programs and would enable a vehicle manufacturer to reduce CO_2 emission and fuel consumption levels further than the level of the standard for one or more vehicles so that ABT credits could be earned. The manufacturer can then use those credits to offset higher emission or fuel consumption levels in other similar vehicles, "bank" the credits for later use, or "trade" the credits to another manufacturer. The agencies are proposing similar ABT provisions for manufacturers of HD engines. To ensure that the overall emission and fuel consumption reductions of the program are achieved, the agencies are proposing to restrict the use of averaging for Classes 7 and 8 combination tractor and Classes 2b–8 vocational vehicle categories and for HD engines to limited sets of vehicles and engines expected to have similar emission or fuel consumption characteristics. For example, averaging would be allowed among Class 7 low-roof day cab vehicles, but not among Class 7 low-roof day cabs and Class 8 sleeper cabs. Similarly, averaging would not be allowed between vocational vehicles and Class 8 combination trucks. Also, NHTSA and EPA propose that credits generated by vehicles not be applicable to engine compliance, and vice versa.

In addition to ABT, the agencies propose to encourage manufacturers to introduce new and innovative technologies capable of reducing fuel consumption and CO_2 emissions through special credits for such technologies. These innovative technology credits would apply to technologies that can produce emission and fuel consumption reductions that are not adequately recognized in the current test procedures and that are not yet in widespread use. Manufacturers would need to quantify the reductions in fuel consumption and CO_2 emissions that the technology could achieve, above and beyond those achieved on the existing test procedures. As with ABT, the agencies propose that the use of innovative technology credits be allowed only among vehicles and engines expected to have similar emission and fuel consumption characteristics (*e.g.*, within each of the Classes 7 and 8 combination tractor classifications, or within each of the Classes 2b–8 vocational vehicle classifications).

Finally, NHTSA and EPA propose to encourage manufacturers of Classes 2b–8 vocational vehicles to incorporate hybrid powertrains to drive the work features of the vehicles (*e.g.*, utility buckets, refuse compactors) through an additional type of credit. The agencies propose that such hybrid powertrain credits be quantified by either a vehicle- or an engine-based method, as discussed in Section V of the NPRM. Unlike credits generated under the other proposed flexibility provisions, hybrid powertrain credits generated for any vocational vehicle could be used broadly toward compliance by any HD vehicle or engine. The agencies propose the greater portability for these credits so that incentives are created to use this promising technology and thereby further its acceptance in the HD sector, with the associated CO_2 emission and fuel consumption reduction benefits.

1.4 PURPOSE AND NEED

NEPA requires that a proposed action's alternatives be developed based on the action's purpose and need. The purpose and need statement explains why the action is needed, describes the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the

NEPA analysis.[26] As discussed above, in accordance with EISA, NHTSA must establish a fuel efficiency improvement program for HD vehicles "designed to achieve the maximum feasible improvement, and [must] adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible for commercial medium- and heavy-duty on-highway vehicles and work trucks."[27] The standards adopted under NHTSA's Fuel Efficiency Improvement Program must provide not fewer than four model years of lead time and three model years of regulatory stability. In considering these various requirements, NHTSA will also account for relevant environmental and safety requirements.

As described in Section 1.1, NHTSA is also guided by President Obama's memorandum of May 21, 2010.

1.5 COOPERATING AGENCIES

Under 40 CFR § 1501.6, a Federal agency that has special expertise with respect to any environmental issue that should be addressed in the EIS may be a cooperating agency upon request of the lead agency. On May 25, 2010, NHTSA invited EPA and the Federal Motor Carrier Safety Administration (FMCSA) to become cooperating agencies with NHTSA in the development of the EIS for the HD rulemaking. EPA has special expertise in the areas of climate change and air quality and FMCSA has special expertise in HD vehicles.

The mission of EPA is to protect human health and the environment. EPA is 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, EPA-issued National Pollutant Discharge Elimination System permits for new sources, and for certain projects funded through EPA annual Appropriations Acts. EPA actions under the CAA , however, including EPA's proposed HD vehicle GHG emission standards, are not subject to the requirements of NEPA. Because of the nearly complete overlap of the impacts of NHTSA's and EPA's proposed fuel consumption and GHG emission standards, NHTSA's analysis of the direct and indirect impacts of its action are identical to the EPA environmental analysis of its proposed GHG emission standards (with the exception of motor homes regulated under the EPA GHG standards but not under the NHTSA fuel consumption standards). The EPA environmental analysis of its proposed rulemaking is summarized in the draft Regulatory Impact Analysis (RIA) available at www.regulations.gov in docket number NHTSA-2010-0079.[28]

FMCSA's primary mission is to prevent fatalities and crashes involving commercial motor vehicles (CMVs). CMVs are large trucks and buses (as defined in 49 CFR Section 383.5[29]) that are the subject of the regulations proposed concurrently with this EIS. Although NHTSA retains jurisdiction over vehicle safety standards applicable at the time of CMV manufacture, FMCSA regulates the operation and maintenance of these vehicles, and performs enforcement activities such as roadside inspections of brake systems. FMCSA also regulates drivers and motor carriers. This close working relationship with CMV drivers and motor carriers, and depth of knowledge regarding the vehicles subject to the proposed regulation, enables FMCSA to assist NHTSA by providing expertise on the trucking industry and the

[26] 40 CFR §1502.13.
[27] 49 U.S.C. § 32902(k)(2).
[28] 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 § 1508.25. For the purposes of this EIS, however, NHTSA has decided to treat EPA's proposed rule as if it were a "connected action" under that regulation to improve the usefulness of the EIS for NHTSA decisionmakers and the public. NHTSA is aware that Section 7(c) of the Energy Supply and Environmental Coordination Act of 1974 (15 U.S.C. § 793(c)(1)) expressly exempts EPA action taken under the CAA from NEPA's requirements.
[29] Note that FMCSA's definition of CMV differs from the population of vehicles included in this rulemaking.

operation and maintenance of CMVs, and to coordinate any necessary associated policy or regulatory action on FMCSA's part.

In its invitation letters, NHTSA suggested that EPA's and FMCSA's roles in the development of the EIS could include the following, as they relate to the agencies' areas of special expertise:

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

EPA and FMCSA accepted NHTSA's invitation and agreed to become cooperating agencies. Both agencies' staff participated in technical discussions and reviewed and commented on draft sections of the EIS.

1.6 PUBLIC REVIEW AND COMMENT

On June 14, 2010, NHTSA published a Notice of Intent (NOI) to prepare an EIS for the new HD Fuel Efficiency Improvement Program.[30] The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[31] by requesting public input on the scope of the environmental analysis to be conducted. Two important purposes of scoping are identifying the substantial environmental issues that merit in-depth analysis in the EIS and identifying and eliminating from detailed analysis the environmental issues that are not substantial and therefore require only brief discussion in the EIS.[32] Scoping should "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[33] Consistent with NEPA and its implementing regulations, NHTSA subsequently mailed the NOI to:

- 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 agencies within DOT;
- The Governors of every State and U.S. territory;
- Organizations representing State and local governments;
- Native American tribal organizations and academic centers that have issued reports on tribal communities and climate change; and

[30] *Notice of Intent to Prepare an Environmental Impact Statement for New Medium- and Heavy-Duty Fuel Efficiency Improvement Program*, 75 *FR* 33565 (June 14, 2010).
[31] 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.
[32] *See* 40 CFR §§ 1500.4(g) and 1501.7(a).
[33] 40 CFR § 1500.4(g).

- Contacts at other stakeholder organizations that NHTSA reasonably expects to be interested in the NEPA analysis for the HD Fuel Efficiency Improvement Program, including vehicle manufacturers, industry organizations, environmental organizations, and other organizations.

1.6.1 Summary of Scoping Comments

NHTSA received 37 responses to its scoping notice. One Federal agency, 5 State agencies, 8 advocacy groups, 17 industry organizations, and 6 individuals provided comments. To view the full comment letters, visit www.regulations.gov and enter the search term "NHTSA-2010-0079," which corresponds to the docket number for this rulemaking. All comments will be displayed within the search results. The draft RIA, referenced in the comment summaries, can also be found in docket number NHTSA-2010-0079.

Several comments, including some from State agencies, advocacy groups, industry organizations, and individuals, went beyond the traditional scoping inquiry related to the nature and content of the environmental analysis. For example, some comments expressed preference for a particular regulatory alternative or urged the removal of an alternative or group of alternatives from consideration. Other comments raised concerns about costs or economic effects on the HD vehicle industry or on some portion of that industry, and recommended such approaches as delayed implementation or relaxed stringency for portions of the industry. Still other comments questioned the regulatory lead time or suggested delayed regulatory enforcement. Finally, various comments raised concerns about the use of computer-simulated models to determine compliance or advocated a "whole vehicle" approach to measuring compliance, rather than the setting of separate standards for different vehicle categories within the HD fleet.

Comments of this nature are more directly relevant to the agency's final decision under the rulemaking than they are to determining the scope of the environmental analysis or identifying those impacts that should be analyzed in-depth and those that require less detailed consideration. NHTSA will evaluate these comments in light of all other substantive comments received prior to making a final decision and issuing the final rule. Although NHTSA acknowledges that there are some areas of overlap, the comments summarized below focus more specifically on the scoping process.

1.6.1.1 Federal Agencies

The Centers for Disease Control and Prevention (CDC) was the only Federal agency that provided scoping comments (Docket No. NHTSA-2010-0079-0035).

CDC suggested that NHTSA gather baseline health data to evaluate impacts of the new fuel efficiency regulations on environmental health. CDC also indicated that the scope of impacts being assessed be broadened to include public and environmental health concerns like the correlation between fuel efficiency, air particulates, and cardiac and respiratory disease; the potential for increased occurrences of heat stroke and vector- and water-borne diseases and the worsening of heart failure due to climate change; the potential for changes in road traffic injuries and accident; and the implications of potential decreases in noise and odor on health. CDC suggested that the potential connection between the use of alternative fuels and health effects be considered as well. CDC suggested that NHTSA evaluate the potential impact that the cost associated with increasing the standards might have on the employee health care coverage that trucking companies and manufacturers are able to provide.

This EIS includes a quantitative analysis of the impacts of the alternatives on various health measures, including mortality, chronic bronchitis, emergency room visits associated with asthma, and work loss days. *See* Section 3.3. In addition, NHTSA includes qualitative discussions of the impacts of the proposed standards on noise and road traffic injuries. *See* Section 3.5.5. NHTSA's proposed standards give manufacturers the flexibility to choose among a suite of technologies in meeting the proposed standards. The choice a manufacturer makes with regard to distribution of costs (*e.g.*, regarding employee health coverage) is beyond the scope of the impacts analyzed in this EIS, and is not considered either a "direct" or "indirect" effect within the meaning of NEPA. *See* 40 CFR 1508.8. Refer to Sections 3.3.2 and 4.3.2 of this EIS for a discussion of the methodology used to analyze health impacts associated with the proposed fuel consumption standards and other action alternatives.

1.6.1.2 States

NHTSA received five letters from State agencies, including the Connecticut Department of Environmental Protection (CT DEP, Docket No. NHTSA-2010-0079-0005), the South Carolina Department of Transportation (SC DOT, Docket No. NHTSA-2010-0079-0015), the West Virginia Department of Transportation (WV DOT, Docket No. NHTSA-2010-0079-0039), the State of Tennessee Department of Transportation (TN DOT, Docket No. NHTSA-2010-0079-0040), and the State of Connecticut Department of Transportation (CT DOT, Docket No. NHTSA-2010-0079-0041).

The State agencies generally supported the rulemaking but suggested that NHTSA implement the program in various ways.

In terms of the range of HD vehicles the agency is considering, SC DOT suggested that the HD classification begin at Class 3 vehicles, that is, not include Class 2b trucks. SC DOT also recommended that the standards not be applicable to trailers, but only to the cab-chassis configurations of combination tractor-trailers. NHTSA is considering a range of alterative proposed standards, including an alternative that would not include the regulation of Class 2b trucks (Alternative 3), and alternatives that would not be applicable to trailers (Alternatives 2 through 6b). For descriptions of the alternatives NHTSA considered in this EIS, *see* Chapter 2.

WV DOT and TN DOT emphasized the importance of explaining the methodology for calculating the baseline HD future vehicle fleet and associated fuel consumption and GHG levels. NHTSA agrees that the methodology for calculating the baseline is an important aspect in measuring the costs and benefits of the proposed rule. The agency has included a detailed discussion of the development of the HD vehicle emission baseline in Chapter 5 of the draft RIA.

All State agency commenters emphasized the environmental and air quality benefits that would result from the HD Fuel Efficiency Improvement Program. CT DEP suggested that the setting of standards be based on comprehensive evaluations of the need for and benefits of a multi-pollutant perspective, including criteria pollutants, air toxics, and GHGs. WV DOT and TN DOT stated that the action could significantly and positively benefit regional air quality. In recognition of these benefits, this analysis includes a comprehensive quantitative analysis of air toxics emissions under each proposed alternative. Refer to Sections 3.3.2 of this EIS for a discussion of the methodology used to analyze air quality impacts associated with the proposed fuel consumption standards and other action alternatives.

CT DOT suggested that the use of hybrid and idle-limiting technologies be considered in the alternatives. In this EIS, NHTSA has included an alternative – Alternative 8, Accelerated Hybrid Adoption – that expressly considers accelerated adoption of hybrid powertrains for pickups and vans and for vocational vehicles. NHTSA's analysis takes into account several fuel consumption and emission reducing technologies that manufacturers could use to meet the proposed standards. As suggested by CT DOT, hybrid and idle-limiting technologies are among the suite of technologies NHTSA analyzes in the draft RIA for the proposed HD vehicle rule. Refer to Chapter 2 of the draft RIA for a discussion of the technologies considered for fuel efficiency improvements under the proposed program.

1.6.1.3 Advocacy Groups

NHTSA received eight letters from advocacy groups, including the American Council for an Energy-Efficient Economy (Docket No. NHTSA-2010-0079-0022), a joint letter from the Environmental Defense Fund and Sierra Club (Docket No. NHTSA-2010-0079-0024), the Center for Biological Diversity (CBD, Docket No. NHTSA-2010-0079-0025), the Sierra Club (Docket No. NHTSA-2010-0079-0028), the National Groundwater Association (Docket No. NHTSA-2010-0079-0042), Road Safe America (Docket No. NHTSA-2010-0079-0002), the American Jewish Committee (Docket No. NHTSA-2010-0079-0034), and the U.S. Chamber of Commerce (Docket No. NHTSA-2010-0079-0021).

The Environmental Defense Fund and Sierra Club stated that the NOI provided insufficient information to allow for a comparison of the alternatives. In this EIS, NHTSA has greatly expanded the NOI discussion to provide a detailed discussion of the differences among alternatives and of the impacts of the proposed alternatives, including NHTSA's Preferred Alternative. For discussion of the proposed alternatives, *see* Chapter 2. For a description of the direct and indirect effects and of the cumulative effects of the proposed alternatives, *see* Chapter 3 and Chapter 4, respectively.

CBD suggested making the optional voluntary compliance standards begin with MY 2011 and making the first mandatory standards begin in 2015. Under EISA, NHTSA must develop a fuel efficiency improvement program for medium- and heavy-duty vehicles that provides for four years of regulatory lead time and three years of regulatory stability. *See* 49 U.S.C. 32902(k)(3). By setting mandatory standards beginning in 2016, as proposed in the NPRM, NHTSA complies with this statutory requirement.

Sierra Club and CBD suggested that the "technology-forcing aspects" of EPCA be incorporated into the range of alternatives. Sierra Club noted that NHTSA is required to include one or more technology-forcing alternatives in the EIS. The Sierra Club, Environmental Defense Fund, and CBD urged NHTSA to consider the full suite of available and emerging technologies and methods when establishing each alternative. In this EIS, NHTSA considers a range of alternative standards, each of which would encourage and require the use of additional fuel saving technologies. NHTSA's proposed standards would allow manufacturers the flexibility to choose a combination of technologies in meeting the standards. *See* Chapter 2 of the draft RIA for additional information on the suite of technologies NHTSA considered. In this EIS, NHTSA has also included a new Alternative 8, the Accelerated Hybrid Adoption. This alternative assumes standards based on accelerated adoption of hybrid powertrains for pickups and vans and for vocational vehicles. *See* Chapter 3 for a discussion of the direct effects of Alternative 8. Although NHTSA cannot at this time conclude that it is technically feasible to develop the manufacturing infrastructure necessary to support such a high rate of hybrid production by 2017, we believe this alternative is useful for the purpose of estimating what additional benefits could be achieved under such a program.

Sierra Club and CBD stated that prescribing no standards for certain classes would not allow NHTSA to fulfill its regulatory duty to achieve the "maximum feasible improvement." In particular, Sierra Club argued that the structure of the alternatives suggested in the NOI, which consists of regulating varying classes of vehicles, is not adequate. Sierra Club suggested that all classes should be regulated, even if there are different standards for each class. NHTSA has added two new alternatives, Alternative 6a and Alternative 6b, which would apply the agency's Preferred Alternative (*e.g.*, regulating engines, tractors, and Class 2b through 8 trucks) at different stringencies. Alternative 6A would set standards 15 percent less stringent than the Preferred Alternative; Alternative 6B would set standards 20 percent more stringent than the Preferred Alternative. These new alternatives demonstrate the benefits that could be achieved in setting the Preferred Alternative (Alternative 6) at a higher or lower stringency, and also address the concerns raised by the commenter.

CBD also suggested that all vehicle classes, as well as engines and trailers, should be simultaneously regulated. This EIS includes an analysis of two alternatives – Alternative 7 and Alternative 8 – that would set standards for engines, tractors, trucks, and trailers. With regard to the requirement under EISA that NHTSA design a fuel efficiency improvement program "to achieve the maximum feasible improvement," NHTSA disagrees that this standard can be met only through the regulation of all vehicle classes. In particular, NHTSA notes that the agency must set standards that are appropriate, cost-effective, and technologically feasible for HD vehicles. *See* 49 U.S.C. § 32902(k)(2). In considering these requirements, NHTSA also accounts for relevant environmental and safety considerations. NHTSA will weigh these various factors in setting standards "designed to achieve the maximum feasible improvement" under EISA.

Sierra Club suggested weight reductions of vehicles as a way to achieve better fuel economy. Road Safe America suggested that because excessive speed is the largest single factor in reduced fuel mileage, the best way to improve fuel efficiency is to limit the top speed of trucks by requiring them to turn on their speed governors, which are in all trucks manufactured after 1992. NHTSA agrees that the technologies suggested by the commenters can lead to increased fuel savings in the HD vehicle sector. In designing a proposed fuel efficiency improvement program under EISA, NHTSA evaluated a wide range of vehicle technologies that manufacturers could adopt to meet the proposed standards. These include vehicle speed limiters and vehicle mass reduction. For a discussion of the full suite of fuel savings technologies that NHTSA considered, including technologies suggested by the commenters, *see* Chapter 2 of the draft RIA.

The U.S. Chamber of Commerce suggested that NHTSA consider the implications of speed limits, truck size and weight, and driver behavior, and how vehicles are actually used when setting a fuel efficiency standard. NHTSA recognizes that a range of policies could effectively reduce fuel consumption by HD vehicles. Nonetheless, the agency is limited in the scope of action it may take with regard to improving fuel efficiency. Pursuant to EISA, NHTSA must implement an HD fuel efficiency improvement program and must "adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols … ." 49 U.S.C. 32902(k)(2). Under the statute, NHTSA has the authority to set fuel efficiency standards. This authority does not include regulating driver behavior or setting speed limits.

Sierra Club stated that impacts of global warming should be analyzed on a scale where differences among alternatives are meaningful such that local, regional, national, and international impacts of global climate change are analyzed in a way that highlights the differences in the costs and benefits of each alternative. It also suggested that all GHG pollutants, criteria pollutants, and hazardous air pollutants, and localized environmental health and climate change scenarios be included in the impacts analysis. Section 3.4.4 discusses the differences among the alternatives in terms of GHG emission reductions and climate change effects. Section 4.5 provides an overview of the impacts of global climate change. The air quality analysis includes all criteria pollutants and the primary mobile source air toxics, at the national and regional (nonattainment area) levels (*see* Section 3.3). Human health impacts are analyzed using a screening methodology based on EPA data. Detailed photochemical air quality modeling of health impacts will be included in the Final EIS (FEIS).

CBD suggested evaluating impacts in the time frames of 2020, 2050, 2080, and 2100. The EIS evaluates air quality impacts for 2018, 2030, and 2050. Air quality impacts beyond 2050 were not evaluated because NHTSA considers the uncertainty in forecasts beyond 2050 to be too great to allow meaningful evaluation (*See* Section 3.3.1 for discussion of the selection of analysis years). As described in Section 3.4.4.1, however, NHSTA estimates annual emissions and emission reductions for the period from 2014 to 2100 for climate change impacts.

CBD also suggested including potential upstream impacts such as changes in fuel use and emission levels resulting from the extraction, production, storage, and distribution of fuel. The air quality analysis includes these upstream impacts. Section 3.3.1 discusses the methodology for analyzing upstream emissions.

CBD and Sierra Club suggested that when considering cumulative effects, the EIS must include an analysis of the impacts of NHTSA's rulemaking on the GHG emissions of the entire U.S. transportation sector and on total overall U.S. GHG emissions. CBD stated that the rulemaking should consider how the reduction of GHG emissions resulting from the standards would contribute to an environmental outcome in which combined cumulative action results in CO_2 stabilization. The climate analysis (Section 3.4.4) includes multiple comparisons to provide the context for the impacts of NHTSA's HD rulemaking. NHTSA discusses the relative contribution of HD vehicles in the United States to GHG emissions from the U.S. transportation sector, total U.S. emissions, and global emissions. NHTSA also compares these emission reductions to other major efforts to reduce GHG emissions (the Regional Greenhouse Gas Initiative and the Western Climate Initiative), expresses emission reductions from the alternatives as a percent decrease in U.S. emissions to 2100, and includes a brief discussion of emission reductions under this action in terms of the relative contribution of HD vehicles toward the White House goal of reducing U.S. GHG emissions in the range of 17 percent below 2005 levels by 2020.

Environmental Defense Fund and Sierra Club stated that it is critical to conduct a social cost of carbon (SCC) analysis, which assigns a net present value to the marginal impact of one additional ton of carbon dioxide equivalent emissions released at a specific point in time. NHTSA has applied SCC estimates to assess the benefits in this EIS. Section 3.4.3.2 describes the methodology used to estimate the potential monetized damages associated with changes in CO_2 emissions from 2014 through 2050, and the potential reduction in damages attributable to each alternative. NHTSA adopted an approach that relies on estimates of the SCC developed by the Interagency Working Group on Social Cost of Carbon;[34] this approach is consistent with the agencies' joint analysis in the draft RIA. For detailed SCC results, *see* Section 3.4.4.2.

Sierra Club commented that the environmental and human health impacts of black carbon from diesel exhaust, which can have significant impacts on regional climate change effects, should be taken into account when differentiating among alternatives. Although EPA has not designated black carbon an air pollutant, it is a component of $PM_{2.5}$ and diesel particulate matter, both of which have potential human health impacts. NHTSA's air quality analysis accounts for health impacts from $PM_{2.5}$ and diesel particulate matter. *See* Section 3.3. Additionally, NHTSA provides a qualitative discussion of the effects of black carbon in Section 3.4.1.7.

CBD suggested that NHTSA include an alternative that accounts for and avoids or minimizes the likelihood of reaching climate change tipping points. NHTSA discusses the impacts on various climate systems of reaching or passing various climate tipping points in Section 4.5.9. Due to the uncertainty surrounding the precise global temperature change or CO_2 concentration level that would constitute a tipping point, however, it is not currently practicable to estimate quantitatively how this action could delay or mitigate the triggering of tipping points. NHTSA does not believe that examining the alternatives in relation to reaching tipping points triggered by CO_2 emissions is possible at this time, as NHTSA cannot relate the reductions in CO_2 emissions, sea-level rise, precipitation changes, and temperatures to tipping-point thresholds or determine to what extent the different alternatives would affect tipping points.

[34] "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon." (EPA 2010b).

CBD suggested that recent scientific literature further demonstrates that the maximum feasible fuel economy improvements must be reached as quickly as possible, because the scientific understanding of climate change impacts has improved and the risks from climate change are substantially greater than assessed in the 2007 Intergovernmental Panel on Climate Change (IPCC) Report. As detailed in Chapter 4.5 of this EIS, our assessment of the impacts of climate change includes both the 2007 IPCC Report and relevant new research issued since publication of that report.

Sierra Club recommended consultation with the U.S. Fish and Wildlife Service and National Marine Fisheries Service when analyzing the overall impact of GHG emissions and other air pollutants on listed threatened and endangered species pursuant to Section 7 of the Endangered Species Act. NHTSA is considering this comment as it finalizes the Rule.[35]

American Jewish Committee, Environmental Defense, and Sierra Club suggested that the costs associated with continued oil consumption should be considered, including the value of reducing the associated external costs, such as economic and national security. CBD argued that the analysis must account properly for all damages caused by climate change and recognize that mitigation costs will sharply increase over time. The agencies include an estimate for energy security benefits due to the rulemaking, discussed in Section 9.5 of the draft RIA.

1.6.1.4 Industry Organizations

Comments from industry organizations comprised most of the scoping comments. NHTSA received 17 letters from industry organizations including the National Truck Equipment Association (Docket No. NHTSA-2010-0079-0006), the American Bus Association (Docket No. NHTSA-2010-0079-0007), Cummins, Inc. (Docket No. NHTSA-2010-0079-0008), Daimler Trucks North America (Docket No. NHTSA-2010-0079-0009), Navistar Inc. (Docket No. NHTSA-2010-0079-0010), Volvo Group/Volvo Powertrain (Docket No. NHTSA-2010-0079-0012), Truck Trailer Manufacturers Association (Docket No. NHTSA-2010-0079-0016), TIAX LLC (Docket No. NHTSA-2010-0079-0017), the National Automobile Dealers Association (Docket No. NHTSA-2010-0079-0018), the Aluminum Association Incorporated’s Aluminum Transportation Group (Docket No. NHTSA-2010-0079-0020), Allison Transmission Inc. (Docket No. NHTSA-2010-0079-0023), Owner-Operator Independent Drivers Association (Docket No. NHTSA-2010-0079-0026), the Rubber Manufacturers Association (Docket No. NHTSA-2010-0079-0029), American Trucking Association (Docket No. NHTSA-2010-0079-0030), Eaton Corporation Truck Innovation (Docket No. NHTSA-2010-0079-0031), the Heavy-Duty Fuel Efficiency Leadership Group (Docket No. NHTSA-2010-0079-0032), and Michelin North America, Inc. (Docket No. NHTSA-2010-0079-0045).

Allison Transmission Inc. commented that during the scoping process, not enough information was provided regarding the alternatives to allow for evaluation of the environmental effects of the proposed standards. For example, Allison had questions concerning how non-engine vehicle components would be tested, what fuel efficiency measures and other inputs would be used for computer modeling and testing, and how different vehicle vocations and classes would be represented in the rule. Due to the lack of information, Allison stated that it was unable to calculate the possible environmental effects for GHG emission and fuel reductions. NHTSA refers readers to the contents of this EIS for a full evaluation of environmental impacts attributable to the various alternatives and to the accompanying NPRM for the proposed HD National Program, which is being released concurrently with this EIS, for discussions of all details relating to the proposal.

[35] *See* Appendix G in NHTSA’s FEIS for MYs 2012–2016 (NHTSA 2010) for discussion of this issue in the context of the CAFE program, *available at*: http://www.nhtsa.gov/fuel-economy.

Several commenters submitted comments regarding the structure of the alternatives NHTSA is considering. Cummins stated that the proposed regulatory structure of alternatives is appropriate and would allow for innovation at the engine and at the vehicle level and would drive the introduction of new technology to the market. Several commenters noted that because the technologies employed to gain fuel efficiency would differ by class, distinguishing the alternatives by classes of vehicles is appropriate. For example, Owner-Operator Independent Drivers Association, Inc. (OOIDA) commented that when setting fuel efficiency standards, NHTSA must consider the multiple uses of HD vehicles and how the end user intends to use any vehicle. The Heavy-Duty Fuel Efficiency Leadership Group[36] and the Rubber Manufacturers Association similarly emphasized that the new HD vehicle program should recognize fleet diversity. In contrast, Volvo suggested that no regulation is needed because operators of commercial vehicles already consider the reduction in fuel costs associated with fuel efficiency improvements compared to the upfront cost of purchasing new vehicles; therefore, economic considerations drive fuel efficiency improvements without regulatory intervention. Alternatively, Volvo suggested that a more appropriate alternative would start by regulating only Class 8 trailers and Classes 2b–3 pickups, which would allow for a more limited initial focus by regulating the vehicle classes that consume the most fuel. In light of the industry's diversity, the agencies are proposing a coordinated national program that recognizes the different sizes and work requirements of this wide range of heavy-duty vehicles and their engines. This EIS analyzes the environmental impacts of a range of alternative standards.

Several commenters suggested that NHTSA's regulations should not cover particular segments of the HD vehicle sector. The American Bus Association stated that NHTSA should be focused on HD vehicles engaged in the transportation of cargo and property, not people, because motorcoaches represent an environmental benefit compared to alternative means of transportation. NHTSA recognizes that motorcoaches, like other types of vehicles in the HD vehicle sector, afford environmental benefits. In consideration of the fact that different vehicle classes offer different potentials for fuel savings, NHTSA's proposed alternatives include different segments of the HD vehicle sector. For example, Alternative 3, which applies only to Class 8 tractors and their engines, would not apply to motorcoaches. Nonetheless, EISA requires that NHTSA set standards designed to achieve the "maximum feasible improvement" in fuel efficiency. 49 U.S.C. 32902(k)(2). This standard allows the agency to consider improvements from each segment of the HD vehicle sector. The Preferred Alternative represents the standard NHTSA has tentatively decided would result in the "maximum feasible improvement" in accordance with the statute.

Several commenters suggested other means that NHTSA could pursue to reduce fuel consumption. Cummins, the American Trucking Association, and TIAX LLC stated that NHTSA should consider policies like reducing speed limits, adopting speed limiters, mitigating congestion, and allowing longer combination vehicles as potential alternatives in lieu of in-vehicle technology, and that these alternative policies would accelerate the demand for and deployment of more fuel-efficient vehicles. Notably, OOIDA suggested that NHTSA resist any effort to require downweighting, automatic engine shutdown technology, or speed limiter technologies, all of which, OOIDA stated, would create highway safety issues. Instead, OOIDA suggested that NHTSA consider driver behavior in addressing efficient ways to reduce GHG emissions and improve vehicle fuel consumption. NHTSA recognizes that a range of policies could reduce fuel consumption by HD vehicles. We note, however, that the agency is limited in the scope of action it may take with regard to improving fuel efficiency. Pursuant to EISA, NHTSA must implement an HD Fuel Efficiency Improvement Program and must "adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols … ." 49 U.S.C. 32902(k)(2). Under the statute, NHTSA has the authority to set fuel efficiency standards; this does not, for example, include the authority to regulate driver behavior or to

[36] The Heavy-Duty Fuel Efficiency Leadership Group is an informal coalition of major trucking fleets and heavy-duty technology providers. Members include Con-way, Inc., Cummins, Inc., Eaton Corporation, FedEx Corporation, Wabash National Corporation, and Waste Management, Inc.

set speed limits, regardless of whether these might meaningfully impact fuel consumption. In designing a proposed fuel efficiency improvement program under EISA, NHTSA evaluated a wide range of vehicle technologies that manufacturers could adopt to meet the proposed standards. These include vehicle speed limiters (*see* draft RIA, Chapter 2.5.5) and vehicle mass reduction (*see* draft RIA, Chapter 2.5.3). For a discussion of the full suite of fuel savings technologies that NHTSA considered, *see* Chapter 2 of the draft RIA.

There were several comments about the various technologies and properties of vehicle technologies that NHTSA should consider when establishing HD vehicle fuel efficiency standards. *See* Section IV of the NPRM and Chapter 2 of the draft RIA for discussions of the various technologies and their cost effectiveness that NHTSA and EPA considered in developing the proposal. Many comments also included opinions regarding the measurement metric on which the proposed standards are based. *See* Section III of the NPRM for discussions of the proposed measurement metrics.

TIAX recommended that the proposed standards require or incentivize fuel, engine, and vehicle technologies that can achieve needed GHG reductions, specifically technologies relating to alternative fuels. *See* Section V of the NPRM for a discussion of the proposed regulatory flexibility provisions. Section IV of the NPRM contains a discussion of the proposed regulatory flexibility provisions.

Several commenters also provided comments regarding the drive cycle NHTSA should use for simulation purposes. Allison stated that testing data reflecting urban congested driving conditions should be incorporated. Volvo suggested that the simulation include the most significant variables such as engine efficiency map, gearing, axle ratio, aerodynamic characteristics, rolling resistance, and vehicle management features. Daimler suggested that NHTSA's simulation program use drive cycles that mimic real-world driving as closely as possible to maximize the real-world environmental benefits from NHTSA's program. For example, Daimler suggested NHTSA create a drive cycle based on a vehicle following a real route, with the modeled vehicle following the route's speed limits. The agencies discuss their proposed approach to choosing different drive cycles for different classes of vehicles in Section II of the NPRM preamble.

The National Automobile Dealers Association identified several issues for consideration. It stated that NHTSA should account for increased driving associated with an increase in fuel efficiency; evaluate environmental impacts associated with alternatively fueled vehicles; and exclude from evaluation environmental impacts associated with voluntary standards. This EIS takes into account increased driving associated with the rebound effect (*see* Section 3.1.4.1.3) and provides a comprehensive discussion of upstream and downstream environmental impacts assuming a variety of scenarios (*see* Sections 3.1.4.1 and 3.1.4.2). The EIS summarizes potential impacts under the HD National Program for 2014–2015, when the NHTSA standards would be voluntary but the companion EPA standards would be mandatory.

Navistar, Inc. warned that the reduction of exhaust gas recirculation creates fuel efficiency gains, but could inadvertently raise the level of NO_x in the exhaust stream, and that NHTSA should consider this type of cumulative impact. OOIDA recommended that NHTSA account for all environmental benefits from increased fuel efficiency and the negative consequences of certain strategies and alternatives, such as speed limiters, that might negatively affect traffic and infrastructure. In the NPRM, the agency considers NO_x impacts in Section VIII.A and congestion impacts in Section VIII.J. The EIS does not evaluate infrastructure impacts, as NHTSA believes these are too remote under this rulemaking.

1.6.1.5 Individuals

NHTSA received six letters from individuals including Donna Ray Mitchell (Docket No. NHTSA-2010-0079-0003), Vernon Haltom (Docket No. NHTSA-2010-0079-0004), Shelly Huber (Docket No. NHTSA-2010-0079-0043), two anonymous commenters (Docket No. NHTSA-2010-0079-0019 and Docket No. NHTSA-2010-0079-0027), and Jason Haller (Docket No. NHTSA-2010-0079-0044).

Donna Ray Mitchell expressed concern that the proposed rule is long overdue, because heavy-duty trucks have been large contributors to GHG emissions for a long time, and that any progress made toward mitigating climate change as a result of this rulemaking effort might be too late. Verna Haltom and Shelly Huber suggested that NHTSA consider the economic and environmental cost of continuing to use oil as a fuel source. An anonymous commenter suggested that the potential effect that tires have on fuel efficiency should be considered; this commenter also suggested that the development of advanced technologies should be encouraged at research institutions and adopted by industry. Another anonymous commenter suggested that the use of fuel catalyst additives to reduce fuel consumption should be explored. NHTSA evaluates the environmental impacts of petroleum in its discussion of the affected environment (*See* Section 3.2.1) and the impacts of tire efficiency (*see* Section 2.5.3). NHTSA does not analyze the impacts of fuel catalyst additives because we do not believe they are a significant means of achieving greater fuel efficiency.

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 environmental impact statement (EIS), the National Highway Traffic Safety Administration's (NHTSA) Proposed Action is to set fuel consumption standards starting with model year (MY) 2016 for commercial medium- and heavy-duty on-highway vehicles and pickups and vans (hereinafter referred to collectively as HD vehicles[4]), in accordance with the Energy Independence and Security Act of 2007 (EISA), and voluntary standards for MYs 2014–2015 HD vehicles. EISA requires that NHTSA implement a fuel efficiency improvement program for commercial medium- and heavy-duty on-highway vehicles, pickups and vans by rulemaking, to include standards, testing, and enforcement protocols.[5] As noted in Chapter 1, in developing the new proposed HD vehicle fuel consumption standards and possible alternatives, NHTSA was guided by the following EISA requirements for the HD Fuel Efficiency Improvement Program:

- The program must be "designed to achieve the maximum feasible improvement;"
- The various required aspects of the program must be appropriate, cost-effective, and technologically feasible for HD vehicles; and
- The standards adopted under the program must provide not less than four model years of regulatory lead time and three model years of regulatory stability.[6]

In considering these various requirements, NHTSA has also accounted for relevant environmental and safety considerations. For instance, in analyzing the benefits of the proposed standards, NHTSA and EPA have placed monetary values on environmental externalities, including the benefits of reductions in

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[1] 42 U.S.C. § 4332(2)(C). NEPA is codified at 42 U.S.C. § 4321, *et seq*.
[2] 40 CFR §§ 1502.14(a), (d).
[3] 40 CFR § 1502.13. *See Vermont Yankee Nuclear Power Corp. v. Natural Res. Def. Council*, 435 U.S. 519, 551 (1978); *City of Alexandria v. Slater*, 198 F.3d 862, 867-69 (D.C. Cir. 1999), *cert. denied sub nom.*, 531 U.S. 820 (2000).
[4] For purposes of this EIS, the term "heavy-duty" or "HD" is used to apply to all highway vehicles and engines that are not within the range of light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles (MDPV) covered by the GHG and Corporate Average Fuel Economy (CAFE) standards issued for model years (MY) 2012–2016. It also does not include motorcycles. In addition, for the purpose of this EIS, it does not include recreational vehicles. Under EISA, NHTSA is required to set standards for "commercial medium- and heavy-duty on-highway vehicles and work trucks." NHTSA interprets this to include all segments of the heavy-duty category described above, except for recreational vehicles, such as motor homes, because recreational vehicles are not commercial.
[5] 49 U.S.C. § 32902(k)(2). Fuel consumption standards satisfy EISA's directive that NHTSA implement a fuel efficiency improvement program because the more efficient an HD vehicle is in completing its work, the less fuel it will consume to move cargo a given distance. Therefore, fuel efficiency and fuel consumption have an inversely proportional relationship.
[6] 49 U.S.C. §§ 32902(k)(2), (3).

carbon dioxide (CO_2) emissions. The NEPA analysis presented in this EIS informs the agency's action in setting HD vehicle fuel consumption standards. During the development of the HD Fuel Efficiency Improvement Program, NHTSA is consulting with the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA) regarding a variety of matters as required by EISA.[7] NHTSA also is guided by President Obama's May 21, 2010 memorandum to the Secretary of Transportation, the Administrator of NHTSA, the Administrator of EPA, and the Secretary of Energy, that calls for coordinated regulation of the HD vehicle market segment, as described in Chapter 1.

2.2 STANDARDS-SETTING

In developing the proposed HD Fuel Efficiency Improvement Program, NHTSA took a new approach to setting standards as compared to the agency's most recent CAFE rulemaking. In the MYs 2012–2016 CAFE rulemaking, the action and various alternatives the agency considered were defined as average percentage increases in stringency. Such an approach to setting standards is especially well-suited to the light-duty vehicle fleet. Unlike light-duty vehicles, however, HD vehicles often vary widely in configuration (*i.e.*, are composed of different vehicle parts combined in different ways). Because of this complexity, the question of how to regulate HD vehicles is as important as how stringent the standards should be in this early phase of this new program. This question must be answered to know how stringent standards should be (or put differently, how much fuel consumption and greenhouse gas [GHG] reductions can be required of the HD industry). For example, engine-only standards that demand the same fuel consumption or GHG reductions of engine manufacturers as would be demanded of engine *and* vehicle manufacturers under industry-wide standards would likely not be appropriate, cost-effective, or feasible, because it would not be reasonable to ask engine manufacturers to shoulder the burden of regulation for the entire industry.

With these points in mind, NHTSA and EPA are proposing a different approach to fuel efficiency and GHG emission reductions for the HD sector, depending on the characteristics of each general type of vehicle. Specifically, in recognition of the many different types of HD vehicles, the agencies propose to divide the industry into discrete categories – heavy-duty pickups and vans, vocational vehicles, and combination tractors – based on the relative degree of homogeneity among vehicles within each category. To arrive at measures of efficiency for HD vehicles, the agencies' proposal identifies specific standards for various vehicle types within these categories and also for HD engines.

As described in further detail in Section 2.3, the alternatives proposed for evaluation in this EIS represent different combinations of regulating different portions of the HD vehicle fleet. For example, Alternatives 2 through 7 would regulate increasing portions of the HD vehicle fleet. Regulating different segments of the HD industry in this way results in different levels of GHG reductions.

NHTSA also recognizes the value to the decisionmaker of evaluating alternatives of different stringencies. To that end, we have included alternatives related to the Preferred Alternative in that they regulate the same vehicle categories as the Preferred Alternative, but at different levels of fuel efficiency. Alternative 6 is NHTSA's Preferred Alternative and Alternatives 6A and 6B represent different stringency levels surrounding the Preferred Alternative. Finally, alternative 8 assumes widespread use of hybrid technologies.

[7] 49 U.S.C. § 32902(k)(2).

2.2.1 Environmental Impacts Analysis Methodology

The methodology for examining the impact of the proposed HD Fuel Efficiency Improvement Program on emissions and energy consumption relies on outputs from an EPA simulation model. The Motor Vehicle Emission Simulator (MOVES), EPA's official mobile source emission inventory model, was the primary tool used to calculate fuel consumption and associated emissions. This EPA model, described further in Section 3.1.4, calculates energy consumption and emissions based on user inputs for characteristics of the vehicle fleet and vehicle operational patterns, including (1) a forecast of the future HD vehicle market; (2) estimates of the availability, applicability, and incremental effectiveness of fuel-saving technologies; (3) estimates of vehicle survival and mileage accumulation patterns, the rebound effect, future fuel prices; and (4) fuel characteristics and vehicular emission rates.

MOVES categorizes vehicle types as tractors, single unit tractors, refuse trucks, motor homes, transit buses, intercity buses, school buses, and light commercial trucks. The fuel consumption and emission reducing technologies considered by the model are briefly described in Chapter 2 of the draft Regulatory Impact Analysis (RIA) (*See* www.regulations.gov, docket number NHTSA-2010-0079).

2.3 ALTERNATIVES

The specific alternatives selected for evaluation by NHTSA encompass a reasonable range to evaluate the potential environmental impacts of the proposed HD Fuel Efficiency Improvement Program and alternatives under NEPA.

At one end of this range is the No Action Alternative (Alternative 1), which assumes no action would occur under the HD National Program. Under this alternative, neither NHTSA nor EPA would issue a rule regarding the HD fuel consumption standards or GHG emissions standards. The No Action Alternative assumes that average fuel efficiency levels in the absence of an HD Fuel Efficiency Improvement Program would equal the agencies' collective market forecast - the level of fuel efficiency and GHG performance NHTSA believes manufacturers would continue to achieve, without regulation. 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. Similarly, the No Action Alternative would yield no additional environmental improvement other than might occur from natural market forces.

NHTSA has also examined nine action alternatives, each of which would regulate the HD vehicle fleet (or portions of that fleet) in a different way. HD vehicles are often divided into classes defined by gross vehicle weight rating, or GVWR, which is a measure of the combined curb (empty) weight and cargo carrying capacity of the truck. In the GVWR framework, the HD vehicle fleet refers to Class 2b through Class 8 vehicles weighing more than 8,500 pounds.[8] As noted above, the analysis of the action alternatives in this EIS examines the environmental impacts associated with applying specific fuel consumption standards to HD engines and to one or more of the following vehicle categories: HD pickups and vans (Classes 2b-3), vocational vehicles (Classes 2b-8), tractors (Classes 7 and 8), and trailers. This analytical approach was selected in view of the complexity of the HD vehicle fleet, the applicability of differing fuel savings technologies to different portions of that fleet, and the relative degree of homogeneity among vehicles within broad categories (HD pickups and vans, vocational vehicles, tractors, and trailers).

[8] As noted above, some Class 2b vehicles, such as a number of pickup models and medium-duty passenger vehicles (MDPVs), are already subject to the CAFE standards promulgated at 49 CFR Part 533 and are therefore not addressed in this rulemaking.

For each regulatory category, the agencies have examined related but distinct program approaches reflecting the relative degree of homogeneity among vehicles within each category and specific challenges for manufacturers in these segments.

Table 2.3-1 outlines how GVWR classes correspond to the HD vehicle categories of pickups and vans, vocational vehicles, and tractors.

Table 2.3-1

HD Tractor Vehicle Segments by Gross Vehicle Weight Rating (pounds)

Class 2b	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
8,501 -10,000 lbs	**10,001- 14,000 lbs**	**14,001- 16,000 lbs**	**16,001- 19,500 lbs**	**19,501 - 26,000 lbs**	**26,001- 33,000 lbs**	**> 33,001 lbs**
HD Pickups and Vans (Work Trucks)						
Vocational Vehicles (*e.g.*, van trucks, utility "bucket" trucks, tank trucks, refuse trucks, buses, fire trucks, flat-bed trucks, and dump trucks)						
					Tractors (for Combination Tractor-Trailers)	

HD pickups and vans, including shuttle vans, span GVWR Classes 2b and 3. Vocational vehicles, which span Classes 2b through 8, include van trucks, utility "bucket" trucks, tank trucks, refuse trucks, buses, fire trucks, flat-bed trucks, and dump trucks, among others. Classes 7 and 8 combination tractors are primarily used for freight transported in trailers pulled by a tractor. Tractors are sold separately from the trailers they pull, and tractors sometimes run between loads without a trailer; most of the time, however, a tractor runs with one or more trailers as a combination tractor/trailer.

The action alternatives examined specify fuel consumption standards for HD engines, vehicles, and trailers, for different segments of the HD vehicle market. In the Notice of Intent (NOI) to Prepare an Environmental Impact Statement[9] that preceded this EIS, NHTSA proposed five alternatives including the No Action Alternative. Since the publication of the NOI, NHTSA has added five additional alternatives. Two of the new alternatives, Alternatives 4 and 5 in this EIS, provide increments of regulatory benefit between alternatives proposed in the NOI. Alternative 8 was added in response to commenter requests for a technology-forcing alternative. Alternatives 6A and 6B were added to demonstrate the benefits that could be achieved in setting the Preferred Alternative (Alternative 6) at a higher or lower stringency. Each alternative is described in detail in this section. Table 2.3-2 summarizes how fuel consumption standards are applied under each of the alternatives examined, with action alternatives from left to right in order of increasing fuel savings (Alternative 2 has the lowest fuel savings relative to the No Action Alternative, and Alternative 8 has the highest fuel savings relative to the No Action Alternative). Brief descriptions of each alternative (which are also described in more detail in Sections 2.3.1 through 2.3.8) are also provided.

- **Alternative 1** specifies no fuel consumption standards (No Action)

- **Alternative 2** specifies standards for all HD engines used in Classes 2b through 8 vehicles (in gallons per 100 brake-horsepower-hour (gal/100 bhp-hr))

[9] *See* 75 FR 33565 (June 14, 2010)

Table 2.3-2

HD Vehicle Engines and Classes Affected by Regulatory Alternatives

Specific Standards	Vehicle Classes	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 6A	Alt. 5	Alt. 6	Alt. 7	Alt. 6B	Alt. 8
Engines by Vehicle Weight Class	2b-7	-	●		●	●	●	●	●	●	●
	8	-	●	●	●	●	●	●	●	●	●
Vehicles by Weight Class (HD Pickups and Vans, Vocational Vehicles, and Tractors)	2b	-				●	●	●	●	●	●
	3	-				●	●	●	●	●	●
	4	-				●		●	●	●	●
	5	-				●		●	●	●	●
	6	-				●		●	●	●	●
	7	-			●	●	●	●	●	●	●
	8	-		●	●	●	●	●	●	●	●
	Trailers	-							●		●
Accelerated Hybrid Adoption	Classes 2b–8 Vocational Vehicles, Pickups and Vans	-									●

- **Alternative 3** specifies standards for each of the following:
  - Class 8 combination tractors (in gallons per 1,000 ton-miles (gal/1,000 ton-miles))
  - Engines used in Class 8 tractors (in gal/100 bhp-hr)
- **Alternative 4** specifies standards for each of the following:
  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
- **Alternative 5** specifies standards for each of the following:
  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickup trucks and vans (in gal/100 miles)
- **Alternative 6, the Preferred Alternative**, specifies standards for each of the following:
  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp- hr)
  - HD pickups and vans (in gal/100 miles)
- **Alternative 6A** specifies standards 15 percent less stringent than the Preferred Alternative, Alternative 6, covering each of the following:
  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (gal/100 miles)

- **Alternative 6B** specifies standards 20 percent more stringent than the Preferred Alternative, Alternative 6, covering each of the following:

  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles)

- **Alternative 7** specifies standards for each of the following:

  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles)
  - Trailers pulled by Classes 7 and 8 tractors (reducing gal/1,000 ton-miles standard for combination tractor-trailers)

- **Alternative 8** specifies standards for each of the following:

  - Classes 7 and 8 combination tractors (in gal/1,000 ton-miles)
  - Classes 2b through 8 vocational vehicles (in gal/1,000 ton-miles)
  - HD engines used in Classes 2b through 8 vehicles (in gal/100 bhp-hr)
  - HD pickups and vans (in gal/100 miles)
  - Trailers pulled by Classes 7 and 8 tractors, with more stringent standards specified for HD pickups and vans and vocational vehicles, associated with accelerated adoption of hybrid engine technology (reducing gal/100 miles standard for HD pickups and vans and reducing gal/1,000 ton-miles standard for combination tractor-trailers and vocational vehicles).

The variability of the HD vehicle fleet is reflected in the different fuel consumption standards for HD engines and for different types of HD vehicles (gal/100 bhp-hr for engines, gal/100 miles for work trucks, and gal/1,000 ton-miles for combination tractor and vocational vehicles). The variety of potential approaches to setting regulatory standards is also reflected in the different segments of the HD vehicle market subject to fuel consumption standards under different alternatives. Each action alternative represents a different regulatory approach the agency has evaluated, in order of increasing fuel savings (Alternative 2 has the lowest fuel savings relative to the No Action Alternative, and Alternative 8 has the highest fuel savings relative to the No Action Alternative).

Fuel consumption standards, including engine standards, are based on specific drive cycles that are chosen based on the typical expected use of each vehicle. The drive cycle used in compliance testing has significant consequences for the technology that will be employed to achieve a standard as well as the ability of the technology to achieve real-world reductions in fuel consumption. Therefore, compliance testing for fuel consumption standards varies to reflect the anticipated drive cycles in different segments of the HD vehicle market.

The specific fuel consumption standards applied under each alternative, and estimated average fuel efficiency resulting from each alternative after application of these standards, are described in more detail below in Sections 2.3.1 through 2.3.8.

2.3.1 Alternative 1: No Action

A "no action" alternative assumes that the agencies would not issue a rule regarding HD fuel efficiency standards or GHG emission standards. This alternative provides an analytical baseline to compare against the environmental impacts of the other regulatory alternatives.[10] NEPA expressly requires agencies to consider a ''no action'' alternative in their NEPA analyses and to compare the effects of not taking action with the effects of the reasonable action alternatives, to demonstrate the environmental effects of the action alternatives. Table 2.3-3 shows the estimated average fuel efficiency (gal/100 miles) for HD pickups and vans (gasoline and diesel), vocational vehicles (gasoline and diesel), and tractors (virtually all diesel vehicles). The estimates in Table 2.3-3 reflect the agencies' forecast for the average fuel efficiency that manufacturers would achieve in the absence of any HD Fuel Efficiency Improvement Program. Section 2.4, and Chapters 3 and 4, compare direct and indirect environmental effects of the action alternatives with the effects of the No Action Alternative.

Table 2.3-3

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 1 (No Action)

	MYs 2010-2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.6	6.6	6.6	6.6	6.6
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.9	6.9	6.9	6.9	6.9
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	11.3	11.3	11.3
Vocational (Classes 2b–8) – diesel	10.2	10.2	10.2	10.2	10.2	10.2
Tractors (Classes 7–8)	20.2	20.2	20.2	20.2	20.2	20.2

2.3.2 Alternative 2: Engine Only

EPA currently regulates heavy-duty engines, that is, engine manufacturers, rather than the vehicle as a whole, to control criteria emissions. Under Alternative 2, NHTSA would similarly set engine performance standards for Class 2b through Class 8 vehicles, and would specify an engine test cell procedure, as EPA currently does for criteria pollutants. HD engine manufacturers would be responsible for ensuring that each engine could meet the applicable vehicle class engine performance standard when tested in accordance with the specified engine test cell procedure. Engine manufacturers could improve HD engine performance by applying combinations of fuel efficiency improvement technologies to the engine. The specific engine performance standards examined under this alternative vary with the intended engine application by vehicle class and the type of fuel used, as shown below in Table 2.3-4.

[10] *See* 40 CFR §§ 1502.2(e), 1502.14(d). The Council on Environmental Quality (CEQ) has explained that "[T]he regulations require the analysis of the no action alternative even if the agency is under a court order or legislative command to act. This analysis provides a benchmark, enabling decision makers to compare the magnitude of environmental effects of the action alternatives. It is also an example of a reasonable alternative outside the jurisdiction of the agency which must be analyzed. [See 40 CFR 1502.14(c).] * * * Inclusion of such an analysis in the EIS is necessary to inform Congress, the public, and the President as intended by NEPA. [See 40 CFR 1500.1(a).]" Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 *FR* 18026 (1981) (emphasis added).

Table 2.3-4

HD Engine Regulatory Subcategories

Engine Category	Intended Application
Light Heavy-Duty Diesel (LHDD)	Class 2b through Class 5 vehicles (8,501 through 19,500 pounds GVWR)
Medium Heavy-Duty Diesel (MHDD)	Class 6 and Class 7 vehicles (19,501 through 33,000 pounds GVWR)
Heavy Heavy-Duty Diesel (HHDD)	Class 8 vehicles (33,001 pounds and greater GVWR)
Gasoline	Primarily for vehicles less than 14,000 pounds, including almost 50% of HD pickups and vans, and less than 10% of vocational vehicles.

As noted above, engine performance standards are based on specific anticipated drive cycles. Therefore, the fuel consumption standards for engines used in HD pickups and vans and vocational vehicles reflect compliance testing based on a heavy-duty Federal Test Procedure (FTP) engine cycle, consistent with the transient drive cycle (frequent accelerations and decelerations with some steady cruise conditions) that is anticipated for typical use of HD pickups and vans and vocational vehicles. The FTP or "city" test is a test procedure used to determine compliance of vehicles with Federal emissions standards. The FTP is conducted on a chassis dynamometer, and is used to simulate typical driving patterns in primarily urban environments. Table 2.3-5 shows the Alternative 2 fuel consumption standards (in gal/100 bhp-hr) for engines used in HD pickups and vans and vocational vehicles, based on the FTP engine cycle.

Table 2.3-5

Standards for Engines Used in HD Pickups and Vans and Vocational Vehicles (gal /100 bhp-hr)

	Light Heavy Duty Diesel (LHDD) Pickups and Vans	Light Heavy Duty Diesel (LHDD) Vocational Vehicles	Medium Heavy Duty Diesel (MHDD)	Heavy Heavy-Duty Diesel (HHDD)	Gasoline
MY 2014 (Voluntary)		5.89	5.89	5.57	
Effective MY 2016	5.57				7.05
Effective MY 2017		5.57	5.57	5.45	

Combination tractors spend most of their operation at steady-state conditions (*e.g.*, 55 to 65 mph cruising speeds with infrequent acceleration or deceleration), and some specific technologies (turbo compounding and other waste-heat recovery technologies) are especially suited to reduce fuel consumption during this type of steady-state engine operation. Therefore, engines installed in tractors would be required to meet standards based on the Supplemental Engine Test (SET), which is a steady-state test cycle. Table 2.3-6 shows the Alternative 2 fuel consumption standards (in gal/100 bhp-hr) for engines used in combination tractors, based on the SET steady-state test cycle.

Table 2.3-6

Standards for HD Tractor Diesel Engines (gal /100 bhp-hr)

	MHDD Engine	HHDD Engine
MY 2014 (Voluntary)	4.93	4.67
Effective MY 2017	4.78	4.52

Table 2.3-7 shows the estimated fleet-wide fuel efficiency (gal/100 miles) for all HD vehicles under Alternative 2. These estimates reflect NHTSA's and EPA's forecast for the average fuel efficiency that manufacturers would achieve by complying with the engine fuel consumption standards specified in Tables 2.3-5 and 2.3-6. (Although Alternative 2 specifies fuel consumption standards in gal/100 bhp-hr

Table 2.3-7

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 2 (Engine Only)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.6	6.6	6.3	6.3	6.3
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.9	6.9	6.3	6.3	6.3
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.8	10.8	10.8
Vocational (Classes 2b–8) – diesel	10.2	9.9	9.9	9.9	9.7	9.7
Tractors (Classes 7–8)	20.2	19.6	19.6	19.6	19.0	19.0

for HD engines, the estimated average fuel efficiency in gal/100 miles under this Alternative is shown to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

2.3.3 Alternative 3: Class 8 Tractors

Combination tractors consume the largest fraction of fuel among the HD vehicle categories. Tractors also offer significant potential for fuel savings due to the high annual mileage and vehicle speed within this vehicle category, as compared to annual mileage and average speeds or duty cycles of other HD vehicle categories. Alternative 3 would set performance standards for engines used in Class 8 combination tractors and standards for the overall vehicle efficiency performance for Class 8 tractors. Under this alternative, the agencies would apply the engine performance standard for Class 8 tractors discussed under Alternative 2 (HD engine standards in Table 2.3-6). In addition, Class 8 tractor manufacturers would be required to meet an overall vehicle performance standard by making various non-engine fuel saving technology improvements. These non-engine improvements could be accomplished, for example, by a combination of improvements to aerodynamics, lowering tire rolling resistance, decreasing vehicle mass (weight), reducing fuel use at idle, or adding intelligent vehicle technologies.[11]

The fuel consumption standards for a Class 8 combination tractor varies depending on whether it is a "day cab" or a "sleeper cab" (sleeper cabs provide overnight accommodations for drivers). Tractors with sleeper cabs tend to have greater empty curb weight tractors with day cabs due to the larger cab accommodations, and some technologies (*e.g.*, extended idle reduction) are appropriate for tractors with sleeper cabs but less so for day cabs. The fuel consumption standards for Class 8 tractors with day cabs versus those with sleeper cabs also reflect different drive cycles. As shown in Table 2.3-8, day cab tractors have a larger percentage of their drive cycle weighted to transient (urban) driving and sleeper cab tractors have a larger percentage of their drive cycle weighted to a cruising speed of 65 miles per hour (mph).

The fuel consumption standards for Class 8 tractors also vary with the height of the roof, designed to correspond to the height of the trailer, because roof height significantly affects aerodynamic

[11] For discussions of the potential fuel efficiency improvement technologies that can be applied to each of these vehicle components, *see* Committee to Assess Fuel Economy Technologies for Medium-and Heavy-Duty Vehicles. *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles* (March 2010), *available at* http://www.nap.edu/catalog.php?record_id=12845 (last accessed May 19, 2010) (hereinafter "HD NAS Report"), Chapter 5. (NAS 2010)

Table 2.3-8

Tractor Drive Cycle Mode Weightings

	Transient (Urban)	55-mph Cruise	65-mph Cruise
Day Cabs	19%	17%	64%
Sleeper Cabs	5%	9%	86%

drag, which is a major component of determining tractor fuel efficiency. Table 2.3-9 shows the Alternative 3 standards for Class 8 tractors (in gal/1,000 ton-miles).

Table 2.3-9

Standards for Class 8 Tractor Fuel Consumption (gal /1,000 ton-miles)

	Day Cab	Sleeper Cab
MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016)a/		
Low Roof	7.8	6.3
Mid Roof	7.8	6.9
High Roof	8.6	7.1
MYs 2017–2018		
Low Roof	7.7	6.3
Mid Roof	7.7	6.8
High Roof	8.5	7.0

a/ Manufacturers may voluntarily opt-in to the NHTSA fuel consumption program in 2014 or 2015.

Compliance with the overall vehicle standards for Class 8 tractors in Table 2.3-9 would be determined using a computer model that would simulate overall vehicle fuel efficiency given a set of vehicle component inputs. Using this compliance approach, the Class 8 vehicle manufacturer would supply certain vehicle characteristics that would serve as model inputs (related to the categories of technologies noted above in Section 2.2.1 and in Chapter 2 of the draft RIA). The agency would supply a standard Class 8 vehicle engine's contribution to overall vehicle efficiency (consistent with the HD engine standards in Table 2.3-6), making the engine component a constant for purposes of compliance with the overall vehicle performance standard. Thus, vehicle manufacturers could make any combination of improvements using non-engine technologies that they believe would best achieve the Class 8 tractor overall fuel consumption standards in Table 2.3-9.

Table 2.3-10 shows the estimated fleet-wide fuel efficiency (gal/100 miles) for all HD vehicles under Alternative 3. These estimates reflect NHTSA's and EPA's forecast for the average fuel efficiency that manufacturers would achieve by complying with the Class 8 tractor fuel consumption standards in Table 2.3-9 (incorporating the HD engine standards in Table 2.3-6). (Alternative 3 specifies fuel consumption standards in gal/1,000 ton-miles for Class 8 tractors, but the estimated average fuel efficiency in gal/100 miles under this alternative is shown here to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

2.3.4 Alternative 4: Engines and Classes 7 and 8 Tractors

This alternative combines Alternative 2 with Alternative 3, and additionally would set an overall vehicle efficiency performance standard for Class 7 tractors. This alternative would thus set standards for all HD engines and would set overall vehicle performance standards for Classes 7 and 8 tractors, as described for Class 8 tractors under Alternative 3. Class 7 tractors make up a small percentage of the

Table 2.3-10

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 3 (Class 8 Tractors)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.6	6.6	6.6	6.6	6.6
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.9	6.9	6.9	6.9	6.9
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	11.3	11.3	11.3
Vocational (Classes 2b–8) – diesel	10.2	10.2	10.2	10.2	10.2	10.2
Tractors (Classes 7–8)	20.2	18.7	18.7	18.7	18.2	18.2

tractor market, approximately 9 percent.[12] Although the segment is currently small, the agencies believe that inclusion of this class of vehicles would help prevent potential class shifting, as noted in the NAS panel report.[13]

Alternative 4 fuel consumption standards for engines used in Class 2b through Class 8 vehicles are the same standards shown above in Tables 2.3-5 and 2.3-6 (under Alternative 2). The Alternative 4 fuel consumption standards for Classes 7 and 8 tractors vary by vehicle class (7 or 8), for day cabs versus sleeper cabs, and with the height of the roof, as shown below in Table 2.3-11, based on the tractor drive cycle mode weightings in Table 2.3-8. Note that the standards for Class 8 tractors in Table 2.3-11 are the same as those shown in Table 2.3-9 for Alternative 3.

Table 2.3-11

HD Combination Tractor Fuel Consumption Standards (gal /1,000 ton-miles)

	Day Cab		Sleeper Cab
	Class 7	Class 8	Class 8
MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016)a/			
Low Roof	10.3	7.8	6.3
Mid Roof	10.3	7.8	6.9
High Roof	11.6	8.6	7.1
MYs 2017–2018			
Low Roof	10.1	7.7	6.3
Mid Roof	10.1	7.7	6.8
High Roof	11.4	8.5	7.0

a/ Manufacturers may voluntarily opt-in to the NHTSA fuel consumption program in 2014 or 2015.

[12] Bradley, M.J, and Associates, LLC. 2009. Setting the Stage for Regulation of Heavy-Duty Vehicle Fuel Economy and GHG Emissions: Issues and Opportunities. Washington, D.C.: International Council on Clean Transportation. (Bradley and Associates 2009)
[13] HD NAS report, *supra* note 12, Page 6-38.

Table 2.3-12 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast manufacturers would achieve under Alternative 4, resulting from the HD engine standards in Tables 2.3-5 and 2.3-6 and the Classes 7 and 8 tractor fuel consumption standards in Table 2.3-11. (Alternative 4 specifies fuel consumption standards in gal/1,000 ton-miles for tractors and gal/100 bhp-hr for HD engines, but the estimated average fuel efficiency in gal/100 miles under this Alternative is shown here to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

Table 2.3-12

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 4 (Engines & Classes 7–8 Tractors)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.6	6.6	6.3	6.3	6.3
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.9	6.9	6.3	6.3	6.3
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.8	10.8	10.8
Vocational (Classes 2b–8) – diesel	10.2	9.9	9.9	9.9	9.7	9.7
Tractors (Classes 7–8)	20.2	18.5	18.5	18.5	17.9	17.9

2.3.5 Alternative 5: Engines, Classes 7 and 8 Tractors, and HD Pickups and Vans

This alternative builds on Alternative 4 through the addition of an overall vehicle efficiency performance standard for HD pickups and vans. Therefore, Alternative 5 combines the standards for all engines used in Classes 2–8 vehicles (in Tables 2.3-5 and 2.3-6), and the overall fuel consumption standards for Classes 7 and 8 tractors (in Table 2.3-11), and would also set overall fuel consumption standards for HD pickup and vans.

For HD pickups and vans, vehicle testing would be conducted on chassis dynamometers using the drive cycles from the EPA FTP (or ‘‘city’’ test) and Highway Fuel Economy Test (HFET or ‘‘highway’’ test). The FTP and HFET results would be weighted by 55 percent and 45 percent, respectively, and then averaged to calculate a combined cycle result. The 55/45 cycle weightings are the same as for the light-duty CAFE program, as NHTSA and EPA believe the real-world driving patterns for HD pickups and vans are similar to those of light-duty trucks. (A detailed discussion of drive cycles for these vehicles is included in Chapter 3 of the draft RIA[14]). Compliance with fuel consumption standards for HD pickups and vans would be determined through a fleet averaging process similar to the process used in determining passenger car and light truck compliance with CAFE standards.

[14] In the light-duty vehicle rule, EPA and NHTSA based tailpipe standards on use of the FTP and HFET, and declined to use alternative tests. *See* 75 *FR* at 25407. NHTSA is mandated to use the FTP and HFET tests for CAFE standards, and all relevant data were obtained by FTP and HFET testing in any case. *Id.* Neither of these constraints exists for Classes 7–8 tractors. The few data that exist on current performance are principally measured by the ARB Heavy Heavy Duty Truck 5 Mode Cycle testing, and NHTSA is not mandated to use the FTP to establish heavy-duty fuel economy standards. *See* 49 U.S.C. § 32902 (k)(2) authorizing NHTSA, among other things, to adopt and implement appropriate “test methods, measurement metrics, … and compliance protocols.”

The fuel consumption standards for HD pickups and vans are based on a “work factor” attribute that combines vehicle payload capacity and vehicle towing capacity, in pounds, with an additional fixed adjustment for four-wheel drive (4wd) vehicles. Fuel consumption targets would be determined for each vehicle with a unique work factor. These targets would then be production-weighted and summed to derive a manufacturer’s annual fleet average standards. Figures 2.3-1 and 2.3-2 illustrate the functional relationship between the work factor for HD pickups and vans and the corresponding fuel consumption targets for the HD pickup and van segment, specified in gal/100 miles (specific formulas for calculating work factors for HD pickups and vans are presented in the Preamble of the NPRM).

Figure 2.3-1 shows that the fuel consumption target standards for HD diesel pickups and vans in 2018 would be about 3 to 7 gal/100 miles, depending on the calculated work factor. Figure 2.3-2 shows that the fuel consumption target standards for HD gasoline pickups and vans in 2018 would be about 3.5 to 8 gal/100 miles, depending on the calculated work factor.

Table 2.3-13 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that EPA and NHTSA forecast that manufacturers would achieve under Alternative 5, resulting from the HD engine standards in Tables 2.3-5 and 2.3-6, the Classes 7 and 8 tractor fuel consumption standards in Table 2.3-11, and the fuel consumption standards for HD pickups and vans by work factor shown in Figures 2.3-1 and 2.3-2. (Alternative 5 specifies fuel consumption standards in gal/1,000 ton-miles for tractors, in gal/100 bhp-hr for HD engines, and in gal/100 miles for HD pickups and vans, but the estimated average fuel efficiency in gal/100 miles under this alternative is shown here for all HD vehicle segments to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

Figure 2.3-1. Proposed EPA CO_2 Target Standards and NHTSA Fuel Consumption Target Standards for Diesel HD Pickups and Vans

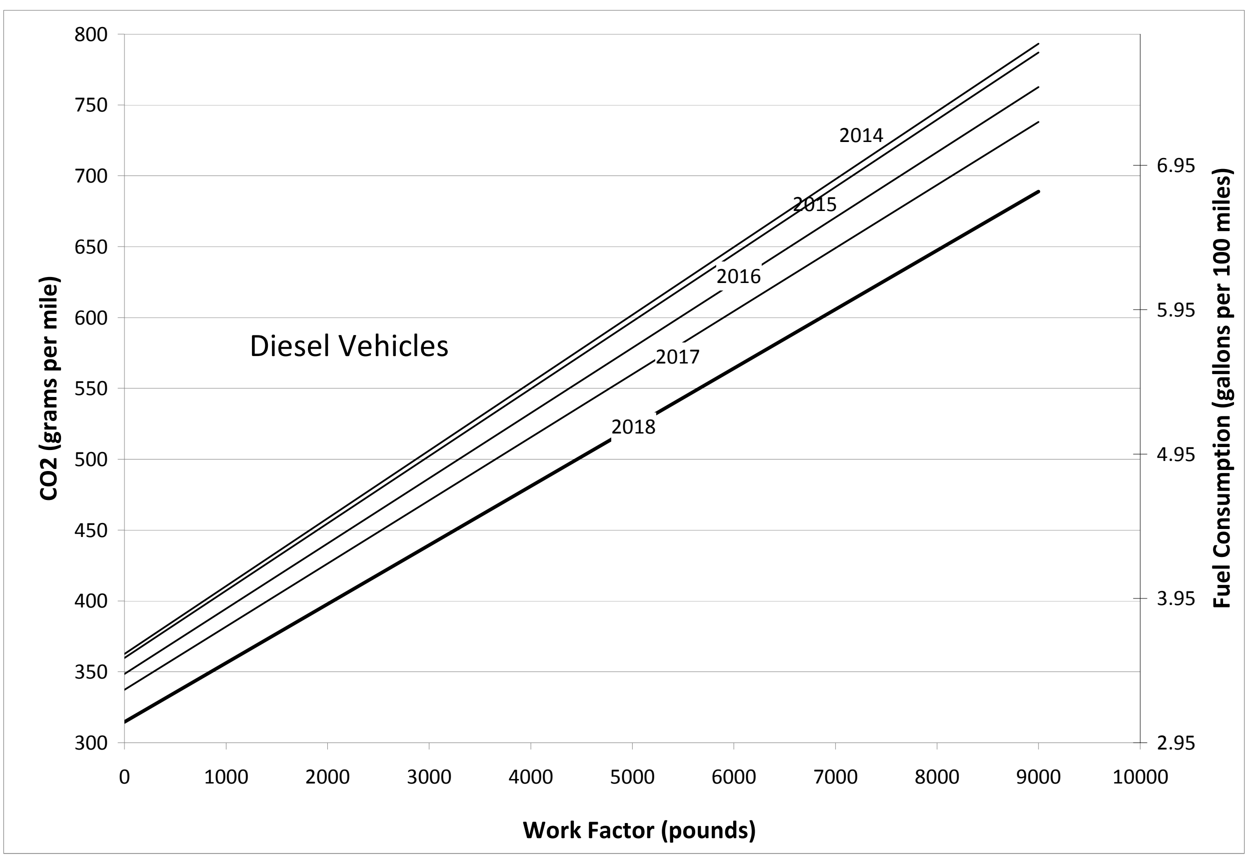


Figure 2.3-2. Proposed EPA CO_2 Target Standards and NHTSA Fuel Consumption Target Standards for Gasoline HD Pickups and Vans

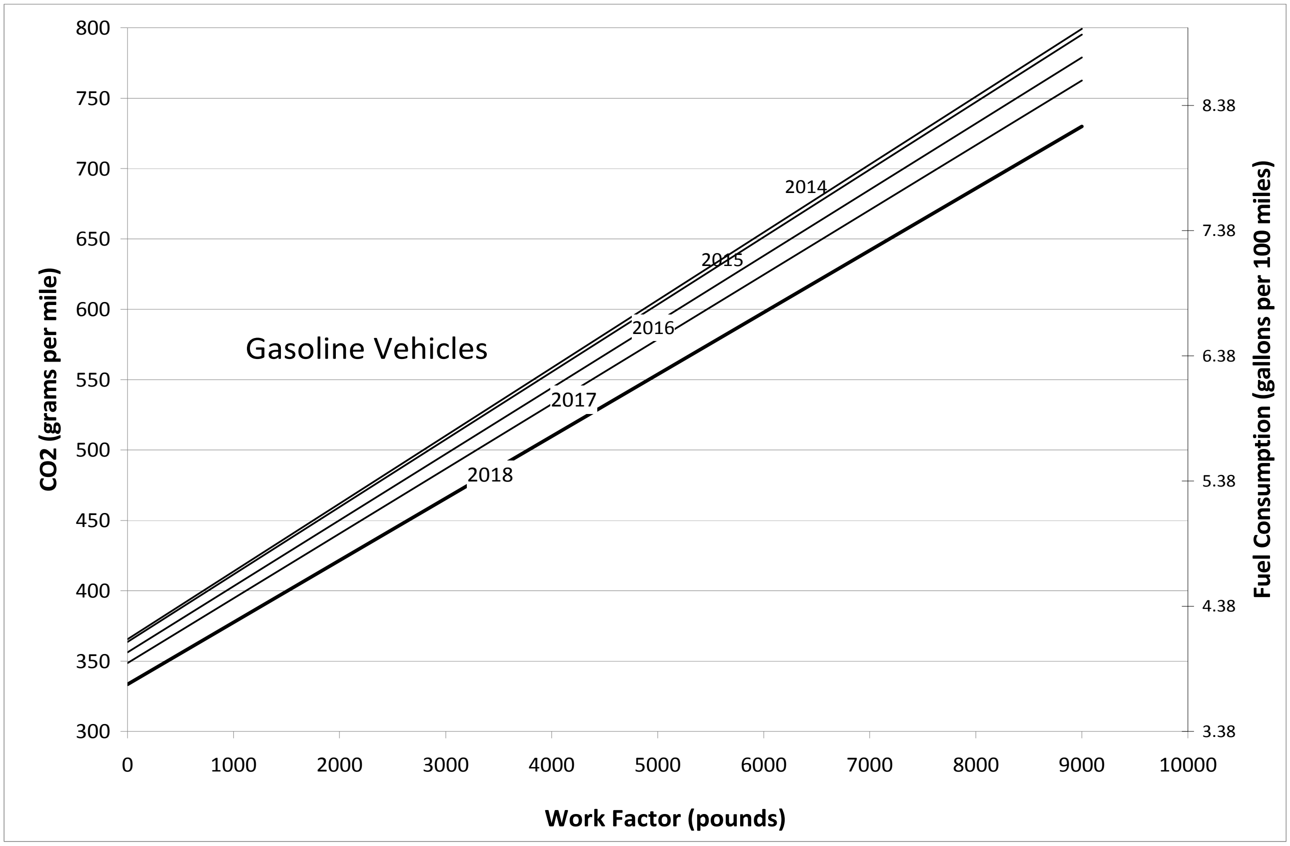


Table 2.3-13

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 5 (Engines, Classes 7–8 Tractors, & Classes 2b–3)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.5	6.5	6.4	6.2	6.0
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.8	6.7	6.5	6.3	5.9
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.8	10.8	10.8
Vocational (Classes 2b–8) – diesel	10.2	9.9	9.9	9.9	9.7	9.7
Tractors (Classes 7–8)	20.2	18.5	18.5	18.5	17.9	17.9

2.3.6 Alternative 6: Preferred Alternative – Engines, Tractors, and Classes 2b–8 Vehicles

Alternative 6 is NHTSA's Preferred Alternative. This alternative would set overall fuel consumption standards for all Classes 2b–8 vehicles and all engines used in those vehicles. Therefore, the Preferred Alternative combines the standards for engines used in Classes 2b–8 vehicles (except engines in HD pickups and vans, which are regulated as complete vehicles (*see* Table 2.3-11)), the overall fuel consumption standards for Classes 7 and 8 tractors (*see* Table 2.3-11), the fuel consumption standards for HD pickups and vans by work factor (*see* Figures 2.3-1 and 2.3-2), and also sets overall vehicle fuel consumption standards for Classes 2b–8 vocational vehicles (in gal/1,000 ton-miles). The fuel consumption standards for vocational vehicles vary by vehicle class (Classes 2b–5, Classes 6 and 7, and Class 8), as shown below in Table 2.3-14.

Table 2.3-14

Standards for Classes 2b–8 Vocational Vehicle Fuel Consumption (gal/1,000 ton-miles)

	Light Heavy Duty Classes 2b 5	Medium Heavy Duty Classes 6 7	Heavy Heavy-Duty Class 8
MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016)a/	35.2	20.8	10.7
MYs 2017–18	33.8	20.0	10.5

a/ Manufacturers may voluntarily opt-in to the NHTSA fuel consumption program in 2014 or 2015.

This alternative sets fuel consumption standards for both the engines and the vehicles in the entire HD vehicle sector. Engine standard compliance for each vehicle class, except engines in HD pickups and vans, which are regulated as complete vehicles, would be determined as discussed in the description of Alternative 2. Compliance with the tractor and vocational vehicle classes' overall vehicle performance standard (Classes 2b through 8 vehicles) would be determined as discussed in the description of Alternative 3. Compliance for HD pickups and vans would be determined through a fleet averaging process as discussed in the description of Alternative 5. This Preferred Alternative represents standards that NHTSA has tentatively determined require the maximum feasible improvement under EISA, based on the balancing of statutory considerations.

Table 2.3-15 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast that manufacturers would achieve under Alternative 6, the Preferred Alternative, resulting from the HD engine standards in Tables 2.3-5 and 2.3-6, the Classes 7 and 8 tractor fuel consumption standards in Table 2.3-11, the fuel consumption standards for HD pickups and vans by work factor shown in Figures 2.3-1 and 2.3-2, and the vocational vehicle fuel consumption standards in Table 2.3-14. (Alternative 6 specifies fuel consumption standards in gal/1,000 ton-miles for tractors and vocational vehicles, in gal/100 bhp-hr for HD engines, and in gal/100 miles for HD pickups and vans, but the estimated average fuel efficiency in gal/100 miles under this alternative is shown here for all HD vehicle categories to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

The agencies also evaluated two alternatives related to Alternative 6 with stringency levels which are 15 percent less stringent and 20 percent more stringent than that alternative. These alternatives are referred to as Alternatives 6A and 6B, respectively.

Table 2.3-15

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 6 (Engines, Tractors, & Classes 2b–8, Preferred)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.5	6.5	6.4	6.2	6.0
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.8	6.7	6.5	6.3	5.9
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.7	10.7	10.7
Vocational (Classes 2b–8) – diesel	10.2	9.7	9.7	9.7	9.3	9.3
Tractors (Classes 7–8)	20.2	18.5	18.5	18.5	17.9	17.9

2.3.6.1 Alternative 6A: 15 Percent Below Preferred Alternative Stringency

Alternative 6A represents an alternative stringency level to the agencies' preferred approach. Like Alternative 6, this alternative would set fuel efficiency and GHG emission standards for HD pickup trucks and vans and for Classes 2b through 8 vocational vehicles and tractors and the engines installed in them. The difference between Alternative 6 and 6A is the level of stringency for each of the proposed standards. Alternative 6A represents a stringency level which is 15 percent less than the preferred approach. The agencies calculated the stringency level by removing the least cost effective technology in each of the vehicle categories (as described in Chapter 6 of the draft RIA).

Table 2.3-16 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast that manufacturers would achieve under Alternative 6A. (Alternative 6A specifies fuel consumption standards in gal/1,000 ton-miles for tractors and vocational vehicles, in gal/100 bhp-hr for

Table 2.3-16

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 6A (15% below Preferred Alternative Stringency)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.6	6.5	6.4	6.3	6.1
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.8	6.7	6.6	6.4	6.0
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.8	10.8	10.8
Vocational (Classes 2b–8) – diesel	10.2	9.9	9.9	9.9	9.7	9.7
Tractors (Classes 7–8)	20.2	18.5	18.5	18.5	17.9	17.9

HD engines, and in gal/100 miles for HD pickups and vans, but the estimated average fuel efficiency in gal/100 miles under this alternative is shown here for all HD vehicle categories to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

2.3.6.2 Alternative 6B: 20 Percent Above Preferred Alternative Stringency

Alternative 6B represents an alternative stringency level to the agencies' preferred approach. Like Alternative 6, this alternative would set fuel efficiency and GHG emission standards for HD pickup trucks and vans and for Classes 2b through 8 vocational vehicles and tractors and the engines installed in them. The difference between Alternative 6 and 6B is the level of stringency for each of the proposed standards. Alternative 6B represents a stringency level which is 20 percent more stringent than the preferred approach. The agencies calculated the stringency level by adding the next most cost effective technology in each of the vehicle categories (as described in Chapter 6 of the draft RIA).

Table 2.3-17 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast that manufacturers would achieve under Alternative 6B. (Alternative 6B specifies fuel consumption standards in gal/1,000 ton-miles for tractors and vocational vehicles, in gal/100 bhp-hr for HD engines, and in gal/100 miles for HD pickups and vans, but the estimated average fuel efficiency in gal/100 miles under this alternative is shown here for all HD vehicle categories to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

Table 2.3-17

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 6B (20% above Preferred Alternative Stringency)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.5	6.5	6.3	6.2	5.8
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.7	6.7	6.4	6.2	5.7
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.7	10.7	10.7
Vocational (Classes 2b–8) – diesel	10.2	9.7	9.7	9.7	9.1	9.1
Tractors (Classes 7–8)	20.2	18.1	18.1	18.1	17.6	17.6

2.3.7 Alternative 7: Engines, Tractors, Trucks, and Trailers

This alternative builds on Alternative 6 by adding a performance standard for the commercial trailers pulled by tractors. Therefore, this alternative includes fuel consumption standards for all Classes 2b through 8 vehicles and the engines used in those tractors, and for trailers. The inclusion of trailer requirements under this alternative results in overall tractor-trailer gal/1,000 ton-mile standards that are lower (more stringent) than those shown in Table 2.3-11 for tractors alone.

Table 2.3-18 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast that manufacturers would achieve under Alternative 7, resulting from standards for HD engines, tractors, trucks, and trailers. (Alternative 7 specifies standards in gal/100 bhp-hr for engines, gal/100 miles for pickup trucks and vans, and gal/1,000 ton-miles for vocational vehicles and tractors, but the

Table 2.3-18

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 7 (Engines, Tractors, Trucks, & Trailers)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.5	6.5	6.4	6.2	6.0
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.8	6.7	6.5	6.3	5.9
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.7	10.7	10.7
Vocational (Classes 2b–8) – diesel	10.2	9.7	9.7	9.7	9.3	9.3
Tractors (Classes 7–8)	20.2	18.2	18.2	18.2	17.7	17.7

estimated average fuel efficiency in gal/100 miles is shown here for all HD market segments to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

2.3.8 Alternative 8: Accelerated Hybrid Adoption

Alternative 8 includes all vehicle categories covered in Alternative 7 with more stringent standards for those vehicles based on accelerated adoption of hybrid powertrains for HD pickup and vans and vocational vehicles. Hybrid powertrain technology makes it possible to optimize engine size and efficiency, and to capture the energy lost during braking. Hybrid vehicles have two propulsion power sources. The main power source is usually a conventional internal combustion engine. Energy recaptured from braking is stored until it can be reused by the second power source. The second power source generates extra power to supply "boost" to the vehicle when needed. Because the main engine no longer has to handle the full range of power demands, it can be optimized to operate within its most efficient performance range.[15] This alternative caps application of hybrids at 10,000 units annually for MYs 2014–2016 (more than double the industry's sales projections for 2010) and increases to 50 percent of new vehicles in those classes starting in 2017. NHTSA cannot at this time conclude that developing the manufacturing infrastructure necessary to support such a high rate of hybrid production is technically feasible by MY 2017. Nevertheless, for the purpose of evaluating what additional benefits could be achieved if such a program were possible, we have evaluated this alternative. The assumed standard and commensurate fuel consumption and emission reductions for this alternative are based on a 25-percent reduction in fuel consumption with the application of hybrid powertrain technology. The actual benefit realized through the application of hybrid technology is highly dependent on vehicle drive cycle and can vary significantly among different applications. The 25-percent reduction assumed here is based on the estimate of the NAS panel for a hybrid refuse truck. The inclusion of accelerated hybrid adoption under this alternative results in fuel consumption standards lower than the gallons-per-100-mile standards shown in Figures 2.3-1 and 2.3-2 for HD pickups and vans and the gallons-per-1,000-ton-mile standards for vocational vehicles in Table 2.3-14.

[15] *See* http://www.epa.gov/smartway/documents/hybrid%20powertrain.pdf (last accessed September 24, 2010).

Table 2.3-19 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA and EPA forecast that manufacturers would achieve under Alternative 8, resulting from standards for HD vehicles, trailers, and engines, including standards that anticipate accelerated hybrid adoption for HD pickups and vans and vocational vehicles. (Alternative 8 specifies standards in gal/100 bhp-hr for engines, gal/100 miles for pickups and vans, and gal/1,000 ton-miles for vocational vehicles and tractors, but the estimated average fuel efficiency in gal/100 miles is shown here to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative, shown in Table 2.3-3).

Table 2.3-19

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 8 (Accelerated Hybrid Adoption)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.7	6.5	6.5	6.4	5.5	5.2
Pickups & Vans (Classes 2b–3) – diesel	6.9	6.8	6.7	6.5	5.5	5.1
Vocational (Classes 2b–8) – gasoline	11.4	11.3	11.3	10.7	10.7	10.7
Vocational (Classes 2b–8) – diesel	10.2	9.6	9.6	9.6	8.0	8.0
Tractors (Classes 7–8)	20.2	18.2	18.2	18.2	17.7	17.7

2.3.9 Greenhouse Gas Emission Standards for Medium- and Heavy-Duty Vehicles

For engines used in Classes 2b–8 HD vehicles, EPA is proposing g/bhp-hr emission standards that correspond to NHTSA gal/100 bhp-hr fuel consumption standards. Tables 2.3-20 and 2.3-21 show the EPA CO_2 emission standards for HD engines that correspond to the NHTSA fuel consumption standards in Tables 2.3-5 and 2.3-6, respectively.

For vocational vehicles and tractors, EPA is proposing grams per ton-mile (g/ton-mile) standards that correspond to NHTSA's gal/1,000 ton-mile fuel consumption standards. Tables 2.3-22 and 2.3-23 show the EPA CO_2 emission standards for vocational vehicles and tractors that correspond to the NHTSA standards in Tables 2.3-11 and 2.3-14.

Table 2.3-20

EPA Standards (CO_2 g/bhp-hr) for Engines Used in HD Pickups and Vans (Classes 2b–3) and Vocational Vehicles (Classes 2b–8)

	Light Heavy Duty Diesel (LHDD) HD Pickups and Vans	Light Heavy Duty Diesel (LHDD) Vocational Vehicles	Medium Heavy Duty Diesel (MHDD)	Heavy Heavy-Duty Diesel (HHDD)	Gasoline
MY 2014		600	600	567	
Effective MY 2016	576				627
Effective MY 2017		576	576	555	

Table 2.3-21

EPA Standards for Heavy Duty Tractor Diesel Engines (Classes 7–8) (CO_2 g/bhp-hr)

	MMD/HDD Engine	HMD/HDD Engine
MY 2014	502	475
Effective MY 2017	487	460

Table 2.3-22

EPA Heavy Duty Tractor Standards (Classes 7–8) (CO_2 g/ton-mile)

	Day Cab		Sleeper Cab
MYs 2014–2016	Class 7	Class 8	Class 8
Low Roof	104	79	65
Mid Roof	104	79	70
High Roof	118	87	73
MYs 2017–2018			
Low Roof	103	78	64
Mid Roof	103	78	69
High Roof	116	86	71

Table 2.3-23

EPA Standards for Vocational Vehicles (Classes 2b–8) (CO_2 g/ton-mile)

	Light Heavy Classes 2b 5	Medium Heavy Classes 6 7	Heavy Heavy Class 8
MY 2016	358	212	109
MYs 2017–18	344	204	107

2.4 COMPARISON OF ALTERNATIVES

The CEQ NEPA regulations direct Federal agencies to use the NEPA process to identify and assess reasonable alternatives to proposed actions that would avoid or minimize adverse effects of the actions upon the quality of the human environment.[16] CEQ regulations state:

> Based on the information and analysis presented in the sections on the Affected Environment (§ 1502.15) and the Environmental Consequences (§ 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.[17]

This section summarizes and compares the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality, and climate. The alternatives in the tables and figures that follow are arranged in ascending order of fuel savings, to aid in the environmental analysis and the comparison of alternatives. Consequently, the alternatives appear out of numerical sequence. For discussions on assumptions and methodologies used to estimate the direct, indirect, and cumulative

[16] *See* 40 CFR § 1500.2(e).
[17] *See* 40 CFR § 1502.14.

effects, *see* Chapters 3 and 4. No quantifiable, alternative-specific effects were identified for the other resource areas discussed in Sections 3.5 and 4.5 of this EIS, so they are not summarized here.

The consideration of these effects extends beyond MYs 2014–2018 vehicles. In the alternatives analyzed in this EIS, the growth in the number of HD vehicles in use throughout the United States and in the annual vehicle-miles traveled (VMT) by HD vehicles outpaces improvements in efficiency resulting from each action alternative, resulting in projected increases in total fuel consumption by HD vehicles. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles. NHTSA estimates that the proposed HD vehicle fuel consumption standards would reduce fuel consumption and CO_2 emissions from the future levels that would otherwise occur in the absence of the HD Fuel Efficiency Improvement Program (*i.e.*, fuel consumption and CO_2 emissions under the No Action Alternative).

For more detailed discussions on assumptions and methodologies associated with the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality, and climate, *see* Sections 3.1 and 4.1.

2.4.1 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. Below is a description of the direct and indirect effects of the proposed action and alternatives on energy, air quality, and climate.

2.4.1.1 Energy

NHTSA's analysis assumes that under each alternative considered, the fuel efficiency standards established for MY 2018 will continue to apply to HD vehicles produced in all subsequent model years. Thus, over time, an increasing fraction of the Nation's vehicle fleet would consist of vehicles that meet the standards established for MY 2018. Table 2.4-1 shows the increasing impact of alternative standards

Table 2.4-1

Total HD Vehicle Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Combination Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	52.06	51.20	50.79	50.31	50.33	50.26	50.13	49.96	49.80	49.50
2030	61.47	58.63	58.05	56.51	56.37	56.13	55.74	55.40	54.78	53.12
2050	88.39	83.88	83.53	80.91	80.62	80.26	79.45	78.98	77.90	74.47
Fuel Savings Compared to No Action										
2018	--	0.86	1.27	1.75	1.72	1.79	1.93	2.09	2.26	2.56
2030	--	2.85	3.42	4.96	5.11	5.34	5.73	6.08	6.69	8.35
2050	--	4.51	4.87	7.48	7.77	8.13	8.94	9.42	10.50	13.93

a/ Preferred Alternative

on annual fuel consumption for all HD vehicles from 2018 through 2050, when the entire HD vehicle fleet is likely to be composed of vehicles that meet the fuel efficiency standards for MY 2018. This table reports total fuel consumption, both gasoline and diesel, for HD pickups and vans, vocational vehicles, and combination tractors, under the No Action Alternative (Alternative 1) and each of the nine action alternatives, which are described in Section 2.3.

Fuel consumption under the No Action Alternative is projected to reach 88.39 billion gallons in 2050. Fuel consumption ranges from 83.88 billion gallons under Alternative 2 (Engine Only) to 74.47 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). Fuel consumption in 2050 is 79.45 billion gallons under the Preferred Alternative. Under all action alternatives, fuel consumption is less than projected under the No Action Alternative, resulting in 2050 fuel savings ranging from 4.51 billion gallons under Alternative 2 (Engine Only) to 13.93 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). In 2050, fuel savings under the Preferred Alternative (Engines, Tractors, & Classes 2b–8 Vehicles) amounts to 8.94 billion gallons as compared to the No Action Alternative.

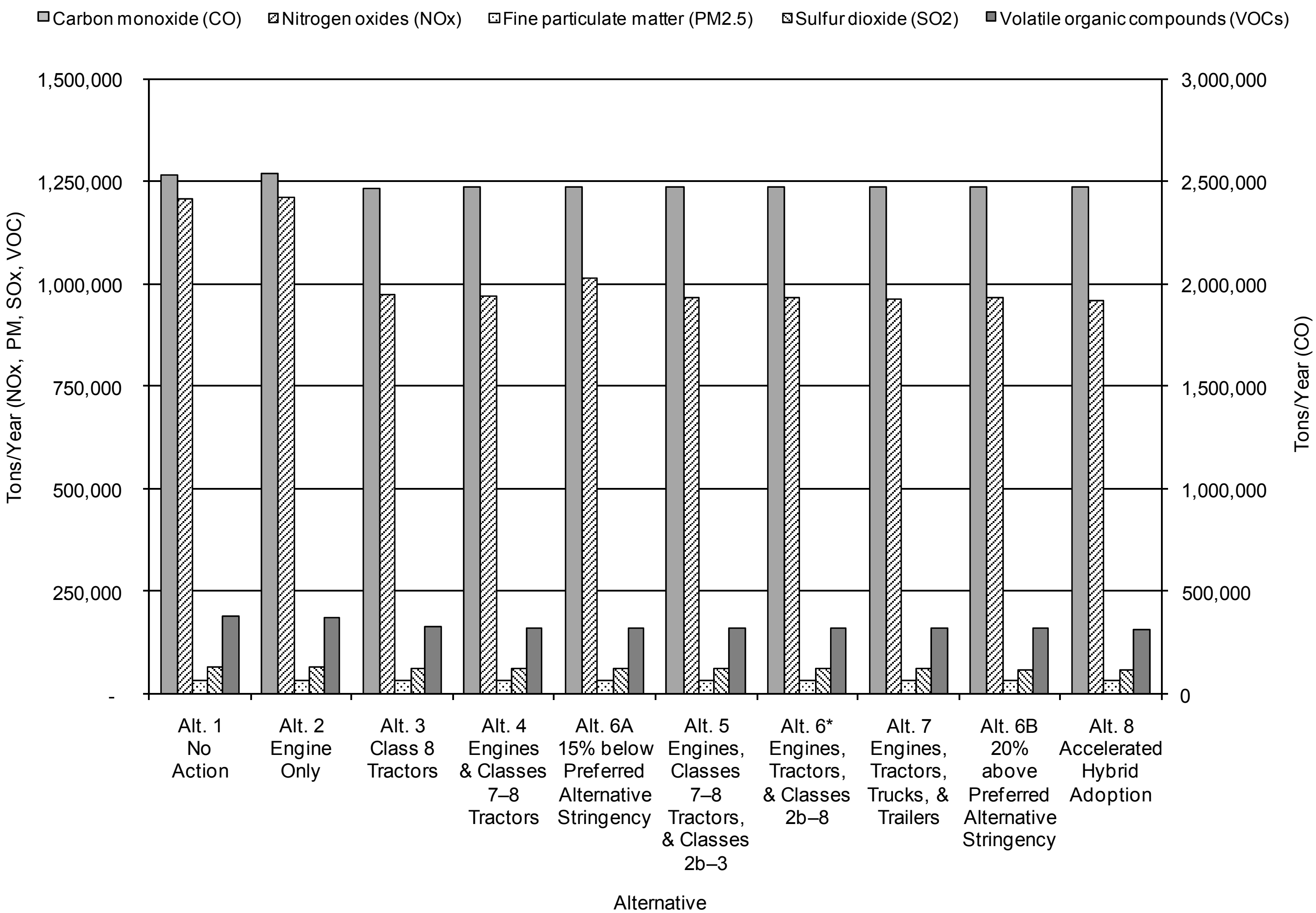
2.4.1.2 Air Quality

The HD Fuel Efficiency Improvement Program would reduce emissions of criteria and toxic air pollutants under most alternatives in most years. The change in emissions resulting from each action alternative is the sum of (1) reductions in emissions from fuel production, refining, and distribution (upstream emissions) due to the decline in fuel consumption, and (2) the increase in emissions from the vehicle tailpipe (downstream emissions) resulting from added vehicle use due to the fuel efficiency rebound effect. NHTSA assumed that changes in air quality, population exposure to criteria and hazardous air pollutants, and health effects, are directly proportional to the changes in emissions. Emissions of some pollutants would increase for some combinations of pollutant, alternative, and year. The ranges of reductions and increases would vary by pollutant, alternative, and year. NHTSA chose to report air quality results for the following years: 2018, to show the immediate effect of the rule; 2030 to show an intermediate effect of the rule when a large portion of the HD vehicle fleet will be MY 2014 or newer; and 2050, to show the effect of the rule when almost all of the HD vehicle fleet will be MY 2014 or newer. The results for 2030 are given below for each pollutant. The mid-term forecast year of 2030 was selected because, by this point, a large proportion of the VMT by HD vehicles would be accounted for by vehicles that meet the MYs 2014–2018 standards and it is consistent with the draft RIA for the proposed rule, which also reports results for 2030.

Figure 2.4-1 shows the nationwide results for criteria pollutants for all alternatives in 2030. Carbon monoxide (CO) emissions in 2030 would range from a high of 2,536,070 tons under Alternative 2 to a low of 2,468,226 tons under Alternative 3 (a difference of 67,844 tons). Nitrogen oxide (NO_x) emissions in 2030 would range from a high of 1,211,776 tons under Alternative 2 to a low of 960,551 tons under Alternative 8 (a difference of 251,225 tons). Particulate matter ($PM_{2.5}$) emissions in 2030 would range from a high of 37,422 tons under Alternative 3 to a low of 36,118 tons under Alternative 2 (a difference of 1,304 tons). Sulfur dioxide (SO_2) emissions in 2030 would range from a high of 70,377 tons under Alternative 1 (the No Action Alternative) to a low of 60,801 tons under Alternative 8 (a difference of 9,576 tons). Volatile organic compound (VOC) emissions in 2030 would range from a high of 190,376 tons under Alternative 1 (the No Action Alternative) to a low of 157,758 tons under Alternative 8 (a difference of 32,618 tons).

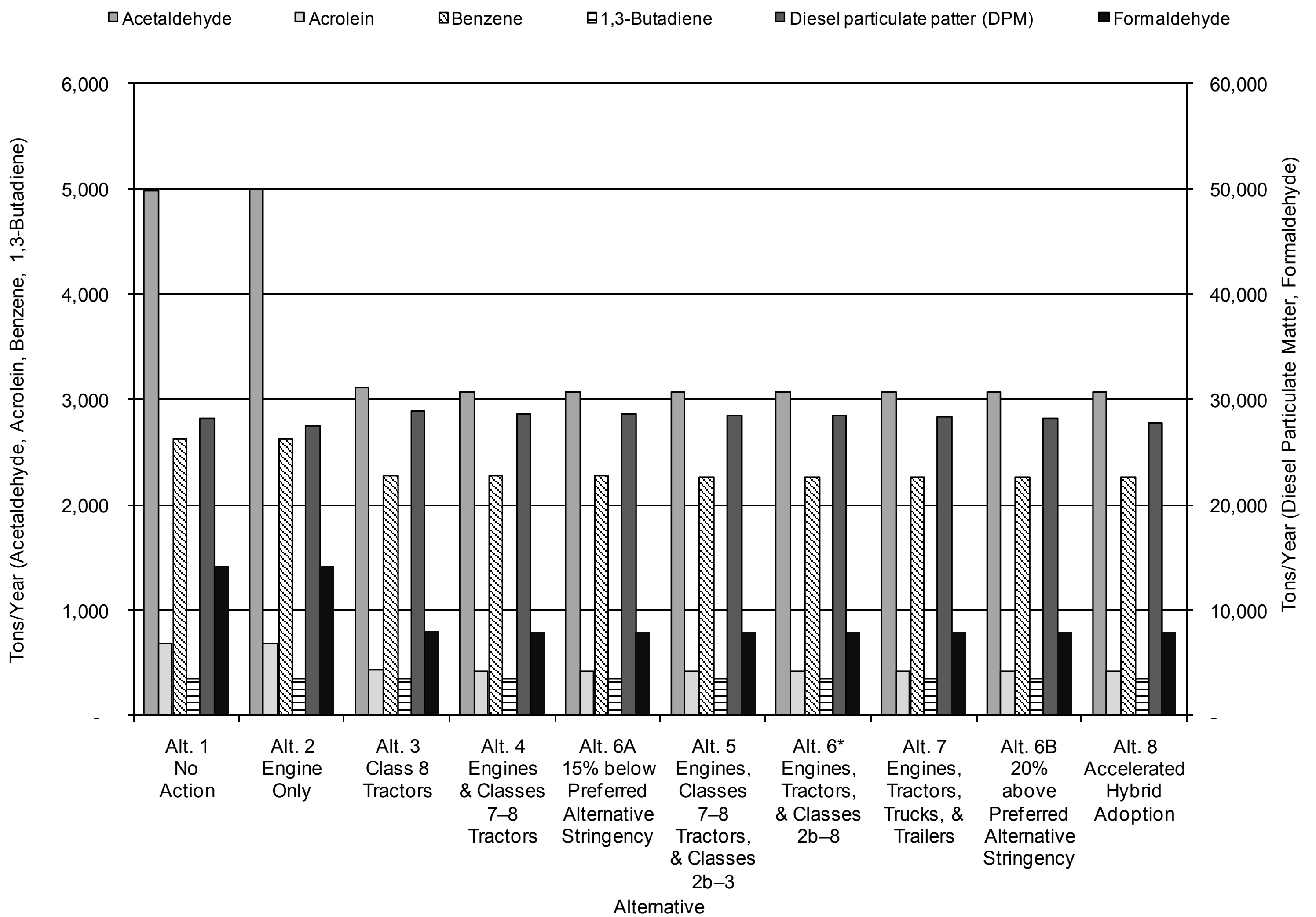
Figure 2.4-2 shows the nationwide results for toxic air pollutants for all alternatives in 2030. Acetaldehyde emissions in 2030 would range from a high of 4,998 tons under Alternative 2 to a low of 3,068 tons under Alternatives 6 and 8 (a difference of 1,930 tons). Acrolein emissions in 2030 would range from a high of 689 tons under Alternative 2 to a low of 424 tons under Alternatives 3 through 8 (a difference of 265 tons). Benzene emissions in 2030 would range from a high of 2,631 tons under

Figure 2.4-1. Nationwide Criteria Pollutant Emissions (tons/year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Figure 2.4-2. Nationwide Toxic Air Pollutant Emissions (tons/year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Alternative 2 to a low of 2,260 tons under Alternative 8 (a difference of 371 tons). Emissions of 1,3-butadiene in 2030 would range from a high of 353 tons under Alternative 2 to a low of 349 tons under Alternative 3 (a difference of 4 tons). Diesel particulate matter (DPM) emissions in 2030 would range from a high of 28,846 tons under Alternative 3 to a low of 27,504 tons under Alternative 2 (a difference of 1,342 tons). Formaldehyde emissions in 2030 would range from a high of 14,162 tons under Alternative 2 to a low of 7,832 tons under Alternative 8 (a difference of 6,330 tons) nationwide.

The projected reductions in nationwide emissions under all action alternatives are expected to lead to reductions in adverse health effects as compared to the No Action Alternative. Despite increases in emissions of some pollutants such as $PM_{2.5}$, reductions would occur in emissions of most pollutants. The resulting decline in health effects from these reductions more than offsets the increase in health effects from higher $PM_{2.5}$ emissions. Reductions in adverse health effects would occur nationwide under all action alternatives compared to the No Action Alternative, and the reductions would become larger as emissions decrease across alternatives. Mortality estimates are based on data from two alternative studies, which EPA considers co-equal. When compared to the No Action Alternative, premature mortality in 2030 would be reduced by 28 cases under Alternative 2 to 212 cases under Alternative 8 based on Pope *et al*. (2002) data, and 71 cases under Alternative 2 to 543 cases under Alternative 8 based on Laden *et al*. (2006) data. The Preferred Alternative (Alternative 6) would reduce premature mortality by 175 (Pope *et al.*) and 448 (Laden *et al.*). The number of work-loss days in 2030 would be reduced by 3,328 days under Alternative 2 to 26,190 days under Alternative 8. The Preferred Alternative would reduce the number of work-loss days by 21,734 days in 2030.

The value of monetized health benefits (such as reductions in respiratory and cardiovascular-related illnesses) would vary proportionally with changes in health outcomes. Monetized health benefits are based on data from Pope *et al.* and Laden *et al.*, and for two alternative discount rate assumptions of 3 percent and 7 percent. The value of monetized health benefits under the 3-percent discount rate would range from $247 million under Alternative 2 to $1,892 million under Alternative 8 based on Pope *et al*. data, or $605 million under Alternative 2 to $4,628 million under Alternative 8 based on Laden *et al*. data. This value would be $1,559 million (Pope *et al.*) and $3,813 million (Laden *et al.*) for the Preferred Alternative (Alternative 6) in 2030. Using Pope *et al*. data, the value of monetized health benefits under the 7-percent discount rate would range from $224 million under Alternative 2 to $1,716 million under Alternative 8, and, based on Laden *et al*. data, $547 million under Alternative 2 to $4,181 million under Alternative 8. The Preferred Alternative would result in monetized health benefits of $1,414 million (Pope *et al.*) and $3,444 million (Laden *et al.*) in 2030.

2.4.1.3 Climate Change

2.4.1.3.1 GHG Emissions

Table 2.4-2 shows total GHG emissions and emission reductions from HD vehicles under each of the ten alternatives, summed for the period 2014 through 2100. Although GHG emissions from this sector will continue to rise over the period (absent other reduction efforts) across all the alternatives, the effect of the alternatives is to slow this increase by varying amounts. Total emissions for the period range from 68,800 million metric tons of carbon dioxide ($MMTCO_2$) for Alternative 8 to 80,400 $MMTCO_2$ for the No Action Alternative (Alternative 1). Compared to the No Action Alternative, projections of emission reductions under the alternatives over the period 2014 to 2100 range from 3,800 to 11,600 $MMTCO_2$. The Preferred Alternative (Alternative 6) would result in total emissions of 72,800 $MMTCO_2$, a reduction in emissions by 7,600 $MMTCO_2$ compared to the No Action Alternative. Compared to

Table 2.4-2

Emissions and Emission Reductions ($MMTCO_2$) from 2014–2100 by Alternative a/

Alternative	Total Emissions	Emissions Reductions Compared to No Action Alternative	Emissions Reductions Compared to No Action Alternative
1 No Action	80,400	0	
2 Engine Only	76,500	3,800	5%
3 Class 8 Tractors	76,200	4,200	5%
4 Engines & Classes 7–8 Tractors	74,000	6,400	8%
6A 15% below Preferred Alternative Stringency	73,800	6,600	8%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	73,500	6,900	9%
6 Engines, Tractors, & Classes 2b–8 b/	72,800	7,600	9%
7 Engines, Tractors, Trucks, & Trailers	72,400	8,000	10%
6B 20% above Preferred Alternative Stringency	71,500	8,900	11%
8 Accelerated Hybrid Adoption	68,800	11,600	14%

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b/ Preferred Alternative

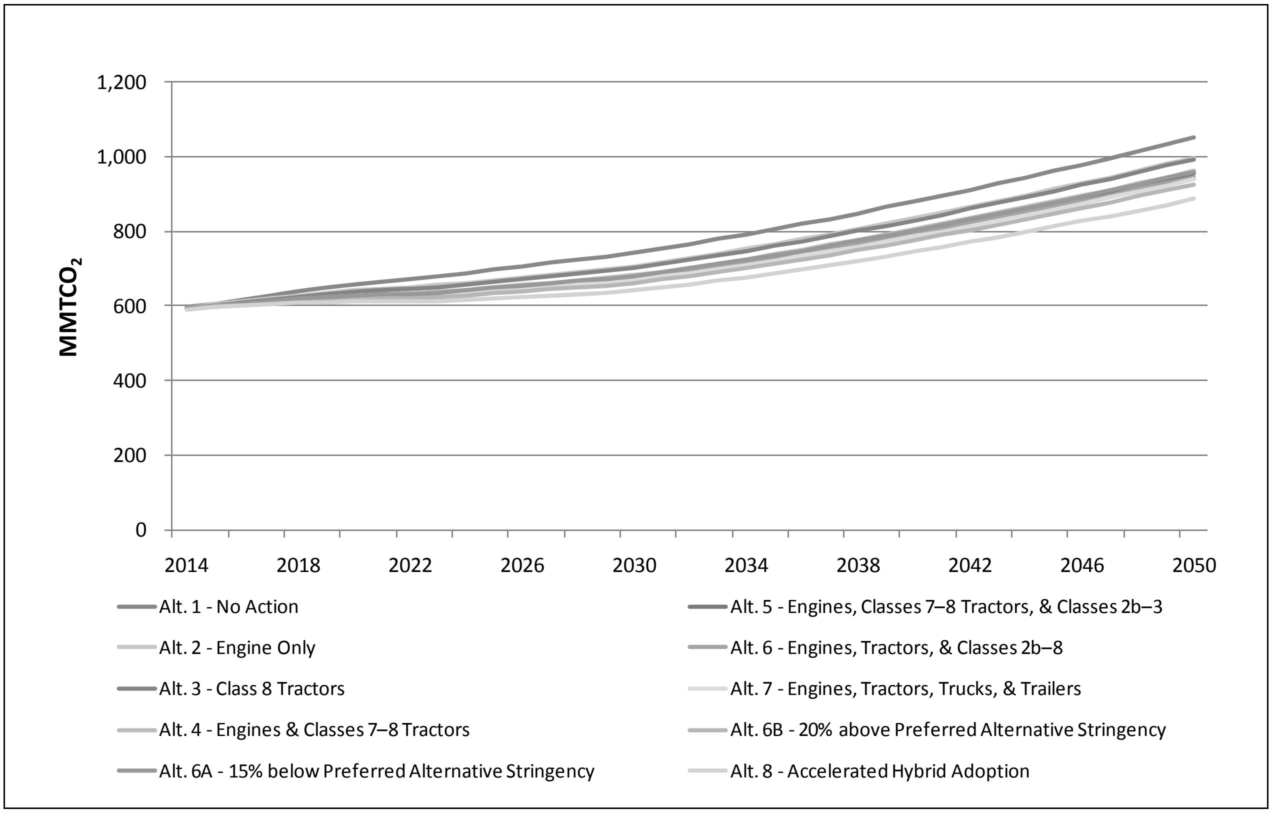
projected cumulative global emissions of 5,204,115 $MMTCO_2$ over this period,[18] this rulemaking would reduce global CO_2 emissions by about 0.1 to 0.2 percent.

To better understand the relative impacts of these reductions, it can be helpful to consider the relative importance of emissions from HD vehicles as a whole and compare them against emissions projections for the United States. In the United States, HD vehicles currently account for approximately 6.9 percent of CO_2 emissions (EPA 2010a). With the action alternatives reducing HD vehicle CO_2 emissions by 5 to 14 percent of total emissions from U.S. HD vehicles from 2014 to 2100 as compared to the No Action Alternative, each action alternative 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 Global Change Assessment Model (GCAM) reference scenario of 7,193 $MMTCO_2$, the action alternatives would reduce annual U.S. CO_2 emissions by 0.7 to 2.1 percent in 2100. As another comparison of the magnitude of these reductions, average annual CO_2 emission reductions from the alternatives range from 44 to 134 $MMTCO_2$ over 2014 to 2100, equivalent to the annual CO_2 emissions of 11 to 35 coal-fired power plants.[19] Figure 2.4-3 shows projected annual emissions from HD vehicles under the alternatives.

Under each alternative, growth in the number of HD vehicles in use throughout the United States combined with assumed increases in their usage (vehicle-miles traveled) is projected to result in a growth of the total HD sector. This growth offsets improvements in fuel efficiency for each alternative, resulting in projected increases in total fuel consumption by HD vehicles in the United States. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles.

[18] Projected by the Global Change Assessment Model (GCAM) reference scenario.
[19] Estimated using EPA's Greenhouse Gas Equivalencies Calculator (EPA 2010b).

Figure 2.4-3. Projected Annual Emissions ($MMTCO_2$) by Alternative



In 2005, the most recent year of data available for global CO_2 emissions, the HD vehicle fleet in the United States was responsible for about 1.2 percent of total global emissions of CO_2, a driver of climate change effects. Although substantial, this source is a small percentage of global emissions. The relative contribution of CO_2 emissions from U.S. HD vehicles to other sources of CO_2 emissions 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).

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

Table 2.4-3 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 nine action alternatives. Figure 2.4-4 graphically illustrates temperature reductions for the nine action alternatives.

Estimated global CO_2 concentrations for 2100 range from 783.8 parts per million (ppm) under Alternative 8 to 784.9 ppm under the No Action Alternative. 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), the differences are small, as shown in Figure 2.4-4. For 2100, the reduction in temperature increase, compared to the No Action Alternative, ranges from 0.001 °C (0.002 °F) to 0.004 °C (0.007 °F). Table 2.4-3 presents the effects on sea-level rise under the alternatives estimated using the Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) under the Reference Concentration Pathway (RCP) GCAM reference scenario. Sea-level rise in 2100 ranges from 37.40 centimeters (cm) under the No Action Alternative to 37.36 cm under Alternative 8, for a maximum reduction of 0.04 cm

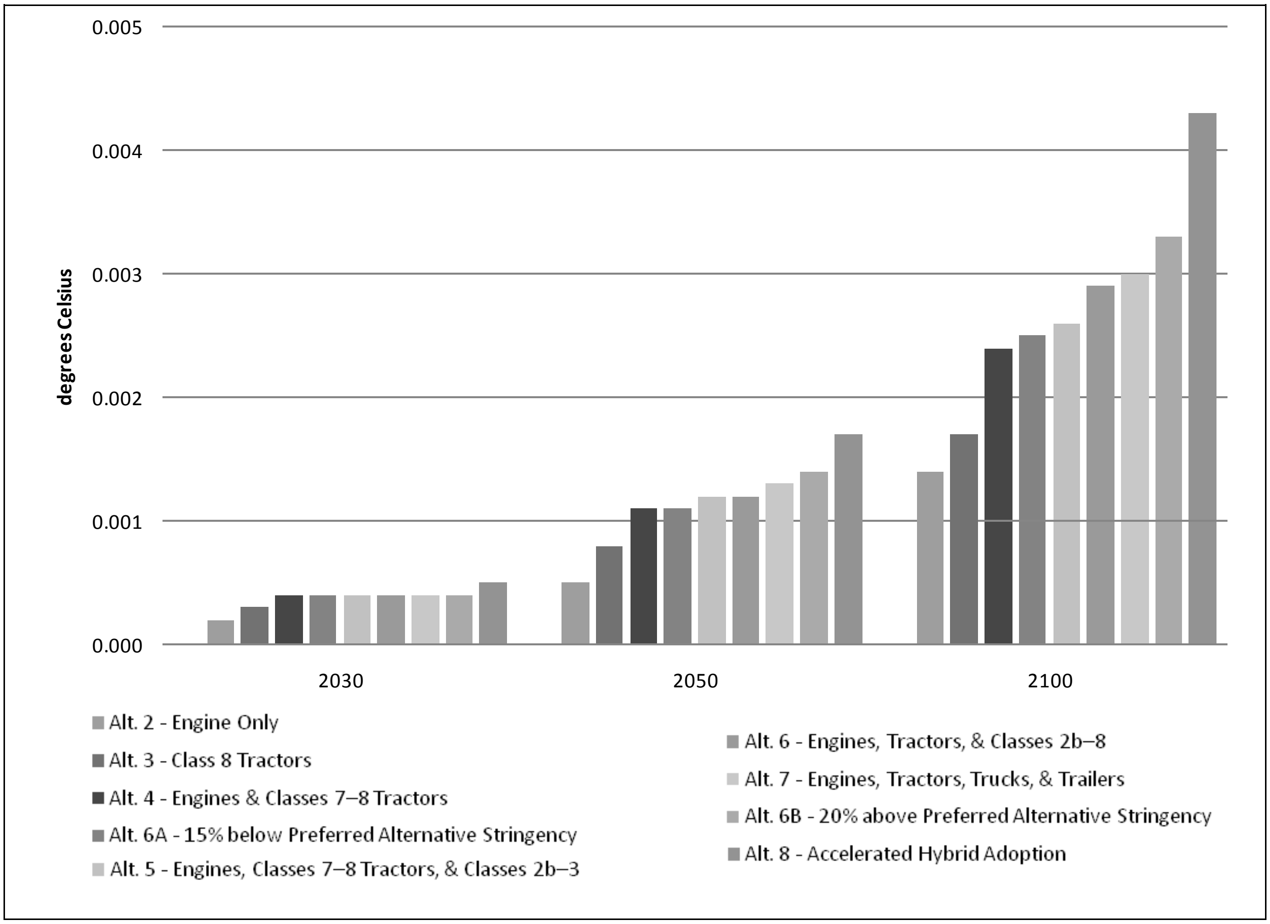
Table 2.4-3

CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-Level Rise Using MAGICC (RCP GCAM Reference) by Alternative a/

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-Level Rise (cm)		
Alternative	2030	2050	2100	2030	2050	2100	2030	2050	2100
Totals									
1 No Action	443.6	519.0	784.9	0.880	1.516	3.064	8.06	14.81	37.40
2 Engine Only	443.6	518.9	784.5	0.880	1.516	3.063	8.06	14.81	37.38
3 Class 8 Tractors	443.6	518.8	784.5	0.880	1.516	3.062	8.06	14.81	37.38
4 Engines & Classes 7–8 Tractors	443.6	518.8	784.3	0.880	1.515	3.062	8.06	14.81	37.38
6A 15% below Preferred Alternative Stringency	443.6	518.8	784.2	0.880	1.515	3.062	8.06	14.81	37.37
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	443.6	518.8	784.2	0.880	1.515	3.061	8.06	14.81	37.37
6 Engines, Tractors, & Classes 2b–8 b/	443.5	518.7	784.1	0.880	1.515	3.061	8.06	14.81	37.37
7 Engines, Tractors, Trucks, & Trailers	443.5	518.7	784.1	0.880	1.515	3.061	8.06	14.81	37.37
6B 20% above Preferred Alternative Stringency	443.5	518.7	784.0	0.880	1.515	3.061	8.06	14.81	37.37
8 Accelerated Hybrid Adoption	443.5	518.6	783.8	0.880	1.515	3.060	8.06	14.80	37.36
Reductions from the No Action Alternative Under Alternative HD Standards									
2 Engine Only	0.0	0.1	0.4	0.000	0.000	0.001	0.00	0.00	0.02
3 Class 8 Tractors	0.0	0.2	0.4	0.000	0.001	0.002	0.00	0.00	0.02
4 Engines & Classes 7–8 Tractors	0.0	0.2	0.6	0.000	0.001	0.002	0.00	0.00	0.02
6A 15% below Preferred Alternative Stringency	0.0	0.2	0.7	0.000	0.001	0.002	0.00	0.00	0.03
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.1	0.2	0.7	0.000	0.001	0.003	0.00	0.00	0.03
6 Engines, Tractors, & Classes 2b–8 b/	0.1	0.3	0.7	0.000	0.001	0.003	0.00	0.00	0.03
7 Engines, Tractors, Trucks, & Trailers	0.1	0.3	0.8	0.000	0.001	0.003	0.00	0.00	0.03
6B 20% above Preferred Alternative Stringency	0.1	0.3	0.9	0.000	0.001	0.003	0.00	0.00	0.03
8 Accelerated Hybrid Adoption	0.1	0.4	1.1	0.000	0.002	0.004	0.00	0.01	0.04

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.
b/ Preferred Alternative

Figure 2.4-4. Reduction in Global Mean Temperature Compared to the No Action Alternative



under Alternative 8 by 2100 from the No Action Alternative. Alternative 6 (the Preferred Alternative) would result in a sea-level rise of 37.37 cm.

Increases in precipitation are a result of higher temperatures causing greater water evaporation, which causes more water vapor to be available for precipitation (EPA 2009). Because all of the action alternatives reduce anticipated future increases in temperature slightly in comparison to the No Action Alternative, they would also reduce the predicted increases in precipitation. NHTSA expects that the alternatives would reduce anticipated changes in precipitation in proportion to their effects on temperature. The predicted effects of the alternatives on precipitation are presented in Section 3.4.4.3.3.

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. The impacts are small because each action alternative would result in a small proportional change in the emissions trajectories in the GCAM reference scenario,[20] due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they would occur on a global scale and would be long-lived.

[20] 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

NHTSA also examined the sensitivity of climate effects to key assumptions used in the analysis. This analysis and the results are described in Section 3.4.4.3.5.

2.4.2 Cumulative Effects

CEQ identifies the impacts that must be addressed and considered by Federal agencies in satisfying the requirements of NEPA, including 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 reflects the effects of continuing increases in HD vehicle fuel efficiency for model years after 2018 under the No Action alternative and each action alternative. As detailed in Section 4.1, the gains in HD vehicle fuel efficiency for 2019 and beyond are derived from the Energy Information Administration's (EIA) Annual Energy Outlook 2010 (EIA 2010) Reference Case forecast.

2.4.2.1 Energy

Table 2.4-4 shows the cumulative impact of alternative standards on annual cumulative fuel consumption for all HD vehicles from 2018 through 2050, when the entire HD vehicle fleet is likely to be composed of MY 2018 or later vehicles. This table reports total cumulative fuel consumption, both gasoline and diesel, for HD pickups and vans, vocational vehicles, and combination tractors, under the No Action Alternative (Alternative 1) and each of the nine action alternatives described in Section 2.3.

Table 2.4-4

Cumulative HD Vehicle Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A **15% below Preferred Alternative Stringency**	Alt. 5 Engines, Classes 7–8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B **20% above Preferred Alternative Stringency**	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	52.06	51.20	50.79	50.31	50.33	50.26	50.13	49.96	49.80	49.50
2030	57.03	54.47	53.89	52.52	52.41	52.20	51.84	51.53	50.98	49.51
2050	80.88	76.76	76.38	74.02	73.78	73.47	72.71	72.28	71.29	68.19
Fuel Savings Compared to No Action										
2018	--	0.86	1.27	1.75	1.72	1.79	1.93	2.09	2.26	2.56
2030	--	2.57	3.14	4.51	4.63	4.83	5.19	5.51	6.06	7.52
2050	--	4.11	4.49	6.86	7.09	7.41	8.16	8.60	9.58	12.68

a/ Preferred Alternative

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.

Cumulative fuel consumption under the No Action Alternative is 80.88 billion gallons in 2050. Cumulative fuel consumption ranges from 76.76 billion gallons under Alternative 2 (Engine Only) to 68.19 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). Cumulative fuel consumption in 2050 is 72.71 billion gallons under the Preferred Alternative. Fuel consumption is less than projected under the No Action alternative for all action alternatives, resulting in cumulative fuel savings in 2050 ranging from 4.11 billion gallons under Alternative 2 (Engine only) to 12.68 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). In 2050, fuel savings under Alternative 6 (the Preferred Alternative) amounts to 8.16 billion gallons.

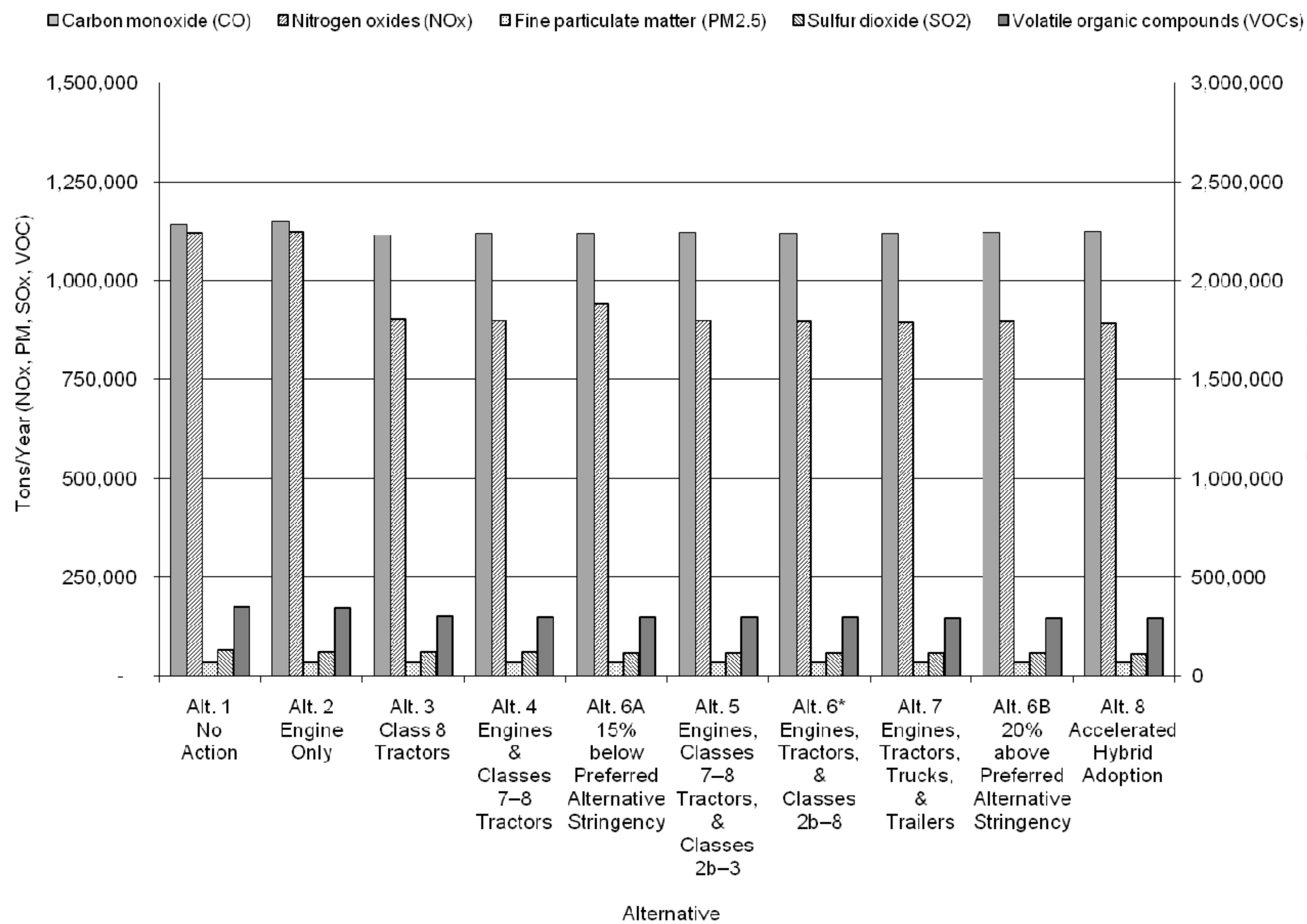
2.4.2.2 Air Quality

The HD Fuel Efficiency Improvement Program would reduce cumulative emissions of criteria and toxic air pollutants under most alternatives in most years. Cumulative emissions of some pollutants would increase for some combinations of pollutant, alternative, and year. The ranges of reductions and increases would vary by pollutant, alternative, and year. Variations are due to the complex interaction of VMT, fuel efficiency, and the specific technological improvements that increase fuel efficiency. In many–but not all–cases, the action alternatives would reduce nationwide emissions compared to the No Action Alternative. The results for 2030 are given below for each pollutant because 2030 is a mid-term forecast year; by this point, a large proportion of HD vehicle VMT would be accounted for by vehicles that meet the MYs 2014–2018 standards.

Figure 2.4-5 shows the cumulative national emissions of criteria pollutants from HD vehicles for MY 2030 by alternative. Figure 2.4-6 shows the cumulative national emissions of toxic air pollutants from HD vehicles by alternative. Cumulative carbon monoxide (CO) emissions in 2030 would range from a high of 2,295,773 tons under Alternative 2 to a low of 2,228,091 tons under Alternative 3. Cumulative nitrogen oxide (NO_x) emissions in 2030 would range from a high of 1,124,949 tons under Alternative 2 to a low of 892,423 tons under Alternative 8. Cumulative particulate matter ($PM_{2.5}$) emissions in 2030 would range from a high of 34,897 tons under Alternative 3 to a low of 33,681 tons under Alternative 2. Cumulative sulfur dioxide (SO_2) emissions in 2030 would range from a high of 65,344 tons under Alternative 1 (the No Action Alternative) to a low of 56,706 tons under Alternative 8. Cumulative volatile organic compound (VOC) emissions in 2030 would range from a high of 174,503 tons under Alternative 1 (the No Action Alternative) to a low of 145,152 tons under Alternative 8. Cumulative acetaldehyde emissions in 2030 would range from a high of 4,654 tons under Alternative 2 to a low of 2,944 tons under Alternative 4. Cumulative acrolein emissions in 2030 would range from a high of 643 tons under Alternative 2 to a low of 395 tons under Alternatives 4 through 7 (including Alternatives 6A and 6B). Cumulative benzene emissions in 2030 would range from a high of 2,397 tons under Alternative 2 to a low of 2,061 tons under Alternative 6B. Cumulative 1,3-butadiene emissions in 2030 would range from a high of 320 tons under Alternative 8 to a low of 316 tons under Alternative 3. Cumulative diesel particulate matter (DPM) emissions in 2030 would range from a high of 26,900 tons under Alternative 3 to a low of 25,645 tons under Alternative 2. Cumulative formaldehyde emissions in 2030 would range from a high of 13,232 tons under Alternative 2 to a low of 7,301 tons under Alternative 4.

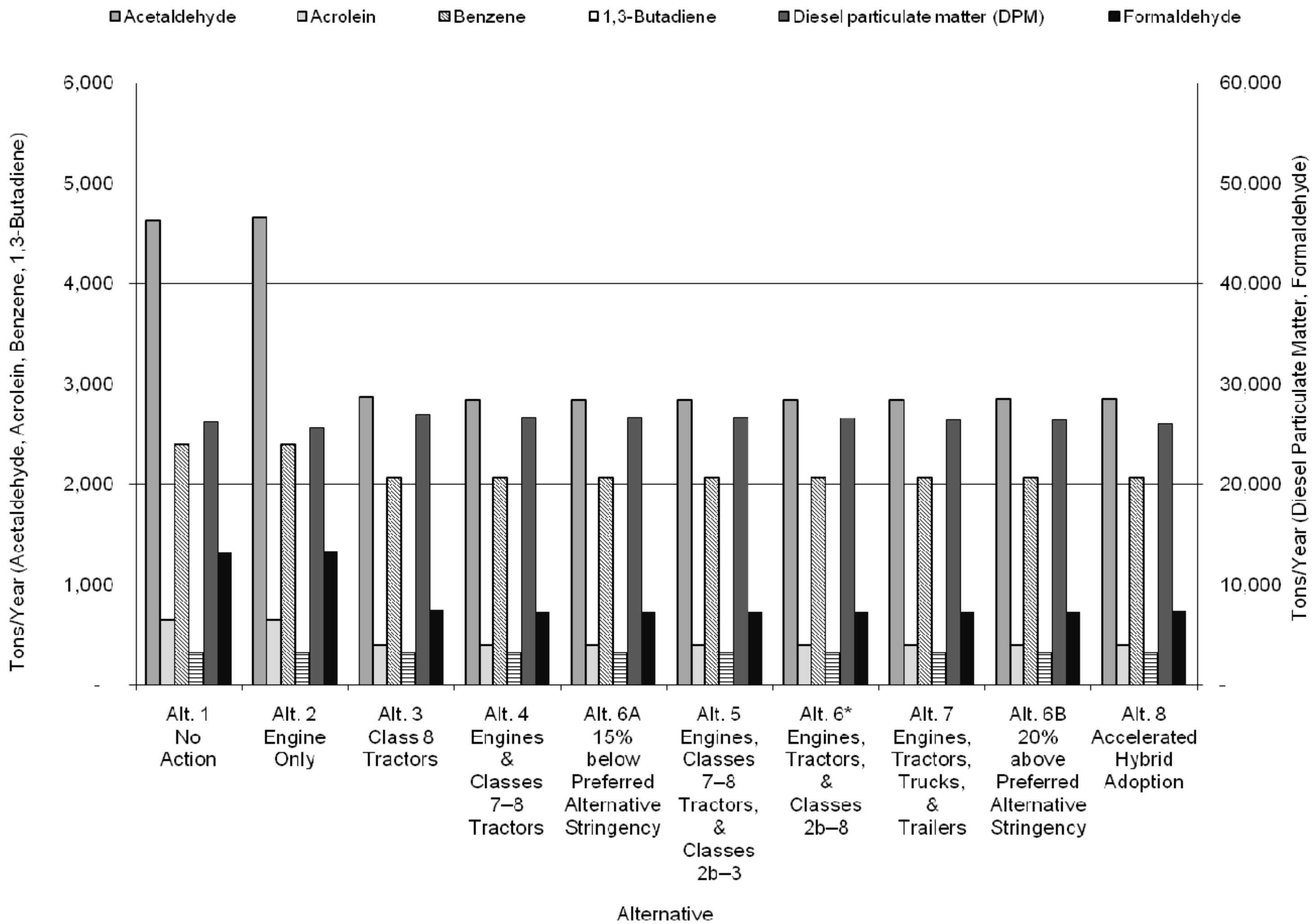
Under the Preferred Alternative (Alternative 6), reductions in nationwide criteria pollutant emissions would occur for CO, NO_x, SO_2, and VOCs compared to the No Action Alternative, while slight increases would occur for $PM_{2.5}$. Cumulative emissions would be lower than direct and indirect emissions for criteria pollutants and air toxics under all alternatives in 2030 and 2050.

Figure 2.4-5. Cumulative Nationwide Criteria Pollutant Emissions (tons/year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Figure 2.4-6. Cumulative Nationwide Toxic Air Pollutant Emissions (tons/year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Under Alternative 6 (the Preferred Alternative), cumulative emissions would be less than direct and indirect emissions in 2030 and 2050. Alternative 6 would reduce cumulative toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde for all analysis years, except for 1,3-butadiene in 2030; and would increase emissions of DPM in 2030 and 2050 compared to the No Action Alternative.

The reductions in cumulative emissions are expected to lead to reductions in adverse health effects as compared to the No Action Alternative. Reductions in adverse health effects would occur nationwide under Alternatives 2 through 8 compared to the No Action Alternative. The reductions become larger as fuel consumption and cumulative emissions decrease across alternatives. As described above, mortality estimates are based on data from two alternative studies, Pope *et al*. (2002) and Laden *et al.*(2006), which EPA considers co-equal. Based on Pope *et al*. data, premature mortality would be reduced in 2030 by 23 cases under Alternative 2 and by 189 cases under Alternative 8, as compared to the No Action Alternative. Based on Laden *et al*. data, premature mortality would be reduced in 2030 by 58 cases under Alternative 2 and 483 cases under Alternative 8, as compared to the No Action Alternative. The number of work-loss days in 2030 would be reduced by 2,641 under Alternative 2 to 23,306 under Alternative 8 compared to the No Action Alternative. Reductions in adverse health effects would occur nationwide under Alternative 6 (the Preferred Alternative) compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to Alternative 1 (No Action), the cumulative impact of Alternative 6 would result in 158 fewer mortalities and 19,668 fewer work-loss days in 2030.

The economic value of health impacts would vary proportionally with changes in health outcomes. Monetized health benefits would occur under all action alternatives in all years. Monetized health benefits are presented based again on Pope *et al*. and Laden *et al.*, and for two alternative discount rate assumptions of 3 percent and 7 percent, consistent with EPA policy for presentation of future health benefits. The value of monetized health benefits under the 3-percent discount rate would range from $203 million under Alternative 2 to $1,682 million under Alternative 8 based on Pope *et al*. data, and $497 million under Alternative 2 to $4,116 million under Alternative 8 based on Laden *et al*. data). The value of monetized health benefits under the 7-percent discount rate would range from $115 million under Alternative 2 to $1,526 million under Alternative 8 based on Pope *et al*. data, and $449 million under Alternative 2 to $3,718 million under Alternative 8 based on Laden *et al*. data. Alternative 6 (the Preferred Alternative) results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6 would be $1.279 billion in 2030, increasing to $2.193 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the economic benefits increase to $3.448 billion in 2030 and $5.916 billion in 2050.

2.4.2.3 Climate Change

2.4.2.3.1 Cumulative GHG Emissions

Table 2.4-5 shows total GHG emissions and emission reductions from HD vehicles, summed for the period 2014 through 2100 under each of the ten alternatives. Although GHG emissions from this sector will continue to rise over the period (absent other reduction efforts) across all the alternatives, the effect of the alternatives is to slow this increase by varying amounts. Total emissions for the period range from 64,000 $MMTCO_2$ for Alternative 8 to 74,600 $MMTCO_2$ for the No Action Alternative (Alternative 1). Projections of emission reductions over the period in comparison to the No Action Alternative range from 3,500 to 10,600 $MMTCO_2$. The Preferred Alternative (Alternative 6) would result in total emissions of 67,700 $MMTCO_2$, a reduction in emissions by 6,900 $MMTCO_2$ compared to the No Action Alternative of 74,600 $MMTCO_2$. Compared to the projected cumulative global emissions of 4,294,482 $MMTCO_2$

Table 2.4-5

Cumulative Effects of Emissions and Emissions Reductions ($MMTCO_2$) from 2014 to 2100 by Alternative a/

Alternative	Total Emissions	Emission Reductions Compared to No Action Alternative	Emission Reductions Compared to No Action Alternative (%)
1 No Action	74,600	0	
2 Engine Only	71,100	3,500	5%
3 Class 8 Tractors	70,700	3,900	5%
4 Engines & Classes 7–8 Tractors	68,700	5,900	8%
6A 15% below Preferred Alternative Stringency	68,600	6,100	8%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	68,300	6,300	8%
6 Engines, Tractors, & Classes 2b–8 b/	67,700	6,900	9%
7 Engines, Tractors, Trucks, & Trailers	67,300	7,300	10%
6B 20% above Preferred Alternative Stringency	66,500	8,200	11%
8 Accelerated Hybrid Adoption	64,000	10,600	14%

a/ Note: The numbers in this table have been rounded for presentation purposes. As a result, the reductions do not reflect the exact differences of the values.
b/ Preferred Alternative

over this period under the No Action Alternative (projected by the GCAM6.0 scenario), this rulemaking would reduce global CO_2 emissions by about 0.1 to 0.2 percent.

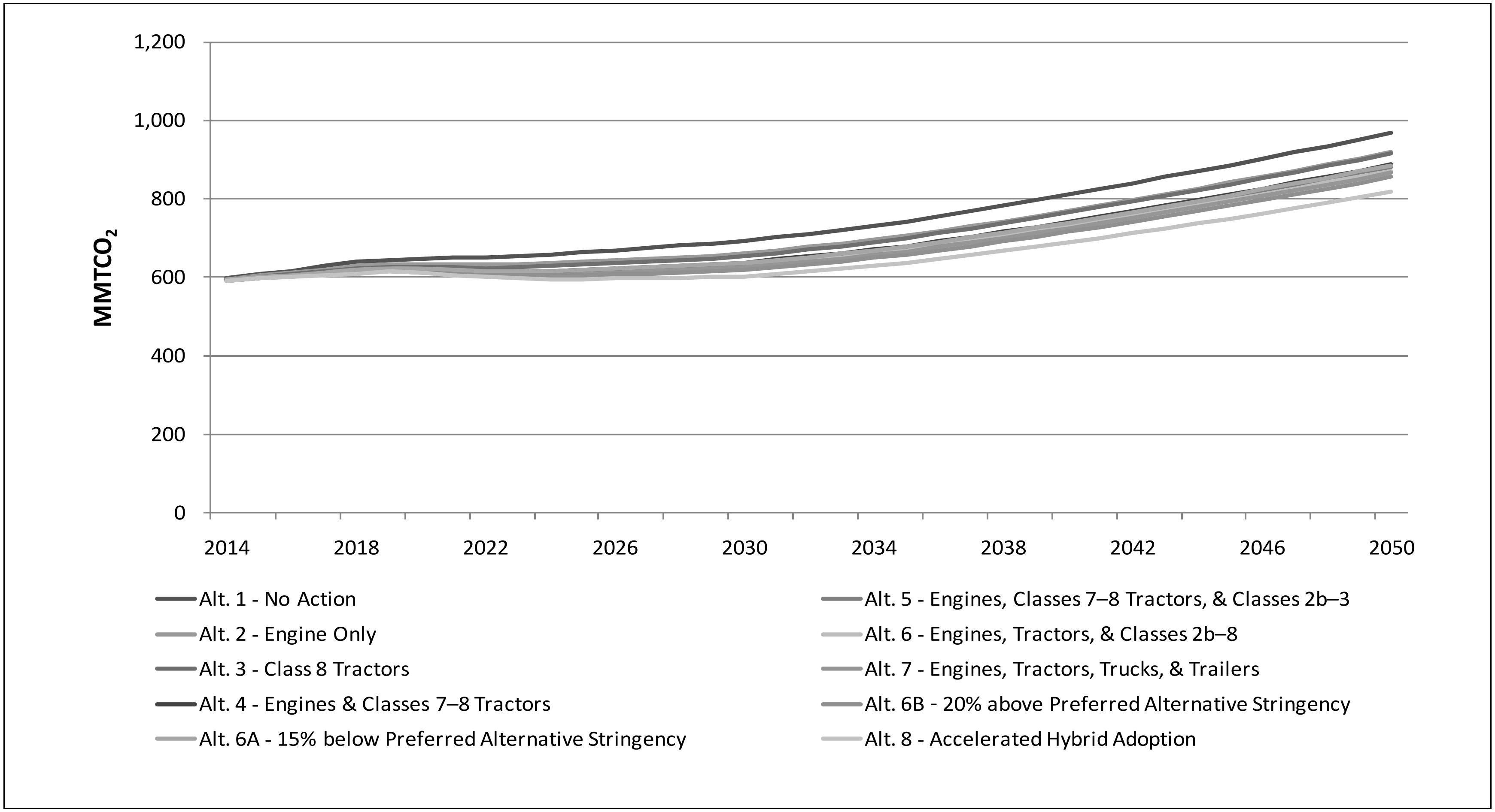
To better understand the relative impact of these reductions, it can be helpful to consider the relative importance of emissions from HD vehicles as a whole and to compare them against emissions projections for the United States. As noted above, HD vehicles currently account for approximately 6.9 percent of CO_2 emissions in the United States (EPA 2010a). With the action alternatives reducing U.S. HD vehicle CO_2 emissions by 5 to 14 percent of cumulative emissions from 2014 to 2100, each action would have a noticeable impact on total U.S. CO_2 emissions. Compared to total U.S. CO_2 emissions in 2100 of 4,401 $MMTCO_2$ (projected by the GCAM6.0 scenario), the action alternatives would reduce annual U.S. CO_2 emissions by 1.0 to 3.1 percent in 2100. As another comparison of the magnitude of these reductions, average annual CO_2 emission reductions from the alternatives range from 41 to 122 $MMTCO_2$ over 2014 to 2100, equivalent to the annual CO_2 emissions of 11 to 31 coal-fired power plants.[21] Figure 2.4-7 shows projected annual emissions from HD vehicles under the alternatives.

Under all of the alternatives, growth in the number of HD vehicles in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth in total VMT by HD vehicles. This growth in VMT overwhelms improvements in fuel efficiency for each alternative, resulting in projected increases in total fuel consumption by HD vehicles in the United States 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 HD vehicles.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. HD vehicle fleet represented about 1.2 percent of total global emissions of CO_2 in 2005. Although substantial, this source is still a small percentage of global emissions. The relative contribution of CO_2 emissions from U.S. HD vehicles 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).

[21] Estimated using EPA's Greenhouse Gas Equivalencies Calculator (EPA 2010b).

Figure 2.4-7. Cumulative Annual Emissions ($MMTCO_2$) Under the MYs 2014–2018 Standards and Other Reasonably Foreseeable Future Actions



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

Table 2.4-6 shows estimated cumulative 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 nine action alternatives. Figure 2.4-8 graphically illustrates temperature reductions for the nine action alternatives.

Table 2.4-6

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAM6.0) by Alternative a/

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Alternative	2030	2050	2100	2030	2050	2100	2030	2050	2100
Totals									
1 No Action	440.1	506.5	677.8	0.838	1.397	2.564	7.9	14.15	33.42
2 Engine Only	440.0	506.4	677.5	0.838	1.397	2.562	7.9	14.14	33.41
3 Class 8 Tractors	440.0	506.4	677.5	0.838	1.396	2.562	7.9	14.14	33.41
4 Engines & Classes 7–8 Tractors	440.0	506.3	677.3	0.838	1.396	2.561	7.9	14.14	33.40
6A 15% below Preferred Alternative Stringency	440.0	506.3	677.3	0.838	1.396	2.561	7.9	14.14	33.40
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	440.0	506.3	677.2	0.838	1.396	2.561	7.9	14.14	33.40
6 Engines, Tractors, & Classes 2b–8	440.0	506.3	677.2	0.838	1.396	2.561	7.9	14.14	33.40
7 Engines, Tractors, Trucks, & Trailers	440.0	506.3	677.1	0.838	1.396	2.561	7.9	14.14	33.40
6B 20% above Preferred Alternative Stringency	440.0	506.3	677.1	0.838	1.396	2.560	7.9	14.14	33.39
8 Accelerated Hybrid Adoption	440.0	506.2	676.8	0.838	1.396	2.559	7.9	14.14	33.39
Reductions Under Alternative HD Standards									
2 Engine Only	0.0	0.1	0.3	0.000	0.000	0.001	0.00	0.01	0.01
3 Class 8 Tractors	0.0	0.1	0.4	0.000	0.001	0.002	0.00	0.01	0.01
4 Engines & Classes 7–8 Tractors	0.1	0.2	0.5	0.000	0.001	0.002	0.00	0.01	0.02
6A 15% below Preferred Alternative Stringency	0.1	0.2	0.6	0.000	0.001	0.002	0.00	0.01	0.02
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.1	0.2	0.6	0.000	0.001	0.002	0.00	0.01	0.02
6 Engines, Tractors, & Classes 2b–8 b/	0.1	0.2	0.6	0.001	0.001	0.003	0.00	0.01	0.02
7 Engines, Tractors, Trucks, & Trailers	0.1	0.2	0.7	0.001	0.001	0.003	0.00	0.01	0.02
6B 20% above Preferred Alternative Stringency	0.1	0.3	0.7	0.001	0.001	0.003	0.00	0.01	0.03
8 Accelerated Hybrid Adoption	0.1	0.3	1.0	0.001	0.002	0.004	0.00	0.01	0.03

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

Estimated CO_2 concentrations for 2100 range from 676.8 ppm under Alternative 8 to 677.8 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. The differences among alternatives are small, as shown in Figure 2.4-8. For 2100, the reduction in temperature increase, in relation to the No Action Alternative, ranges from about 0.001 to 0.004 °C (0.002 to 0.007 °F).

Figure 2.4-8. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)

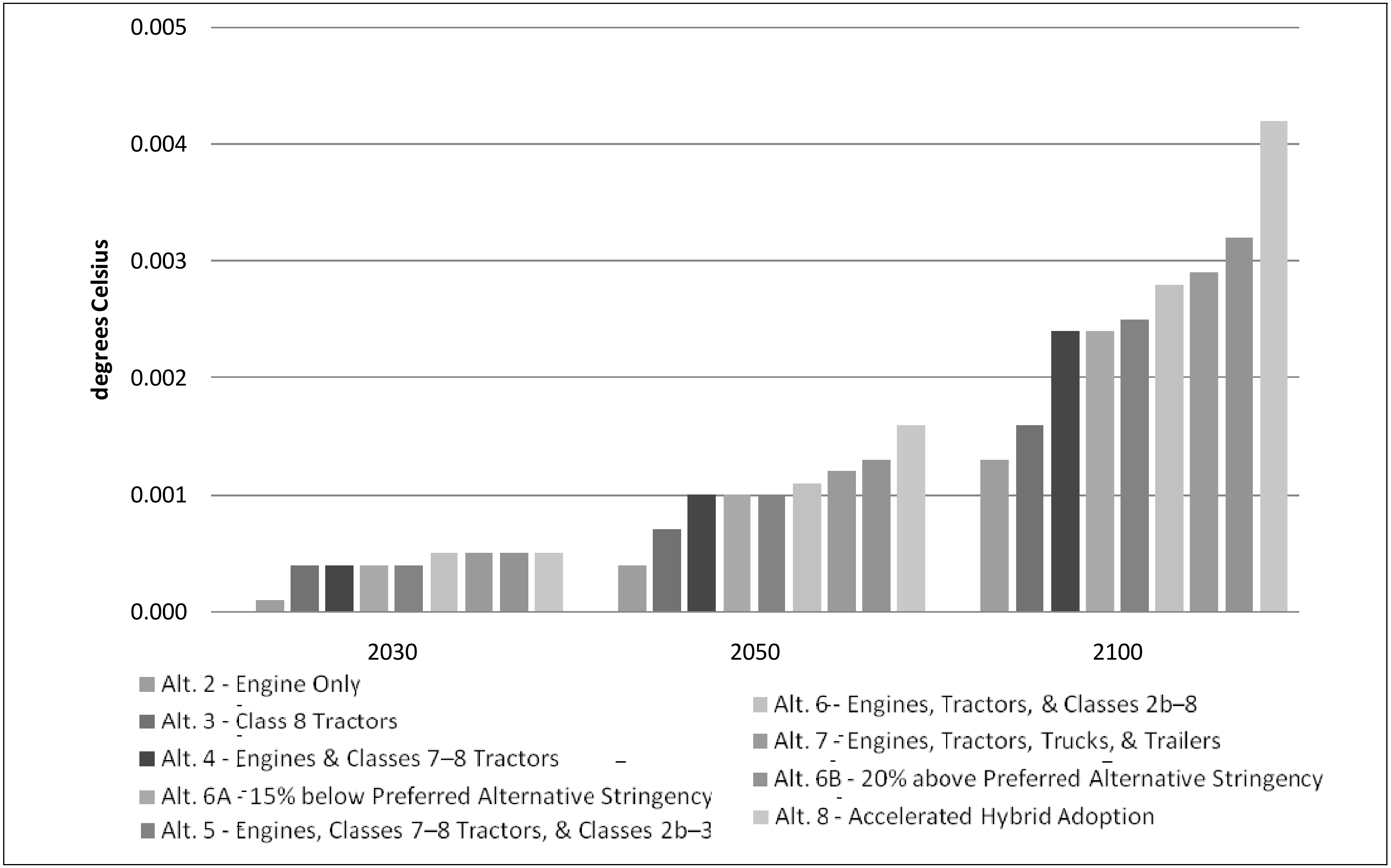


Table 2.4-6 lists the impacts on sea-level rise under the alternatives and shows sea-level rise in 2100 ranging from 33.42 cm (13.16 inches) under the No Action Alternative to 33.39 cm (13.15 inches) under Alternative 8, for a maximum reduction of 0.03 cm (0.01 inch) by 2100.

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. Results for effects of the alternatives on precipitation are presented in Section 4.4.4.3.3.

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 because the action alternatives have a small proportional change in the emissions trajectories in the GCAM6.0 scenario.[22] This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they would occur on a global scale and would be long-lived.

NHTSA examined the sensitivity of climate effects to key assumptions used in the analysis. This analysis and results are described in Section 4.4.4.3.5.

[22] 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.

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 describing the affected environment (existing conditions) and a section describing 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 a heading for each affected resource – 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 focus quickly upon existing environmental conditions and potential environmental consequences related to each specific resource area. Finally, Section 3.6 identifies unavoidable impacts and irreversible and irretrievable commitments of resources associated with the implementation of the Heavy-Duty (HD) Fuel Efficiency Improvement Program evaluated in this EIS.

3.1.1 Direct and Indirect Impacts

CEQ regulations state that an EIS "shall succinctly describe" the environment that would be affected by the alternatives under consideration and provide data and analyses "commensurate with the importance of the impact[s]." 40 CFR § 1502.15. This chapter presents NHTSA's analysis for determining and comparing 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 on other resource areas including biological resources, water resources, noise, safety, and other impacts on human health, hazardous materials and regulated wastes, and environmental justice. For these resource areas, NHTSA conducted a qualitative analysis because sufficient data were not available in the literature to allow a quantitative analysis and because many of these effects are not localized.

3.1.2 Areas Not Affected

NHTSA has considered the impact of the proposed action and alternatives on all areas outlined in the Department of Transportation (DOT) NEPA procedures, aided by scoping to solicit comments on particular areas of concern. NHTSA has determined that the proposed action would not have a direct or indirect effect on several areas, or that those effects would be insignificant. These areas include considerations related to pedestrians and bicyclists, floodplain management, historic and cultural resources, land use, Section 4(f) resources,[1] and construction impacts. NHTSA does not analyze direct or

[1] Section 4(f) resources are publicly owned parks, recreational areas, wildlife and waterfowl refuges, or historical sites to which the DOT gives special consideration. Originally included as part of the Department of Transportation Act of 1966, Section 4(f) (as codified) stipulates that the Secretary of Transportation may approve a transportation program or project requiring the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or historic sites only if "(1) there is no prudent and feasible alternative to using that land; and (2) the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuge, or historic site resulting from the use." 49 U.S.C. § 303(c).

indirect impacts to these resource areas in this EIS. Some aspects of these resource areas, however, could be affected indirectly by global climate change or its consequences. Accordingly, NHTSA considers the effects of climate change on these resources as a cumulative impact of the proposed action and the alternatives considered in this DEIS, and provides discussion in Section 4.5.

3.1.3 Approach to Scientific Uncertainty and Incomplete Information

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

1. A statement that such information is incomplete or unavailable;

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

3. A summary of existing credible scientific evidence relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

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).

Throughout this EIS, NHTSA uses this mechanism – acknowledging incomplete or unavailable information – to address areas for which the agency cannot develop a credible estimate of the potential environmental impacts of the HD Fuel Efficiency Improvement Program or reasonable alternatives. 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)). 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

To analyze impacts relevant to GHGs, energy, and air quality, the U.S. Environmental Protection Agency (EPA) calculated fuel usage as well as emissions of GHGs and air pollutants associated with HD vehicle use that would occur under each alternative, and assessed the changes in energy consumption and emissions under each action alternative from the levels anticipated to occur under the No Action Alternative (Alternative 1).

NHTSA has undertaken this EIS with an eye toward the comprehensive nature of the HD National Program jointly proposed by NHTSA and EPA. Specifically, although NHTSA's proposed fuel consumption regulations would be voluntary in model years (MYs) 2014 and 2015, becoming mandatory with MY 2016 for most regulatory categories, EPA's proposed GHG emission standards under the Clean Air Act (CAA) would begin with MY 2014. Because EPA's proposed standards are mandatory for MYs 2014 and 2015, NHTSA has assumed, for the purpose of modeling the environmental impacts of the proposed action, full compliance with the EPA standards during those years as required by the CAA. Thus the environmental impacts reported in this EIS reflect compliance with the HD National Program as a whole.[2] The alternatives in the tables and figures in this chapter are arranged in ascending order of fuel savings, to aid in the environmental analysis and the comparison of alternatives. Consequently, the alternatives appear out of numerical sequence.

Emissions, including those of GHGs, criteria pollutants, and airborne toxics are categorized for purposes of this analysis as either "downstream" or "upstream." Downstream emissions are released from a vehicle while it is in operation, and consist primarily of tailpipe exhaust. These emissions are estimated using the EPA Motor Vehicle Emission Simulator (MOVES) model (EPA 2009a). Upstream emissions are those associated with petroleum extraction and the refining, storage, and distribution of transportation fuels. Estimates of these emissions were based on the Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET, version 1.8) model developed by the U.S. Department of Energy's (DOE) Argonne National Laboratory (Argonne 2002).

3.1.4.1 Downstream Emissions

The basic method used to estimate tailpipe emissions entails multiplying activity levels of HD vehicles, expressed as the total number of vehicle-miles traveled (VMT) accounted for by each type of vehicle during a specified year, by emission factors for that vehicle type measured in grams of each pollutant emitted per VMT. EPA developed national emission estimates for all HD vehicles projected to be in use during various future years using EPA's 2010 Motor Vehicle Emission Simulator (MOVES2010) model (EPA 2009a). MOVES reflects EPA's updated estimates of real-world emissions from HD vehicles, and accounts for emission control requirements on tailpipe and evaporative emissions. Recent requirements include the highway heavy-duty engine emission standards and heavy-duty diesel fuel standards issued by EPA in 2000 and 2001, respectively (EPA 2000, EPA 2001), and the Mobile Source Air Toxics (MSAT) rule (EPA 2007). The MOVES2010 database includes default distributions of vehicles by type and age, vehicle activity levels, vehicle characteristics, national-level fuel quality estimates, and other key parameters that are used to generate emission estimates.

MOVES categorizes HD vehicle types by their use. The use categories in MOVES are combination tractors, single-unit tractors, refuse trucks, motor homes, transit buses, intercity buses, school buses, and light commercial trucks. Because MOVES2010 vehicle sales and activity data were originally developed from the Energy Information Administration (EIA) 2006 Annual Energy Outlook (EIA 2006), EPA first updated these data for purposes of this analysis using sales and activity forecasts from the 2010 Annual Energy Outlook (EIA 2010). EPA also updated the fuel supply information in MOVES to include a 100-percent E10 fuel supply (E10 is a gasoline blend consisting of 10 percent ethanol and 90 percent gasoline) to reflect the Renewable Fuels Standard (RFS).[3] In modeling tailpipe emissions of particulate matter 2.5 microns or less in diameter ($PM_{2.5}$), EPA included emissions from

[2] NHTSA's analysis of environmental impacts does not, however, include impacts related to EPA's proposed regulation of recreational vehicles, such as motor homes, under the CAA. As noted above, NHTSA's statutory authority to regulate the fuel efficiency of HD vehicles does not cover recreational vehicles because they are not considered commercial vehicles or work trucks as defined under EISA (see Section 1.3.1). Accordingly, for the purpose of the EIS analysis, NHTSA is analyzing the impacts of the HD Program for the vehicles within NHTSA's jurisdiction under EISA, that is, all HD vehicles covered by the National Program with the exception of recreational vehicles.

[3] *See* 40 CFR § 80 Subpart M.

brake and tire wear in addition to exhaust. MOVES2010 defaults were used for all other parameters to estimate tailpipe and other components of downstream emissions under the No Action Alternative.[4]

To account for improvements in engine and vehicle efficiency under the action alternatives, EPA developed several user inputs to model the alternatives in MOVES. EPA first estimated the increase in vehicle/engine efficiency based on technologies available to each vehicle or engine class, and then used these efficiency increases to estimate the corresponding reductions in engine power requirements and thus CO_2 emissions. Because MOVES calculates emissions based on engine power output under various operating conditions, rather than on engine Federal Test Procedure results such as those used for passenger vehicles and light trucks, EPA used the expected percent reductions in engine CO_2 emissions under each action alternative to develop corresponding estimates of the reductions in fuel energy inputs used by each vehicle/engine class. In other words, the (percent) reductions in CO_2 emission rates under each action alternative were assumed to reflect reductions in vehicle power output under various operating conditions, and these were in turn used to estimate changes in fuel energy consumption and vehicle emissions. Also, EPA estimated the percent reductions in aerodynamic drag and tire rolling resistance coefficients under each alternative, and used its estimates of changes in these coefficients to develop vehicle movement energy demand (or road load) inputs to MOVES.

In MOVES, emission rates for criteria air pollutants, such as nitrous oxides (NO_x) and particulate matter (PM), and airborne toxics are assumed not to change in response to increases in vehicle fuel efficiency. Changes in the levels of tailpipe emissions of criteria pollutants and air toxics are influenced in MOVES by three factors: reduced engine load, such as from improved aerodynamics and lower tire rolling resistance; increased use of auxillary power units (APUs) during extended idling; and additional driving (VMT rebound). In addition, sulfur dioxide (SO_2) is one criteria pollutant that is directly proportional to fuel consumption and is thus affected by engine efficiency.

EPA also made modifications to MOVES' default inputs to calculate extended idle emissions. Extended idling, or "hoteling," means idling the truck's engine to provide heat, air conditioning, and electric power to the cab while the truck is occupied but parked for extended periods such as overnight. For all alternatives, the agencies assumed that about 30 percent of all combination long-haul tractors of MYs 2010–2013 would use an APU, rather than the truck's engine, as a power source during extended idling. For Alternatives 1 and 2, which do not regulate long-haul trucks, the agencies assumed that 30 percent of those trucks that are MY 2014 and later use APUs during extended idling. For alternatives under which combination long-haul trucks are regulated (Alternatives 3 through 8), the agencies assumed that 100 percent[5] of MY 2014 and later trucks use APUs during extended idling. EPA assumed a diesel fuel consumption rate of 0.2 gallons per hour and an extended idle load demand of 4.5 kilowatt (kW) or 6 horsepower (hp) for APUs. Diesel APUs are regulated as non-road small engines for purposes of controlling criteria pollutants. Assuming that these APUs emit criteria pollutants at the level of the current EPA Tier 4 standard, the emission rates that EPA used in the analysis are 36 grams per hour of carbon monoxide (CO), 33.6 grams per hour of NO_x and nonmethane hydrocarbons combined, and 1.8 grams per hour of PM.

[4] The 2009-December-21 version of MOVES was used for this EIS analysis along with the 2010-May-15 default database. The user input tables that were modified and included for the MOVES runs were "fuelsupply," "fuelformulation," "sourcetypeyear," and "hpmsvtypeyear."

[5] For this EIS, EPA and NHTSA modeled a technology package for sleeper cabs that included an assumption that APUs were present in 100 percent of the trucks. Truck manufacturers, however, might build their vehicles with different technologies to meet the proposed standard (including the use of other types of idle reduction such as battery systems).

3.1.4.2 Upstream Emissions

EPA also estimated the impacts of the action alternatives on upstream emissions, which are emissions associated with petroleum extraction, and with the refining, storage, and distribution of transportation fuels. Upstream emissions were estimated using the GREET model (version 1.8b) developed by DOE Argonne National Laboratory (Argonne 2002). For the direct and indirect analyses of environmental impacts, the agencies assumed that the only effects of increased fuel efficiency on upstream emissions result from changes in the volumes of gasoline and diesel produced and consumed under each action alternative. In contrast, the agencies assumed that the proportions of total fuel production and consumption that are represented by ethanol and other renewable fuels (such as biodiesel) under each of the action alternatives would be identical to those under the No Action Alternative.

EPA previously modified GREET for use in analyzing its Renewable Fuel Standard 2 (RFS2) rulemaking.[6] The updates and enhancements EPA made to the GREET model for purposes of that rulemaking included updated crude oil and gasoline transport emission factors that account for recently-adopted emission standards such as the Tier 4 diesel truck standards (adopted in 2001) and the locomotive and commercial marine standards (finalized in 2008). In addition, EPA modified the GREET model to add emission factors for the following air toxics: acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde.[7]

The actual calculations of the impacts of decreased fuel production on total emissions of each pollutant use the decreased volumes of petroleum-based fuels estimated to result from adopting each action alternative, together with the emission factors for individual phases of the fuel production and distribution process derived from GREET. EPA developed a spreadsheet model to perform these calculations (EPA2008, EPA 2009b). The emission factors derived from GREET (expressed as grams of pollutant per million British thermal units (BTU)) for each phase of the fuel production and distribution process were multiplied by the amount of fuel production and distribution resulting from each action alternative to get emissions during each phase of fuel production and distribution. These emissions were added together to get the total emissions from each action alternative. This process was repeated for each alternative, and the change in upstream emissions of each pollutant resulting from each action alternative was estimated as the difference between total upstream emissions of that pollutant under the action alternative and its total emissions under the No Action Alternative.

3.1.4.3 Rebound Effect

By reducing the cost of fuel consumed per mile driven, requiring increased fuel efficiency could create an incentive for additional vehicle use. Commercial trucking companies would be expected to use the resulting savings in fuel costs to lower their shipping rates, possibly attracting new business that would generate additional truck VMT. At the same time, trucking firms might also respond to reduced truck operating costs by reorganizing their logistics operations in ways that entail more frequent or longer shipments, which would also increase total truck mileage. Any resulting increase in truck use will offset part of the fuel savings that would otherwise be expected to result from requiring higher fuel efficiency; this phenomenon is known as the "rebound effect." The total amount of HD vehicle VMT would increase slightly due to the rebound effect, and tailpipe emissions of pollutants that are strictly related to vehicle use would increase in proportion to the increased VMT.

[6] 74 *FR* 24904 (May 26, 2009).
[7] These emission factors were calculated from the 2002 National Emissions Inventory (NEI), a risk and technology review for petroleum refineries, speciated emission profiles in EPA's SPECIATE database, and the MSAT rule inventory for benzene.

Unlike the light-duty vehicle rebound effect, the HD vehicle rebound effect has not been studied extensively. Further, because the factors influencing the HD vehicle rebound effect generally differ from those affecting the light-duty rebound effect, much of the research on the light-duty rebound effect is not likely to apply to the HD sector. According to the National Academy of Sciences (NAS 2010) study, it is "not possible to calculate with a great deal of confidence what the magnitude of the 'rebound' effect is for heavy-duty trucks;" despite this, however, the NAS study also cautioned that "estimates of fuel savings from regulatory standards will be somewhat misestimated if the 'rebound' effect is not considered."[8] Although the HD rebound effect should be studied in more detail, the agencies have attempted to capture the potential impact of the rebound effect in our analysis. For this proposal, NHTSA used a rebound effect for vocational vehicles (Classes 2b–8) of 15 percent, a rebound effect for HD pickups and vans (Classes 2b and 3) trucks of 10 percent, and a rebound effect for tractors (Classes 7 and 8) of 5 percent. For a more detailed discussion of these estimates and of the HD vehicle rebound effect, see Section VIII of the joint HD National Program Preamble. These VMT impacts are reflected in the estimates of total GHG and other air pollutant emissions under each of the proposed alternatives.

For the purposes of this analysis, NHTSA has not quantified potential impacts to fuel consumption due to any change in rail shipping that might be expected to accompany a reduction in truck shipping rates. If commercial trucking companies use the savings in fuel costs to reduce their shipping rates, and succeed in attracting new business as a result, some of the new business might consist of freight that previously had been shipped by rail. Depending on its magnitude and geographic distribution, as well as on freight railroads' responses to reduced shipment volumes, a decrease in rail shipping could lead to a decrease in fuel consumption and emissions by locomotives.

As one example, a study by Cambridge Systematics, Inc. estimated that an increase in fuel efficiency of Class 8 trucks would increase their VMT by between 5 and 31, percent depending on the cost and magnitude of fuel efficiency improvements. [9] Taking into account the potential shift of freight from rail to truck, the study concluded that total fuel use could decline between 3 and 15 percent. Because the response of freight railroad operations, including such variables as train configurations, service frequencies, and routing, to incremental reductions in shipment volumes remains uncertain, the agencies have not attempted to estimate potential fuel savings and emission reductions for locomotives. By omitting this potential effect, the reductions in emissions resulting from the action alternatives are likely to be slightly underestimated.

In addition, the agencies' air quality analysis methodology assumes that no reduction in tailpipe emissions will occur solely as a consequence of improvements in fuel efficiency. Because the proposed standards are not intended to dictate the design and technology choices that manufacturers must make to comply, a manufacturer could employ technologies that increase fuel efficiency (and thus reduce CO_2 emissions), while at the same time increasing emissions of certain criteria air pollutants or air toxics, as long as the manufacturer's production still meets both the fuel efficiency standards and prevailing EPA emission standards. For this reason, the air quality analysis methodology does not assume any reduction in tailpipe emissions from motor vehicle use solely due to improvements in fuel efficiency. Therefore, the agencies assume that, as a result of the rebound effect, the total amount of HD VMT would increase slightly and that tailpipe emissions of most air pollutants from these vehicles would increase in proportion to increased VMT. In contrast, tailpipe emissions of pollutants that are products of fuel consumption *per se* (rather than of vehicle use), such as CO_2, the main GHG emitted as a consequence of fuel combustion, are still projected to decline under each of the action alternatives in comparison to the No Action

[8] *See* Finding 6-11 in NAS (2010).

[9] *See* the"Draft Regulatory Impact Analysis" accompanying the joint rule (available on docket number NHTSA-2010-0079) citing Cambridge Systematics, Inc., "Assessment of Fuel Economy Technologies for Medium and Heavy Duty Vehicles: Commissioned Paper on Indirect Costs and Alternative Approaches," September 17, 2009.

Alternative. This occurs because the increase in fuel consumption associated with the rebound effect is small by comparison to the reduction in fuel use resulting from increased fuel efficiency, so that total fuel use declines from its level under the No Action alternative under each of the action alternatives.

In contrast to tailpipe or downstream emissions of most pollutants, the agencies project that the proposed standards will lead to reductions in upstream emissions of all pollutants, because the total amount of fuel used by HD vehicles will decline. This, in turn, reduces the volume of fuel that must be refined, stored, and transported. Although the rebound effect is assumed to result in identical percentage increases in VMT and tailpipe emissions from vehicle use in all regions of the United States, 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 fuel consumption standards, depending on the relative magnitudes of the nationwide increase in emissions from vehicle use and the regional decline in emissions resulting from reduced fuel production and distribution.

In summary, the change in total emissions of each pollutant projected to result under an action alternative is the sum of (1) reductions in upstream emissions due to the decline in fuel consumption, and the resulting lower volume of fuel production and distribution, and (2) any increase in vehicle (downstream) emissions that result from added vehicle use due to the rebound effect.

3.2 ENERGY

Energy intensity (energy use per dollar of gross domestic product [GDP]) for the entire U.S. economy declined at an average rate of 2.8 percent per year from 1973 to 2008. This decline is primarily due to a combination of increased efficiency and 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 as U.S. population and economic growth have more than offset the fall in energy intensity. The DOE forecasts that energy intensity for the entire U.S. economy will continue to decline at an average annual rate of 1.9 percent from 2008 to 2035, but ongoing economic and population growth are expected to more than offset gains in energy efficiency, resulting in continuing increases in transportation fuel consumption.[10]

3.2.1 Affected Environment

NHTSA uses energy projections from the EIA, a DOE agency, 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 energy consumption and projections by energy mode, sector, and geographic region. The modeling used to formulate EIA's projections incorporates all Federal and State laws and regulations that are in force at the time of modeling. Potential laws and regulations and laws under debate in Congress are not included. All EIA projections cited in this report refer to estimates from 2035 in the reference case, which is a scenario that incorporates all existing legislation in place, as well as other assumptions, including annual average real GDP growth rate (2.4 percent), nonfarm business and employment productivity (1.5 percent), and nonfarm business and employment growth rate (0.6 percent) from 2008 to 2035.[11]

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. Since 1990, the transportation sector has been the second largest consumer of energy after the industrial sector, and by 2007, it comprised 28.5 percent of U.S. energy use and 17.5 percent of international (less U.S.) energy use. According to the EIA, more than half of U.S. energy consumption in the transportation sector – ranging from 60 percent in 2008 to 50 percent by 2035–can be attributed to gasoline consumption from light vehicles. Diesel consumption from heavy-duty vehicles made up 17 percent of energy consumption in the U.S. transportation sector in 2008, and is projected to increase to 20 percent of energy consumption in the U.S. transportation sector in 2035. Going forward in time, the transportation sector will continue to be the largest component of total U.S. energy consumption after the industrial sector. For the United States, however, the gap between energy consumption in the two sectors narrows considerably in the forecasted out-years. These various sectors consume different types of fuels (*e.g.,* primarily gasoline in the transportation sector and natural gas in the industrial sector). The energy-consumption gap between the industrial and transportation sectors in the United States, measured in quads (a unit of energy equal to 1 quadrillion British thermal units often used to compare consumption volume for different types of fuels) falls from 10.2 quads in 1995 to 1.1 quads in 2035.[12] This decrease reflects not only the decline of the U.S. industrial sector, but most importantly, efficiency changes in the U.S. transportation sector. As a percentage of total economy-

[10] EIA (2010). "Pg. 30 – Energy intensity trends" and "Pg. 75 – Liquid Fuels Supply."
[11] EIA (2010). "Pg. 3, 6, and 7 – Introduction."
[12] EIA (2010). "Table 2 – Energy Consumption by Sector and Source."

Table 3.2.1-1

Energy Consumption by Sector

Sector	Actual a/				Forecast b/				
(Quadrillion BTU c/)	1990	1995	2000	2007	2015	2020	2025	2030	2035
United States									
Residential	17.0	18.6	20.5	21.5	21.3	22.0	22.8	23.4	23.9
Commercial	13.3	14.7	17.2	18.3	19.8	20.1	22.0	23.1	24.3
Industrial	31.9	34.0	34.8	32.8	32.1	32.9	33.2	33.3	33.7
Transportation	22.4	23.8	26.6	29.0	28.5	29.2	30.3	31.4	32.6
Total	84.7	91.2	99.0	101.7	101.6	105.0	108.3	111.2	114.5
Transportation (%)	26.5	26.2	26.8	28.5	28.1	27.8	28.0	28.2	28.5
Residential	- -	- -	- -	50.1	56.6	60.0	63.2	65.9	69.0
Commercial	- -	- -	- -	26.5	30.4	32.7	35.3	37.8	40.4
Industrial	- -	- -	- -	184.9	194.3	212.5	229.3	244.7	261.8
Transportation	- -	- -	- -	97.9	107.0	115.1	123.4	132.5	142.1
Total	347.4	365.0	398.1	495.2	543.5	590.5	638.7	686.5	738.7
Transportation (%)	- -	- -	- -	19.8	19.7	19.5	19.3	19.3	19.2
International (World less United States)									
Residential	- -	- -	- -	28.6	35.3	38.0	40.4	42.5	45.1
Commercial	- -	- -	- -	8.2	10.6	12.6	13.3	14.7	16.1
Industrial	- -	- -	- -	152.1	162.2	179.6	196.1	211.4	228.1
Transportation	- -	- -	- -	68.9	78.5	85.9	93.1	101.1	109.5
Total	262.8	273.9	299.2	393.5	441.9	485.5	530.4	575.3	624.2
Transportation (%)	- -	- -	- -	17.5	17.7	17.7	17.6	17.6	17.5

a/ Actual United States data: EIA (2009b).
Actual World data: EIA (2009a).
b/ Forecasted United States data: EIA *Annual Energy Outlook, 2010* (EIA 2010).
Forecasted World data: *EIA International Energy Outlook 2010* (EIA 2009a).
c/ Btu = British thermal unit.

wide energy consumption, projected energy use in the U.S. transportation sector remains fairly constant, albeit growing at a gradual rate of 0.6 percent, throughout the projection years from 2008 to 2035.[13]

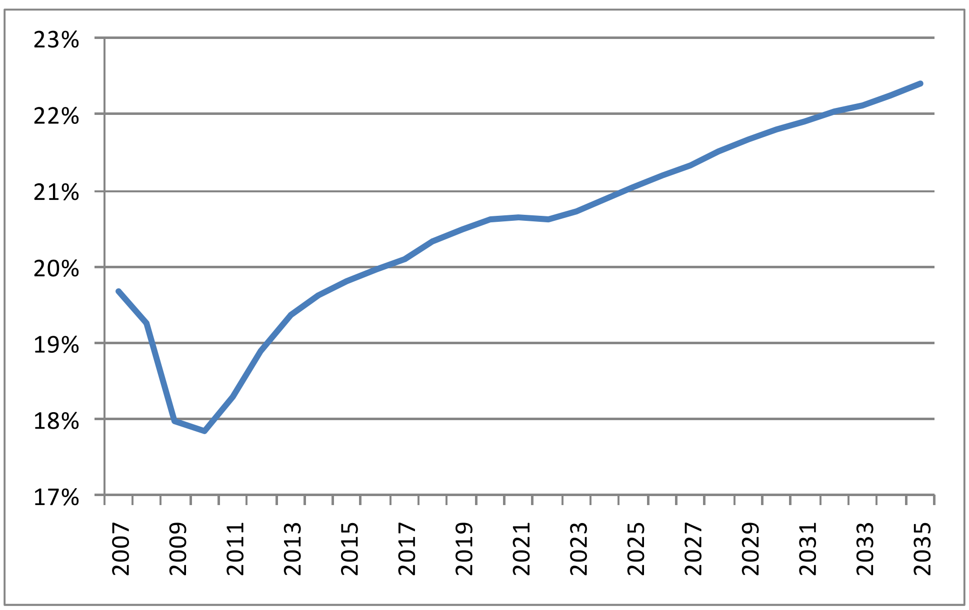
The EIA projections take into account all forms of energy, including renewable fuels and biofuels. Despite efforts to increase use of non-fossil fuels in transportation, such as EPA's adoption of the Renewable Fuel Standard (RFS) which aims to increase use of non-fossil fuels in transportation to 36 billion gallons by 2022 (RFA 2010), fuel use remains largely petroleum based.[14] In both 2007 and 2008, finished motor gasoline and on-road diesel constituted 89 percent of all finished petroleum products consumed for transportation in the United States. This proportion is expected to decline to 83 percent by 2018 and to 79 percent by 2035.[15] If other transportation fuels (aviation fuels, marine and locomotive diesel, and bunkers) are included, transportation fuels constituted approximately 70 percent of the finished petroleum products used in the United States in 2007.

[13] EIA (2010). "Pg. 63 – Transportation Sector Demand."
[14] EIA (2010). "Pg. 75 – Liquid Fuels Supply."
[15] EIA (2010). "Table 2 – Energy Consumption by Sector and Source."

Consumption of biofuels (*e.g.*, ethanol used in E85, ethanol used in gasoline blending, biodiesel used in distillate blending, liquids from biomass) in the transportation sector is projected to increase in the future. The biofuel component of the total U.S. transportation sector energy consumption was 0.64 in 2007 and 0.96 quads in 2008, equal to slightly more than 2 and 3 percent of all energy consumed in the U.S. transportation sector, respectively. According to AEO projections, the biofuels share of energy consumption in the transportation sector will rise to 3.92 quads, or approximately 12 percent of all energy consumed in the U.S. transportation sector, by 2035.[16]

NHTSA's analysis of fuel consumption in this EIS assumes that fuel consumed by HD vehicles will consist predominantly of diesel and gasoline fuel derived from petroleum for the foreseeable future. Petroleum consumption by HD vehicles will continue to grow. In 2008, HD vehicles consumed 19 percent of the petroleum consumed by all highway modes of transportation (*e.g.* light-duty vehicles, commercial light trucks – 8,500 to 10,000 pounds, and HD vehicles). In the reference case, EIA projects that this proportion will drop by 1 to 2 percent from 2009 to 2012, along with total energy consumption in the transportation sector, due to the onset of the economic recession that began during the latter half of 2008. However, AEO projects that petroleum consumption by HD vehicles will recover by 2013 and will reach 23 percent of the total petroleum consumed by highway modes of transportation by 2035. This translates to approximately 5 quads (36 billion gallons) per year from 2007 to 2013 and nearly 6.5 quads (47 billion gallons) by 2035. Total energy consumption by the transportation sector is approximately 30 quads (219 billion gallons) from 2007 to 2013 and nearly 32.5 quads (237 billion gallons) by 2035.[17] Figure 3.2.1-1 illustrates the progression of petroleum consumption by HD vehicles from 2007 up until 2035.

Figure 3.2.1-1. Proportion of Petroleum Consumption by HD Vehicles from 2007–2013



EIA (2010). "Table 7. Transportation Sector Key Indicators and Delivered Energy Consumption."

[16] EIA (2010). "Table 17 – Renewable Energy Consumption by Sector and Source (quadrillion Btu)."
[17] EIA (2010). "Table 7 – Transportation Sector Key Indicators and Delivered Energy Consumption."

The estimates of gasoline consumption reported in this analysis include ethanol used as a gasoline additive to increase its oxygen content (as in E10), while the estimates of diesel fuel consumption include biodiesel used as a blending agent.[18]

Historically, to meet demand, the U.S. transportation sector was heavily dependent on imports of refined petroleum-products and crude oil for domestic refining. More recently, however, imports of crude petroleum and refined products have decreased. According to the EIA *Annual Energy Review* 2009, domestic production of crude oil has not increased. From 2006-2008, it declined from approximately 1.9 to 1.8 billion barrels, a decrease that averaged 0.9 percent per year. During the same period, imports of petroleum products declined from 1.3 to 1.1 billion barrels, a decrease that averaged 4 percent per year. Factors that could have contributed to declining imports of petroleum-products and crude oil include improvements in fuel efficiency standards required for passenger cars and light trucks, biofuels mandates on state- and nationwide levels, increasing prices, and the lift of banned drilling in various U.S. offshore areas from July 2008 to May 2010, even as onshore domestic production continued to decrease.

Statistics demonstrate that lowered imports of petroleum products and crude oil into the US signify either decreased or displaced consumption of petroleum products in various US economic sectors. Statistics demonstrate this trend with regard to petroleum imports. In 2006, 2.30 percent of finished motor gasoline and 1.76 percent of distillate fuel oil supplied to the U.S. economy – mostly to the transportation sector – were imported. By 2007 and 2008, these numbers had dropped to 2 and 1.55 percent of motor gasoline and 1.47 and 1.09 percent of distillate fuel oil supplied to the U.S. economy, respectively. Although imports had typically hovered around 66 percent of all petroleum products supplied to the U.S. economy from 2005 to 2008, by 2009, this figure was estimated to have declined to 63 percent.[19]

With regard to crude oil, imports declined from 10 million barrels per day in 2005-2008 to an estimated 9 million barrels per day in 2009.[20] However, some of this decline was probably attributable to the economic recession that began during the latter part of 2008, rather than fuel efficiency and increased consumption of biofuels Moreover, imports of crude oil are projected to decline further from 20 to roughly 19 quads (138 billion gallons) over the 2009-2035 period.[21] It should be noted that these projections were made before the oil spill in the Gulf of Mexico in 2010, and the effect of the spill is difficult to predict at this time. Most important, the growth of domestic offshore production might be slower than previously thought.

3.2.2 Methodology

The methodology for examining the impact of HD vehicle fuel efficiency standards on energy consumption relies on outputs from MOVES, EPA's official mobile source emission inventory model. This EPA model, described previously in Section 3.1.4, calculates energy consumption and emissions based on user inputs for characteristics of the vehicle fleet and vehicle operational patterns such as (1) a forecast of the future HD vehicle market; (2) estimates of the availability, applicability, and incremental effectiveness of fuel-saving technologies; (3) estimates of vehicle survival and mileage accumulation

[18] EIA data indicate that, during 2007 and 2008, ethanol accounted for approximately 3.3 and 5.0 percent of the energy content of fuel labeled at retail as gasoline, while biodiesel accounted for about 1.0 and 1.5 percent of the energy content of fuel sold at retail as diesel. Computed from information reported in: EIA (2010). "Table 17 – Renewable Energy Consumption by Sector and Source (quadrillion Btu)" and "Table 2 – Energy Consumption by Sector and Source."
[19] EIA (2009b). "Table 5.3 – Petroleum Imports by Type, 1948-2009 (Excel version)" and "Table 5.11 – Petroleum Products Supplied by Type, 1949-2009 (Excel version)."
[20] EIA (2009b). "Table 5.3 – Petroleum Imports by Type, 1948-2009 (Excel version)."
[21] EIA (2010). "Table 1 – Total Energy Supply, Disposition, Price Summary (quadrillion Btu, unless otherwise noted)."

patterns, the rebound effect; and (4) fuel characteristics and vehicular emission rates. Fuel consumption reducing technologies considered by the MOVES model are described in Chapter 2 of the Draft Regulatory Impact Analysis (RIA) (*See* www.regulations.gov, docket number NHTSA-2010-0079).

3.2.3 Environmental Consequences

Table 3.2.3-1 shows the impact of a decrease in consumption over time and an increase in fuel savings for all HD vehicles from 2018 through 2050, when the entire HD vehicle fleet is likely to be composed of MY 2018 or later vehicles. This table reports total fuel consumption, both gasoline and diesel, for HD pickups and vans (Classes 2b–3), vocational vehicles (Classes 2b–8), and tractors (Classes 7–8), under the No Action Alternative (Alternative 1) and under each of the nine action alternatives described in Section 2.3. It also shows the fuel savings for all HD vehicles for each action alternative as compared to the No Action Alternative in these years.

Table 3.2.3-1

Total HD Vehicle Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	52.06	51.20	50.79	50.31	50.33	50.26	50.13	49.96	49.80	49.50
2030	61.47	58.63	58.05	56.51	56.37	56.13	55.74	55.40	54.78	53.12
2050	88.39	83.88	83.53	80.91	80.62	80.26	79.45	78.98	77.90	74.47
Fuel Savings Compared to No Action										
2018	--	0.86	1.27	1.75	1.72	1.79	1.93	2.09	2.26	2.56
2030	--	2.85	3.42	4.96	5.11	5.34	5.73	6.08	6.69	8.35
2050	--	4.51	4.87	7.48	7.77	8.13	8.94	9.42	10.50	13.93

a/ Preferred Alternative

Fuel consumption under the No Action Alternative is 88.39 billion gallons in 2050. Fuel consumption generally decreases across the alternatives, ranging from 83.88 billion gallons under Alternative 2 (Engine Only) to 74.47 billion gallons under Alternative 8 (Accelerated Hybrid Adoption).

Fuel consumption in 2050 is 79.11 billion gallons under the Preferred Alternative. As compared to the No Action Alternative, fuel consumption is less under all action alternatives, resulting in 2050 fuel savings ranging from 4.51 billion gallons under Alternative 2 (Engine Only) to 13.93 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). As compared to the No Action Alternative, fuel savings under the Preferred Alternative (Alternative 6) amounts to 8.94 billion gallons in 2050.

Table 3.2.3-2 shows the impact over time on annual fuel consumption, both gasoline and diesel, for HD pickups and vans (Classes 2b–3) under the No Action Alternative (Alternative 1) and each of the nine action alternatives. It also shows the fuel savings for HD pickups and vans for each of the action alternatives as compared with the No Action Alternative. Fuel consumption for HD pickups and vans is 11.64 billion gallons in 2050 under the No Action Alternative and under Alternative 3 because Alternative 3 does not regulate HD pickups and vans. Fuel consumption for HD pickups and vans is 10.92 billion gallons in 2050 under Alternative 2 (Engine Only) and under Alternative 4 because both

Table 3.2.3-2

HD Pickups and Vans (Classes 2b–3) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	9.71	9.59	9.71	9.59	9.58	9.55	9.55	9.55	9.52	9.40
2030	8.98	8.53	8.98	8.53	8.29	8.14	8.14	8.14	8.00	7.36
2050	11.64	10.92	11.64	10.92	10.50	10.27	10.27	10.27	10.03	8.99
Fuel Savings Compared to No Action										
2018	--	0.12	0.00	0.12	0.13	0.17	0.17	0.17	0.20	0.32
2030	--	0.46	0.00	0.46	0.69	0.84	0.84	0.84	0.98	1.63
2050	--	0.72	0.00	0.72	1.13	1.37	1.37	1.37	1.60	2.65

a/ Preferred Alternative

alternatives regulate only the engines of HD pickups and vans. Fuel consumption is 10.50 billion gallons in 2050 under Alternative 6A. Fuel consumption is 10.27 billion gallons in 2050 under Alternative 5, Alternative 6, (the Preferred Alternative), and Alternative 7, because each of these alternatives requires the same fuel efficiency standards for HD pickups and vans. Fuel consumption in 2050 is 10.03 billion gallons under Alternative 6B and 8.99 billion gallons under Alternative 8, reflecting the higher fuel efficiency standards for HD pickups and vans under these alternatives.

There are no HD pickup and van fuel savings in 2050 under Alternative 3 relative to the No Action Alternative because Alternative 3 does not regulate HD pickups and vans. As compared to the No Action Alternative, HD pickup and van fuel savings in 2050 are 0.72 billion gallons under Alternative 2 (Engine only) and Alternative 4. Fuel savings in 2050 are 1.13 billion gallons under Alternative 6A. Fuel savings in 2050 are 1.37 billion gallons under Alternative 6 (the Preferred Alternative) and under Alternatives 5 and 7, as compared to the No Action Alternative. HD pickup and van fuel savings in 2050 relative to the No Action Alternative are 1.60 billion gallons under Alternative 6B, and 2.65 billion gallons under Alternative 8 (Accelerated Hybrid Adoption).

Table 3.2.3-3 shows the impact over time on annual fuel consumption, both gasoline and diesel, for HD vocational vehicles (Classes 2b–8) under the No Action Alternative (Alternative 1) and each of the action alternatives. It also shows the fuel savings for HD vocational vehicles for each action alternative as compared to the No Action Alternative.

HD vocational vehicle fuel consumption is 25.1 billion gallons in 2050 under the No Action Alternative and under Alternative 3 because Alternative 3 does not regulate HD vocational vehicles. HD vocational vehicle fuel consumption is 23.92 billion gallons in 2050 under Alternative 2 (Engine Only) and under Alternatives 4, 5, and 6A because each of these alternatives regulates only the engines of HD vocational vehicles. Fuel consumption is 23.11 billion gallons in 2050 under Alternative 6 (the Preferred Alternative) and Alternative 7, because both of these alternatives require the same fuel efficiency standards for HD vocational vehicles. Fuel consumption is 22.59 billion gallons in 2050 under Alternative 6B, and 19.88 billion gallons in 2050 under Alternative 8, reflecting higher fuel efficiency standards for HD vocational vehicles under these alternatives.

Table 3.2.3-3

HD Vocational Vehicle (Classes 2b–8) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	9.81	9.64	9.81	9.64	9.64	9.64	9.51	9.51	9.46	9.19
2030	13.43	12.86	13.43	12.86	12.86	12.86	12.47	12.47	12.23	10.98
2050	25.10	23.92	25.10	23.92	23.92	23.92	23.11	23.11	22.59	19.88
Fuel Savings Compared to No Action										
2018	--	0.17	0.00	0.17	0.17	0.17	0.31	0.31	0.35	0.62
2030	--	0.57	0.00	0.57	0.57	0.57	0.97	0.97	1.20	2.46
2050	--	1.18	0.00	1.18	1.18	1.18	1.99	1.99	2.51	5.22

a/ Preferred Alternative

There are no HD vocational vehicle fuel savings in 2050 under Alternative 3 relative to the No Action Alternative because Alternative 3 does not regulate vocational vehicles. HD vocational vehicle fuel savings in 2050 are 1.18 billion gallons under Alternatives 2, 4 6A, and 5. Fuel savings in 2050 are 1.99 billion gallons under Alternative 6 (the Preferred Alternative) and Alternative 7. HD vocational vehicle fuel savings in 2050 relative to the No Action Alternative are 2.51 billion gallons under Alternative 6B, and 5.22 billion gallons under Alternative 8 (Accelerated Hybrid Adoption).

Table 3.2.3-4 shows the impact over time on annual fuel consumption for HD tractors (Classes 7–8) under the No Action Alternative (Alternative 1) and each of the action alternatives. It also shows the fuel savings for HD tractors for each action alternative as compared to the No Action Alternative.

Table 3.2.3-4

HD Tractors (Classes 7–8) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	32.53	31.97	31.27	31.08	31.12	31.08	31.08	30.91	30.82	30.91
2030	39.06	37.24	35.63	35.13	35.22	35.13	35.13	34.78	34.55	34.78
2050	51.65	49.04	46.79	46.07	46.20	46.07	46.07	45.60	45.27	45.60
Fuel Savings Compared to No Action										
2018	--	0.56	1.27	1.45	1.41	1.45	1.45	1.62	1.71	1.62
2030	--	1.81	3.42	3.93	3.84	3.93	3.93	4.27	4.50	4.27
2050	--	2.61	4.87	5.58	5.46	5.58	5.58	6.06	6.39	6.06

a/ Preferred Alternative

HD tractor fuel consumption in 2050 is 51.65 billion gallons under the No Action Alternative, 49.04 billion gallons under Alternative 2 (Engine Only), and 46.79 billion gallons under Alternative 3. HD tractor fuel consumption is 46.07 billion gallons in 2050 under Alternatives 4, 5, and 6 (the Preferred Alternative) because each of these alternatives requires the same fuel efficiency standards for HD tractors. Fuel consumption in 2050 is 46.20 billion gallons under Alternative 6A, and 45.27 billion gallons under Alternative 6B. Fuel consumption in 2050 is 45.60 billion gallons in 2050 under Alternative 7, reflecting higher fuel efficiency standards for HD tractors under this Alternative resulting from the regulation of combination truck trailers as well as tractors. Fuel consumption is also 45.60 billion gallons in 2050 under Alternative 8 (Accelerated Hybrid Adoption), because this alternative reflects accelerated hybrid adoption in the HD pickup and van and vocational vehicle segments of the HD vehicle market, but not in the HD tractor segment.

HD tractor fuel savings in 2050 relative to the No Action Alternative are 2.61 billion gallons under Alternative 2 and 4.87 billion gallons under Alternative 3. Fuel savings in 2050 are 5.58 billion gallons under Alternatives 4, 5, and 6 (the Preferred Alternative). Fuel savings in 2050, as compared to the No Action Alternative, are 5.46 billion gallons under Alternative 6A, and 6.39 billion gallons under Alternative 6B. Fuel savings in 2050, as compared to the No Action Alternative, are 6.06 billion gallons under Alternative 7 and under Alternative 8.

3.3 AIR QUALITY

3.3.1 Affected Environment

3.3.1.1 Relevant Pollutants and Standards

The proposed HD Fuel Efficiency Improvement Program would affect air pollutant emissions and air quality, which in turn could affect public health and welfare and the natural 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 (relatively commonplace pollutants that can accumulate in the atmosphere as a result of normal levels of human activity).[22] This EIS air quality analysis assesses the impacts of the No Action Alternative and action alternatives in relation to criteria pollutants and some hazardous air pollutants from mobile sources.

The criteria pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2) (one of several oxides of nitrogen), ozone, sulfur dioxide (SO_2), particulate matter (PM) with an aerodynamic diameter equal to or less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$ or fine particles), and lead. Because ozone is not emitted directly by motor vehicles, the effect of the proposed HD Fuel Efficiency Improvement Program with respect to ozone is evaluated based on emissions of the ozone precursor pollutants nitrogen oxides (NO_x) and volatile organic compounds (VOCs).[23]

Total emissions from on-road mobile sources 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, 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 2009h).

Nevertheless, the U.S. transportation sector remains a major source of emissions of certain criteria pollutants or their chemical precursors. On-road mobile sources (highway vehicles) 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 2009h). HD vehicles contribute 6 percent of U.S. highway emissions of CO, 66 percent of highway emissions of $PM_{2.5}$, and 55 percent of highway emissions of PM_{10}. Almost all of the PM in motor-vehicle exhaust is $PM_{2.5}$ (Gertler *et al.* 2000); 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. HD vehicles contribute 8 percent of U.S. highway emissions of VOC and 50 percent of NO_x. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors.[24] SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the

[22] "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 or environmentally based criteria (science-based guidelines) for setting permissible levels. "Hazardous air pollutants," by contrast, refers to substances defined as hazardous by the 1990 CAA amendments. These substances include certain VOCs, compounds in PM, pesticides, herbicides, and radionuclides that present tangible hazards, based on scientific studies of human (and other mammal) exposure.

[23] 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.

[24] NO_x can undergo chemical transformations in the atmosphere to form nitrates. VOCs can undergo chemical transformations in the atmosphere to form other various compounds. Nitrates and carbon compounds can be major constituents of $PM_{2.5}$. Highway vehicle emissions are large contributors to nitrate formation nationally (EPA 2004).

formation of $PM_{2.5}$ in the atmosphere; however, on-road mobile sources contribute less than 1 percent of U.S. SO_2 emissions. With the elimination of lead in automotive gasoline, lead is no longer emitted from motor vehicles in more than negligible quantities. Lead is therefore 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 by EPA under the CAA at levels intended to protect against adverse effects on human health; secondary standards are usually less stringent, and 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 different potential effects on human health and public

Table 3.3.1-1

National Ambient Air Quality Standards

	Primary Standards		Secondary Standards	
Pollutant	**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	
	0.100 ppm (200 µg/m^3)	1 hour c/	None	
Particulate matter (PM_{10})	150 µg/m^3	24 hours d/	Same as Primary	
Particulate matter ($PM_{2.5}$)	15.0 µg/m^3	Annual (arithmetic mean) e/	Same as Primary	
	35 µg/m^3	24 hours f/	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8 hours g/ h/	Same as Primary	
	0.08 ppm (1997 std.)	8 hours h/ i/ j/	Same as Primary	
Sulfur dioxide	0.075 ppm (200 µg/m^3)	1 hour k/	0.5 ppm (1,300 µg/m^3)	3 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/ To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average at each monitor within an area must not exceed 0.100 ppm.
d/ Not to be exceeded more than once per year on average over 3 years.
e/ To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m^3.
f/ To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 µg/m^3 (effective December 17, 2006).
g/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm (effective May 27, 2008).
h/ EPA is considering changes to the ozone standard. EPA expects to issue the revised ozone standard by the end of October 2010.
i/ 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.
j/ 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.
k/ The 1-hour sulfur dioxide standard is attained when the 3-year average of the 99th percentile of the daily maximum 1-hour average concentrations does not exceed 0.075 ppm.
Source: 40 CFR Part 50, as presented in EPA 2010a.

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.

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. The NAAQS formerly included an annual PM_{10} standard, but EPA revoked it in 2006 based on an absence of evidence of health effects associated with annual PM_{10} levels. In September 2006, EPA tightened the 24-hour $PM_{2.5}$ standard from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$. In March 2008, EPA tightened the 8-hour ozone standard from 0.08 part per million (ppm) to 0.075 ppm. At present, EPA is considering further changes to the $PM_{2.5}$ standards and to the ozone standard. EPA expects to issue the revised ozone standard at the end of October 2010.

NAAQS are most commonly used to help assess the air quality of a geographic region 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 (ppm) or in micrograms of a pollutant per cubic meter of air ($\mu g/m^3$) 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 less than 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 are now in compliance with the NAAQS are designated as maintenance areas. Each State in which a nonattainment area is located 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 that are known or suspected to cause cancer or other serious health and environmental effects are referred to as mobile source air toxics (MSATs). [25] The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde. EPA and the Federal Highway Administration (FHWA) have identified these air toxics as the MSATs that typically are of greatest concern for impacts of highway vehicles (EPA 2007, FHWA 2006). DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class.

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

[25] A list of all MSATs identified by EPA to date can be found in Regulatory Impact Analysis for Final Rule: Control of Hazardous Air Pollutants from Mobile Sources (signed February 9, 2007), EPA420-R-07-002, Tables 1.1-1 and 1.1-2.

3.3.1.2 Health Effects of Criteria Pollutants

The following paragraphs briefly describe the health effects of the six 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/).

3.3.1.2.1 Ozone

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 among 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. Ozone-related health effects also include respiratory symptoms, aggravation of asthma, increased hospital and emergency room visits, increased asthma medication usage, and a variety of other respiratory-related effects. 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.

3.3.1.2.2 Particulate Matter (PM)

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, sulfur oxides (SO_x), and VOCs. Fine particles are produced primarily by combustion processes and by these atmospheric transformations. 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 considers $PM_{2.5}$ only because almost all of the PM emitted in exhaust from HD vehicles is $PM_{2.5}$.

3.3.1.2.3 Carbon Monoxide (CO)

CO is a colorless, odorless, poisonous gas produced by incomplete combustion of carbon in fuels. Motor vehicles are the single largest source of CO emissions nationally.[26] 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 affect the central nervous system and 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. Epidemiologic studies show associations between short-term CO exposure and cardiovascular morbidity, particularly increased emergency room visits and hospital admissions for coronary heart disease. Some epidemiological studies suggest a causal relationship between long-term exposures to CO and developmental effects and birth outcomes.

[26] Highway motor vehicles overall accounted for 50 percent of national CO emissions in 2008. Passenger cars and light trucks accounted for about 76 percent of the CO emissions from highway motor vehicles (EPA 2009e) while HD vehicles accounted for most of the remaining 24 percent.

3.3.1.2.4 Lead

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

3.3.1.2.5 Sulfur Dioxide (SO_2)

SO_2, one of various oxides of sulfur, 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 in breathing), irritate the upper respiratory tract, and aggravate existing respiratory and cardiovascular disease. The immediate effect of SO_2 on the respiratory system in humans is bronchoconstriction. Asthmatics are more sensitive to the effects of SO_2 likely because of preexisting inflammation associated with asthma. SO_2 also is a primary contributor to acidic deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues.

3.3.1.2.6 Nitrogen Dioxide (NO_2)

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, aggravate asthma, cause bronchitis and pneumonia, and lower resistance to respiratory infections. NO_2 has also been linked to other health endpoints including all-cause (nonaccidental) mortality, hospital admissions or emergency department visits for cardiovascular disease, and reductions in lung function growth associated with chronic exposure. Oxides of nitrogen are an important precursor to both 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 1999). 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 POM can occur as a component of DPM and is addressed under DPM below. Naphthalene also is not analyzed separately in this EIS but it is a member of the POM class of compounds and is also discussed under DPM.

3.3.1.3.1 Acetaldehyde

Acetaldehyde is classified in the EPA 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 (NTP 2005) and is classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (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 (Appelman *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 and bronchoconstriction upon acetaldehyde inhalation (Myou *et al.* 1993). EPA is reassessing the health hazards from inhalation exposure to acetaldehyde.

3.3.1.3.2 Acrolein

Acrolein is extremely acrid and is irritating to humans when inhaled, with acute exposure resulting in upper respiratory tract irritation, mucus hypersecretion, and congestion. The intense irritancy of this carbonyl compound has been demonstrated during controlled tests in human subjects, who suffer intolerable eye and nasal mucosal sensory reactions within minutes of exposure (EPA2003a[27]). These data and additional studies regarding acute effects of human exposure to acrolein are summarized in EPA's 2003 IRIS human health risk assessment for acrolein (EPA 2003a). Evidence available from studies in humans indicate that levels as low as 0.09 ppm (0.21 mg/m^3) for 5 minutes can elicit subjective complaints of eye irritation with increasing concentrations leading to more extensive eye, nose, and respiratory symptoms (Weber-Tschopp *et al*. 1977, EPA 2003a[28]). Lesions to the lungs and upper respiratory tracts of rats, rabbits, and hamsters have been observed after subchronic exposure to acrolein (EPA 2003b). Acute exposure effects in animal studies report bronchial hyper-responsiveness (EPA 2003a[29]). In a recent study, the acute respiratory irritant effects of exposure to 1.1 ppm acrolein were more pronounced in mice with allergic airway disease by comparison to non-diseased mice, which also showed decreases in respiratory rate (Morris *et al.* 2003). Based on these animal data and demonstration of similar effects in humans (*e.g.*, reduction in respiratory rate), 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.

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 2003b). IARC determined that acrolein was not classifiable as to its carcinogenicity in humans (IARC 1995).

[27] EPA 2003a, at p. 10.
[28] EPA 2003a, at p. 11.
[29] EPA 2003a, at p. 15.

3.3.1.3.3 Benzene

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 2000, 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).

Several adverse noncancer health effects, including blood disorders such as preleukemia and aplastic anemia, have also been associated with long-term exposure to benzene (Aksoy 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.

3.3.1.3.4 1,3-butadiene

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). Numerous studies have demonstrated that animals and humans in experiments metabolize 1,3-butadiene into compounds that are genotoxic (capable of causing damage to a cell's genetic material such as DNA). The specific mechanisms of 1,3-butadiene-induced carcinogenesis are not known; scientific evidence strongly suggests, however, 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 on 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).

3.3.1.3.5 Diesel Particulate Matter (DPM)

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 (*see* Section 3.4.1.7). EPA has not provided special status, such as an NAAQS or other health protective measures, for black carbon, but addresses black carbon in terms of $PM_{2.5}$ and DPM emissions. 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) or 212 degrees Fahrenheit (ºF). 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. Numerous 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.

3.3.1.3.6 Formaldehyde

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 (upper throat) cancer and lymphohematopoietic (lymph and blood cells) 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 of 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 (abnormal change in the structure of a tissue) and loss of cilia. Animal studies suggest that formaldehyde might also cause airway inflammation, including eosinophil (a type of white blood cell) infiltration into the airways. Several studies suggest that formaldehyde might increase the risk of asthma, particularly in the young (ATSDR 1999, WHO 2002).

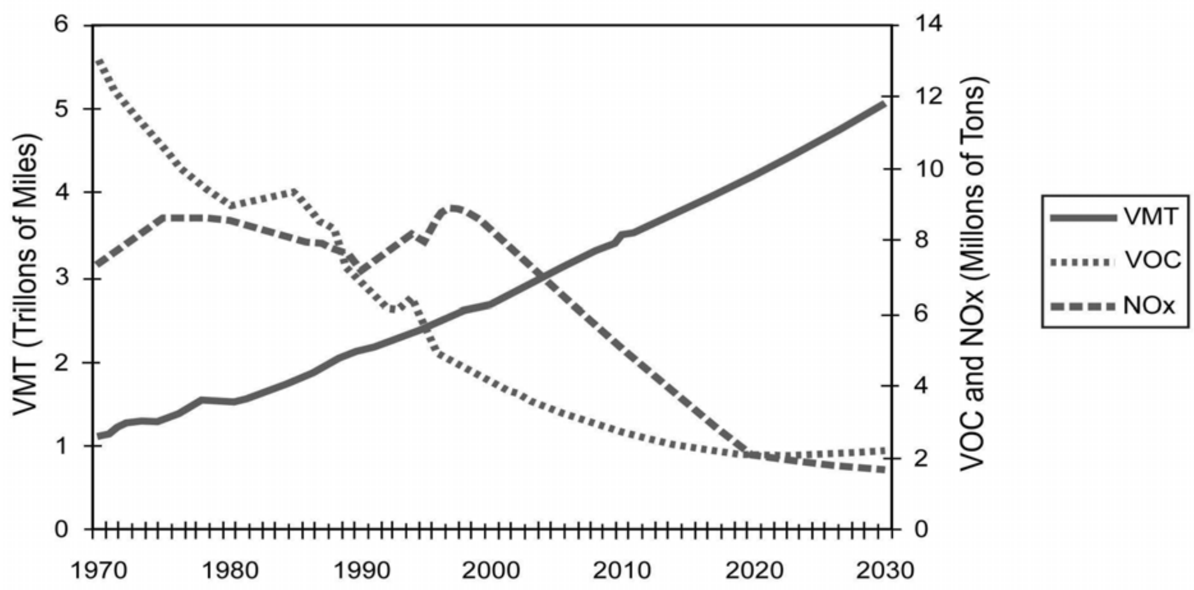
3.3.1.4 Clean Air Act and Conformity Regulations

3.3.1.4.1 Vehicle Emission Standards

Under the CAA, EPA has established criteria pollutant 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 for passenger cars and light trucks and for heavy-duty vehicles are responsible for the declines in total criteria pollutant emissions from motor vehicles, as discussed above. EPA adopted new emission control requirements for heavy-duty highway engines and vehicles on October 6, 2000 (65 *FR* 59896) and January 18, 2001 (66 *FR* 5002). These rules also required that the Nation's refiners and importers of diesel fuel manufacture diesel fuel with sulfur levels capped at 15 ppm, an approximately 97-percent reduction from the previous maximum of 500 ppm. This fuel, known as ultra-low-sulfur diesel fuel, enables post-2006 model year heavy-duty vehicles to use emission controls that reduce exhaust (tailpipe) emissions of NO_x by 95 percent and PM by 90 percent, compared to 2003 model year levels. As a result of these programs, new trucks meeting current emission standards emit 98 percent less NO_x and 99 percent less PM than new trucks emitted 20 years ago. [30] Figure 3.3.1-1 illustrates current trends in travel and emissions from highway vehicles. Figure 3.3.1-1 does not show the effects of the proposed action and alternatives; *see* Section 3.3.3.

[30] Model year 1984 heavy-duty engines met standards of 10.7 grams per brake horsepower-hour (g/bhp-hr) NO_x and 0.6 g/bhp-hr PM; model year 2007 and later heavy-duty engines meet standards of 0.2 g/bhp-hr NO_x and 0.01 g/bhp-hr PM.

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



Note: Projection was developed prior to 2008 and does not reflect the decrease in VMT in 2008 due to economic conditions.

Since 1970, aggregate emissions traditionally associated with vehicles have substantially decreased (with the exception of NO_x) even as VMT has increased by approximately 149 percent. NO_x emissions increased 16 percent between 1970 and 1999, due mainly to emissions from light trucks and heavy-duty vehicles. As future trends show, however, changes in vehicle travel are 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 fuel-efficiency standards.

EPA is also 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, light trucks, and heavy-duty vehicles 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 emission 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 or funding actions in nonattainment or maintenance areas that do not “conform” to the SIP. The purpose of this conformity requirement is to ensure that 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 or delay any interim milestones. 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 or approved under U.S.C. Title 23 or the

Federal Transit Laws (49 U.S.C. Chapter 53). Projects funded by the Federal Highway Administration (FHWA) or the Federal Transit Administration (FTA) usually are subject to transportation conformity. *See* 40 CFR § 93.102.

- The General Conformity Rules (40 CFR Part 93, Subpart B) 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 attributable 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 proposed fuel consumption standards and associated program activities are not funded or approved under U.S.C. Title 23 or the Federal Transit Act. Further, NHTSA's HD Fuel Efficiency Improvement Program is not a highway or transit project funded or approved by FHWA or FTA. Accordingly, the proposed fuel consumption standards and associated rulemakings are not subject to transportation conformity.

Under the General Conformity Rule, a conformity determination is required where a Federal action would result in total direct and indirect emissions of a criteria pollutant or precursor equaling or exceeding the rates specified in 40 CFR § 93.153(b)(1) and (2) for nonattainment and maintenance areas. As explained below, NHTSA's action results in neither direct nor indirect emissions as defined in 40 CFR § 93.152.

The General Conformity Rule defines direct emissions as those of "a criteria pollutant or its precursors that are caused or initiated by the Federal action and originate in a nonattainment or maintenance area and occur at the same time and place as the action and are reasonably foreseeable." 40 CFR § 93.152. Because NHTSA's proposed action only sets fuel consumption standards for HD vehicles, this proposed action causes no direct emissions within the meaning of the General Conformity Rule.

Indirect emissions under the General Conformity Rule include emissions or precursors: (1) that are caused or initiated by the Federal action and originate in the same nonattainment or maintenance area but occur at a different time or place than the action; (2) that are reasonably foreseeable; (3) that the agency can practically control; and (4) for which the agency has continuing program responsibility. 40 CFR § 93.152. Each element of the definition must be met to qualify as an indirect emission. NHTSA has determined that, for the purposes of general conformity, emissions that occur as a result of the fuel consumption standards are not caused by NHTSA's action, but rather occur due to subsequent activities that the agency cannot practically control. "[E]ven if a Federal licensing, rulemaking, or other approving action is a required initial step for a subsequent activity that causes emissions, such initial steps do not mean that a Federal agency can practically control any resulting emissions" (75 *FR* 17254, 17260; 40 CFR § 93.152). NHTSA cannot control vehicle manufacturers' production of HD vehicles and consumer purchasing and driving behavior. For the purposes of analyzing the environmental impacts of this proposed rule under NEPA, NHTSA has made assumptions regarding the technologies manufacturers will install and how companies will react to increased fuel consumption standards. Specifically, NHTSA's NEPA analysis predicted increases in air toxic and criteria pollutants to occur in some nonattainment areas under certain alternatives based on assumptions about the use of Auxiliary Power Units (APUs) and the rebound effect. For example, NHTSA's NEPA analysis assumes that some manufacturers will install anti-idling technologies (APUs) on some vehicle classes to meet the requirements of the rule and that drivers' subsequent use of those APUs will result in an increase in some criteria pollutants. However, NHTSA's proposed regulation does not mandate this specific manufacturer decision or driver behavior – it does not require that manufacturers install APUs to meet the requirements of the rule and it does not require drivers to use anti-idling technologies instead of, for example, shutting off all power when parked. Similarly, NHTSA's NEPA analysis assumes a rebound effect, wherein the proposed action could create an incentive for additional vehicle use by reducing the cost of fuel consumed per mile driven. This rebound effect is an estimate of how NHTSA assumes some drivers will react to the proposed rule and is useful for estimating the costs and benefits of the rule, but the agency does not have the statutory authority, nor the program responsibility, to control, among other items discussed above, the actual vehicle miles traveled by drivers. Accordingly, changes in any emissions that result from NHTSA's HD Fuel Efficiency Improvement Program are not changes that the agency can practically control; therefore, this action causes no indirect emissions and a general conformity determination is not required.

3.3.2 Methodology

3.3.2.1 Overview

To analyze air quality and human health impacts, NHTSA calculated the emissions of criteria pollutants and MSATs from HD vehicles that would occur under each alternative. NHTSA then estimated the resulting changes in emissions by comparing each action alternative to the No Action Alternative (Alternative 1). The resulting changes in air quality and effects on human health were assumed to be proportional to the changes in emissions that are projected to occur under each action alternative.

For purposes of analyzing potential direct and indirect impacts (environmental consequences), the No Action Alternative in this EIS consists of the existing fuel-efficiency levels of HD vehicles with no changes in the future. That is, the No Action Alternative assumes that average fuel-efficiency levels in the absence of fuel consumption standards for HD vehicles would equal the agencies' collective market forecast. *See* Section 2.3.1.

The air quality analysis accounted for downstream emissions, upstream emissions, and the rebound effect as discussed in Section 3.1.4. In summary, the change in emissions resulting from each alternative is the sum of (1) reductions in upstream emissions due to the decline in fuel consumption and thus a lower volume of fuel production and distribution, and (2) the increase in vehicle (downstream) emissions resulting from added vehicle use due to the fuel-efficiency rebound effect.

3.3.2.2 Regional Analysis

To assess regional differences in the effects of the alternatives, NHTSA estimated net emission changes for individual nonattainment and maintenance areas.[31] The distribution of emissions is not uniform nationwide, and both increases and decreases in emissions can occur in nonattainment and maintenance areas. *See* Sections 3.3.2.4 and 3.3.2.5 for detail on the assumptions NHTSA used to allocate upstream and downstream emissions to nonattainment and maintenance areas. NHTSA used nonattainment areas because these are the regions in which air quality problems have been greatest. All nonattainment areas assessed are in nonattainment for ozone or $PM_{2.5}$ because these are the pollutants for which emissions from HD vehicles are of greatest concern. Currently there are no NO_2 nonattainment areas, and only one area is designated nonattainment for CO. There are many areas designated as being in nonattainment for SO_2 or PM_{10}. There are maintenance areas for CO, NO_2, ozone, PM_{10}, and SO_2.

[31] In Section 3.3.3, where the term nonattainment is used, it includes both nonattainment areas and maintenance areas.

NHTSA did not quantify PM_{10} emissions separately from $PM_{2.5}$ because almost all the PM in the exhaust from HD vehicles is $PM_{2.5}$. Emission estimates for all nonattainment areas for all criteria pollutants (except lead, as discussed above) are presented in Appendix D. The road-dust component of PM_{10} and $PM_{2.5}$ concentrations due to HD vehicles would increase in proportion to the rebound effect; road-dust emissions, however, would not be regulated under this rulemaking and accordingly are not assessed in this EIS.

The air quality analysis is national and regional, but does not attempt to address the specific geographic locations of increases in emissions within nonattainment areas. Emission increases due to the rebound effect consist of higher emissions from HD vehicles operating on entire regional roadway networks, so that any emission increases due to the VMT rebound effect would be distributed relatively uniformly throughout a region's entire road network. At any one location within a regional network, the resulting increase in emissions would be small compared to total emissions from all sources surrounding that location (including existing emissions from traffic already using the road), so the localized impacts on ambient concentrations and health should also be small. The nationwide aggregated consequences of such small near-source impacts on ambient pollutant concentrations and health might be larger, but are not feasible to quantify.

3.3.2.3 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.[32] This air quality analysis considers the emissions that would occur over annual periods, consistent with the NAAQS. As described below, NHTSA selected calendar years that are meaningful for the timing of likely effects of the alternatives.

HD vehicles could remain in use for many years, so the change in emissions due to any change in the proposed fuel-efficiency standards would also continue for many years. The influence of vehicles produced during a particular model year declines over time as those vehicles are gradually retired from service as they age, while those that remain in use are driven progressively less. MOVES tracks vehicle age by year up to 30 years, then groups older vehicles into a 30-plus age category. In the MOVES database, Class 2b trucks over 30 years of age account for about 0.8 percent of all Class 2b VMT, and Classes 3–8 trucks over 30 years of age account for about 0.04 percent of all Classes 3–8 VMT. Of course, any individual vehicle might not necessarily survive to these maximum ages; the typical lifetimes for HD vehicles are less than their respective maximum lifetimes. The MOVES database indicates that about 50 percent of Class 2b HD pickups and vans survive to an age of 16 years, and about 50 percent of Classes 3–8 vehicles survive to an age of 19 years.

The survival of vehicles and the amount they are driven can be forecast with reasonable accuracy for a decade or two, although the influences of fuel prices and general economic conditions are less certain. To evaluate impacts on air quality, specific years must be selected for which emissions will be estimated and their effects on air quality calculated. NHTSA assumed that the fuel consumption standards for MYs 2014–2018 would remain in force indefinitely at the 2018 level; NHTSA did not include potential fuel consumption standards for later model years because they are not within the scope of the proposed action and the provisions of any such potential fuel-efficiency standards cannot be known at present.

[32] 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 98th percentile concentrations averaged over a 3-year period; and compliance with the annual $PM_{2.5}$ NAAQS is based on the 3-year average of the weighted annual mean concentrations.

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

- 2018 – First year of complete implementation of the MYs 2014–2018 fuel consumption standards; year of highest overall emissions from HD vehicles following complete implementation.
- 2030 – A mid-term forecast year; by this point a large proportion of HD vehicle VMT would be accounted for by vehicles that meet the MYs 2014–2018 standards.
- 2050 – By 2050, almost all HD vehicles in operation would meet the MYs 2014–2018 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 fuel consumption standards for MYs 2014–2018 and the EPA emission standards by 2050 will change little from model year turnover, and most changes in emissions from year to year will come from added driving due to the rebound effect.

3.3.2.4 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 emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years comprising the HD vehicle fleet, VMT projections, emissions from fuel refining and distribution, and economic factors. To approximate the health benefits associated with each alternative, NHTSA used screening-level estimates of health outcomes in the form of cases per ton of criteria pollutant emissions reduced, and of monetized health benefits in the form of dollars per ton of criteria pollutant emissions reduced. The use of such dollars-per-ton numbers, however, does not account for all potential health and environmental benefits because the information necessary to monetize all potential health and environmental benefits is unavailable. As a result, NHTSA has probably underestimated the total criteria pollutant benefits. Reductions in emissions of toxic air pollutants should result in health benefits as well, but scientific data that would support quantification and monetization of these benefits are not available.

Where information in the analysis included in the EIS is incomplete or unavailable, NHTSA has relied on CEQ regulations regarding incomplete or unavailable information. *See* 40 CFR § 1502.22(b). NHTSA 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.

3.3.2.5 Allocation of Exhaust Emissions to Nonattainment Areas

For each alternative, the MOVES modeling provided national emission 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 estimated heavy-duty truck VMT data for all counties in the United States for 2018, 2030, and 2050, consistent with the EPA National Emissions Inventory (NEI) . Data for 2018, 2030, and 2050 were based on growth from economic modeling and EIA (2006). 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 estimates of county-level VMT from the NEI only to allocate nationwide total emissions to counties, and not to calculate the county-level emissions directly. The estimates of nationwide total emissions are based on the national VMT data used in the MOVES modeling.

NHTSA used the county-level VMT allocations, expressed as the fractions of national VMT that takes place within each county, to derive the county-level emissions from the estimates of nationwide total emissions. Emissions for each nonattainment area were then derived by summing the emissions for the counties included in each nonattainment area. Many nonattainment areas comprise one or more counties, and because county-level emissions are aggregated for each nonattainment area, uncertainties in the country-level emission estimates carry over to 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 include forecasts of the county allocation up to 2050. 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 emission 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 years 2030 and 2050 compared to 2018.

The geographic definitions of ozone and $PM_{2.5}$ nonattainment areas came from the current EPA Greenbook list (EPA 2010b). 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. Partial county boundaries were taken from geographic information system (GIS) files based on 2010 nonattainment area definitions. The populations of these partial-county areas were calculated using U.S. Census data applied to the boundaries mapped by GIS. This method assumes that per-capita VMT is constant within each county, so that the proportion of county-wide VMT in the partial county area reflects the proportion of total county population residing in that same 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).

Table 3.3.2-1 lists the current nonattainment and maintenance areas for ozone and $PM_{2.5}$ and their status/classification and general conformity threshold.

Table 3.3.2-1

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
Albany-Schenectady-Troy, NY	Ozone	Former Subpart 1	50
Allegan County, MI	Ozone	Former Subpart 1	50
Allentown-Bethlehem-Easton, PA	Ozone	Maintenance	100
Altoona, PA	Ozone	Maintenance	100
Amador and Calaveras Counties (Central Mountain), CA	Ozone	Former Subpart 1	50
Atlanta, GA	Ozone	Moderate	50
Atlanta, GA	$PM_{2.5}$	Nonattainment	100
Baltimore, MD	Ozone	Moderate	50
Baltimore, MD	$PM_{2.5}$	Nonattainment	100
Baton Rouge, LA	Ozone	Moderate	50
Beaumont-Port Arthur, TX	Ozone	Moderate	50
Benton Harbor, MI	Ozone	Maintenance	100

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
Benzie County, MI	Ozone	Maintenance	100
Berkeley and Jefferson Counties, WV	Ozone	Maintenance	100
Birmingham, AL	Ozone	Maintenance	100
Birmingham, AL	$PM_{2.5}$	Nonattainment	100
Boston-Lawrence-Worcester (eastern MA), MA	Ozone	Moderate	50
Boston-Manchester-Portsmouth (southeast NH), NH	Ozone	Moderate	50
Buffalo-Niagara Falls, NY	Ozone	Former Subpart 1	50
Canton-Massillon, OH	Ozone	Maintenance	100
Canton-Massillon, OH	$PM_{2.5}$	Nonattainment	100
Case County, MI	Ozone	Maintenance	100
Charleston, WV	Ozone	Maintenance	100
Charleston, WV	$PM_{2.5}$	Nonattainment	100
Charlotte-Gastonia-Rock Hill, NC-SC	Ozone	Moderate	50
Chattanooga, TN-GA-AL	$PM_{2.5}$	Nonattainment	100
Chattanooga, TN-GA	Ozone	Former Subpart 1	50
Chicago-Gary-Lake County, IL-IN	Ozone	Moderate	50
Chicago-Gary-Lake County, IL-IN	$PM_{2.5}$	Nonattainment	100
Chico, CA	Ozone	Former Subpart 1	50
Cincinnati-Hamilton, OH-KY-IN	Ozone	Former Subpart 1	50
Cincinnati-Hamilton, OH-KY-IN	$PM_{2.5}$	Nonattainment	100
Clarksville-Hopkinsville, TN-KY	Ozone	Maintenance	100
Clearfield and Indiana Counties, PA	Ozone	Maintenance	100
Cleveland-Akron-Lorain, OH	Ozone	Maintenance	100
Cleveland-Akron-Lorain, OH	$PM_{2.5}$	Nonattainment	100
Columbia, SC	Ozone	Former Subpart 1	50
Columbus, OH	Ozone	Maintenance	100
Columbus, OH	$PM_{2.5}$	Nonattainment	100
Dallas-Fort Worth, TX	Ozone	Moderate	50
Dayton-Springfield, OH	Ozone	Maintenance	100
Dayton-Springfield, OH	$PM_{2.5}$	Nonattainment	100
Denver-Boulder-Greeley-Fort Collins-Loveland, CO	Ozone	Former Subpart 1	50
Detroit-Ann Arbor, MI	Ozone	Maintenance	100
Detroit-Ann Arbor, MI	$PM_{2.5}$	Nonattainment	100
Door County, WI	Ozone	Former Subpart 1	50
Erie, PA	Ozone	Maintenance	100
Essex County (Whiteface Mountain), NY	Ozone	Former Subpart 1	50
Evansville, IN	Ozone	Maintenance	100
Evansville, IN	$PM_{2.5}$	Nonattainment	100
Fayetteville, NC	Ozone	Former Subpart 1	50
Flint, MI	Ozone	Maintenance	100
Fort Wayne, IN	Ozone	Maintenance	100
Franklin County, PA	Ozone	Maintenance	100
Frederick County, VA	Ozone	Former Subpart 1	50
Fredericksburg, VA	Ozone	Maintenance	100

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
Grand Rapids, MI	Ozone	Maintenance	100
Greater Connecticut, CT	Ozone	Moderate	50
Greene County, IN	Ozone	Maintenance	100
Greene County, PA	Ozone	Maintenance	100
Greensboro-Winston Salem-High Point, NC	Ozone	Marginal	50
Greensboro-Winston Salem-High Point, NC	$PM_{2.5}$	Nonattainment	100
Greenville-Spartanburg-Anderson, SC	Ozone	Former Subpart 1	50
Hancock-Knox-Lincoln-Waldo Counties, ME	Ozone	Maintenance	100
Harrisburg-Lebanon-Carlisle, PA	Ozone	Maintenance	100
Harrisburg-Lebanon-Carlisle, PA	$PM_{2.5}$	Nonattainment	100
Haywood and Swain Counties (Great Smoky Mountain NP), NC	Ozone	Maintenance	100
Hickory, NC	$PM_{2.5}$	Nonattainment	100
Hickory-Morgantown-Lenoir, NC	Ozone	Former Subpart 1	50
Houston-Galveston-Brazoria, TX	Ozone	Severe	25
Huntington-Ashland, WV-KY-OH	$PM_{2.5}$	Nonattainment	100
Huntington-Ashland, WV-KY	Ozone	Maintenance	100
Huron County, MI	Ozone	Maintenance	100
Imperial County, CA	Ozone	Moderate	50
Indianapolis, IN	Ozone	Maintenance	100
Indianapolis, IN	$PM_{2.5}$	Nonattainment	100
Jackson County, IN	Ozone	Maintenance	100
Jamestown, NY	Ozone	Former Subpart 1	50
Jefferson County, NY	Ozone	Moderate	50
Johnson City-Kingsport-Bristol, TN	Ozone	Former Subpart 1	50
Johnstown, PA	Ozone	Maintenance	100
Johnstown, PA	$PM_{2.5}$	Nonattainment	100
Kalamazoo-Battle Creek, MI	Ozone	Maintenance	100
Kent and Queen Anne’s Counties, MD	Ozone	Maintenance	100
Kern County (Eastern Kern), CA	Ozone	Former Subpart 1	50
Kewaunee County, WI	Ozone	Maintenance	100
Knoxville, TN	Ozone	Former Subpart 1	50
Knoxville, TN	$PM_{2.5}$	Nonattainment	100
Lancaster, PA	Ozone	Maintenance	100
Lancaster, PA	$PM_{2.5}$	Nonattainment	100
Lansing-East Lansing, MI	Ozone	Maintenance	100
La Porte, IN	Ozone	Maintenance	100
Las Vegas, NV	Ozone	Former Subpart 1	50
Libby, MT	$PM_{2.5}$	Nonattainment	100
Liberty-Clairton, PA	$PM_{2.5}$	Nonattainment	100
Lima, OH	Ozone	Maintenance	100
Los Angeles South Coast Air Basin, CA	Ozone	Extreme	10
Los Angeles South Coast Air Basin, CA	$PM_{2.5}$	Nonattainment	100
Los Angeles-San Bernardino Counties (western Mohave), CA	Ozone	Moderate	50
Louisville, KY-IN	Ozone	Maintenance	100

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
Louisville, KY-IN	$PM_{2.5}$	Nonattainment	100
Macon, GA	Ozone	Maintenance	100
Macon, GA	$PM_{2.5}$	Nonattainment	100
Madison and Page Counties (Shenandoah NP), VA	Ozone	Maintenance	100
Manitowoc County, WI	Ozone	Former Subpart 1	50
Mariposa and Tuolumne Counties (Southern Mountain), CA	Ozone	Former Subpart 1	50
Martinsburg, WV-Hagerstown, MD	$PM_{2.5}$	Nonattainment	100
Mason County, MI	Ozone	Maintenance	100
Memphis, TN-AR	Ozone	Maintenance	100
Milwaukee-Racine, WI	Ozone	Moderate	50
Muncie, IN	Ozone	Maintenance	100
Murray County (Chattahoochee NF), GA	Ozone	Maintenance	100
Muskegon, MI	Ozone	Maintenance	100
Nashville, TN	Ozone	Former Subpart 1	50
Nevada County (western part), CA	Ozone	Former Subpart 1	50
New York-N. New Jersey-Long Island, NY-NJ-CT	$PM_{2.5}$	Nonattainment	100
New York-northern New Jersey-Long Island, NY-NJ-CT	Ozone	Moderate	50
Norfolk-Virginia Beach-Newport News, VA	Ozone	Maintenance	100
Parkersburg-Marietta, WV-OH	Ozone	Maintenance	100
Parkersburg-Marietta, WV-OH	$PM_{2.5}$	Nonattainment	100
Philadelphia-Wilmington, PA-NY-DE	$PM_{2.5}$	Nonattainment	100
Philadelphia-Wilmington-Atlantic City, PA-NY-MD-DE	Ozone	Moderate	50
Phoenix-Mesa, AZ	Ozone	Former Subpart 1	50
Pittsburgh-Beaver Valley, PA	Ozone	Former Subpart 1	50
Pittsburgh-Beaver Valley, PA	$PM_{2.5}$	Nonattainment	100
Portland, ME	Ozone	Maintenance	100
Poughkeepsie, NY	Ozone	Moderate	50
Providence (entire State), RI	Ozone	Moderate	50
Raleigh-Durham-Chapel Hill, NC	Ozone	Maintenance	100
Reading, PA	Ozone	Maintenance	100
Reading, PA	$PM_{2.5}$	Nonattainment	100
Richmond-Petersburg, VA	Ozone	Maintenance	100
Riverside County (Coachella Valley), CA	Ozone	Severe	25
Roanoke, VA	Ozone	Former Subpart 1	50
Rochester, NY	Ozone	Former Subpart 1	50
Rocky Mount, NC	Ozone	Maintenance	100
Rome, GA	$PM_{2.5}$	Nonattainment	100
Sacramento Metro, CA	Ozone	Severe	25
San Antonio, TX	Ozone	Former Subpart 1	50
San Diego, CA	Ozone	Former Subpart 1	50
San Francisco Bay Area, CA	Ozone	Marginal	50
San Joaquin Valley, CA	Ozone	Extreme	10
San Joaquin Valley, CA	$PM_{2.5}$	Nonattainment	100
Scranton-Wilkes Barre, PA	Ozone	Maintenance	100

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
Sheboygan, WI	Ozone	Moderate	50
South Bend-Elkhart, IN	Ozone	Maintenance	100
Springfield (western MA), MA	Ozone	Moderate	50
St Louis, MO-IL	Ozone	Moderate	50
St. Louis, MO-IL	$PM_{2.5}$	Nonattainment	100
State College, PA	Ozone	Maintenance	100
Steubenville-Weirton, OH-WV	Ozone	Maintenance	100
Steubenville-Weirton, OH-WV	$PM_{2.5}$	Nonattainment	100
Sutter County (Sutter Buttes), CA	Ozone	Former Subpart 1	50
Terre Haute, IN	Ozone	Maintenance	100
Tioga County, PA	Ozone	Maintenance	100
Toledo, OH	Ozone	Maintenance	100
Ventura County, CA	Ozone	Serious	50
Washington County (Hagerstown), MD	Ozone	Former Subpart 1	50
Washington, DC-MD-VA	Ozone	Moderate	50
Washington, DC-MD-VA	$PM_{2.5}$	Nonattainment	100
Wheeling, WV-OH	Ozone	Maintenance	100
Wheeling, WV-OH	$PM_{2.5}$	Nonattainment	100
York, PA	Ozone	Maintenance	100
York, PA	$PM_{2.5}$	Nonattainment	100
Youngstown-Warren-Sharon, OH-PA	Ozone	Maintenance	100

a/ Pollutants for which the area is designated nonattainment or maintenance as of 2010, and severity classification.
b/ Tons per year of VOCs or NO_x in ozone maintenance and nonattainment areas; primary $PM_{2.5}$ in $PM_{2.5}$ maintenance and nonattainment areas.
Source: EPA (2010b).

3.3.2.6 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, the materials (*e.g.*, crude oil) that are the main inputs to the refining process. 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 emission 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 did not take into account emission reductions from feedstock recovery in nonattainment areas.

- Feedstock transportation – NHTSA assumed that little to no crude oil is transported through nonattainment areas. Most refineries are outside, or on the outskirts, of urban areas. Crude oil is typically transported hundreds of miles from extraction points and ports to reach refineries. Most transportation is by ocean tanker and pipeline. Probably only a very small proportion of criteria pollutants emitted in the transport of crude oil occur in nonattainment areas. Therefore, NHTSA did not consider emission reductions from feedstock transportation within nonattainment areas.

Because NHTSA did not take into account emission 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 emission benefit 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 per unit of fuel produced and distributed (based on EPA's modeling using GREET). NHTSA used projected emission data from EPA's 2005-based air quality modeling platform (EPA 2009f) to allocate reductions in nationwide total emissions from fuel refining to individual nonattainment areas. These EPA data were for the year 2022, the most representative year available in the EPA dataset. EPA's NEI includes estimates of emissions of criteria and toxic pollutants by both county and source category. Because fuel refining represents a separate source category in the NEI, it is possible to estimate the share of nationwide emissions from fuel refining that occurs within each nonattainment area. This analysis assumes that the share of fuel refining emissions allocated to each nonattainment area does not change over time, which in effect means that that fuel refining emissions are assumed to change uniformly across all refineries nationwide as a result of each alternative.

- TS&D – NHTSA used data from the EPA modeling platform (EPA 2009g) to allocate TS&D emissions to nonattainment areas in the same way as for fuel refining emissions. NHTSA's analysis assumes 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 emission inventories provided by the EPA air quality modeling platform (EPA 2009g) do not include 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 1,3-butadiene because, among toxic air pollutants for which county-level data were available, 1,3-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 1,3-butadiene because, among toxic air pollutants for which county-level data were available, 1,3-butadiene has the ratio of fuel refining and TS&D emissions that is closest to the ratio for formaldehyde emissions.

3.3.2.6.1 Health Outcomes and Monetized Benefits

Overview

This section describes NHTSA's approach to providing quantitative estimates of adverse health effects of conventional air pollutants associated with each alternative.

In this analysis, NHTSA quantified and monetized the impacts on human health that were anticipated to result from the changes in pollutant emissions, and related changes in human exposure to air pollutants under each alternative. The agency evaluated the changes in four health impacts that would result from increased fuel efficiency: premature mortality, chronic bronchitis, respiratory emergency-room visits, and work-loss days. This methodology estimates the health impacts of each alternative for each analysis year, expressed as the number of additional or avoided outcomes per year.

Health and monetary outcomes are calculated from factors for each primary pollutant, expressed as health outcomes avoided or monetary health benefits gained per ton of reduced emissions. The general approach to calculating the health outcomes associated with each alternative is to multiply these factors by the estimated annual reduction in emissions of that pollutant, and to sum the results of these calculations for all pollutants. This calculation provides the total health impacts and monetized health benefits achieved in each alternative. In calculating the health impacts and monetized health benefits of emission reductions, NHTSA estimated only the $PM_{2.5}$-related human health impacts that are expected to result from reduced population exposure to atmospheric concentrations of $PM_{2.5}$. Three other pollutants – NO_x, SO_2, and VOCs – are included in the analysis as precursor emissions that contribute to $PM_{2.5}$ not emitted directly from a source, but instead formed by chemical reactions in the atmosphere (secondary $PM_{2.5}$). While this analysis only estimates PM-related incidence of four health endpoints, the monetized PM-related benefits include the value of the suite of all currently monetized PM-related health endpoints.

Finally, the approach does not include any reductions in health impacts resulting from lower population exposure to other criteria air pollutants (particularly ozone) and air toxics.

Monetized Health Impacts

The $PM_{2.5}$ benefit-per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of directly emitted $PM_{2.5}$, or its precursors (such as NO_x, SO_2, and VOCs), from a specified source. NHTSA followed the benefit-per-ton technique used in the EPA Ozone NAAQS 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 $PM_{2.5}$-related benefits captured in those benefit-per-ton estimates, as well as potential $PM_{2.5}$-related benefits that were not quantified in this analysis.

Table 3.3.2-2

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

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

The benefits estimates use 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.[33]

As described in the documentation for the benefit-per-ton estimates cited above, EPA developed national per-ton estimates for selected pollutants emitted through both stationary and mobile activity. Because the per-ton values vary slightly between the two categories, the total health and monetized health impacts were derived by multiplying the stationary per-ton estimates by total stationary emissions and the mobile per-ton estimates by total mobile emissions. 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. Although Fann *et al.*

[33] Note that since the 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). NHTSA's analysis follows this EPA method. Refer to the following website for updates to the dollar-per-ton estimates: http://www.epa.gov/air/benmap/bpt.html.

assumes that there is a threshold in PM-related models of health impacts, EPA's updated methodology excludes this assumption.

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, although the benefit-per-ton results vary between the two studies, EPA considers Pope *et al.* and Laden *et al.* to be co-equal in terms of strengths and weaknesses and the quality of results, and that both studies should be used to generate benefits estimates. Due to the analytical limitations associated with this analysis, however, NHTSA chose to use the benefit-per-ton value derived from the American Cancer Society study and notes 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[34] (VSL) estimate that was vetted and endorsed by the EPA Science Advisory Board (SAB) in the Guidelines for Preparing Economic Analyses (EPA 2000).[35] 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. [36]

Table 3.3.2-3

Benefit-per-ton Values (2007$) Derived Using the ACS Cohort Study for PM-related Premature Mortality (Pope *et al.* 2002) a/ and a 3-Percent Discount Rate b/

	All Sources d/		Stationary (Non-EGU e/) Sources		Mobile Sources	
Year c/	SO_2	VOC	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
2018	$29,074	$1,205	$4,806	$224,556	$5,010	$274,105
2030	$35,374	$1,488	$5,923	$271,298	$6,219	$339,189
2050	$40,663	$1,726	$6,865	$310,418	$7,238	$393,863

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 2015, 2020, and 2030. For 2018, NHTSA interpolated exponentially between 2015 and 2020. For 2050, NHTSA extrapolated exponentially based on the growth between 2020 and 2030.
d/ Note that the benefit-per-ton value for SO_2 is based on the value for stationary (non-EGU) sources; no SO_2 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).

[34] The "value of statistical life" refers to the aggregate estimated value of reducing small risks across a large number of people. It is based on how people themselves would value reducing these risks (*i.e.*, "willingness to pay").
[35] In the (draft) update of the Economic Guidelines (EPA 2008b), 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.
[36] The VSL derived by EPA and used for this study is $6.3 million in year 2000 dollars. This value is significantly higher than the standard VSL adopted by the U.S. Department of Transportation for benefit-cost analyses, which is $3.0 million (FHWA 2007). This discrepancy is not unexpected, as no single dollar value has been accepted in the academic community or across the Federal government.

Quantified Health Impacts

Table 3.3.2-4 lists the incidence-per-ton estimates for select PM-related health impacts (derived by the same process as described above for the dollar-per-ton estimates).

For the analysis of direct and indirect impacts (*see* Section 3.3) and cumulative impacts (s*ee* Section 4.3), NHTSA used the values for 2018, 2030, and 2050 (*see* Section 3.3.2.6).

Table 3.3.2-4

Incidence-per-ton Values for Health Outcomes – Pope *et al.* (2002)

Outcome and Year a/	All Sources b/		Stationary (Non-EGU c/) Sources		Mobile Sources	
	SO_2	VOC	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
Premature Mortality – Pope *et al.* (2002)						
2018	0.003392551	0.000140359	0.000559011	0.026226383	0.000582867	0.031911324
2030	0.003975998	0.000167016	0.003975998	0.030515150	0.000697373	0.038060658
2050	0.004493326	0.000190635	0.004493326	0.034314755	0.000798739	0.043482308
Chronic Bronchitis						
2018	0.002329952	0.000098935	0.000407200	0.017799906	0.000425139	0.022756846
2030	0.002620989	0.000111857	0.000463516	0.019910922	0.000485821	0.025857828
2050	0.002860369	0.000122472	0.000509890	0.021646564	0.000535739	0.028416315
Emergency Room Visits – Respiratory						
2018	0.003165030	0.000105060	0.000460765	0.025989663	0.000450458	0.026134066
2030	0.003532001	0.000116470	0.000510860	0.028909897	0.000501965	0.029178012
2050	0.003833675	0.000125898	0.000551915	0.031307870	0.000544186	0.031694483
Work-Loss Days						
2018	0.442468901	0.018885616	0.078818286	3.388223635	0.082357004	4.351957667
2030	0.469122336	0.019971564	0.083960270	3.583248983	0.087993991	4.649346930
2050	0.491701164	0.020880043	0.088269266	3.750312593	0.092702517	4.900623988

a/ Benefit-per-ton values were estimated for 2018, 2030, and 2050. For 2018, NHTSA interpolated exponentially between 2015 and 2020. For 2050, 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 many 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. Emission changes and benefit-per-ton estimates alone are not a good indication of local or regional air quality and health impacts, because there could be localized impacts associated with the proposed action. Because the atmospheric chemistry related to ambient concentrations of $PM_{2.5}$, ozone, and air toxics is very complex, full-scale photochemical air quality modeling would be necessary to control for local variability. Full-scale photochemical modeling would provide the needed spatial and temporal detail to more completely and accurately estimate changes in ambient levels of these pollutants and their associated health and welfare impacts. To support and confirm the screening-level, benefit-per-ton estimates, NHTSA plans to perform full-scale photochemical air quality modeling of a selection of alternatives for the FEIS. This modeling will provide insight into the uncertainties associated with the use of benefit-per-ton estimates. EPA is conducting full-scale photochemical modeling for its Final Rule on HD vehicle GHG standards, which is an element of the joint NHTSA-EPA HD National Program.

- 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 benefit-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 benefit-per-ton estimates because of issues associated with the complexity of the atmospheric air chemistry and nonlinearities associated with ozone formation. The PM-related benefit-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 Analysis

As discussed in Section 3.3.1, most criteria pollutant emissions from vehicles have been declining since 1970 as a result of EPA's emission regulations under the CAA, and EPA projects that they will continue to decline. As future trends show, however, 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 fuel consumption standards. *See* Section 2.4 for additional discussion of trends and for a comparison across all of the alternatives.

The analysis in this section shows that the action alternatives considered in this analysis will have varying impacts on emissions from HD vehicles when measured against projected trends without the proposed fuel consumption standards, with the reductions or increases in emissions varying by pollutant, calendar year, and action alternative. The more stringent/comprehensive action alternatives generally would result in greater emission reductions compared to the No Action Alternative. Tables 3.3.3-1 through 3.3.3-10 and Figures 3.3.3-1 and 3.3.3-2 below present the results of the air quality analysis. These tables and figures are referred to in the discussions of individual alternatives in Sections 3.3.3.2 through 3.3.3.9.

3.3.3.1.1 Criteria Pollutants Overview

Table 3.3.3-1 summarizes the total national emissions from HD vehicles by alternative for each of the criteria pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 8) left to right in order of decreasing fuel consumption 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 Alternative 2 are generally smaller than those between the No Action Alternative and Alternatives 3 through 8. CO and NO_x emissions under Alternative 2 are slightly higher than under the No Action Alternative (except for NO_x in 2018). Emissions under Alternatives 3 through 8 are lower and relatively flat across alternatives. $PM_{2.5}$ emissions are highest under Alternative 3, and are generally higher under Alternatives 3 through 7 than under the No Action Alternative. These differences are small, however, and overall there is little change in $PM_{2.5}$ emissions from the No Action Alternative to any other alternative. In the case of SO_2 and VOCs, the No Action Alternative results in the highest emissions and SO_2 and VOC emissions decline as fuel consumption standards become more stringent across alternatives. Overall, as shown in Table 3.3.3-1, many of the differences in national emissions of criteria air pollutants, particularly those between Alternatives 1 and 2 and those among Alternatives 3 through 8, are only slight. Consequently, such differences might not lead to measurable changes in ambient concentrations of criteria pollutants.

Total emissions are composed of eight components, consisting of tailpipe emissions and upstream emissions for each of four vehicle classes: Classes 2b–3 HD pickups and vans, Classes 3 through 8 vocational vehicles, day cab combination unit tractors (and/or trailers), and sleeper cab combination unit tractors (and/or trailers). To show the relationship among these eight 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 criteria pollutant emissions from HD vehicles for each of the criteria pollutants and analysis years. After the No Action Alternative (Alternative 1), the table presents the action alternatives (Alternatives 2 through 8) in approximate order of decreasing fuel consumption. Each numbered alternative from Alternative 4 through Alternative 7 includes additional regulated vehicle classes compared to each previous alternative. (Alternatives 6A and 6B regulate the same vehicle classes as Alternative 6.) Alternative 8 would increase the rate of technology adoption across vehicle classes. Compared to the No Action Alternative, emissions of CO increase under Alternative 2 and then decline unevenly under Alternatives 3 through 8, reflecting the complex interactions between tailpipe emission rates of the various vehicle types, upstream emission rates, the relative proportions of gasoline and diesel in total fuel consumption reductions, and increases in VMT. In most years, NO_x emissions increase under Alternative 2 compared to the No Action Alternative and then decline unevenly with subsequent alternatives. The differences in NO_x emissions among Alternatives 3 through 8 are slight, with the exception of higher emissions under Alternative 6A. Emissions of $PM_{2.5}$ increase with Alternative 3, due to the regulation of Class 8 vehicles, then decline unevenly under Alternatives 4 through 8. The peak in $PM_{2.5}$ emissions in Alternative 3 is due to assumption that tractor trailers will use APUs that have relatively high PM emission rates while idling for extended periods. Under Alternatives 3 through 8 the contribution of $PM_{2.5}$ emissions from APUs approximately offsets the reductions due to the regulation of vehicle and engine classes other than Class 8. Emissions of SO_2 and VOCs decline relatively smoothly across all alternatives because reductions in upstream emissions are greater than the increases due to the VMT rebound effect. Table 3.3.3-4 summarizes the criteria air pollutant results by nonattainment area. Tables in Appendix D list the emission reductions for each nonattainment area. For CO, NO_x, and $PM_{2.5}$ emissions, some nonattainment areas will experience increases while others will experience decreases. For SO_2 and VOC emissions, all nonattainment areas will experience decreases.

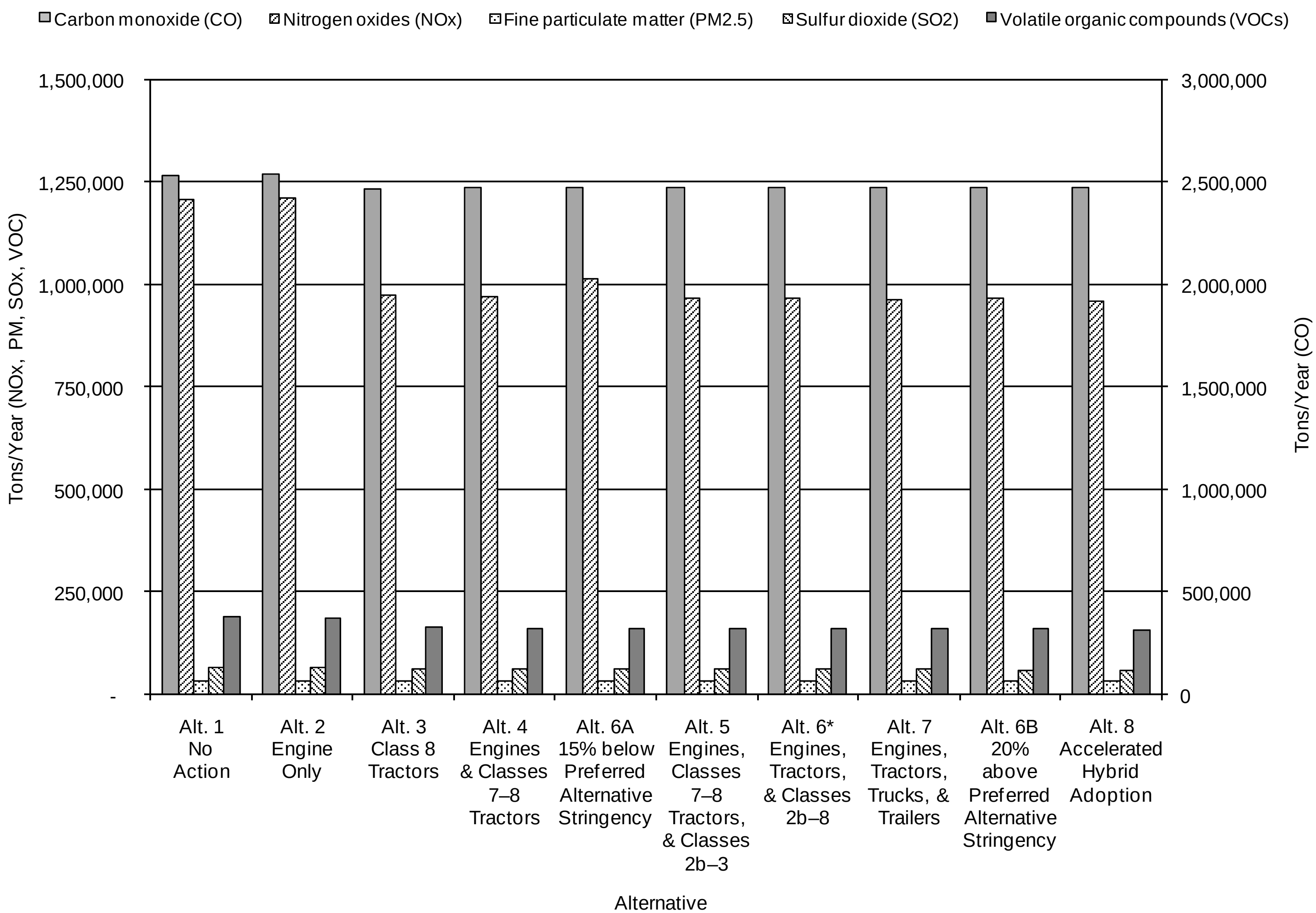
Table 3.3.3-1

Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles by Alternative

Pollutant and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
2018	3,073,944	3,074,884	3,047,782	3,048,367	3,049,049	3,048,979	3,048,691	3,048,464	3,048,358	3,048,027
2030	2,529,555	2,536,070	2,468,226	2,473,691	2,474,084	2,473,941	2,472,888	2,472,567	2,472,357	2,471,320
2050	3,002,389	3,012,851	2,915,938	2,924,928	2,924,804	2,924,590	2,923,019	2,922,578	2,922,172	2,920,139
Nitrogen oxides (NO_x)										
2018	2,023,599	2,023,367	1,924,671	1,921,698	1,940,878	1,921,877	1,921,188	1,919,241	1,920,212	1,917,958
2030	1,209,793	1,211,776	976,030	970,675	1,015,606	970,189	968,646	964,295	967,055	960,551
2050	1,542,259	1,545,254	1,212,739	1,205,382	1,268,447	1,204,363	1,201,304	1,195,216	1,198,786	1,187,948
Particulate matter ($PM_{2.5}$)										
2018	80,890	80,556	80,975	80,819	80,839	80,807	80,755	80,667	80,610	80,476
2030	36,667	36,118	37,422	37,198	37,174	37,113	37,037	36,924	36,818	36,406
2050	46,933	46,092	48,011	47,630	47,886	47,488	47,333	47,177	47,280	46,180
Sulfur dioxide (SO_2)										
2018	104,791	103,016	102,092	101,118	101,182	101,046	100,770	100,412	100,079	99,504
2030	70,377	67,117	66,416	64,659	64,500	64,233	63,784	63,390	62,687	60,801
2050	100,361	95,239	94,784	91,817	91,506	91,100	90,173	89,635	88,411	84,541
Volatile organic compounds (VOC)										
2018	290,586	289,661	279,649	278,812	278,831	278,686	278,551	278,384	277,956	277,688
2030	190,376	187,911	164,712	162,530	161,937	161,397	161,070	160,820	159,935	157,758
2050	235,265	231,547	199,130	195,816	194,733	193,876	193,267	192,930	191,583	187,674

a/ Preferred Alternative

Figure 3.3.3-1. Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Table 3.3.3-2

Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
Class 2b-3 Work Trucks Tailpipe	1,815,175	1,820,909	1,815,175	1,820,909	1,821,361	1,821,361	1,821,361	1,821,361	1,821,361	1,821,361
Class 2b-3 Work Trucks Upstream	4,711	4,466	4,711	4,466	4,340	4,264	4,264	4,264	4,188	3,852
Class 3-8 Vocational Vehicles Tailpipe	450,637	451,698	450,637	451,698	451,698	451,698	450,864	450,864	450,864	450,864
Class 3-8 Vocational Vehicles Upstream	7,456	7,137	7,456	7,137	7,137	7,137	6,918	6,918	6,785	6,083
Class 7-8 Day Cab Combination Unit Tailpipe	40,050	40,235	40,134	40,158	40,164	40,158	40,158	40,075	40,158	40,075
Class 7-8 Day Cab Combination Unit Upstream	8,425	8,024	7,915	7,720	7,733	7,720	7,720	7,608	7,614	7,608
Class 7-8 Sleeper Cab Combination Unit Tailpipe	189,638	190,753	130,143	129,637	129,646	129,637	129,637	129,589	129,637	129,589
Class 7-8 Sleeper Cab Combination Unit Upstream	13,463	12,848	12,055	11,966	12,005	11,966	11,966	11,887	11,750	11,887
Total	2,529,555	2,536,070	2,468,226	2,473,691	2,474,084	2,473,941	2,472,888	2,472,567	2,472,357	2,471,320
Nitrogen oxides (NO_x)										
Class 2b-3 Work Trucks Tailpipe	288,071	289,932	288,071	289,932	290,057	290,057	290,057	290,057	290,057	290,057
Class 2b-3 Work Trucks Upstream	14,248	13,511	14,248	13,511	13,130	12,900	12,900	12,900	12,670	11,654
Class 3-8 Vocational Vehicles Tailpipe	172,845	173,757	172,845	173,757	173,757	173,757	172,868	172,868	172,868	172,868
Class 3-8 Vocational Vehicles Upstream	22,328	21,372	22,328	21,372	21,372	21,372	20,718	20,718	20,320	18,220
Class 7-8 Day Cab Combination Unit Tailpipe	135,464	136,268	133,664	133,219	133,393	133,219	133,219	130,809	133,219	130,809
Class 7-8 Day Cab Combination Unit Upstream	25,189	23,988	23,664	23,079	23,118	23,079	23,079	22,744	22,763	22,744
Class 7-8 Sleeper Cab Combination Unit Tailpipe	511,398	514,537	285,168	280,029	324,889	280,029	280,029	278,660	280,029	278,660
Class 7-8 Sleeper Cab Combination Unit Upstream	40,251	38,411	36,042	35,776	35,890	35,776	35,776	35,538	35,129	35,538
Total	1,209,793	1,211,776	976,030	970,675	1,015,606	970,189	968,646	964,295	967,055	960,551

Table 3.3.3-2 (continued)

Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Particulate matter ($PM_{2.5}$)										
Class 2b-3 Work Trucks Tailpipe	3,675	3,692	3,675	3,692	3,693	3,692	3,692	3,692	3,692	3,692
Class 2b-3 Work Trucks Upstream	1,973	1,871	1,973	1,871	1,818	1,786	1,786	1,786	1,755	1,614
Class 3-8 Vocational Vehicles Tailpipe	5,589	5,617	5,589	5,617	5,617	5,617	5,631	5,631	5,631	5,631
Class 3-8 Vocational Vehicles Upstream	3,089	2,956	3,089	2,956	2,956	2,956	2,866	2,866	2,811	2,520
Class 7-8 Day Cab Combination Unit Tailpipe	4,288	4,308	4,276	4,277	4,279	4,277	4,277	4,261	4,277	4,261
Class 7-8 Day Cab Combination Unit Upstream	3,484	3,318	3,273	3,192	3,197	3,192	3,192	3,146	3,148	3,146
Class 7-8 Sleeper Cab Combination Unit Tailpipe	9,002	9,044	10,561	10,645	10,651	10,645	10,645	10,628	10,645	10,628
Class 7-8 Sleeper Cab Combination Unit Upstream	5,567	5,312	4,985	4,948	4,964	4,948	4,948	4,915	4,859	4,915
Total	36,667	36,118	37,422	37,198	37,174	37,113	37,037	36,924	36,818	36,406
Sulfur dioxide (SO_2)										
Class 2b-3 Work Trucks Tailpipe	915	872	915	872	849	834	834	834	820	754
Class 2b-3 Work Trucks Upstream	9,041	8,572	9,041	8,572	8,330	8,184	8,184	8,184	8,038	7,393
Class 3-8 Vocational Vehicles Tailpipe	1,075	1,029	1,075	1,029	1,029	1,029	999	999	981	885
Class 3-8 Vocational Vehicles Upstream	14,315	13,702	14,315	13,702	13,702	13,702	13,283	13,283	13,027	11,679
Class 7-8 Day Cab Combination Unit Tailpipe	1,146	1,091	1,076	1,050	1,051	1,050	1,050	1,034	1,035	1,034
Class 7-8 Day Cab Combination Unit Upstream	16,177	15,406	15,198	14,822	14,847	14,822	14,822	14,607	14,619	14,607
Class 7-8 Sleeper Cab Combination Unit Tailpipe	1,859	1,776	1,649	1,636	1,641	1,636	1,636	1,625	1,607	1,625
Class 7-8 Sleeper Cab Combination Unit Upstream	25,850	24,669	23,147	22,976	23,050	22,976	22,976	22,823	22,561	22,823
Total	70,377	67,117	66,416	64,659	64,500	64,233	63,784	63,390	62,687	60,801

Table 3.3.3-2 (continued)

Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Volatile organic compounds (VOC)										
Class 2b-3 Work Trucks Tailpipe	51,508	51,664	51,508	51,664	51,636	51,606	51,606	51,606	51,575	51,606
Class 2b-3 Work Trucks Upstream	27,327	26,350	27,327	26,350	25,716	25,275	25,275	25,275	24,834	22,821
Class 3-8 Vocational Vehicles Tailpipe	21,741	21,590	21,741	21,590	21,590	21,590	21,454	21,454	21,393	21,454
Class 3-8 Vocational Vehicles Upstream	10,723	10,280	10,723	10,280	10,280	10,280	10,089	10,089	9,992	9,481
Class 7-8 Day Cab Combination Unit Tailpipe	9,407	9,193	9,127	9,017	9,025	9,017	9,017	8,955	8,955	8,955
Class 7-8 Day Cab Combination Unit Upstream	6,139	5,846	5,767	5,625	5,634	5,625	5,625	5,543	5,548	5,543
Class 7-8 Sleeper Cab Combination Unit Tailpipe	53,721	53,625	29,736	29,285	29,309	29,285	29,285	29,237	29,076	29,237
Class 7-8 Sleeper Cab Combination Unit Upstream	9,810	9,362	8,784	8,719	8,747	8,719	8,719	8,661	8,562	8,661
Total	190,376	187,911	164,712	162,530	161,937	161,397	161,070	160,820	159,935	157,758

a/ Preferred Alternative

Table 3.3.3-3

Nationwide Changes in Criteria Pollutant Emissions (tons per year) from HD Vehicles by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
2018	0	940	-26,162	-25,577	-24,895	-24,965	-25,252	-25,480	-25,585	-25,917
2030	0	6,516	-61,328	-55,863	-55,470	-55,613	-56,666	-56,988	-57,197	-58,235
2050	0	10,462	-86,451	-77,461	-77,585	-77,799	-79,369	-79,811	-80,216	-82,250
Nitrogen oxides (NO_x)										
2018	0	-231	-98,928	-101,900	-82,720	-101,721	-102,410	-104,358	-103,386	-105,641
2030	0	1,983	-233,763	-239,118	-194,187	-239,605	-241,147	-245,499	-242,738	-249,243
2050	0	2,995	-329,520	-336,877	-273,812	-337,896	-340,955	-347,043	-343,473	-354,311
Particulate matter ($PM_{2.5}$)										
2018	0	-334	86	-70	-51	-82	-135	-223	-280	-414
2030	0	-549	754	531	507	446	369	257	150	-261
2050	0	-841	1,078	697	953	555	400	244	347	-753
Sulfur dioxide (SO_2)										
2018	0	-1,775	-2,698	-3,673	-3,608	-3,745	-4,021	-4,379	-4,712	-5,287
2030	0	-3,260	-3,961	-5,718	-5,878	-6,144	-6,593	-6,987	-7,690	-9,577
2050	0	-5,123	-5,578	-8,544	-8,856	-9,262	-10,189	-10,727	-11,950	-15,820
Volatile organic compounds (VOC)										
2018	0	-925	-10,936	-11,773	-11,754	-11,899	-12,035	-12,201	-12,630	-12,897
2030	0	-2,465	-25,664	-27,845	-28,439	-28,979	-29,306	-29,556	-30,441	-32,618
2050	0	-3,718	-36,135	-39,449	-40,532	-41,389	-41,998	-42,335	-43,682	-47,591

a/ Preferred Alternative

Table 3.3.3-4

Criteria Pollutant Emissions from HD Vehicles, Maximum Changes by Nonattainment Area and Alternative a/

Criteria Pollutant	Maximum Increase/ Decrease	Change (tons per year)	Year	Alt. Number	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	1,459	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-10,219	2050	Alt. 3	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	1,088	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-40,520	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Particulate matter ($PM_{2.5}$)	Maximum Increase	225	2050	Alt. 6A	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-261	2050	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Sulfur dioxide (SO_2)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,214	2050	Alt. 8	Chicago-Gary-Lake County, IL-IN (Ozone, $PM_{2.5}$)
Volatile organic compounds (VOC)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-4,422	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)

a/ Emission changes have been rounded to the nearest whole number.

3.3.3.1.2 Toxic Air Pollutants Overview

Table 3.3.3-5 summarizes the total national emissions of toxic air pollutants from HD vehicles by alternative for each of the pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 8, including Alternatives 6A and 6B) from left to right in order of decreasing fuel consumption requirements. Figure 3.3.3-2 shows these data by alternative for 2030, the mid-term forecast year which is also the year EPA used in its analysis. Emissions of acetaldehyde, acrolein, and formaldehyde are highest under Alternative 2, and emissions of DPM are highest under Alternative 3. Emissions of benzene are highest under Alternative 1 in 2018, but highest under Alternative 2 in 2030 and 2050. Emissions of 1,3-butadiene are highest under Alternatives 1 and 2 in 2018 and 2050 and highest under Alternative 2 in 2030. The trends for toxic air pollutant emissions across the alternatives are mixed, for the same reasons as for criteria pollutants (*see* Section 3.3.3.1.1). Table 3.3.3-5 shows that emissions of acetaldehyde, acrolein, and formaldehyde increase slightly from Alternative 1 to Alternative 2, then decrease or remain stable under each successive alternative from Alternative 2 to Alternative 8, except for acetaldehyde under Alternative 7 in 2030 and for formaldehyde under Alternative 6A in 2018. Emissions of benzene decrease or remain stable under each successive alternative from Alternative 1 to Alternative 8, except for Alternative 2 in 2030 and 2050 and for Alternative 6A in 2018. Emissions of 1,3-butadiene decrease or remain stable under each successive alternative from Alternative 1 to Alternative 8, except for Alternatives 2 and 4 in 2030 and Alternative 4 in 2050. Emissions of DPM decrease under each successive alternative from Alternative 1 to Alternative 8, except for Alternative 3 in all analysis years and Alternative 6A in 2018. Under Alternatives 3 through 8, emissions of acetaldehyde, acrolein, and formaldehyde are below or approximately equivalent to those under the No Action Alternative, and the differences in these emissions among Alternatives 3 through 8 are slight. These

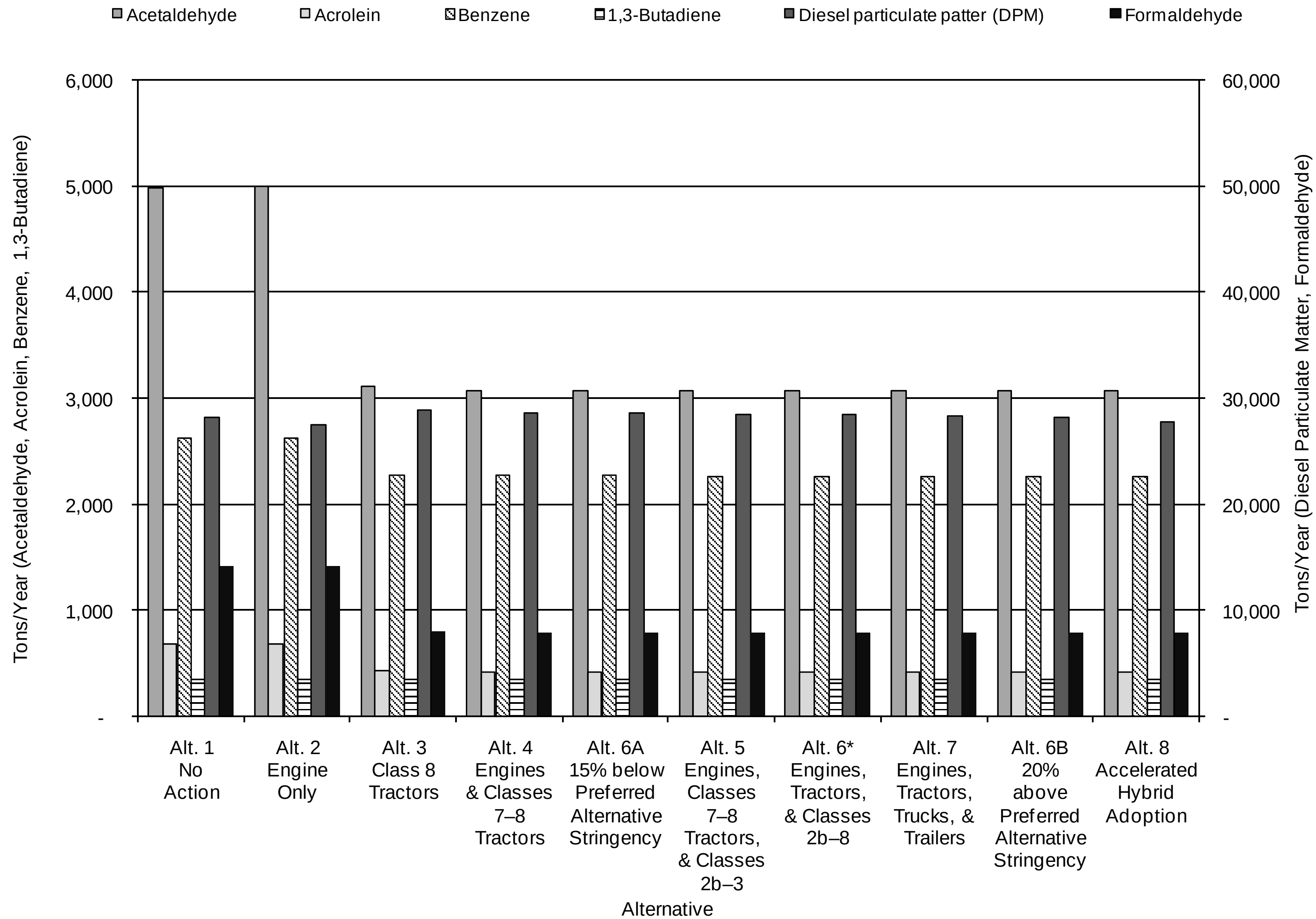
Table 3.3.3-5

Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
2018	6,954	6,964	6,173	6,158	6,158	6,158	6,158	6,158	6,158	6,158
2030	4,973	4,998	3,104	3,070	3,070	3,069	3,068	3,069	3,068	3,068
2050	6,413	6,453	3,780	3,734	3,733	3,733	3,732	3,731	3,731	3,729
Acrolein										
2018	1,059	1,060	952	950	950	950	950	950	950	950
2030	685	689	428	424	424	424	424	424	424	424
2050	872	878	510	504	504	504	504	504	504	503
Benzene										
2018	4,147	4,145	3,999	3,993	3,995	3,994	3,994	3,993	3,991	3,989
2030	2,628	2,631	2,278	2,274	2,274	2,273	2,271	2,270	2,268	2,260
2050	3,121	3,127	2,629	2,624	2,621	2,620	2,617	2,616	2,612	2,598
1,3-Butadiene										
2018	741	741	739	739	739	739	739	739	739	738
2030	351	353	349	351	351	351	351	351	351	351
2050	378	378	375	376	376	376	376	376	376	376
Diesel particulate patter (DPM)										
2018	74,823	74,462	74,896	74,727	74,746	74,713	74,650	74,552	74,503	74,360
2030	28,106	27,504	28,846	28,591	28,571	28,508	28,407	28,274	28,188	27,759
2050	34,377	33,427	35,416	34,965	34,916	34,821	34,611	34,425	34,258	33,407
Formaldehyde										
2018	16,945	16,971	14,384	14,328	14,329	14,329	14,329	14,328	14,326	14,325
2030	14,095	14,162	7,977	7,846	7,847	7,846	7,843	7,843	7,839	7,832
2050	18,813	18,914	10,188	10,010	10,008	10,007	10,003	10,002	9,997	9,984

a/ Preferred Alternative

Figure 3.3.3-2. Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

trends are accounted for by the classes of the HD vehicle fleet that would be affected by each proposed alternative and the fuel consumption requirements for those vehicle classes (due to the fuel consumption requirements, the overall fuel consumption decreases across successive years). Overall, the differences in national emissions of toxic air pollutants between Alternatives 1 and 2 are only slight and consequently might not lead to measurable changes in ambient concentrations. The same is true of the differences in national emissions among Alternatives 3 through 8.

Total emissions are composed of eight components: tailpipe emissions and upstream emissions for Classes 2b-3 HD pickups and vans, tailpipe emissions and upstream emissions for Classes 3 through 8 vocational vehicles, tailpipe emissions and upstream emissions for day cab combination unit tractors (and/or trailers), and tailpipe emissions and upstream emissions for sleeper cab combination unit tractors (and/or trailers). To show the relationship among these eight components for air toxic pollutants, Table 3.3.3-6 breaks down the total emissions of air toxic pollutants by component for calendar year 2030.

Table 3.3.3-7 lists the net change in nationwide emissions from HD vehicles for each of the toxic air pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 8, including Alternatives 6A and 6B) from left to right in order of decreasing fuel consumption requirements. In Table 3.3.3-7, the nationwide emission changes are uneven in relation to pollutant and alternative, although some demonstrate reductions, reflecting the changes in VMT and emissions by vehicle class projected to occur with the decreasing fuel consumption requirements assumed under successive alternatives.

Table 3.3.3-8 summarizes the air toxic results by nonattainment area. Tables in Appendix D list the emission reductions for each nonattainment area. For all toxic air pollutant emissions, some nonattainment areas will experience increases while others will experience decreases.

3.3.3.1.3 Health Effects and Monetized Health Benefits Overview

Adverse health effects would decrease nationwide under each of the action alternatives compared to the No Action Alternative (*see* Table 3.3.3-9). The reductions in adverse health effects become greater with increasing stringency of the alternatives. Table 3.3.3-10 lists the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative. The monetized health benefits become greater with increasing stringency of the alternatives.

Sections 3.3.3.2 through 3.3.3.9 describe the results of the analysis of emissions for Alternatives 1 through 8 in greater detail.

3.3.3.2 Alternative 1: No Action

3.3.3.2.1 Criteria Pollutants

Under Alternative 1 (No Action), the average fuel efficiency for HD vehicles would remain at the MY 2013 level in future years. Current trends in the levels of criteria pollutant emissions from vehicles would continue, with emissions continuing to decline due to tightening EPA emission standards, despite a growth in total VMT from 2018 to 2030, but increasing from 2030 to 2050 due to growth in total VMT during that period. The No Action Alternative would not change these trends and therefore would not result in any change in criteria pollutant emissions nationally or in nonattainment areas, beyond those changes projected to result from projected future trends in emissions and VMT.

Table 3.3.3-6

Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
Class 2b-3 Work Trucks Tailpipe	993	998	993	998	998	998	998	998	998	998
Class 2b-3 Work Trucks Upstream	5	5	5	5	5	4	4	4	4	4
Class 3-8 Vocational Vehicles Tailpipe	752	756	752	756	756	756	755	755	755	755
Class 3-8 Vocational Vehicles Upstream	8	7	8	7	7	7	7	7	7	6
Class 7-8 Day Cab Combination Unit Tailpipe	281	282	282	283	283	283	283	283	283	283
Class 7-8 Day Cab Combination Unit Upstream	9	8	8	8	8	8	8	8	8	8
Class 7-8 Sleeper Cab Combination Unit Tailpipe	2910	2929	1043	1002	1002	1002	1002	1002	1,002	1,002
Class 7-8 Sleeper Cab Combination Unit Upstream	14	13	12	12	12	12	12	12	12	12
Acrolein										
Class 2b-3 Work Trucks Tailpipe	99	100	99	100	100	100	100	100	100	100
Class 2b-3 Work Trucks Upstream	1	1	1	1	1	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	111	111	111	111	111	111	111	111	111	111
Class 3-8 Vocational Vehicles Upstream	1	1	1	1	1	1	1	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	42	42	42	42	42	42	42	42	42	42
Class 7-8 Day Cab Combination Unit Upstream	1	1	1	1	1	1	1	1	1	1
Class 7-8 Sleeper Cab Combination Unit Tailpipe	428	431	171	166	166	166	166	166	166	166
Class 7-8 Sleeper Cab Combination Unit Upstream	2	2	2	2	2	2	2	2	2	2

Table 3.3.3-6 (continued)

Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Benzene										
Class 2b-3 Work Trucks Tailpipe	1,474	1,481	1,474	1,481	1,482	1,482	1,482	1,482	1,482	1,482
Class 2b-3 Work Trucks Upstream	63	60	63	60	59	58	58	58	57	52
Class 3-8 Vocational Vehicles Tailpipe	335	336	335	336	336	336	335	335	335	335
Class 3-8 Vocational Vehicles Upstream	45	43	45	43	43	43	42	42	41	38
Class 7-8 Day Cab Combination Unit Tailpipe	53	54	54	54	54	54	54	54	54	54
Class 7-8 Day Cab Combination Unit Upstream	41	39	38	37	37	37	37	37	37	37
Class 7-8 Sleeper Cab Combination Unit Tailpipe	552	556	212	205	205	205	205	205	205	205
Class 7-8 Sleeper Cab Combination Unit Upstream	65	62	58	58	58	58	58	57	57	57
1,3-butadiene										
Class 2b-3 Work Trucks Tailpipe	243	245	243	245	245	245	245	245	245	245
Class 2b-3 Work Trucks Upstream	1	1	1	1	1	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	45	45	45	45	45	45	45	45	45	45
Class 3-8 Vocational Vehicles Upstream	2	2	2	2	2	2	2	2	2	2
Class 7-8 Day Cab Combination Unit Tailpipe	5	5	5	5	5	5	5	5	5	5
Class 7-8 Day Cab Combination Unit Upstream	2	2	2	2	2	2	2	2	2	2
Class 7-8 Sleeper Cab Combination Unit Tailpipe	49	49	47	48	48	48	48	48	48	48
Class 7-8 Sleeper Cab Combination Unit Upstream	3	3	3	3	3	3	3	3	3	3

Table 3.3.3-6 (continued)

Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Diesel particulate matter (DPM)										
Class 2b-3 Work Trucks Tailpipe	1,872	1,876	1,872	1,876	1,876	1,876	1,876	1,876	1,876	1,876
Class 2b-3 Work Trucks Upstream	1,954	1,853	1,954	1,853	1,801	1,769	1,769	1,769	1,737	1,598
Class 3-8 Vocational Vehicles Tailpipe	2,718	2,727	2,718	2,727	2,727	2,727	2,716	2,716	2,716	2,716
Class 3-8 Vocational Vehicles Upstream	3,068	2,936	3,068	2,936	2,936	2,936	2,847	2,847	2,792	2,503
Class 7-8 Day Cab Combination Unit Tailpipe	2,807	2,817	2,774	2,771	2,774	2,771	2,771	2,739	2,771	2,739
Class 7-8 Day Cab Combination Unit Upstream	3,462	3,297	3,252	3,172	3,177	3,172	3,172	3,126	3,128	3,126
Class 7-8 Sleeper Cab Combination Unit Tailpipe	6,694	6,720	8,255	8,340	8,348	8,340	8,340	8,317	8,340	8,317
Class 7-8 Sleeper Cab Combination Unit Upstream	5,532	5,279	4,953	4,917	4,932	4,917	4,917	4,884	4,828	4,884
Formaldehyde										
Class 2b-3 Work Trucks Tailpipe	1,926	1,934	1,926	1,934	1,934	1,934	1,934	1,934	1,934	1,934
Class 2b-3 Work Trucks Upstream	37	35	37	35	34	34	34	34	33	30
Class 3-8 Vocational Vehicles Tailpipe	2,145	2,154	2,145	2,154	2,154	2,154	2,153	2,153	2,153	2,153
Class 3-8 Vocational Vehicles Upstream	58	56	58	56	56	56	54	54	53	47
Class 7-8 Day Cab Combination Unit Tailpipe	854	859	858	859	859	859	859	860	859	860
Class 7-8 Day Cab Combination Unit Upstream	66	63	62	60	60	60	60	59	59	59
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,904	8,962	2,797	2,655	2,655	2,655	2,655	2,656	2,655	2,656
Class 7-8 Sleeper Cab Combination Unit Upstream	105	100	94	93	94	93	93	93	92	93

a/ Preferred Alternative

Table 3.3.3-7

Nationwide Changes in Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Poll. and Year	Alt. 1 c/ No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors & Classes 2b–3	Alt. 6 d/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
2018	0	10	-781	-796	-796	-796	-796	-795	-796	-795
2030	0	25	-1,869	-1,903	-1,903	-1,904	-1,904	-1,904	-1,904	-1,905
2050	0	40	-2,633	-2,679	-2,680	-2,680	-2,681	-2,681	-2,682	-2,683
Acrolein										
2018	0	1	-107	-109	-109	-109	-109	-109	-109	-109
2030	0	4	-257	-261	-261	-261	-261	-261	-261	-261
2050	0	6	-362	-368	-368	-368	-368	-368	-368	-369
Benzene										
2018	0	-2	-148	-154	-152	-153	-153	-154	-156	-158
2030	0	3	-350	-354	-355	-356	-358	-359	-361	-369
2050	0	6	-493	-497	-501	-502	-505	-506	-510	-524
1,3-Butadiene										
2018	0	-1	-3	-2	-2	-2	-2	-2	-2	-3
2030	0	2	-1	1	1	1	1	1	1	1
2050	0	0	-3	-2	-2	-2	-2	-2	-2	-2
Diesel particulate matter (DPM)										
2018	0	-360	73	-96	-77	-110	-172	-271	-319	-463
2030	0	-602	740	485	465	401	301	167	82	-347
2050	0	-951	1,039	587	539	444	234	48	-120	-970
Formaldehyde										
2018	0	26	-2,561	-2,617	-2,616	-2,616	-2,616	-2,618	-2,619	-2,621
2030	0	67	-6,118	-6,249	-6,248	-6,249	-6,252	-6,252	-6,256	-6,263
2050	0	101	-8,625	-8,803	-8,805	-8,806	-8,810	-8,811	-8,816	-8,829

a/ Emission changes have been rounded to the nearest whole number.
b/ Negative emission changes indicate reductions; positive emission changes are increases.
c/ Emission 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.
d/ Preferred Alternative

Table 3.3.3-8

Changes in Toxic Air Pollutant Emissions from HD Vehicles, Maximum Changes by Nonattainment Area and Alternative a/

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons per year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	5	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, PM2.5)
	Maximum Decrease	-323	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Acrolein	Maximum Increase	0.7	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-44	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Benzene	Maximum Increase	2	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-58	2050	Alt. 3	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	0.3	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-0.9	2018	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Diesel particulate matter (DPM)	Maximum Increase	215	2050	Alt. 6A	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-263	2050	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Formaldehyde	Maximum Increase	14	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-1,059	2050	Alt. 6 b/	Los Angeles South Coast Air Basin, CA (O_3, $PM_{2.5}$)

a/ Emission changes have been rounded to the nearest whole number except to present values greater than zero but less than one.
b/ Preferred Alternative

Table 3.3.3-9

Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions (cases per year) from HD Vehicles by Alternative a/

Outcome and Year	Alt. 1 b/ No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors & Classes 2b–3	Alt. 6 d/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Mortality (ages 30 and older), Pope *et al.* (2002)										
2018	0	-15	-62	-71	-59	-72	-74	-79	-81	-88
2030	0	-28	-148	-165	-135	-170	-175	-183	-187	-212
2050	0	-48	-238	-269	-211	-278	-290	-303	-302	-366
Mortality (ages 30 and older), Laden *et al.* (2006)										
2018	0	-38	-160	-183	-152	-184	-191	-203	-208	-226
2030	0	-71	-379	-422	-346	-434	-448	-469	-479	-543
2050	0	-124	-607	-686	-539	-710	-740	-773	-770	-936
Chronic bronchitis										
2018	0	-10	-45	-51	-42	-51	-53	-56	-58	-62
2030	0	-18	-102	-114	-93	-117	-120	-126	-128	-145
2050	0	-30	-159	-178	-140	-184	-192	-200	-199	-241
Emergency Room Visits for Asthma										
2018	0	-15	-52	-61	-51	-61	-64	-68	-70	-76
2030	0	-27	-112	-128	-107	-132	-137	-144	-148	-170
2050	0	-45	-171	-198	-157	-206	-217	-227	-227	-282
Work-Loss Days										
2018	0	-1,906	-8,614	-9,781	-8,101	-9,838	-10,191	-10,819	-11,076	-11,982
2030	0	-3,238	-18,564	-20,558	-16,768	-21,125	-21,734	-22,744	-23,190	-26,190
2050	0	-5,244	-27,459	-30,845	-24,202	-31,863	-33,161	-34,631	-34,483	-41,626

a/ Negative changes indicate fewer health impacts; positive changes are additional health impacts.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the other alternatives are compared.
c/ Preferred Alternative

Table 3.3.3-10

Nationwide Monetized Health Benefits (2007 U.S. million dollars per year) from Criteria Pollutant Emissions from HD Vehicles by Alternative a/

Rate and Year	Alt. 1 b/ No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors & Classes 2b–3	Alt. 6 d/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
3-Percent Discount Rate										
Pope *et al.* (2002)										
2018	0	-126	-535	-611	-509	-615	-638	-679	-696	-755
2030	0	-247	-1,321	-1,470	-1,204	-1,513	-1,559	-1,633	-1,668	-1,892
2050	0	-437	-2,155	-2,434	-1,912	-2,518	-2,624	-2,743	-2,732	-3,318
Laden *et al.* (2006)										
2018	0	-310	-1,308	-1,496	-1,245	-1,505	-1,562	-1,661	-1,704	-1,848
2030	0	-605	-3,230	-3,597	-2,944	-3,701	-3,813	-3,994	-4,081	-4,628
2050	0	-1,072	-5,270	-5,955	-4,677	-6,160	-6,421	-6,711	-6,686	-8,121
7-Percent Discount Rate										
Pope *et al.* (2002)										
2018	0	-115	-485	-555	-462	-558	-579	-616	-632	-685
2030	0	-224	-1,198	-1,334	-1,092	-1,373	-1,414	-1,481	-1,513	-1,716
2050	0	-396	-1,954	-2,208	-1,734	-2,284	-2,380	-2,488	-2,478	-3,010
Laden *et al.* (2006)										
2018	0	-280	-1,182	-1,351	-1,125	-1,360	-1,411	-1,501	-1,539	-1,669
2030	0	-547	-2,917	-3,249	-2,660	-3,344	-3,444	-3,608	-3,686	-4,181
2050	0	-968	-4,761	-5,379	-4,225	-5,564	-5,800	-6,062	-6,039	-7,336

a/ Negative changes indicate monetized health benefits; positive emission changes indicate monetized health disbenefits.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the other alternatives are compared.
c/ Preferred Alternative

3.3.3.2.1 Toxic Air Pollutants

Under Alternative 1 (No Action), the average fuel efficiency for HD vehicles would remain at the MY 2013 level in future years. EPA regulates toxic air pollutants from motor vehicles through vehicle emission standards and fuel quality standards, as discussed in Section 3.3.1. 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 emission standards, despite a growth in total VMT from 2018 to 2030, but increasing from 2030 to 2050 due to growth in total VMT during that period. The No Action Alternative would not change the current fuel consumption standards and therefore would not result in any change in toxic air pollutant emissions throughout the United States, beyond current trends.

The magnitude of emission change from one alternative to the next generally increases between Alternative 2 and Alternative 8 (including Alternatives 6A and 6B) because a larger share of HD vehicles is included or each alternative requires greater overall fuel efficiency.

3.3.3.2.2 Health Outcomes and Monetized Benefits

Under Alternative 1 (No Action), average fuel efficiency would remain at the MY 2013 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 emission standards, despite a growth in total VMT. The human health-related impacts that are expected to occur under current trends would continue. The No Action Alternative would not result in any other increase or decrease in human health impacts throughout the United States.

3.3.3.3 Alternative 2: Engine Only

3.3.3.3.1 Criteria Pollutants

Under Alternative 2, nationwide emissions of CO and NO_x compared to the No Action Alternative would increase slightly (except for NO_x in 2018). CO emissions would increase by up to 0.3 percent (in 2050), and NO_x emissions would increase by up to 0.2 percent (in 2050). Additionally, there would be decreases in emissions of $PM_{2.5}$, SO_2, and VOCs. $PM_{2.5}$ emissions would be reduced by 1.5 percent in 2018 to 1.8 percent in 2050. Likewise, SO_2 emissions would be reduced by 1.7 percent in 2018 to 5.1 percent in 2050, and VOC emissions would be reduced by 0.3 percent in 2018 to 1.6 percent in 2050.

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. The reductions in upstream emissions are not uniformly distributed to individual nonattainment areas, however. 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 emission reductions if the reduction in upstream emissions in the nonattainment area more than offsets the increase due to the rebound effect.

Under Alternative 2, all nonattainment areas would experience reductions in emissions of SO_2 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.

3.3.3.3.2 Toxic Air Pollutants

Nationwide emissions of acetaldehyde, acrolein, and formaldehyde would increase slightly in all analysis years under Alternative 2 compared to the No Action Alternative. Emissions of DPM would be slightly lower under Alternative 2 compared to the No Action Alternative. Emissions of benzene and 1,3-butadiene under Alternative 2 compared to Alternative 1 would be approximately equivalent in all analysis years.

Compared to Alternatives 3 through 8, Alternative 2 would have higher emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene. For DPM, Alternative 2 would have lower emissions than all other alternatives except for Alternative 8 in 2018 and 2050.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As noted above, 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. Net reductions in emissions of some pollutants can occur in such areas if the reduction in upstream emissions within the nonattainment area more than offsets the increase in emissions due to the rebound effect.

Under Alternative 2, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in all of the analysis years (*see* Appendix D). The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.3.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 2 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 2 would reduce the number of cases of premature mortality by 28 in 2030 (using the Laden *et al.* values, premature mortality would be reduced by 71 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 3,238.

These health benefits increase greatly in 2050. Premature mortality is reduced by 48 cases compared to the No Action Alternative (124 cases under Laden *et al.*), and the number of work-loss days is reduced by 5,244.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 2 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7 percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 2 would be $224 million in 2030, increasing to $396 million in 2050. Under more aggressive assumptions (3 percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $605 million in 2030 and $1.072 billion in 2050.

Health and monetized health benefits generally increase with each alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 2 are the smallest of all alternatives (excluding the No Action Alternative).

3.3.3.4 Alternative 3: Class 8 Tractors

3.3.3.4.1 Criteria Pollutants

Under Alternative 3, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. The reductions would increase from 2018 to 2030 to 2050. Depending on the year, CO emissions would be reduced 0.9 to 2.9 percent, NO_x emissions would be reduced 4.9 to 21.4 percent, SO_2 emissions would be reduced 2.6 to 5.6 percent, and VOC emissions would be reduced 3.8 to 15.4 percent. Reductions of NO_x, SO_2, and VOC emissions are generally greater than would occur under Alternative 2 but less than would occur under Alternatives 4 through 8, with the exception of NOx emissions under Alternative 6A. Reductions of CO are greater than would occur under all other alternatives. Under Alternative 3, emissions of $PM_{2.5}$ would be 0.1 (in 2018) to 2.3 (in 2050) percent higher than under the No Action Alternative depending on the year and also would be higher than under all other alternatives. Because Alternative 3 assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has $PM_{2.5}$ emissions that are higher than under the No Action Alternative.

Under Alternative 3, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.4.2 Toxic Air Pollutants

Alternative 3 would reduce emissions of toxic air pollutants compared to the No Action Alternative for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde in all years. For DPM, Alternative 3 would increase emissions compared to the No Action Alternative. Alternative 3 would have approximately equivalent or slightly higher emissions of acetaldehyde, acrolein, benzene, and formaldehyde compared to Alternatives 4 through 8, and higher or slightly higher emissions of DPM compared to Alternatives 4 through 8, in all years. Alternative 3 would have approximately equivalent emissions of 1,3-butadiene compared to Alternatives 4 through 8 in all analysis years.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As with Alternative 2, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 3, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM which would increase in most nonattainment areas in all years. The sizes of the emission increases would be quite small, however, as shown in Appendix D and emission increases would be distributed throughout each nonattainment area.

3.3.3.4.3 Health Outcomes and Monetized Benefits

There would be reductions in adverse health effects nationwide under Alternative 3 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 3 would reduce the number of cases of premature mortality by 148 in 2030 (using the Laden *et al.* values, premature mortality would be reduced by 379 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 18,564.

These health benefits increase greatly in 2050. Premature mortality is reduced by 238 cases compared to the No Action Alternative (607 cases under Laden *et al.*), and the number of work-loss days is reduced by 27,459.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 3 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7 percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 3 would be $1.198 billion in 2030, increasing to $1.954 billion in 2050. Under more aggressive assumptions (3 percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.230 billion in 2030 and $5.270 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 3 are greater than those of Alternatives 2 and 6A, but less than under the remaining action alternatives.

3.3.3.5 Alternative 4: Engines and Classes 7–8 Tractors

3.3.3.5.1 Criteria Pollutants

Under Alternative 4, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. The reductions would increase from 2018 to 2030 to 2050. Depending on the year, CO emissions would be reduced 0.8 to 2.6 percent, NO_x emissions would be reduced 5.0 to 21.8 percent, SO_2 emissions would be reduced 3.5 to 8.5 percent, and VOC emissions would be reduced 4.1 to 16.8 percent. For SO_2, and VOCs, these emission reductions are slightly greater than would occur under Alternative 3 but slightly less than would occur under the more stringent alternatives. For CO, emissions reductions are slightly less than would occur under Alternative 3, and generally slightly less than would occur under more stringent alternatives as well. For NOx, emission reductions are greater than would occur under Alternative 3 but less than under the more stringent alternatives, with the exception of Alternative 6A. Compared to the No Action Alternative, changes in $PM_{2.5}$ emissions under Alternative 4 range from a 0.1-percent reduction to a 1.5-percent increase, depending on the year. Emissions of $PM_{2.5}$ are lower than under Alternative 3, but higher than or roughly equal to emissions under the more stringent alternatives. Because Alternative 4 assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has higher $PM_{2.5}$ emissions than the No Action Alternative does.

Under Alternative 4, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.5.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 4 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years; slightly reduced emissions of DPM in 2018; and increased emissions of DPM in 2030 and 2050. Compared to Alternatives 5 through 8 (including Alternatives 6, 6A, and 6B), Alternative 4 would have slightly higher or approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, and higher or slightly higher emissions of DPM (except for Alternative 6A in 2018).

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As shown for less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 4, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area. Potential air quality impacts from these increases would be minor, because the VMT and emission increases would be distributed throughout each nonattainment area.

3.3.3.5.3 Health Outcomes and Monetized Benefits

The analysis projects that reductions in adverse health effects would occur nationwide under Alternative 4 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 4 would reduce the number of cases of premature mortality by 165 in 2030 (using the Laden *et al.* values, premature mortality would be reduced by 422 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 20,558.

These health benefits increase greatly in 2050. Premature mortality is reduced by 269 cases compared to the No Action Alternative (686 cases under Laden *et al.*), and the number of work-loss days is reduced by 30,845.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 4 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7 percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 4 would be $1.334 billion in 2030, increasing to $2.208 billion in 2050. Under more aggressive assumptions (7 percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.597 billion in 2030 and $5.955 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 4 are greater than those of Alternatives 3 and 6A, but less than those of the remaining action alternatives.

3.3.3.6 Alternative 6A: 15 percent below Preferred Alternative Stringency

3.3.3.6.1 Criteria Pollutants

Under Alternative 6A, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.6 percent, NO_x emissions would be reduced 4.1 to 17.8 percent, SO_2 emissions would be reduced 3.4 to 8.8 percent, and VOC emissions would be reduced 4.0 to 17.2 percent. For CO, reductions would be approximately the same as under Alternative 4, but less than under the more stringent alternatives. For NO_x, reductions would be less than under Alternative 4, due to changes increases in tailpipe emissions from sleeper cab combination vehicles, and less than under the more stringent alternatives. For $PM_{2.5}$, emissions would be approximately the same as under Alternative 4 and higher than under the more stringent alternatives except in 2050, when emissions are higher than under Alternative 4, due to the use of APUs. Because Alternative 6A assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has $PM_{2.5}$ emissions that are higher than under the No Action

Alternative. For SO_2 and VOCs, reductions compared to the No Action Alternative are greater than under Alternative 4 (except in 2018) but less than under the more stringent alternatives.

Under Alternative 6A, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission changes for each nonattainment area.

3.3.3.6.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 6A would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years; slightly reduced emissions of DPM in 2018; and increased emissions of DPM in 2030 and 2050. Compared to Alternatives 5 through 8 (including Alternatives 6 and 6B), Alternative 6A would have slightly higher or approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, and higher or slightly higher emissions of DPM.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As shown with the less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 6A, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.6.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 6A compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 6A would reduce the number of cases of premature mortality by 135 in 2030 (using the Laden *et al.* values, premature mortality would be reduced by 346 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 16,768.

These health benefits increase greatly in the year 2050. Premature mortality is reduced by 211 cases compared to the No Action Alternative (539 cases under Laden *et al.*), a nd the number of work-loss days is reduced by 24,202.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 6A and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6A would be \$1.092 billion in 2030, increasing to \$1.734 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to \$2.944 billion in 2030 and \$4.677 billion in 2050.

Health and monetized health benefits generally increase with each alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 6A are greater than those of Alternative 2, but less than those of the remaining action alternatives.

3.3.3.7 Alternative 5: Engines, Classes 7–8 Tractors, and Classes 2b–3 Trucks

3.3.3.7.1 Criteria Pollutants

Under Alternative 5, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.6 percent, NO_x emissions would be reduced 5.0 to 21.9 percent, SO_2 emissions would be reduced 3.6 to 9.2 percent, and VOC emissions would be reduced 4.1 to 17.6 percent. Reductions would be slightly greater than under Alternative 6A, but would be less than under the more stringent alternatives. Compared to the No Action Alternative, changes in $PM_{2.5}$ emissions under Alternative 5 range from a 0.1-percent reduction to a 1.2-percent increase, depending on the year. Emissions of $PM_{2.5}$ would be slightly lower than under Alternative 6A, but slightly higher than under the more stringent alternatives. Because Alternative 5 assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has $PM_{2.5}$ emissions that are higher than under the No Action Alternative.

Under Alternative 5, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.7.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 5 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years; slightly reduced emissions of DPM in 2018; and increased emissions of DPM in 2030 and 2050. Compared to Alternatives 6 through 8 (including Alternative 6B), Alternative 5 would have approximately equivalent emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde; slightly higher or approximately equivalent emissions of benzene; and higher or slightly higher emissions of DPM.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As shown with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 5, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.7.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 5 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 5 would reduce the number of cases of premature mortality by by 170 in 2030 (using the Laden *et al.* values, premature mortality would be reduced by 434 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 21,125.

These health benefits increase greatly in the year 2050. Premature mortality is reduced by 278 cases compared to the No Action Alternative (710 cases under Laden *et al.*), and the number of work-loss days is reduced by 31,863.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 5 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 5 would be $1.373 billion in 2030, increasing to $2.284 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.701 billion in 2030 and $6.160 billion in 2050.

Health and monetized health benefits generally increase with each alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 5 are greater than those of Alternatives 1 through 4 and 6A, but less than those of Alternatives 6, 6B, 7, and 8.

3.3.3.8 Alternative 6 (Preferred Alternative): Engines, Tractors, and Classes 2b–8 Trucks

3.3.3.8.1 Criteria Pollutants

Under the Preferred Alternative (Alternative 6), nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.6 percent, NO_x emissions would be reduced 5.1 to 22.1 percent, SO_2 emissions would be reduced 3.8 to 10.2 percent, and VOC emissions would be reduced 4.1 to 17.9 percent. Reductions of these pollutants would be slightly greater than under Alternative 5 but less than under the more stringent alternatives. Compared to the No Action Alternative, changes in $PM_{2.5}$ emissions under the Preferred Alternative are only slight, ranging from a 0.2-percent reduction to a 0.9-percent increase, depending on the year. Emissions of $PM_{2.5}$ would be slightly lower than under Alternative 5, but higher than under the more stringent alternatives. Because Alternative 6 assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, the $PM_{2.5}$ emissions for this alternative are higher than for the No Action Alternative.

Under Alternative 6, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.8.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 6 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and slightly reduced or approximately equivalent emissions of 1,3-butadiene, for all years; slightly reduced emissions for DPM in 2018; and slightly increased emissions for DPM in 2030 and 2050. Compared to Alternatives 7, 6B, and 8, Alternative 6 would have slightly higher or approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde; and higher or slightly higher emissions of DPM.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 6, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.8.3 Health Outcomes and Monetized Benefits

Reductions in adverse health effects would occur nationwide under Alternative 6 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 6 would reduce the number of cases of premature mortality by 175 in year 2030 (using the Laden *et al.* values, premature mortality would be reduced by 448 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 21,734.

These health benefits increase greatly in 2050. Premature mortality is reduced by 290 cases compared to the No Action Alternative (740 cases under Laden *et al.*), and the number of work-loss days is reduced by 33,161.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 6 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6 would be $1.414 billion in 2030, increasing to $2.380 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.813 billion in 2030 and $6.421 billion in 2050.

Health and monetized health benefits generally increase with each alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 6 are greater than those of Alternatives 1 through 5 and 6A, but less than those of Alternatives 6B, 7, and 8.

3.3.3.9 Alternative 7: Engines, Tractors, Trucks, and Trailers

3.3.3.9.1 Criteria Pollutants

Under Alternative 7, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.7 percent, NO_x emissions would be reduced 5.2 to 22.5 percent, SO_2 emissions would be reduced 4.2 to 10.7 percent, and VOC emissions would be reduced 4.2 to 18.0 percent. Reductions of these pollutants would be slightly greater than under Alternative 6 but slightly less than under the more stringent alternatives, with the exception of NO_x under Alternative 6B. Compared to the No Action Alternative, changes in $PM_{2.5}$ emissions under the Alternative 7 would change only slightly, ranging from a 0.3-percent reduction to a 0.5-percent increase, depending on the year. Emissions of $PM_{2.5}$ would be slightly lower than under Alternative 6, but slightly higher than under the more stringent alternatives, with the exception of NOx in 2050 under Alternative 6B. Because Alternative 7 assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has $PM_{2.5}$ emissions that are slightly higher than under the No Action Alternative.

Under Alternative 7, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.9.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 7 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and slightly reduced or approximately equivalent emissions of 1,3-butadiene, for all analysis years; slightly reduced emissions of DPM in 2018; and slightly increased emissions of DPM in 2030 and 2050. Compared to Alternatives 6B and 8, Alternative 7 would have approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde; and higher or slightly higher emissions of DPM for all analysis years.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 7, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.9.3 Health Outcomes and Monetized Benefits

Adverse health effects would be reduced nationwide under Alternative 7 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 7 would reduce the number of cases of premature mortality by 183 in year 2030 (using the Laden *et al.* values, premature mortality would be reduced by 469 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 22,744.

These health benefits increase greatly in the year 2050. Premature mortality is reduced by 303 cases compared to the No Action Alternative (773 cases under Laden *et al.*), and the number of work-loss days is reduced by 34,631.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 7 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 7 would be $1.481 billion in 2030, increasing to $2.488 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.994 billion in 2030 and $6.711 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 7 are less than alternatives 6B and 8, but greater than all other alternatives. As an exception, the benefits of Alternative 7 are equal to or slightly greater than those of Alternative 6B in year 2050.

3.3.3.10 Alternative 6B: 20 percent above Preferred Alternative Stringency

3.3.3.10.1 Criteria Pollutants

Under Alternative 6B, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.7 percent, NO_x emissions would be reduced 5.1 to 22.3 percent, SO_2 emissions would be reduced 4.5 to 11.9 percent, and VOC emissions would be reduced 4.3 to 18.6 percent. Reductions of these pollutants would be slightly greater than under Alternative 7 (with the exception of NOx) and slightly less than under Alternative 8. Compared to the No Action Alternative, $PM_{2.5}$ emissions under the Preferred Alternative would change only slightly, ranging from a 0.3-percent reduction to a 0.7-percent increase, depending on the year. Emissions of $PM_{2.5}$ would be slightly lower than under Alternative 7 (except in 2050), but slightly higher than under Alternative 8. Because Alternative 6B assumes the use of APUs that have relatively high PM emission rates for extended idling trucks, this alternative has $PM_{2.5}$ emissions that are slightly higher than under the No Action Alternative.

Under Alternative 6B, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.10.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 6B would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years; slightly reduced emissions of DPM in 2018 and 2050; and slightly increased emissions of DPM in 2030. Compared to Alternative 8, Alternative 6B would have approximately equivalent emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde; slightly higher emissions of benzene; and higher or slightly higher emissions of DPM for all analysis years.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 6B, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.10.3 Health Outcomes and Monetized Benefits

Adverse health effects would be reduced nationwide under Alternative 6B compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 6B would reduce the number of cases of premature mortality by by 187 in year 2030 (using the Laden *et al.* values, premature mortality would be reduced by 479 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 23,190.

These health benefits increase greatly in the year 2050. Premature mortality is reduced by 302 cases compared to the No Action Alternative (770 cases under Laden *et al.*), and the number of work-loss days is reduced by 34,631.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 6B and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6B would be $1.513 billion in 2030, increasing to $2.478 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $4.081 billion in 2030 and $6.686 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 6B are less than those of Alternative 8 but are greater than those of all other Alternatives. As an exception, the benefits of Alternative 6B are equal to or slightly less than those of Alternative 7 in year 2050.

3.3.3.11 Alternative 8: Accelerated Hybrid Adoption

3.3.3.11.1 Criteria Pollutants

Under Alternative 8, nationwide emissions of all criteria pollutants compared to the No Action Alternative would be reduced. Depending on the year, CO emissions would be reduced 0.8 to 2.7 percent, NO_x emissions would be reduced 5.2 to 23.0 percent, $PM_{2.5}$ emissions would be reduced 0.5 to 1.6 percent, SO_2 emissions would be reduced 5.0 to 15.8 percent, and VOC emissions would be reduced 4.4 to 20.2 percent. For NO_x, SO_2, and VOCs, emission reductions under Alternative 8 are greater than reductions under any other alternative. For CO, reductions under Alternative 8 are second to reductions under Alternative 3, though the differences among the alternatives are slight. For $PM_{2.5}$, reductions under Alternative 8 are second to the reductions under Alternative 2 (except in 2018), though these differences are slight as well.

Under Alternative 8, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative. The increases in $PM_{2.5}$ emissions are the result of increased tailpipe emissions due to the rebound effect. Tables in Appendix D list the emission reductions for each nonattainment area.

3.3.3.11.2 Toxic Air Pollutants

Alternative 8 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, in all analysis years compared to the No Action Alternative. Emissions of DPM under Alternative 8 would be lower or slightly lower than under the No Action Alternative. Except for 1,3-butadiene in 2030 and 2050, and DPM in 2030, emissions of air toxics under Alternative 8 would be lower than those under any other alternative (or tied for lowest); however, the differences in emissions among Alternatives 3 through 8 (including Alternatives 6A and 6B) are slight.

At the national level, emissions of toxic air pollutants could decrease because the reduction in upstream emissions of toxic air pollutants due to improved fuel efficiency, and the resulting decline in the volume of fuel refined and distributed, tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under

Alternative 8, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment years in all years, and 1,3-butadiene, which would increase in most nonattainment areas in 2030 and 2050. The sizes of the emission increases would be quite small, however, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

3.3.3.11.3 Health Outcomes and Monetized Benefits

Reductions in adverse health effects nationwide would occur under Alternative 8 compared to the No Action Alternative (*see* Table 3.3.3-9). Compared to the No Action Alternative, Alternative 8 would reduce the number of cases of premature mortality by 212 in year 2030 (using the Laden *et al.* values, premature mortality would be reduced by 543 cases, an increase of 155 percent). In the same year, the number of work-loss days would be reduced by 26,190.

These health benefits increase greatly in the year 2050. Premature mortality is reduced by 366 cases compared to the No Action Alternative (936 cases under Laden *et al.*), and the number of work-loss days is reduced by 41,626.

Table 3.3.3-10 lists the corresponding monetized health benefits under Alternative 8 and the other action alternatives compared to the No Action Alternative. Using conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 8 would be $1.716 billion in 2030, increasing to $3.010 billion in 2050. Under more aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $4.628 billion in 2030 and $8.121 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 8 are greater than those of all other alternatives.

3.4 CLIMATE

This section describes how the HD Fuel Efficiency Improvement Program would affect the anticipated pace and extent of future changes in the global climate. Because there is no formal guidance or regulation for addressing climate change within the structure of an EIS,[37] several reasonable judgments were required to distinguish the direct and indirect effects of the alternative HD standards (Chapter 3) from the cumulative impacts associated with those same alternatives (Chapter 4).

The discussion of climate issues in this chapter focuses on impacts associated with reductions in GHG emissions due exclusively to NHTSA's action under the HD National Program (which is assumed to remain in place at the MY 2018 levels from 2018 onward). The discussion of consequences focuses on GHG emissions and their effects on the climate system, *i.e.*, atmospheric CO_2 concentrations, temperature, sea level, and precipitation. Under the cumulative impacts analysis in Chapter 4, NHTSA evaluates the potential GHG emission reductions associated with the HD alternatives together with those of reasonably foreseeable future actions, including projected increases in fuel efficiency based on AEO projections. For an explanation of the application of this assumption, *see* Section 4.1. These reasonably foreseeable future actions would affect fuel consumption and emissions attributable to HD vehicles through 2100.[38]

Section 3.4.1 introduces key topics on GHGs and climate change, and Section 3.4.2 describes the affected environment. Section 3.4.3 outlines the methodology NHTSA used to evaluate climate effects, and Section 3.4.4 describes the direct and indirect environmental consequences of the proposed action and alternative actions that NHTSA considered.

3.4.1 Introduction – Greenhouse Gases and Climate Change

This document primarily draws on panel-reviewed synthesis and assessment reports from the IPCC, U.S. Climate Change Science Program (CCSP), and U.S. Global Change Research Program (USGCRP). It also cites EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act* (EPA 2009), which heavily relied on these panel reports. NHTSA similarly relies on panel reports because these reports assess numerous individual studies to draw general conclusions about the state of science; are reviewed and formally accepted by, commissioned by, or in some cases authored by U.S. government agencies and individual government scientists; and in many cases, reflect and convey the consensus conclusions of expert authors. This material has been vetted by both the climate change research community and by the U.S. government and is the foundation for the discussion of climate change in this EIS.

This document also refers to new panel-reviewed reports and new peer-reviewed literature that has been published since the release of the IPCC, CCSP, and USGCRP panel-reviewed reports, to provide the most current review of climate change science. The new peer-reviewed literature has not been assessed or synthesized by an expert panel and supplements but does not supersede the findings of the panel-reviewed reports. In virtually every case, it corroborates the findings of these reports.

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[37] CEQ is currently drafting guidance for agencies regarding the treatment of GHG emissions under NEPA, but has not released its final guidance as of the publication of this document.

[38] 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. Chapter 4 also extends the discussion of consequences to include not only the immediate effects of emissions on the climate system (atmospheric CO_2 concentrations, temperature, sea level, and precipitation), but also the impacts of changes in the climate system on key resources (*e.g.,* 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 analysis in this EIS.

NHTSA's consideration of newer studies and highlighting of particular issues responds to public comments received on the scoping document and the EIS for the MYs 2012–2016 CAFE standards, as well as the Ninth Circuit's decision in *Center for Biological Diversity (CBD) v. NHTSA*, 538 F.3d 1172 (9th Cir. 2008). The level of detail regarding the science of climate change in this EIS, and NHTSA's consideration of other studies that demonstrate 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 its EIS for the MYs 2012–2016 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 Report Summary for Policymakers* and the *IPCC Fourth Assessment Synthesis Report* (IPCC 2007b, IPCC 2007c) 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 in the context of the IPCC findings.[39]

As addressed in the *IPCC Fourth Assessment Synthesis Report*, 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 Working Group I 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:

[39] NHTSA notes that these terms could have different meaning than language describing uncertainty used elsewhere in the EIS, in accordance with CEQ regulations requiring an agency to acknowledge areas of scientific uncertainty. *See* Section 3.1.3.

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

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 twentieth century, Earth's global average surface temperature rose by about 0.74 °C (1.3 °F) (EPA 2009, IPCC 2007b); global average sea level has been gradually rising, increasing about 0.17 meters (6.7 inches) during the twentieth century (IPCC 2007b) with a maximum rate of about 2 millimeters (0.08 inch) per year over the past 50 years on the northeastern coast of the United States (EPA 2009); Arctic sea-ice cover has been decreasing at a rate of about 4.1 percent per decade since 1979, 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 2009, 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 extending from Earth's surface to approximately 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 is changing Earth's energy balance.

The observed changes in the global climate described in Section 3.4.1.2 are largely a result of GHG emissions from human activities. Both EPA and the IPCC have recently concluded that "[m]ost of the observed increase in global average temperatures since the mid-20th Century is *very likely* due to the observed increase in anthropogenic [human-caused] GHG concentrations" (EPA 2009, IPCC 2007b).

Most GHGs, including CO_2, CH_4, 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 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 through industrial processes and emitted into the atmosphere (*e.g.*, as a result of leaks in refrigeration and air-conditioning systems).

Figure 3.4.1-1. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover (Source: IPCC 2007b)

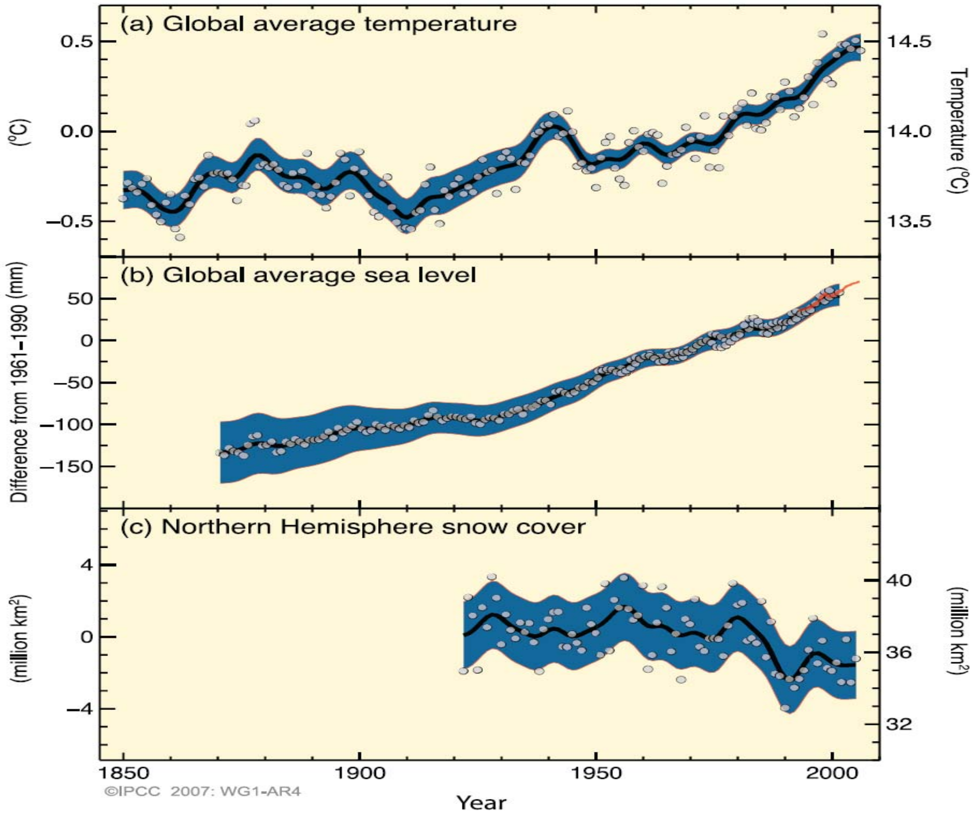
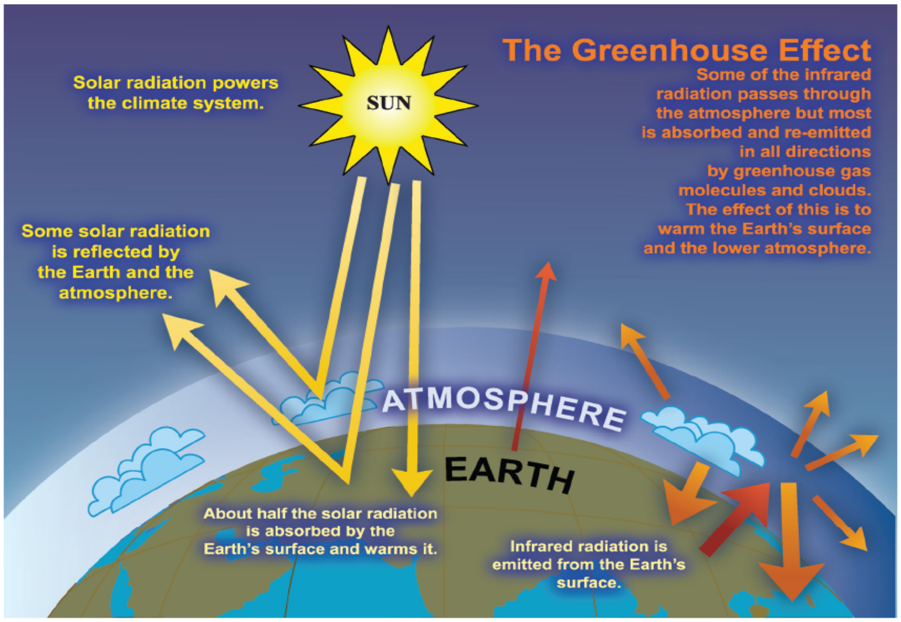


Figure 3.4.1-2. The Greenhouse Effect (Source: Le Treut *et al.* 2007)



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 approximately 99 percent of annual anthropogenic GHG emissions addressed by national inventory reports (WRI 2010)[40] – have increased approximately 38, 149, and 23 percent, respectively, since the beginning of the Industrial Revolution in the mid-1700s (EPA 2009). During this time, the atmospheric CO_2 concentration has increased from about 280 ppm to 386 ppm in 2008 (EPA 2009). Isotopic and inventory-based studies make clear that this rise in the CO_2 concentration is largely a result of releasing carbon stored underground through the combustion of fossil fuels (coal, petroleum, and gas) used to produce electricity, heat buildings, and power motor vehicles and airplanes, among other uses.

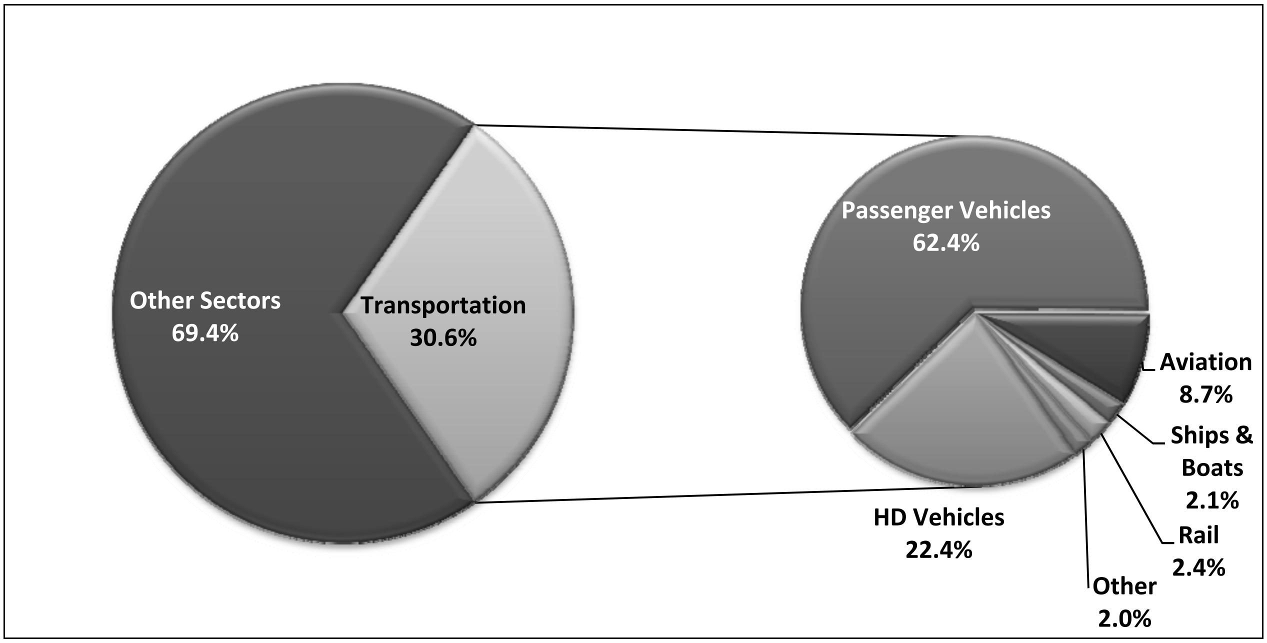
Contributions to the buildup of GHGs in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity, population, standard of living, character of a country's buildings and transportation system, available energy options, and climate. Emissions from the United States account for about 17.4 percent of total global CO_2 emissions (WRI 2010). The U.S. transportation sector contributed 30.6 percent of total U.S. CO_2 emissions in 2008, with HD vehicles accounting for 22.4 percent of total U.S. CO_2 emissions from transportation (EPA 2010a). Thus, approximately 6.9 percent of total U.S. CO_2 emissions are from HD vehicles, and HD vehicles in the United States account for roughly 1.2 percent of total global CO_2 emissions, as compared to 3.3 percent for U.S. light-duty vehicles (based on comprehensive global CO_2 emissions data available for 2005).[41] Figure 3.4.1-3 shows the proportion of U.S. emissions attributable to the transportation sector and the contribution of each mode of transportation to U.S. emissions.

3.4.1.5 Evidence of Climate Change

Observations and studies across the globe report evidence that Earth is undergoing climatic change much more quickly than would be expected from natural variations. The global average temperature is rising, with decades from 1980 to 2010 being the warmest on record (Arndt *et al*. 2010). Eight of the ten warmest years on record have occurred since 2001 (EPA 2009), with 2009 recorded at 0.1°C (0.2°F) warmer than 2008 (Arndt *et al*. 2010). Cold-dependent habitats are shifting to higher altitudes and latitudes, and growing seasons are becoming longer (EPA 2009 Montoya and Rafealli 2010). 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 been observed (EPA 2009, IPCC 2007b). Oceans are becoming more acidic as a result of increasing absorption of CO_2, driven by higher atmospheric concentrations of CO_2 (EPA 2009). Recent evidence suggests that oceans have become 30 percent more acidic since the Industrial Revolution (Allison *et al*. 2009 citing McNeil and Matear 2008, Orr *et al.* 2005, and Riebsell *et al*. 2009). Statistically significant trends based on various indicators of climate change have been observed on every continent (Rosenzweig *et al.* 2008). Additional evidence of climate change is discussed throughout this section.

[40] 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 (CO_2e) using their unique global warming potential (GWP).
[41] Percentages include land-use change and forestry and exclude international bunker fuels (*i.e.*, international marine and aviation travel).

Figure 3.4.1-3. Contribution of Transportation to U.S. CO_2 Emissions and Proportion Attributable by Mode, 2008 (Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2008, EPA 2010a)



3.4.1.6 Future Climatic Trends and Expected Impacts

As the world population grows over the twenty-first century, accompanied by industrialization and increases in living standards in developing countries, fossil-fuel use and resulting GHG emissions are expected to grow substantially 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 pre-industrial levels by 2100 (EPA 2009, IPCC 2007b).

By 2100, the IPCC projects an average increase in surface warming of 1.8 °C (3.2 °F) to 4.0 °C (7.2 °F) compared to 1980–1999 levels for a number of emissions scenarios, with a likely range of 1.1°C (2.0 °F) to 6.4 °C (11.5 °F) when including uncertainty regarding climate parameters. In addition, IPCC projects that this temperature increase will impact sea level, causing a rise of 0.18 meters (0.6 feet) to 0.59 meters (1.9 feet) due only 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. Satellite observations suggest such changes are beginning, and recent studies indicate that sea-level rise could be even greater, and have estimated ranges of 0.8 to 2.0 meters (2.6 to 6.6 feet) (Pfeffer *et al*. 2008), 0.5 to 1.4 meters (1.6 to 4.6 feet) (Rahmstorf 2007), and 0.97 to 1.56 meters (3.2 to 5.1 feet) (Vermeer and Rahmstorf 2009) by 2100. The National Research Council suggests a more modest increase in sea level of 0.5 to 1.0 meter (1.6 to 3.3 feet) by 2100 (NRC 2010). 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

Significant scientific uncertainties remain regarding black carbon's total climate effect,[42] as do concerns about how to treat the short-lived black carbon emissions alongside the long-lived, well-mixed GHGs in a common framework (*e.g.*, what are the appropriate metrics to compare the warming or climate effects of the different substances, given that, unlike GHGs, the magnitude of aerosol effects can vary immensely with location and season of emissions).

No single accepted methodology for transforming black carbon emissions into temperature change or CO_2-equivalent (CO_2e) emissions has been developed. The interaction of black carbon (and other co-emitted aerosol species) with clouds is especially poorly quantified, and this factor is key to any attempt to estimate the net climate impacts of black carbon. Although black carbon is likely to be an important contributor to climate change, including quantification of black carbon climate impacts in an analysis of the proposed standards would be premature at this time.

The model chosen to simulate climate change effects (Model for Assessment of Greenhouse Gas-Induced Climate Change [MAGICC] 5.3v2, discussed in Section 3.4.3) does not provide the capability to model the effects of changes black carbon emissions on temperature, sea level, or other endpoints, and whether other models would be able to distinguish the effect of changes in black carbon emissions attributable to the regulatory alternatives is unclear. The climatic effects and general characteristics of black carbon, however, are qualitatively discussed here.

3.4.1.7.1 Emissions

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).[43] Developing countries are the primary emitters of black carbon because they depend more heavily on biomass-based fuel sources for cooking and heating and on diesel vehicles for transport, and have less stringent air emission control standards and technologies. The United States contributes about 7 percent of the world's black carbon emissions (Battye *et al.* 2002, Bond *et al.* 2004).[44] There is uncertainty concerning these emission estimates; one study estimates that there is a 50-percent uncertainty in global emission estimates, while the uncertainty in regional emission estimates can range from a factor of 2 to 5 (Ramanathan and Carmichael 2008).

[42] The range of uncertainty in the current magnitude of black carbon's climate forcing effect is evidenced by the ranges presented by the IPCC Fourth Assessment Report (2007a) and the more recent study by Ramanathan, V. and G. Carmichael (2008). Global and regional climate changes due to black carbon. Nature Geoscience 1(4): 221–227.

[43] 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 Gelencsér (2006), "black carbon" is often used interchangeably with other similar terms with slightly different definitions. Furthermore, definitions across literature sources are inconsistent.

[44] Battye *et al.* (2002) calculated total U.S. (433 gigatons [Gg]) and U.S. on-road diesel vehicle (65 Gg) and non-road diesel vehicle (91 Gg) emissions of black carbon in fine particles ($PM_{2.5}$) from EPA's 2001 NEI database. Bond *et al.* (2004) estimated global black carbon emissions (in $PM_{2.5}$) to be 6.5 teragrams (Tg). This sector alone is responsible for 36 percent of all black carbon emissions in the United States similar to that for prescribed forest burning. (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.)

3.4.1.7.2 Climatic Interactions

Although black carbon has been an air pollutant of concern for years due to its direct human health effects, climate change experts are currently concerned with it because of its influence on climate change (EPA 2009). Recent studies suggest black carbon is a major contributor to changes in the annual net radiative forcing. Black carbon impacts regional net radiative forcing in several ways: (1) it absorbs incoming or reflected solar radiation, warming the atmosphere around it, (2) it deposits on snow or ice, reducing the albedo[45] and enhancing their melting, (3) as it warms the atmosphere, it triggers cloud evaporation, and (4) as it ages in the atmosphere, it can become hygroscopic, reducing precipitation and increasing the lifetime of the cloud (IPCC 2007b, EPA 2009, Ramanathan and Carmichael 2008, Kopp and Mauzerall 2010). Each of these interactions is discussed below.

Black carbon absorbs solar radiation and re-emits this energy into the surrounding air, warming it. Whether this causes a regional warming or cooling effect depends on the surface below. When black carbon particles are suspended in the air above a dark surface, solar radiation that would have reached the surface is reduced, thereby causing a cooling effect referred to as surface “dimming” (Ramanathan and Carmichael 2008). When black carbon particles are suspended in the air above a light, reflective surface (such as snow or ice), which would normally reflect sunlight at a high rate, it does not cause significant cooling at the surface. The net radiative impact of black carbon suspended over a surface is a balance of the reduction of solar radiation reaching the surface and the additional atmospheric warming. Hence, black carbon’s net radiative impacts vary by location.

When black carbon deposits onto snow and ice, it reduces the albedo as it absorbs incoming solar radiation and contributes to enhanced melting (EPA 2009, Ramanathan and Carmichael 2008, Flanner *et al.* 2007). For example, in places where black carbon emissions are high, such as upwind of the Himalayan glaciers and the snow-laden Tibetan plateau, earlier snowmelt has been observed and attributed to black carbon deposition (Zemp and Haeberli 2007, Meehl *et al*. 2008, IPCC 2007b). The Arctic has also experienced accelerated spring melting and the lengthening of the melt season in response to black carbon deposition (Quinn *et al.* 2008). In fact, recent research indicates that black carbon has contributed approximately 0.5 to 1.4 °C (0.9 to 2.52 °F) to Arctic warming since 1890 (Shindell and Faluvegi 2009).

The complex interaction of black carbon with the radiative properties of clouds is an area under active research. Some aerosols suppress formation of larger cloud drops, which can extend the lifetime of the cloud and increase cloud cover (Ramanathan and Carmichael 2008). In addition, reducing precipitation can extend the atmospheric lifetimes of aerosols. Although initially hydrophobic, black carbon becomes hygroscopic as it ages in the atmosphere, thus acting as a cloud condensation nucleus; this increases the number of droplets in clouds, thereby increasing the cloud albedo (Kopp and Mauzerall 2010). Conversely, black carbon radiatively warms the surrounding air as it absorbs solar radiation, which leads to evaporation of cloud drops by lowering the relative humidity and reducing cloud cover (Ramanathan and Carmichael 2008). An important issue, which can vary by region, is whether the non-black carbon aerosols or the black carbon aerosols dominate in cloud effects (Ramanathan and Carmichael 2008). The observed weakening of the summertime Indian monsoon is attributed, in part, to black carbon atmospheric absorption (Ramanathan and Carmichael 2008, Meehl *et al*. 2008).

[45] 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.

3.4.1.7.3 Net Radiative Effect

In a recent study, black carbon was estimated to have more than half of the positive radiative forcing effect of CO_2, and to have a larger forcing effect than other GHGs, including CH_4 and N_2O (Ramanathan and Carmichael 2008). This study estimates that black carbon contributes a net global radiative forcing[46] of +0.9 watts per square meter (W/m^2), which is more than twice that estimated by the IPCC (2007a). There is large uncertainty, however, associated with these estimates. The different treatment of black carbon across global-scale modeling studies hinders obtaining a consistent estimate of its radiative effects. For example, modeling studies vary in how several key factors are weighted, including emission source strength and categories, changes in particle properties as it "ages" in the atmosphere, and the vertical distribution of black carbon (Ramanathan and Carmichael 2008, Jacobson 2010, Kopp and Mauzerall 2010).

3.4.1.7.4 Comparison to Properties of Greenhouse Gases

Black carbon has a much shorter atmospheric lifespan than GHGs. The CCSP (CCSP 2009) estimates the lifetime of black carbon in the atmosphere as being between 5.3 and 15 days, generally dependent on meteorological conditions, quite short in comparison to the atmospheric lifetime of CO_2 in the atmosphere, which is of the order of hundreds of years. This short lifetime suggests black carbon's effects are largest near the emission source; the nearby air molecules heated by black carbon's absorption of solar radiation, however, can travel long distances, spreading this acquired warmth (Jacobson 2010). Given that 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.

3.4.1.7.5 Controls and Regulatory Options Impacting Black Carbon Emissions from Diesel Trucks

Based on estimates of U.S. on-road and non-road diesel 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), HD vehicles in the United States contribute just over 3 percent of global black carbon emissions. The impact that the proposed HD standards could have on black carbon emissions is uncertain. Historically, diesel vehicles have emitted more black carbon than gasoline vehicles on a per-mile basis. Widespread deployment of recent, more effective control technologies for particulate matter emissions from diesel vehicles and the use of low-sulfur fuel would likely reduce emissions of black carbon.

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 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 begin with a description of conditions in the United States, followed by a description of global conditions.

[46] Radiative forcing for a given gas (*e.g.*, CO_2) or particle (*e.g.*, black carbon) is determined by assessing the change in the net stratospherically adjusted radiative flux (*i.e.*, the flow of energy from earth to space) at the tropopause. A positive radiative forcing provides surface warming while a negative radiative forcing provides surface cooling. Radiative forcing is expressed in units of watts per square meter (W/m^2). Black carbon can have both negative and positive radiative forcing.

Many themes in the discussions regarding conditions in the United States reappear in the global discussions.[47]

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 2008[48] were estimated at 6,956.8 million metric tons of CO_2 ($MMTCO_2$)[49] (EPA 2010a); these amount to about 17 percent of total global emissions[50] (WRI 2010). Annual U.S. emissions, which have increased 16 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 2010a).

CO_2 is by far the primary GHG emitted in the United States, representing almost 85.1 percent of all U.S. GHG emissions in 2008 (EPA 2010a). 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 total GHGs on a GWP-weighted basis, followed by N_2O (4.6 percent) and the high-GWP gases (2.2 percent) (EPA 2010a).

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 more than 80 percent of total U.S. emissions (EPA 2010a). These CO_2 emissions are due to fuels consumed in the electric power (42 percent of fossil-fuel emissions), transportation (32 percent), industry (15 percent), residential (6 percent), and commercial (4 percent) sectors (EPA 2010a). When U.S. CO_2 emissions are apportioned by end use, however,[51] 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 2010a).

The U.S. transportation sector contributed 30.6 percent of total U.S. CO_2 emissions in 2008, with HD vehicles accounting for 22.4 percent of total U.S. CO_2 emissions from transportation (EPA 2010a). Thus, approximately 6.9 percent of total U.S. CO_2 emissions are from HD vehicles. With the United States accounting for 17.4 percent of global CO_2 emissions (WRI 2010), HD vehicles in the United States account for roughly 1.2 percent of global CO_2 emissions.[52]

HD vehicles account for 22.4 percent of U.S. transportation CO_2 emissions, and CO_2 emissions from these vehicles have increased by 68 percent since 1990 (EPA 2010a). This increase was driven by several factors – (1) the convenience of extensive and easily accessible infrastructure, (2) a recently developed inventory system called Just in Time (JIT), in which businesses attempt to minimize the

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[47] 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 August 25, 2010) (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"). (CEQ 1997a).

[48] Most recent year for which an official EPA estimate is available (EPA 2010a).

[49] 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 GWP.

[50] Based on 2005 data and excluding carbon sinks from forestry and agriculture.

[51] Apportioning by end use allocates emissions associated with electricity generation to the sectors (residential, commercial, industrial, transportation) where it is used.

[52] Percentages include land-use change and forestry, and exclude international bunker fuels (*i.e.*, international marine and aviation travel).

quantity of goods that they hold at a given time, and (3) the low fuel prices during the 1990s and much of the 2000s. A combination of logistics planning ease, extensive highway accessibility, and minimized loading and unloading of cargo has led to increasing use of trucks for freight transport and more VMT in this vehicle category (Pew Center on Global Climate Change 2010). Due to these trends, VMT has increased more rapidly in the HD vehicle sector than in the light-duty vehicle sector over the past few decades (National Academy of Sciences 2010). For comparison, CO_2 emissions from passenger cars and light trucks grew approximately 17 percent over the same period (EPA 2010a).

3.4.2.1.2 Global Emissions

Although humans have always contributed some level of GHG emissions to the atmosphere through activities like farming and land clearing, substantial anthropogenic 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 2009). In addition, the concentrations of CH_4 and N_2O in the atmosphere have increased 149 and 23 percent, respectively (EPA 2009).

In 2005, gross global GHG emissions were calculated to be 44,130.3 $MMTCO_2$ equivalent, a 20.3-percent increase since 1990[53] (WRI 2010). In general, global GHG emissions have increased regularly, although 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 2005, CO_2 emissions comprised 77 percent of global emissions on a GWP-weighted basis, followed by CH_4 (15 percent) and N2O (7 percent). Collectively, fluorinated gases represented 1 percent of global emissions covered by national inventories (WRI 2010).

Various sectors contribute to global GHG emissions, including energy, industrial processes, waste, agriculture, land-use change, and forestry. The energy sector is the largest contributor of global GHG emissions, accounting for 66 percent of global emissions in 2005. Within this sector, the generation of electricity and heat accounts for 29 percent of total global emissions. The next highest contributors to emissions are agriculture (14 percent) and land-use change and forestry (12 percent) (WRI 2010).

Transportation CO_2 emissions comprise 12 percent of the global total, and are included in the 66 percent cited above for the energy sector (WRI 2010). 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 12 percent of total global GHG emissions and 16 percent of CO_2 emissions; in absolute terms, global transportation CO_2 emissions increased by 35 percent from 1990 to 2005 (WRI 2010).[54]

[53] All GHG estimates cited in this section (3.4.2.1.2) include contributions from land-use change and forestry, as well as bunker fuels, unless noted otherwise.
[54] 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 2009), *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), *Global Climate Change Impacts in the United States* (GCRP 2009), and *Climate Change Indicators in the United States* (EPA 2010b). The impacts associated with these observed trends are further discussed in Section 4.5.

Increased Temperatures

The past decade has been the warmest in more than a century of direct observations, with average temperatures for the contiguous United States rising at a rate near 0.58 °F per decade in the past few decades. U.S. average temperatures are now 1.25 °F warmer than they were at the beginning of the twentieth century with an average warming of 0.13 °F per decade over 1895–2008, and this rate of warming is increasing (EPA 2009).

Since 1950, the frequency of heat waves has increased, although those recorded in the 1930s remain the most severe. Also, fewer unusually cold days occurred in the past few decades with fewer severe cold waves for the most recent 10-year period in the record (GCRP 2009).

Since 1985, the final spring frost has occurred an average of four days earlier compared to the long-term average from 1900, while the first fall frost has occurred about three days later (EPA 2010b citing Kunkel 2009).

Sea-level Rise

Relative sea level is rising 0.8 to 1.2 inches per decade along most of the Atlantic and Gulf Coasts, and a few inches per decade along the Louisiana Coast (due to land subsidence); sea level is falling (due to land uplift) at the rate of a few inches per decade in parts of Alaska (National Science and Technology Council 2008, EPA 2009). These observations demonstrate that sea level does not rise uniformly across the globe.

Sea-level rise extends the zone of impact of storm surges 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 (EPA 2009 citing Nicholls *et al.* 2007).

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 and some notable decreases in parts of the United States, including Hawaii and the Southwest (EPA 2010b). Heavy precipitation events also increased, primarily during the last 3 decades of the twentieth century, and mainly over eastern regions (GCRP 2009). A recent analysis found that 8 of the top 10 years of extreme 1-day precipitation events have been observed from 1990 to 2010 (EPA 2010b). Most regions experienced decreases in drought severity and duration during the second half of the twentieth century, although severe drought occurred in the Southwest from 1999 to 2008 (EPA 2009). The Southeast has also recently experienced severe drought (GCRP 2009). From 2001 through 2009, 30 to 60 percent of land area in the United States experienced drought conditions at any given time (EPA 2010b).

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 (National Science and Technology Council 2008 citing CCSP 2008c) and that Atlantic sea-surface temperatures have increased over the same period. Six of the ten most active hurricane seasons have occurred since the mid-1990s, mirroring the variations in sea surface temperatures of the tropical Atlantic (EPA 2010a). These trends, however, 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 two 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 (Field *et al.* 2007 citing Rood *et al.* 2005), while in the eastern United States it increased 25 percent in the past 60 years (Field *et al.* 2007 citing Groisman *et al.* 2004). Annual peak stream flow (dominated by snowmelt) in western mountains is occurring at least a week earlier than in the middle of the twentieth 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). 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 snowpack in the western United States.

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 (National Science and Technology Council 2008 citing Field *et al.* 2007). Total snow-cover area in the United States, however, increased in the November-to-January season from 1915 to 2004 (National Science and Technology Council 2008). For North America as a whole, EPA (2010a) found that snow coverage has declined from approximately 3.4 million square miles to 3.2 million square miles from the 1970s to this past decade.

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). During the second half of the twentieth century, the depth of snow cover in early spring decreased for most of the western United States and Canada, with some areas experiencing up to a 75-percent decrease (EPA 2010a).

Annual average Arctic sea ice extent decreased 4.1 percent per decade since 1979 (EPA 2009). 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 2009, 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).

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 2009), *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008), and *Global Climate Change Impacts in the United States* (GCRP 2009).

Increased Temperatures

The IPCC states that scientific evidence shows that the increase in GHGs (specifically, CO_2, CH_4, and N_2O) since 1750 has led to an increase in global positive radiative forcing of 2.30 W/m^2 (+/− 0.23 W/m^2) (EPA 2009). 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 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 2009). 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 2009). Over the past 30 years, average global temperatures have risen even faster, for an average of 0.29 °F per decade (EPA 2009 citing NOAA 2009). Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Temperature increases are more pronounced over land, because air temperatures over oceans are warming at about half the rate as air over land (EPA 2009).

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 2009).

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 twentieth century (EPA 2009), and plant flowering and animal spring migrations are occurring earlier (EPA 2009). 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 2009).

Some temperature-related climate variables are not changing. The diurnal temperature range[55] has not changed from 1979 to 2004; 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).

Global ocean temperatures have continued to warm. For example, demonstrated high ocean surface temperatures were observed in summer 2009, reaching 0.58 °C (1.04 °F) above the average global temperature recorded for the twentieth century (Hoegh-Guldberg and Bruno 2010); January 2010 was the second warmest January on record in terms of global ocean temperature.

Sea-level Rise

Higher temperatures cause sea level to rise due to both thermal expansion of water and 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 2009).

Between 1961 and 2003, global ocean temperature warmed by about 0.18 °F from the surface to a depth of 700 meters (0.43 mile) (EPA 2009). This warming contributed an average of 0.4 +/− 0.1 millimeter (0.016 +/− 0.0039 inch) per year to sea-level rise (EPA 2009), 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). Recent reports indicate that since the beginning of satellite measurements in the early 1990s, sea level has risen at a rate of 3.4 millimeters (0.13 inches) per year (Rahmstorf 2010 citing Cezanave and Llovel 2010). For the period of 1993 to 2007, Cezanave and Llovel (2010) suggest that approximately 30 percent of the observed rate of sea-level rise is due to thermal expansion and approximately 55 percent is due to the melting of land ice. 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)

[55] 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.

per year from 1993 to 2003 (EPA 2009). Total twentieth century rise is estimated at 0.17 +/− 0.05 meter (0.56 +/− 0.16 foot) (EPA 2009). Since the publication of the IPCC Fourth Assessment Report, however, 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.[56] Furthermore, this study estimated the globally averaged sea-level trend from 1961 to 2003 to be a rise of 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. This estimate is consistent with the estimated trend of 2.3 millimeters (0.091 inch) per year from tidal 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 2009).[57]

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 2009).

Longer, more intense droughts caused by higher temperatures and decreased precipitation have been observed since the 1970s, particularly in the tropics and subtropics. Changes in sea surface temperatures, wind patterns, and decreased snowpack and snow cover have also been linked to droughts (EPA 2009). A recent study found that the duration of the snow season from 1967 to 2008 has decreased by 5 to 25 days in Western Europe, Central and East Asia, and the mountainous western United States (Choi *et al.* 2010).

Increased Incidence of Severe Weather Events

Long-term trends in tropical cyclone activity have been reported, but no clear trend in the number of tropical cyclones each year has been demonstrated. There is observational evidence of an increase in intense tropical cyclone activity correlated with increases of tropical sea surface temperatures in the North Atlantic since about 1970. Concerns about data quality and multi-decadal variability, however, persist (EPA 2009). 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).

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[56] Volcanic eruptions can emit large number of particles into the stratosphere. These particles, such as sulfates, scatter sunlight away from Earth’s surface causing cooling (*i.e.,* a negative radiative forcing). These particles can remain in the stratosphere for more than a year.

[57] Note that parts of the U.S. 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.

Evidence is also insufficient to determine whether trends exist in large-scale phenomena such as the Meridional Overturning Circulation (MOC) (a mechanism for heat transport in the North Atlantic Ocean, by which 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 2009a); since 1979, the annual average Arctic sea ice area has been declining at a rate of 4.1 percent per decade (EPA 2009). Additionally, some Arctic ice that previously was thick enough to last through summer has now thinned enough to melt 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 2009a).

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, the hydrogen ion concentration of the water increases, which is measured as a decline in pH. Relative to the pre-industrial period, the pH of the world's oceans has dropped 0.1 pH unit (EPA 2009). Because pH is measured on a logarithmic scale, this represents a 30 percent 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 acidification is likely to interfere with the calcification of coral reefs and thus inhibit the growth and survival of coral reef ecosystems (EPA 2009).

3.4.3 Methodology

The methodology NHTSA used to characterize the effects of the alternatives on climate has three key elements, as follows:

1. Analyzing the effects of the proposed action and alternatives on GHG emissions;

2. Estimating the monetized damages associated with CO_2 emissions and reductions attributable to each regulatory alternative; and

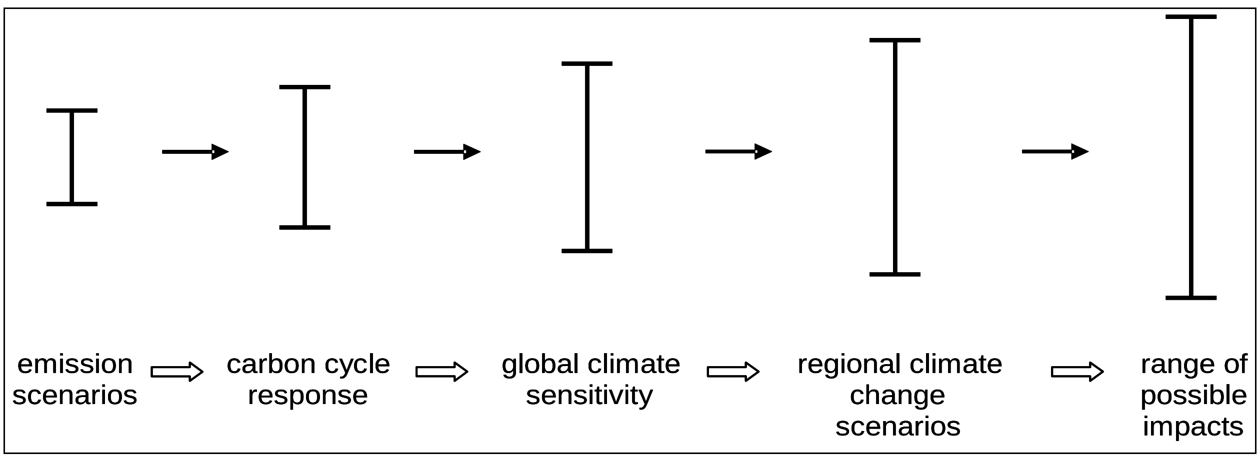
3. Analyzing how GHG emissions and reductions under each action alternative affect the climate system (climate effects).

For effects on GHG emissions and 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 8) are also presented to illustrate the differences in environmental effects among the alternatives. The impact of each action alternative on these results is measured by the difference in the climate parameter (CO_2 concentration, temperature, sea level, and precipitation) under the No Action Alternative and the climate parameter 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 change, 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 emission 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 change on affected resources (such as terrestrial and coastal ecosystems, human health, and other resources discussed in Section 4.5). Although the uncertainty bands broaden with each successive step in the analytic chain, all values within the bands are not equally likely; the mid-range values have the highest likelihood.

Figure 3.4.3-1. Cascade of Uncertainty in Climate Change Simulations (Source: Moss and Schneider 2000) a/



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 that have been subjected to extensive peer review and scrutiny. In fact, the information cited throughout this section that is extracted from the most recent EPA, IPCC, and USGCRP 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 and the Global Change Assessment Model (GCAM, formerly MiniCAM) reference emission scenario, are widely available and generally accepted in the scientific community.[58]

[58] GCAM is used as the basis for the Representative Concentration Pathway (RCP) 4.5 scenario (Thomson *et al.*, in review).

The U.S. Climate Change Science Program Synthesis and Assessment Product 3.1 (CCSP SAP 3.1) on the strengths and limitations of climate models (CCSP 2008b) 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

The emission estimates include global emissions resulting from direct fuel combustion (tailpipe emissions) and from the production and distribution of fuel (upstream emissions). GHG emissions were estimated by EPA using two models: the MOVES model, described in Section 3.1.4, to determine tailpipe emissions, and the GREET model, developed by DOE's Argonne National Laboratory, to estimate emissions associated with production of gasoline and diesel from crude oil.[59] Emissions under each action alternative were then compared against those under the No Action Alternative to determine the impact of the action alternative on emissions. GHG emissions from MYs 2014−2050 vehicles were estimated using the methodology described in Section 3.1. For the climate analysis, GHG emission trajectories are needed to year 2100. The MOVES modeling would not be appropriate for the post 2050 time frame given the uncertainties in fleet composition. Instead, NHTSA estimated GHG emissions for the HD vehicle fleet for 2051–2100 by scaling GCAM assumptions for the change in U.S. transportation fuel consumption.[60] For years 2051−2100, the GCAM reference scenario projects that U.S. road transportation fuel consumption will decline slightly due primarily to (1) assumed improvements in efficiency of internal combustion engine-powered vehicles and (2) increased deployment of non-internal combustion engine vehicles with higher drivetrain efficiencies. However, the projection of road transport fuel consumption beyond 2050 does not change significantly and thus emissions remain relatively constant from 2050 through 2100. The assumptions and methods used to develop the GHG emission estimates for this EIS are broadly consistent with those used in the EIS prepared by NHTSA for the MYs 2012−2016 CAFE standards for passenger cars and light trucks (NHTSA 2010).

The emission estimates included 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 MOVES model also accounted for and estimated the following non-GHGs: SO_2, NO_x, CO, and VOCs.

Fuel savings from stricter HD standards result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[61] There is a direct relationship among fuel efficiency, fuel consumption, and CO_2 emissions. Fuel efficiency describes how much fuel a vehicle requires to perform a certain amount of work (for example, how many miles it can travel, or how many tons it can carry per mile traveled). A vehicle is more fuel-efficient if it can perform more work while consuming less fuel. Lower fuel consumption reduces CO_2 emissions directly because the primary source of vehicle-related CO_2 emissions is the combustion of carbon-based fuel in internal-combustion engines;

[59] Note that the only difference between the GHG emission estimates in the Regulatory Impact Analysis accompanying EPA's and NHTSA's joint proposed HD standards and the estimates presented here is that the results presented here do not include emission reductions from recreational vehicles, as described in Section 2.2.4.
[60] The last year for which the MOVES model provides estimates of fleet CO_2 emissions is 2050.
[61] For this rulemaking, NHTSA estimated emissions of vehicular CO_2, CH_4, and N_2O emissions, but did not estimate vehicular emissions of HFCs. HFCs are released to the atmosphere only through air-conditioning system leakage, and are not directly related to fuel efficiency, which is what NHTSA is authorized to regulate under the EISA. NHTSA does not have authority under EISA to regulate GHGs generally if they are not related to HD fuel efficiency. For the reader's reference, CH_4 and N_2O account for 0.2 percent of the tailpipe GHG emissions from HD vehicles, and CO_2 emissions account for the remaining 99.8 percent. Of the total (including non-tailpipe) GHG emissions from HD vehicles, tailpipe CO_2 represents about 96.9 percent, tailpipe CH_4 and N_2O represent about 0.2 percent, and HFCs represent about 2.9 percent. (Values are calculated from EPA 2010a.)

combustion of a hydrocarbon essentially produces energy (used to power the vehicle), CO_2, and water. Therefore, fuel consumption is directly related to CO_2 emissions and CO_2 emissions are directly related to fuel efficiency. EPA estimated reductions in CO_2 emissions resulting from fuel savings by assuming that the carbon content of gasoline, diesel, and other fuels is converted entirely to CO_2 during the combustion process.[62] Specifically, EPA 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. EPA estimated the global reductions in CO_2 emissions during each phase of fuel production and distribution (*i.e.,* upstream emissions) using CO_2 emissions rates obtained from the GREET version 1.8 model using the previous assumptions about how fuel savings are reflected in reductions in activity during each phase of fuel production and distribution.[63] The total reduction in CO_2 emissions from improving fuel efficiency under each 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 Social Cost of Carbon

This section describes the methodology used to estimate the monetized damages associated with CO_2 emissions, and the reductions in those damages that would be attributable to each action alternative. NHTSA adopted an approach that relies on estimates of the social cost of carbon (SCC) developed by the Interagency Working Group on Social Cost of Carbon; this approach is consistent with the analysis in the Draft RIA for the proposed HD vehicle rule (*See* www.regulations.gov, docket number NHTSA-2010-0079).

The SCC is an estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions. NHTSA multiplied the estimated value of the SCC during each future year by the emission reductions estimated to result during that year from each of the alternatives that are examined in this EIS to estimate the monetized climate-related benefits associated with each alternative. The following description mirrors the discussion in the draft RIA and provides details of this analysis.

The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. The SCC estimates used in this analysis were developed through an interagency process that included DOT/NHTSA, EPA, and other executive branch entities, and concluded in February 2010. These SCC estimates were used previously in the benefits analysis for the final joint EPA/DOT Rulemaking to establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy

[62] 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. The magnitude of this overestimation, however, 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).

[63] Some modifications were made to the estimation of upstream emissions, consistent with EPA's assumptions in the recent joint Light-Duty Vehicle Greenhouse Gas Emissions and CAFE rulemaking for MYs 2012–2016. More information regarding these modifications can be found in Chapter 5 of EPA's RIA for the May 2010 final rule for that rulemaking.

Standards.[64] The SCC Technical Support Document (TSD) provides a complete discussion of the methods used to develop these SCC estimates.[65]

The interagency group selected four SCC values for use in regulatory analyses, which NHTSA has applied in this analysis: approximately $5, $22, $36, and $66 per metric ton of CO_2 emissions occurring in 2010, in 2008 dollars.[66] The first three values are based on the average SCC from three integrated assessment models, at discount rates of 5, 3, and 2.5 percent, respectively. SCCs at several discount rates are included because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context. The fourth value is the 95th percentile of the SCC from all three models at a 3-percent discount rate. This value is included to represent higher-than-expected impacts from temperature change farther out in the tails of the SCC probability distribution. Low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages.

The SCC increases over time because incremental increases in emissions are expected to produce progressively larger incremental damages over future years, as physical and economic systems become more stressed in response to greater climatic change. Note that the interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual growth rate. This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 3.4.3-1 presents the SCC estimates used in this analysis. Note that the interagency group only provided estimates of the SCC through 2050. Therefore, unlike other elements of the climate change analysis in the EIS which generally extend to 2100, the SCC covers a shorter time frame.

Many serious challenges arise when attempting to assess the incremental economic impacts of CO_2 emissions. A recent report from the National Academies (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of GHGs, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harm associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

The interagency group noted several limitations to the SCC analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking

[64] For a discussion about the application of the SCC, see the preamble to the joint Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Final Rule, 75 *FR* 25324 (May 7, 2010).
[65] (EPA 2010c) Docket ID EPA-HQ-OAR-2009-0472-114577, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon*, with participation by Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also *available at* http://epa.gov/otaq/climate/regulations.htm.
[66] The SCC estimates were converted from 2007 dollars to 2008 dollars using a GDP price deflator (1.021) obtained from the Bureau of Economic Analysis, National Income, and Product Accounts Table 1.1.4, *Prices Indexes for Gross Domestic Product* (BEA 2010).

climate impacts to economic damages makes the interagency modeling exercise even more difficult. The interagency group hopes that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. Additional details on these limitations are discussed in the SCC TSD.

Although CO_2 is the most prevalent GHG emitted into the atmosphere, other GHGs including methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride also contribute to climate change. Because these gases differ in both radiative forcing (the increase in temperature likely to result from increasing atmospheric concentrations of each gas) and atmospheric lifetimes, however, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Thus, transforming gases into CO_2 equivalents using GWP and multiplying the carbon equivalents by the SCC would not result in accurate estimates of the social costs of non-CO_2 gases; the SCC estimates used in this analysis account only for the effects of changes in CO_2 emissions.

Although the SCC analysis omits the effects of changes in non-CO_2 GHG emissions, most of the emission reductions for this proposed action are for CO_2. Given the broad range in the values of SCC used in this EIS, the omission of the other GHGs does not pose a barrier to distinguishing among alternatives.

The global SCC estimates, in constant 2008 dollars per metric ton of CO_2 emitted, are presented in Table 3.4.3-1. These are the average SCCs across all three of the integrated assessment models used in the interagency group's SCC analysis. The final column indicates the 95th percentile of the SCC at a 3-percent discount rate averaged across the three models. Annual versions of these values are used in the subsequent calculations in this section. The figures are in 2008 dollars for emissions occurring in the years shown in the table.

Table 3.4.3-1

Social Cost of CO_2, 2010 – 2050 (in 2008 dollars per metric ton)

	Discount Rate and Statistic			
Year	**5% Average**	**3% Average**	**2.5% Average**	**3% 95th percentile**
2010	$4.80	$21.85	$35.84	$66.26
2015	$5.87	$24.35	$39.21	$74.33
2020	$6.94	$26.85	$42.58	$82.39
2025	$8.45	$30.15	$46.84	$92.25
2030	$9.95	$33.44	$51.10	$102.10
2035	$11.46	$36.73	$55.36	$111.95
2040	$12.97	$40.02	$59.63	$121.81
2045	$14.50	$42.93	$63.00	$130.43
2050	$16.03	$45.84	$66.37	$139.06

3.4.3.3 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, 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, in turn, influences each of the indirect effects including global mean surface temperature, changes in regional temperature and precipitation, and changes in sea level.

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 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 MOVES model (tailpipe) and the associated estimated upstream reductions from GREET. A sensitivity analysis was also completed to examine variation in the direct and indirect climate impacts of selected alternatives under different assumptions about the sensitivity of climate change to GHG concentrations in Earth's atmosphere. The results of the sensitivity analysis can be used to infer the effect of variation in emissions associated with the alternatives on the magnitude of direct and indirect climate effects.

This section describes MAGICC, the climate sensitivity analysis, and the baseline emissions scenario used to represent the No Action Alternative in this analysis.

3.4.3.3.1 MAGICC Version 5.3.v2

The selection of MAGICC for this analysis was driven by several factors, as follows:

- MAGICC has been used in the peer-reviewed literature to evaluate changes in global mean surface temperature and sea-level rise. Past applications include the IPCC Fourth Assessment Report for Working Group I (WGI) (IPCC 2007a), where it was used to estimate global mean surface temperature and sea-level rise for simulations of global emissions scenarios that were not run with the more complex atmospheric-ocean general circulation models (AOGCMs).[67]

- 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 the HD National Program RIA, which accompanies the joint NHTSA and EPA Notice of Proposed Rulemaking (NPRM).

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

- NHTSA used MAGICC to assess direct and indirect effects of climate change in the EIS for the MYs 2012–2016 CAFE standards for passenger cars and light trucks released in February 2010 (NHTSA 2010).

NHTSA assumed that global emissions under the No Action Alternative (Alternative 1) follow the trajectory provided by the Global Change Assessment Model (GCAM, formerly MiniCAM) reference emission scenario used as the basis for the RCP 4.5 scenario (Thomson *et al*., in review). This scenario represents a reference case in which future global emissions continue to rise unchecked assuming no additional climate policy. Section 3.4.3.4 describes the GCAM reference scenario.

3.4.3.3.2 Reference Case Modeling Runs

The modeling runs and sensitivity analysis are designed to use information on the alternatives, climate sensitivities, and the GCAM reference emissions scenario (Thomson *et al.,* in review)[68] to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise that could result under each alternative.

The modeling runs are based on the reductions in emissions estimated to result from each of the ten alternatives, a climate sensitivity of 3 °C (5.4 °F) for a doubling of CO_2 concentrations in the atmosphere, and the GCAM reference scenario.

The approach uses the following four steps to estimate these changes:

1. NHTSA assumed that global emissions under the No Action Alternative follow the trajectory provided by the GCAM reference scenario.

2. NHTSA assumed that global emissions for each action alternative is equal to the global emissions under the No Action Alternative minus the reductions in emissions of CO_2, CH_4, N_2O, SO_2, NO_x, CO, and VOCs estimated to result from each action alternative (for example, the global emissions scenario under Alternative 2 equals the GCAM 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 alternative developed in Steps 1 and 2 above.

4. NHTSA used the increase in global mean surface temperature, along with factors relating the increase in global average precipitation to this increase in global mean surface temperature, to estimate the increase in global average precipitation for each alternative using the GCAM reference scenario.

Section 3.4.4 presents the results of the model runs for the alternatives.

[68] The use of different emissions scenarios provides insight into the impact of alternative global emissions scenarios on the effect of the HD alternatives.

3.4.3.3.3 Sensitivity Analysis

NHTSA conducted a sensitivity analysis to examine the effect of various equilibrium climate sensitivities on the results. Equilibrium climate sensitivity[69] (or climate sensitivity) is the projected responsiveness of Earth's global climate system to increased radiative forcing from higher GHG concentrations, and is 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) (EPA 2009 citing NRC 2001). In the past 8 years, confidence in climate sensitivity projections has increased significantly (EPA 2009 citing Meehl *et al.* 2007b). According to IPCC, with a doubling of the concentration of atmospheric CO_2, there is a *likely* probability of an increase in surface warming of 2.0 to 4.5 °C (3.6 to 8.1 °F), and a *very likely* probability of an increase of 1.5 to 6.0 °C (2.7 to 10.8 °F), with a best estimate of 3 °C (5.4 °F) (IPCC 2007a, EPA 2009, Meehl et al. 2007a).

NHTSA assessed climate sensitivities of 1.5, 2.0, 2.5, 3.0, 4.5, and 6.0 °C (2.7, 3.6, 4.5, 5.4, 8.1, and 10.8 °F) for a doubling of CO_2 concentrations in the atmosphere. NHTSA conducted the sensitivity analysis around two of the alternatives – the No Action Alternative (Alternative 1) and the Preferred Alternative (Alternative 6) – as this was deemed sufficient to assess the effect of various climate sensitivities on the results.

The approach uses the following four steps to estimate the sensitivity of the results to alternate estimates of the climate sensitivity:

1. NHTSA used the GCAM reference scenario to represent emissions from the No Action Alternative.

2. Starting with the GCAM 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 a range of climate sensitivity values consistent with the 10-90 percent probability distribution from the IPCC Fourth Assessment Report (IPCC 2007a) of 1.5, 2.0, 2.5, 3.0, 4.5, and 6.0 °C (2.7, 3.6, 4.5, 5.4, 8.1, and 10.8 °F).[70]

4. For each climate sensitivity value 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 steps 1 and 2.

Section 3.4.4 presents the results of the model runs for the alternatives.

3.4.3.4 Global Emissions Scenarios

As described above, MAGICC uses long-term emissions scenarios representing different assumptions about key drivers of GHG emissions. The reference scenario is the GCAM (formerly MiniCAM) reference scenario (*i.e.,* it does not assume a comprehensive global policy to mitigate GHG emissions) used as the basis for the RCP 4.5 scenario (Thomson *et al.*, in review). This scenario is used because it contains a comprehensive suite of greenhouse and pollutant gas emissions including

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[69] In this EIS, the term "climate sensitivity" refers to "equilibrium climate sensitivity."
[70] *See* Box 10.2, Figure 2 in IPCC (2007a).

carbonaceous aerosols. The GCAM reference scenario is based on scenarios presented in Clarke *et al.* (2007). It uses non-CO_2 and pollutant gas emissions implemented as described in Smith and Wigley (2006); land-use change emissions as described in Wise *et al.* (2009); and updated base-year estimates of global GHG emissions. 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 use 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, 5 from each of the 3 modeling groups (IGSM, MiniCAM, and MERGE).[71]

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 GCAM 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 GCAM reference scenario based on the following factors:

- The GCAM 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. The GCAM 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 GCAM reference scenario is an updated version of the MiniCAM model scenario and illustrates a pathway of emissions between the IGSM and MERGE reference scenarios for most of the twenty-first century. In essence, the GCAM reference scenario is a “middle ground” scenario.

- CCSP SAP 2.1 is more than a decade newer than the IPCC SRES, and therefore has updated economic and technology data and assumptions and uses improved integrated assessment models that account for advances in economics and science over the past 10 years.

[71] IGSM is the Massachusetts Institute of Technology’s Integrated Global System Model. MERGE is Model for Evaluating the Regional and Global Effects of GHG Reduction Policies developed jointly by Stanford University and the Electric Power Research Institute.

- EPA also used the GCAM reference scenario for the HD National Program RIA, which accompanies the joint NHTSA and EPA NPRM.

The GCAM reference scenario provides a global context for emissions of a full suite of GHGs and ozone precursors. Some inconsistencies exist 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 MOVES model in terms of economic growth, energy prices, energy supply, and energy demand. These inconsistencies affect the characterization of each alternative in equal proportion, however, so the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives.

Each alternative 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 GCAM 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 HD vehicles in the United States in 2020 under Alternative 1 (No Action) are 659 $MMTCO_2$; the emissions in 2020 under Alternative 6 (Preferred Alternative) are 625 $MMTCO_2$ (*see* Table 3.4.4-2). The difference of 34 $MMTCO_2$ represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global emissions for the GCAM reference scenario in 2020 are 38,017 $MMTCO_2$, which are assumed to incorporate emissions from HD vehicles in the United States under the No Action Alternative. Global emissions under the Preferred Alternative are thus estimated to be 34 $MMTCO_2$ less than this reference level, or 37,983 $MMTCO_2$ in 2020.

Many of the economic assumptions used in the MOVES model (such as VMT, freight miles, freight modal shares) are based on the EIA AEO 2010 (EIA 2010a) and IEO 2010 (EIA 2010b), which forecast energy supply and demand in the United States and globally to 2035. Appendix C to this EIA includes a discussion of how the EIA forecasts of global and U.S. GDP, CO_2 emissions from energy use, and primary energy use compare with the assumptions used to develop the GCAM scenario.

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 GCAM assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the emission estimates for the U.S. transportation sector provided by the MOVES 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.

3.4.3.5 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,[72] and biosphere) reaches a point at which a disproportionally large or singular response in a climate-affected system occurs 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" (EPA 2009 citing NRC 2002), could result in abrupt changes in the climate or any part of the climate system. Abrupt climate changes

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

could occur so quickly and unexpectedly that human systems would have difficulty adapting to them (EPA 2009 citing NRC 2002).

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 2009), 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, potential thresholds, and estimates of the causes, likelihood, timing, and impacts of abrupt climate events. Although there are methodological approaches to estimate changes in temperatures resulting from a reduction in GHG emissions and associated radiative forcing, the current state of science does not allow for quantifying how emission reductions from a specific policy or action might affect the probability and timing of abrupt climate change. This area of climate science is one of the most complex and scientifically challenging; given the difficulty of simulating the large-scale processes involved in these tipping points, or inferring their characteristics from paleoclimatology, considerable uncertainties remain on tipping points and the rate of change. Despite the lack of a precise quantitative methodological approach, NHTSA has provided a qualitative and comparative analysis of tipping points and abrupt climate change.[73] The analysis applies equally to the direct effects discussion (Chapter 3) and the cumulative impacts discussion (Chapter 4); given that tipping points are best viewed in the perspective of long-term, large-scale global trends (the focus of the cumulative impacts discussion), however, and to reduce redundancy in this EIS, NHTSA's qualitative discussion of results is presented in Section 4.5.9.

3.4.4 Environmental Consequences

This section describes the environmental consequences of the proposed action and alternatives in relation to GHG emissions and climate effects.

3.4.4.1 Greenhouse Gas Emissions

Emission reductions resulting from the proposed action and alternatives for MYs 2014–2018 HD vehicles were estimated for 2014 to 2100. In the following discussion and table, emission reductions represent the differences in total annual emissions by all HD vehicles in use between their estimated future levels under the No Action Alternative (Alternative 1) and each action alternative (Alternatives 2 through 8). The change in fuel production and use projected to result from each alternative HD standard determines the resulting impacts on total energy use and petroleum consumption, which in turn determine the reduction in CO_2 emissions that will result from adopting each alternative. 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 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 efficiency.[74]

Table 3.4.4-1 and Figure 3.4.4-1 show total emissions and emission reductions resulting from applying the ten alternative standards to new HD vehicles from 2014 to 2100. Emissions for this period

[73] *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* (1997b), *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).
[74] Includes land-use change and forestry, and excludes international bunker fuels.

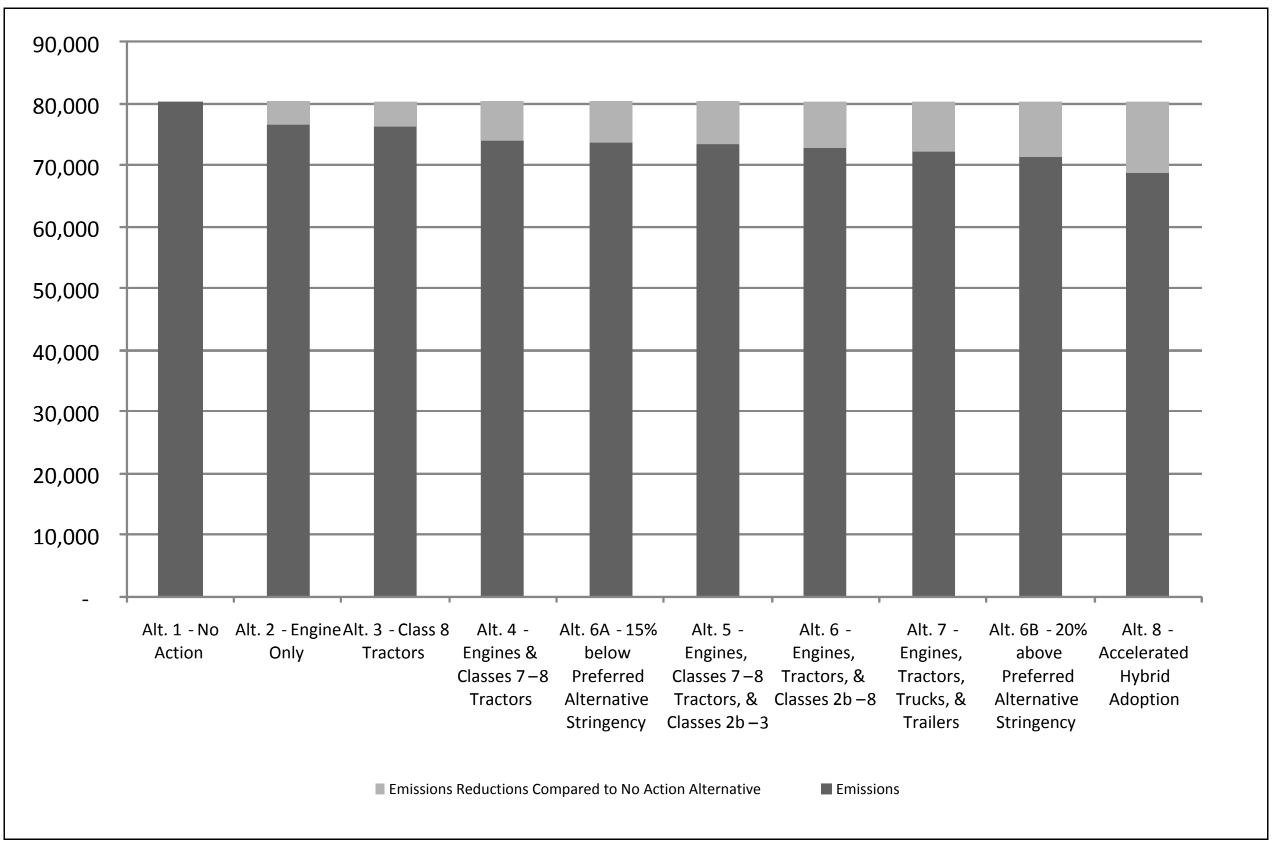
Table 3.4.4-1

Emissions and Emission Reductions ($MMTCO_2$) from 2014 to 2100 by Alternative a/

Alternative	Total Emissions	Emission Reductions Compared to No Action Alternative	Percent Emission Reductions Compared to No Action Emissions
1 No Action	80,400	0	
2 Engine Only	76,500	3,800	5%
3 Class 8 Tractors	76,200	4,200	5%
4 Engines & Classes 7–8 Tractors	74,000	6,400	8%
6A 15% below Preferred Alternative Stringency	73,800	6,600	8%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	73,500	6,900	9%
6 Engines, Tractors, & Classes 2b–8 b/	72,800	7,600	9%
7 Engines, Tractors, Trucks, & Trailers	72,400	8,000	10%
6B 20% above Preferred Alternative Stringency	71,500	8,900	11%
8 Accelerated Hybrid Adoption	68,800	11,600	14%

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.
b/ Preferred Alternative

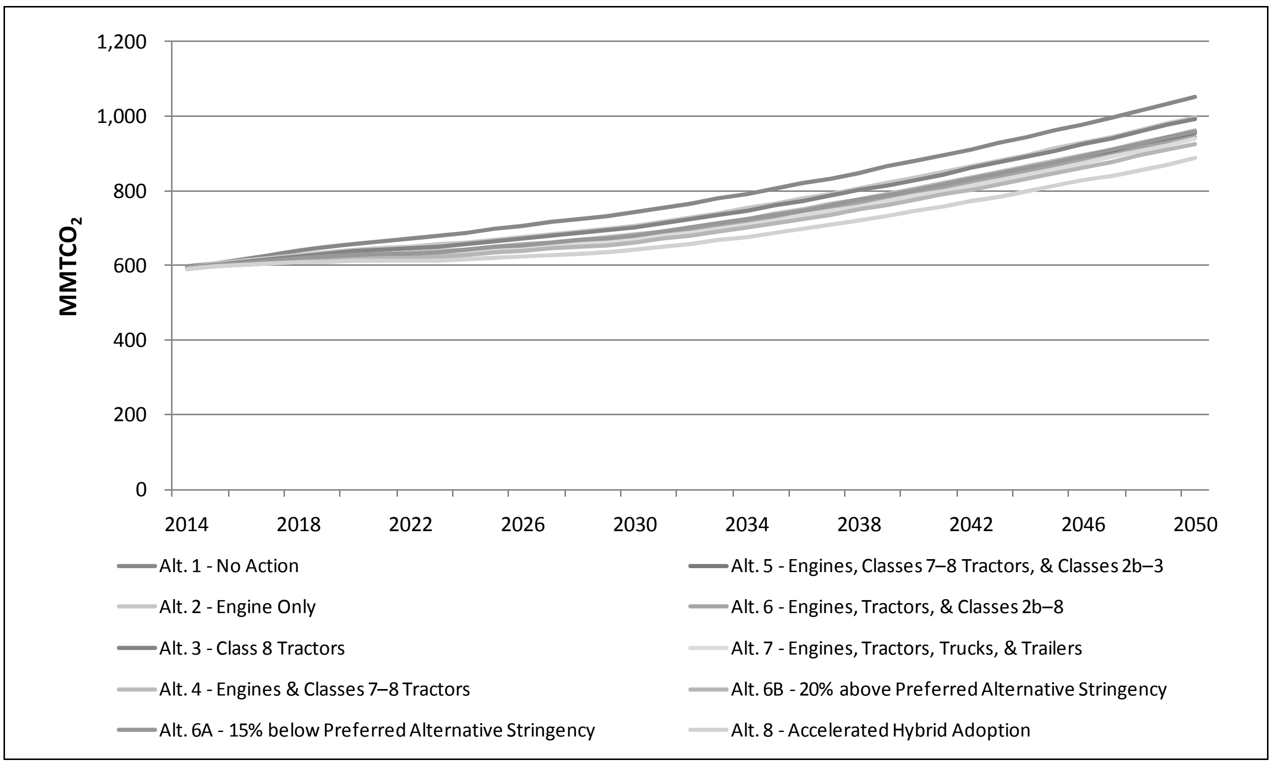
Figure 3.4.4-1. Emissions and Emission Reductions ($MMTCO_2$) from 2014 to 2100 by Alternative



range from a low of 68,800 $MMTCO_2$ under the Accelerated Hybrid Adoption (Alternative 8) to 80,400 $MMTCO_2$ under the No Action Alternative (Alternative 1). Compared to the No Action Alternative, projections of emission reductions from 2014 to 2100 due to the action alternatives range from 3,800 to 11,600 $MMTCO_2$. Compared to cumulative global emissions of 5,204,115 $MMTCO_2$ over this period (projected by the GCAM reference scenario), this rulemaking is expected to reduce global CO_2 emissions by about 0.1 to 0.2 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 HD vehicles in the context of emissions projections from the transportation sector, and expected or stated goals from existing programs designed to reduce CO_2 emissions. As mentioned earlier in Section 3.4.2.1, HD vehicles in the United States currently account for a significant amount of CO_2 emissions in the United States. The action alternatives reduce CO_2 emissions in the United States by 5−14 percent of total emissions from U.S. HD vehicles from 2014 to 2100 as compared to the No Action Alternative. Compared to total U.S. CO_2 emissions in 2100 of 7,193 $MMTCO_2$ projected by the GCAM reference scenario (Thomson *et al.*, in review), the action alternatives would reduce total U.S. CO_2 emissions from all sources by 0.7–2.1 percent in 2100. Figure 3.4.4-2 shows projected annual emissions from HD vehicles under the alternatives.

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



As Table 3.4.4-2 shows, total CO_2, CH_4, and N_2O emissions from the HD vehicles in the United States are projected to increase substantially after 2020 under the No Action Alternative, which assumes average fuel efficiency would remain at the 2014 level for all future model years. The table also shows that each action alternative would reduce HD vehicle CO_2. CH_4, and N_2O emissions in future years significantly from their projected levels under the No Action Alternative. Progressively larger reductions in CO_2, CH_4, and N_2O emissions from their levels under the No Action Alternative are projected to occur across Alternatives 2 through 8 because the action alternatives require increasingly higher fuel efficiency

Table 3.4.4-2

Nationwide Emissions of Greenhouse Gases ($MMTCO_2e$ per year) a/ from HD Vehicles by Alternative

GHG and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors, & Classes 2b–3	Alt. 6 Engines, Tractors, & Classes 2b–8 b/	Alt.7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon dioxide (CO_2)										
2020	659	643	637	629	629	627	625	622	619	612
2030	742	707	701	682	681	678	673	669	661	642
2050	1,051	997	994	963	959	955	945	940	927	887
2080	1,038	985	982	951	948	944	934	928	916	876
2100	965	916	913	884	882	878	869	863	852	815
Methane (CH_4)										
2020	20.41	19.97	19.80	19.56	19.56	19.53	19.46	19.39	19.30	19.12
2030	19.35	18.46	18.27	17.79	17.74	17.67	17.55	17.44	17.25	16.73
2050	25.09	23.82	23.72	22.98	22.90	22.79	22.56	22.43	22.12	21.16
2080	24.79	23.53	23.43	22.70	22.62	22.52	22.29	22.16	21.86	20.90
2100	23.06	21.88	21.79	21.11	21.04	20.94	20.73	20.61	20.33	19.44
Nitrous oxide (N_2O)										
2020	1.73	1.72	1.71	1.71	1.71	1.70	1.70	1.70	1.70	1.69
2030	1.28	1.26	1.25	1.24	1.24	1.23	1.23	1.23	1.22	1.20
2050	1.55	1.51	1.51	1.49	1.48	1.48	1.47	1.47	1.46	1.43
2080	1.53	1.49	1.49	1.47	1.47	1.46	1.46	1.45	1.44	1.41
2100	1.42	1.39	1.38	1.37	1.36	1.36	1.35	1.35	1.34	1.31

a/ $MMTCO_2e$ is million metric tons CO_2 equivalent
b/ Preferred Alternative

levels for MYs 2014 through 2018, and the 2018 levels are assumed to remain in place indefinitely, affecting all HD vehicles manufactured subsequently.

Under each alternative analyzed, growth in the number of HD vehicles in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth of HD vehicle travel. This growth in travel more than offsets the effect of improvements in fuel efficiency for each alternative, thus resulting in projected increases in total fuel consumption by HD vehicles in the United States over most of the period shown in Table 3.4.4-1. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles.

Emissions of CO_2, the primary gas that drives climate effects, from HD vehicles in the United States represented about 1.2 percent of total global emissions of all CO_2 emissions in 2005 (EPA 2010a, WRI 2010).[75] Although substantial, this source contributes a small percentage of global emissions, and the relative contribution of CO_2 emissions from the HD vehicle fleet in the United States is expected to decline in the future. This expected decline is due primarily to rapid growth of emissions from

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

developing economies, which partly reflects growth in global transportation sector emissions. In the GCAM reference scenario, the share of transportation final energy use[76] from the United States as a percent of total primary energy consumption declines from 41 percent in 2005 to 36 percent in 2100.[77]

As another way to provide context for these GHG results, President Obama recently submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG emissions reduction target for the United States in the range of 17 percent below 2005 levels by 2020, in association with the Copenhagen Accord, and in conformity with anticipated U.S. energy and climate legislation.[78] Although the action alternatives would reduce projected CO_2 emissions in 2020 compared to what they would otherwise be without action, CO_2 emissions from the HD vehicle sector in 2020 would actually increase (in the range of 8.2−13.6 percent) above 2005 levels.[79] This increase occurs because even the alternatives that would require the greatest increases in fuel efficiency are insufficient to offset the effect on total emissions from projected increases in total VMT by HD vehicles.

NHTSA emphasizes, however, that the President's stated policy goal outlined above does not specify that every emitting sector of the economy must contribute equally proportional emission reductions. Significantly, the action of setting fuel efficiency standards does not directly regulate total emissions from HD vehicles. NHTSA's authority to promulgate new fuel efficiency standards is a limited authority and does not allow NHTSA to regulate other factors affecting emissions, including driving habits – NHTSA cannot control VMT. Specifically, NHTSA notes that under all of the alternatives analyzed, growth in the number of HD vehicles in use throughout the United States, combined with assumed increases in their average use (annual vehicle-miles traveled per vehicle), due to economic improvement and a variety of other factors, is projected to result in growth in HD VMT.

This projected growth in travel is expected to more than offset the effect of improvements in fuel efficiency required under each alternative, resulting in increases in total fuel consumption by HD vehicles in the United States. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles.

Nevertheless, as Figure 3.4.4-3 shows, NHTSA estimates that the proposed HD fuel efficiency standards will reduce CO_2 emissions significantly from future levels that would otherwise be estimated to occur in the absence of the HD Fuel Efficiency Improvement Program, although these reductions in emissions are not sufficient to reduce total HD vehicle emissions during 2020 below their 2005 levels.

[76] Final energy use is defined as consumption of energy in a given sector and does not include any energy consumed to produce or convert primary energy sources to the energy type consumed (*e.g.*, does not include energy consumed in oil production, refineries, or transport of crude oil or petroleum products from the production site to refineries or the end-users).

[77] The GCAM reference scenario used in the climate modeling is based on scenarios presented in Clarke *et al.* (2007) with non-CO_2 and pollutant gas emissions implemented as described in Smith and Wigley (2006) and land-use change emissions as described in Wise *et al.* (2009). Base-year information has been updated to the latest available data for the RCP process. The GCAM reference scenario is used as the basis for the RCP 4.5 (Thomson *et al.*, in review). Both reference scenarios in these models use the same assumptions for GDP, energy use, and CO_2 emissions.

[78] On January 28, 2010, the United States submitted this target to the U.N. Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the [U.N.] in light of enacted legislation." (U.S. Department of State 2010)

[79] A 17-percent reduction would mean a reduction of 96.2 $MMTCO_2$ from 2005 levels, or a reduction of 189.2 $MMTCO_2$ from the No Action baseline.

Figure 3.4.4-3. Projected Annual Emissions by Alternative, Compared to 2005 Levels for HD Vehicles

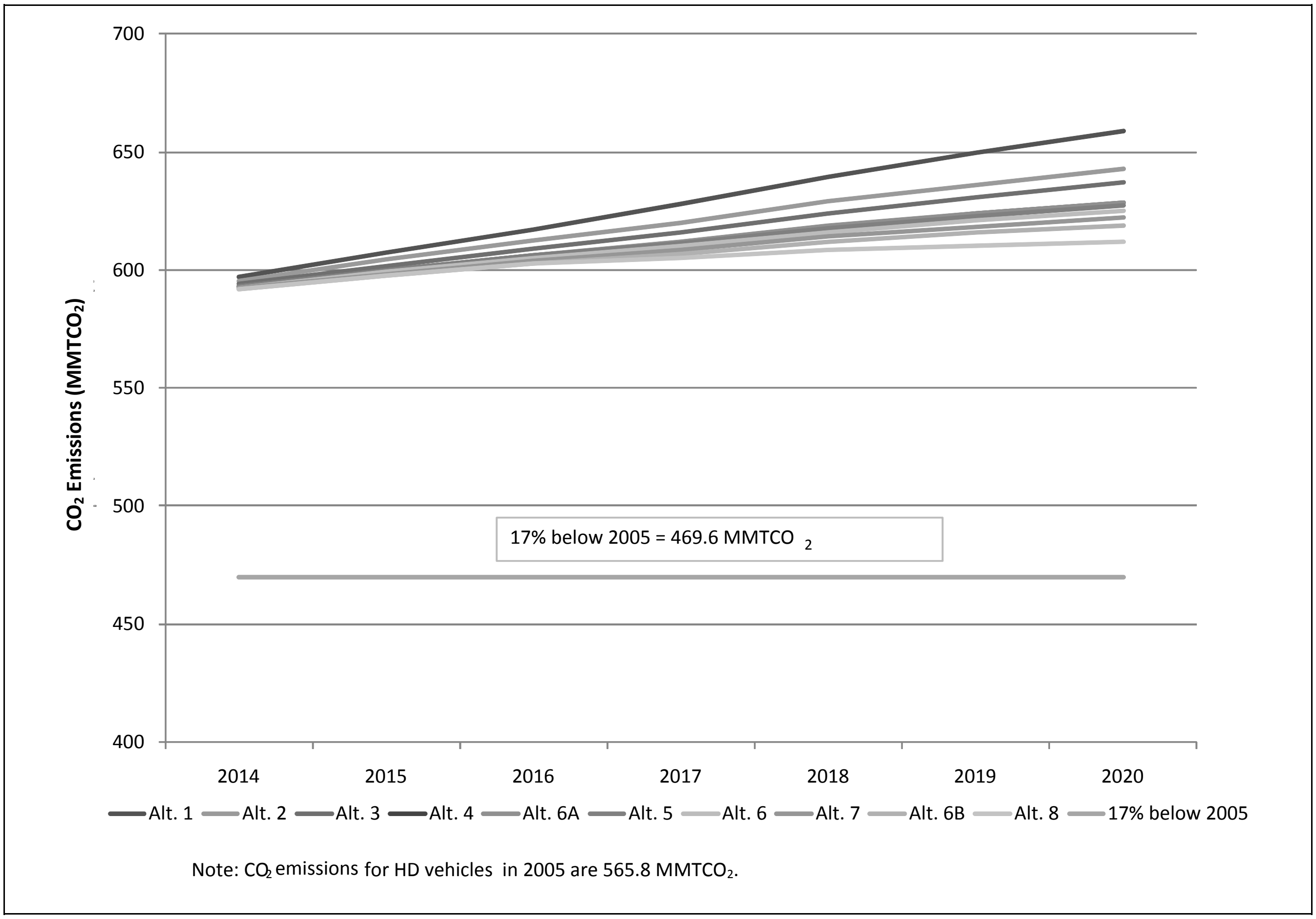
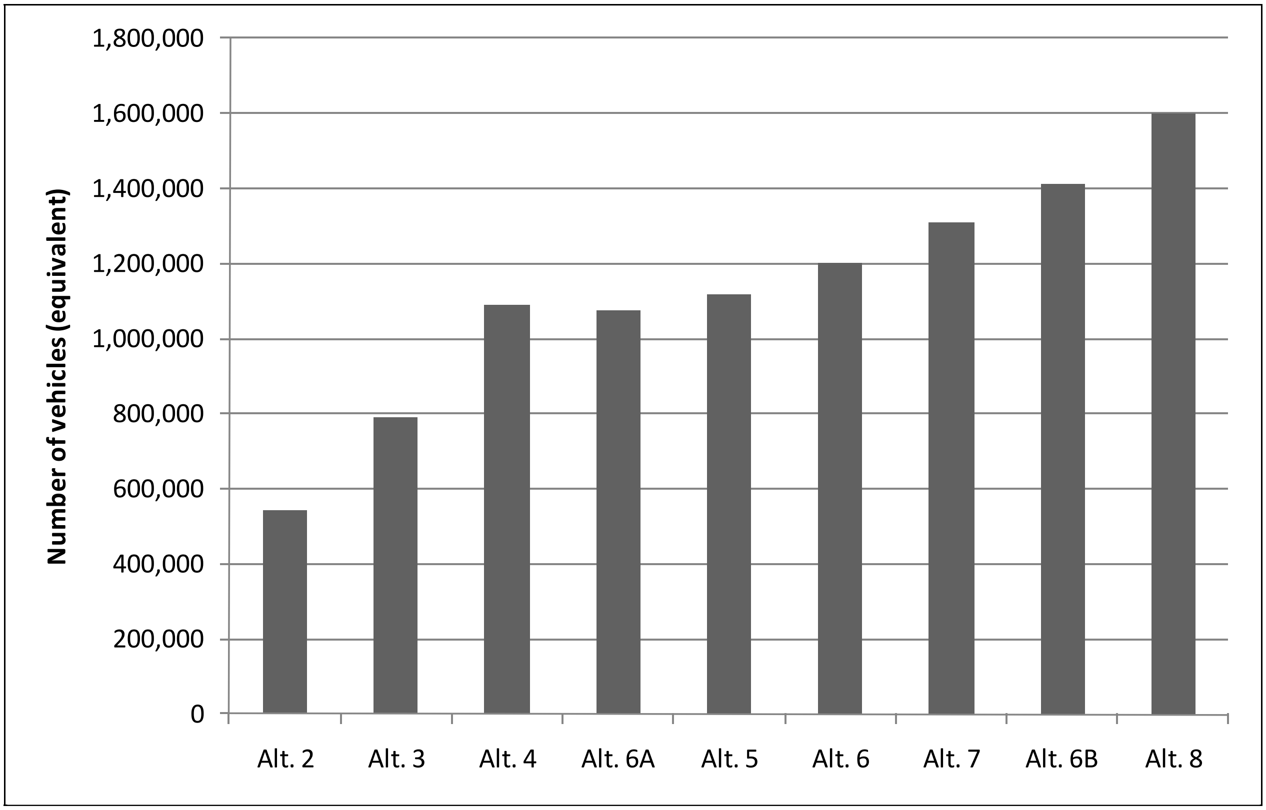


Figure 3.4.4-4 shows CO_2 reductions from the alternatives in 2018 expressed as equivalent to the number of HD vehicles that would produce those emissions in that year. The emission reductions from the action alternatives are equivalent to the annual emissions of between 0.54 million HD vehicles (Alternative 2) and 1.60 million HD vehicles (Alternative 8) in 2018, as compared to the annual emissions that would occur under the No Action Alternative. Emission reductions in 2018 from the Preferred Alternative (Alternative 6) are equivalent to the annual emissions of 1.20 million HD vehicles. Annual CO_2 reductions, their equivalent in vehicles, and differences among alternatives grow larger in future years as older vehicles are increasingly replaced by newer ones meeting the progressively higher fuel efficiency standards required by each alternative.[80,81]

[80] The HD vehicle equivalency is based on an average per-vehicle emissions estimate, which includes both tailpipe CO_2 emissions and associated upstream emissions from fuel production and distribution. The average HD vehicle accounts for approximately 19.62 metric tons of CO_2 in the year 2018 based on MOVES and GREET model analysis.

[81] In the year 2018, emission reductions from Alt. 4 are slightly *higher* than Alt 6A. However, in later years this trend reverses, and cumulative emission reductions from Alt 4 are *lower* than Alt 6A over the entire time period assessed in this analysis (2014-2100).

Figure 3.4.4-4. Number of HD Vehicles Equivalent to CO_2 Reductions in 2018, Compared to the No Action Alternative



These emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate Initiative (WCI) to develop regional strategies to address climate change. The WCI stated a goal of reducing 350 $MMTCO_2e$ over the period 2009 to 2020 (WCI 2007a).[82] If this goal is achieved, emissions levels in 2020 would be 33 percent lower than projected 2020 emissions levels under a "business as usual" scenario, and 15 percent lower than those at the beginning of the WCI action (WCI 2007b). By comparison, the proposed HD Fuel Efficiency Improvement Program is expected to reduce CO_2 emissions by 57 to 169 $MMTCO_2$ between 2014 and 2020 (depending on the alternative), with emissions levels in 2020 representing a 2- to 8-percent reduction from the future baseline emissions for HD vehicles.

Nine northeastern and mid-Atlantic States have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce CO_2 emissions from power plants in the Northeast. Emission reductions from 2006 to 2024 under the initiative were estimated at 268 $MMTCO_2$ (RGGI 2006).[83] This estimate represents a 23-percent reduction relative to the future baseline and a 10-percent reduction in 2024 emissions from their

[82] Since this goal was initially stated, Montana, Quebec, and Ontario joined the WCI. Thus, the total emissions reduction would likely be greater than 350 $MMTCO_2$.

[83] 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.

levels at the beginning of the action (RGGI 2006). By comparison, NHTSA forecasts that the proposed HD Fuel Efficiency Improvement Program would reduce CO_2 emissions by 144 to 420 $MMTCO_2$ between 2014 and 2024 (depending on the alternative), with emissions levels in 2024 representing a 4- to 11-percent reduction relative to the future baseline emissions for HD vehicles.

Two features of these comparisons are 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 (conforming to the programs' goals, which are to reduce overall emissions), while emissions from HD vehicles are projected to increase under all alternatives for this proposed rulemaking due to increases in vehicle ownership and use. Second, these projections are estimates only, and the scope of these climate programs differs from the scope of the proposed rulemaking in terms of geography, sector, and purpose.

In this case, the comparison of emission reductions from the alternative HD fuel efficiency standards to emission 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 emission reductions that are on a scale similar to many of the most progressive and ambitious GHG emissions reduction programs underway in the United States.

3.4.4.2 Social Cost of Carbon

Table 3.4.4-3 provides the benefits of the HD vehicle rule, in terms of reduced monetized damages. By applying each future year's SCC estimate to the estimated reductions in CO_2 emissions during that year for each policy scenario, discounting the resulting figure to its present value, and summing those estimates for each year from 2014 to 2050, NHTSA derived the net present value of the benefits in 2014 (Table 3.4.4-3). For internal consistency, the annual benefits are discounted to net present value terms using the same discount rate as each SCC estimate (*i.e.*, 5 percent, 3 percent, and 2.5 percent), rather than the 3-percent and 7-percent discount rates applied to other future benefits. Consistent with Table 3.4.4-3, these estimates show increasing benefits with decreasing discount rates (and higher damage estimates). The estimated net present value for a given policy alternative varies by approximately an order of magnitude across the discount rates. The estimated net present value computed using a single discount rate differs by roughly a factor of three across policy alternatives.

Table 3.4.4-3

Reduced Monetized Damages of Climate Change for each Regulatory Alternative Net Present Value in 2011 of CO_2 Emission Reductions between 2014 and 2050 (in millions of 2008 dollars)

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2	$ 3,904	$ 21,039	$ 35,954	$ 64,081
3	$ 4,573	$ 24,459	$ 41,736	$ 74,515
4	$ 6,726	$ 36,086	$ 61,615	$ 109,926
6A	$ 6,900	$ 37,060	$ 63,290	$ 112,890
5	$ 7,212	$ 38,737	$ 66,155	$ 117,996
6	$ 7,818	$ 42,031	$ 71,794	$ 128,027
7	$ 8,299	$ 44,587	$ 76,151	$ 135,818
6B	$ 9,162	$ 49,264	$ 84,151	$ 150,058
8	$ 11,563	$ 62,411	$ 106,691	$ 190,083

3.4.4.3 Direct and Indirect Effects on Climate Change

Sections 3.4.4.3.1 through 3.4.4.3.4 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.

3.4.4.3.1 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 3.4.4-4.[84] 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 3.4.4-4

Comparison of MAGICC Modeling 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 (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 1980–1989 and 2090−2099.

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 GCAM reference scenario to represent the No Action Alternative in the MAGICC modeling runs. Table 3.4.4-5 and Figures 3.4.4-5 through 3.4.4-8 present the results of MAGICC simulations for the No Action Alternative and the nine action alternatives in terms of CO_2 concentrations and increases in global mean surface temperature in 2030, 2050, and 2100. As shown in Table 3.4.4-5 and Figures 3.4.4-5 through 3.4.4-8, estimated CO_2 concentrations for 2100 range from 783.8 ppm under Alternative 8 to 784.9 ppm under the No Action Alternative. For 2030 and 2050, the corresponding range is even smaller. Because CO_2 concentrations are the key determinant 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. Even though these effects are small, they occur on a global scale and are long-lived.

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

Table 3.4.4-5

CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-Level Rise Using MAGICC (RCP GCAM Reference) by Alternative a/

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C) from 1990			Sea-Level Rise (cm)		
Totals by Alternative	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
1 No Action	443.6	519.0	784.9	0.880	1.516	3.064	8.06	14.81	37.40
2 Engine Only	443.6	518.9	784.5	0.880	1.516	3.063	8.06	14.81	37.38
3 Class 8 Tractors	443.6	518.8	784.5	0.880	1.516	3.062	8.06	14.81	37.38
4 Engines & Classes 7–8 Tractors	443.6	518.8	784.3	0.880	1.515	3.062	8.06	14.81	37.38
6A 15% below Preferred Alternative Stringency	443.6	518.8	784.2	0.880	1.515	3.062	8.06	14.81	37.37
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	443.6	518.8	784.2	0.880	1.515	3.061	8.06	14.81	37.37
6 Engines, Tractors, & Classes 2b–8 b/	443.5	518.7	784.1	0.880	1.515	3.061	8.06	14.81	37.37
7 Engines, Tractors, Trucks, & Trailers	443.5	518.7	784.1	0.880	1.515	3.061	8.06	14.81	37.37
6B 20% above Preferred Alternative Stringency	443.5	518.7	784.0	0.880	1.515	3.061	8.06	14.81	37.37
8 Accelerated Hybrid Adoption	443.5	518.6	783.8	0.880	1.515	3.060	8.06	14.80	37.36
Reductions Under Alternative HD Standards									
2 Engine Only	0.0	0.1	0.4	0.000	0.000	0.001	0.00	0.00	0.02
3 Class 8 Tractors	0.0	0.1	0.4	0.000	0.001	0.002	0.00	0.00	0.02
4 Engines & Classes 7–8 Tractors	0.1	0.2	0.6	0.000	0.001	0.002	0.00	0.00	0.02
6A 15% below Preferred Alternative Stringency	0.0	0.2	0.7	0.000	0.001	0.002	0.00	0.00	0.03
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.1	0.2	0.7	0.000	0.001	0.003	0.00	0.00	0.03
6 Engines, Tractors, & Classes 2b–8 b/	0.1	0.2	0.7	0.000	0.001	0.003	0.00	0.00	0.03
7 Engines, Tractors, Trucks, & Trailers	0.1	0.3	0.8	0.000	0.001	0.003	0.00	0.00	0.03
6B 20% above Preferred Alternative Stringency	0.1	0.3	0.9	0.000	0.001	0.003	0.00	0.00	0.03
8 Accelerated Hybrid Adoption	0.1	0.4	1.1	0.000	0.002	0.004	0.00	0.01	0.04

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.
b/ Preferred Alternative

Figure 3.4.4-5. CO_2 Concentrations (ppm)

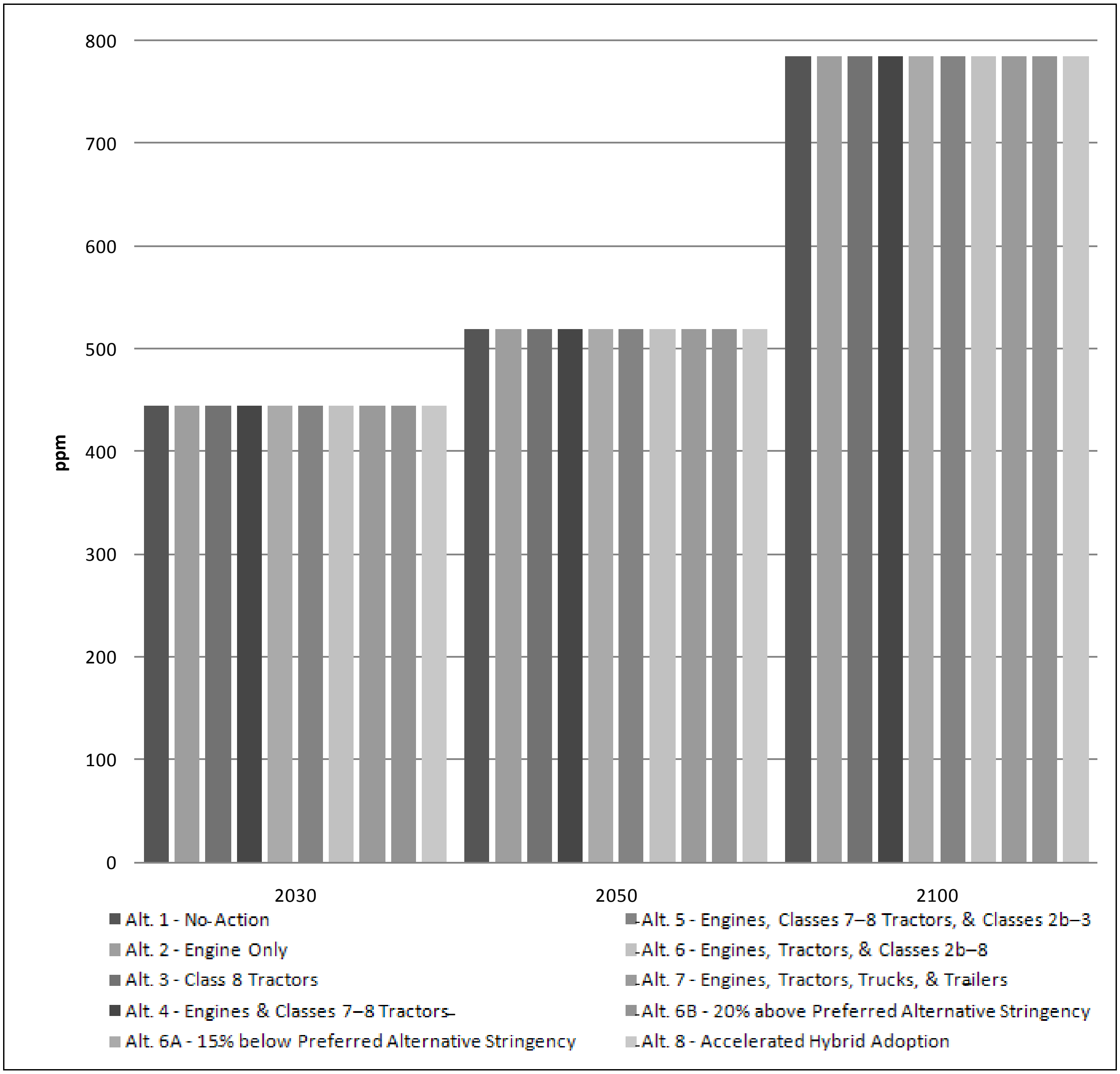


Figure 3.4.4-6. Change in Global Mean Surface Temperature Increase (°C)

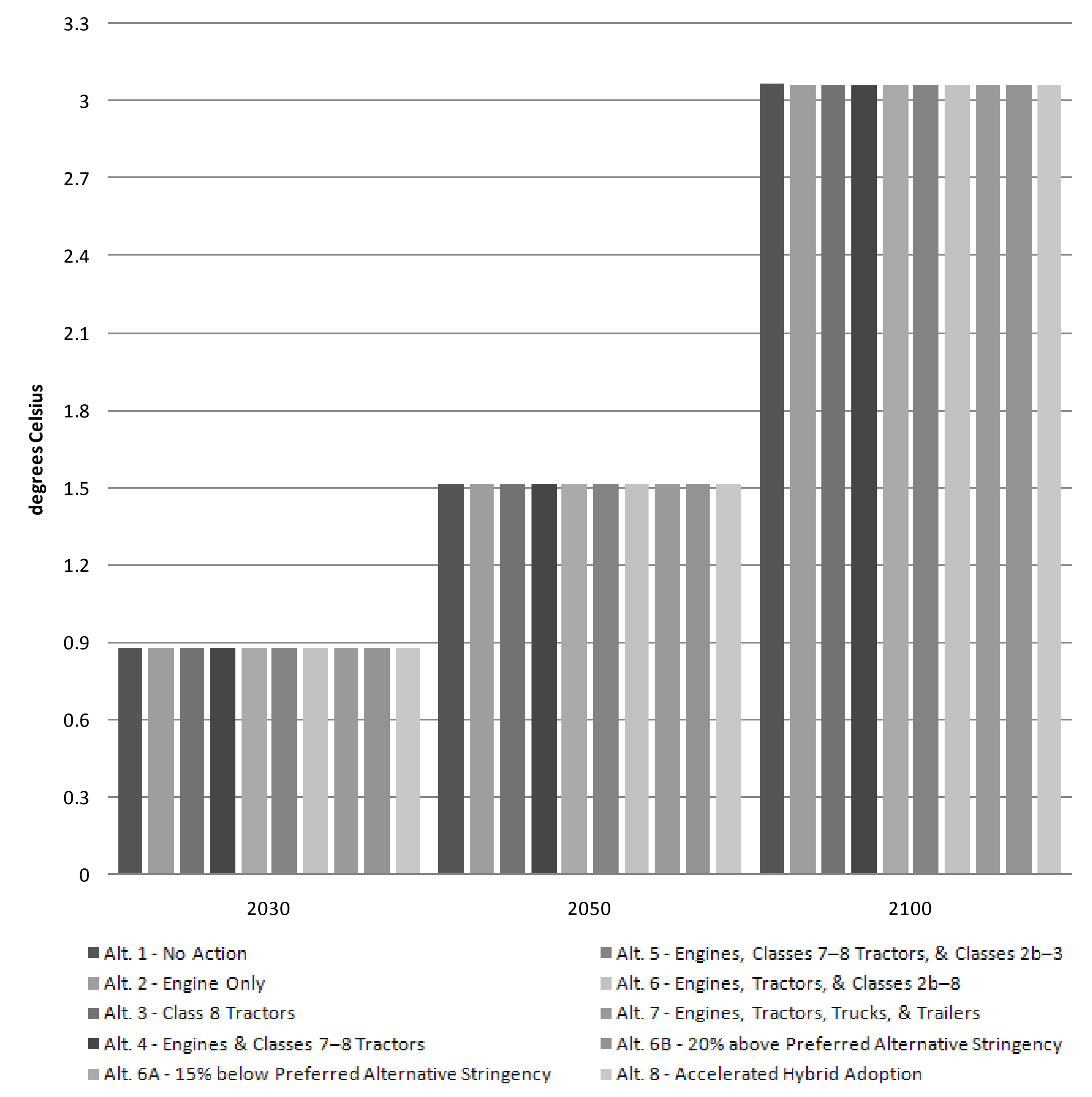
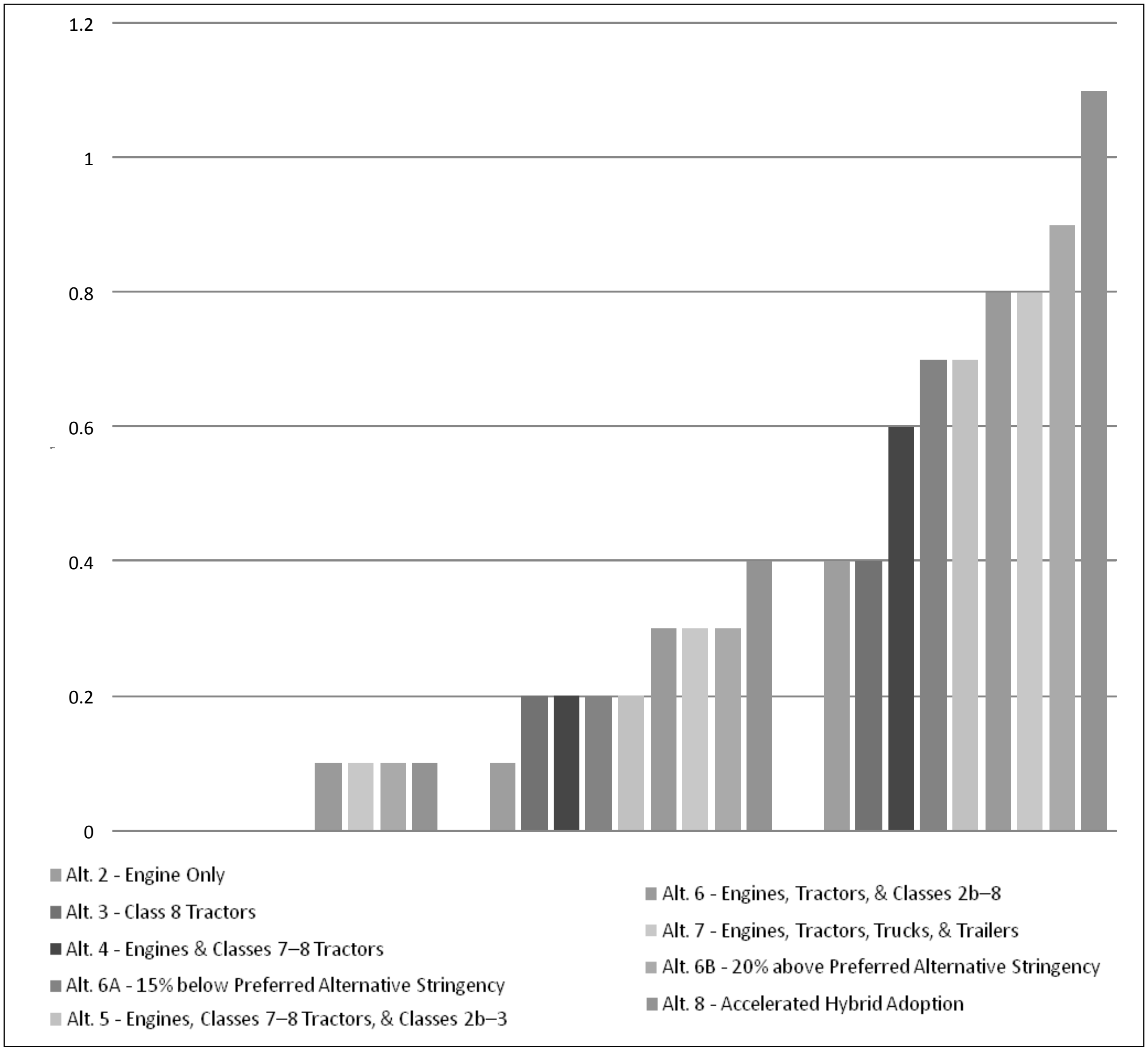
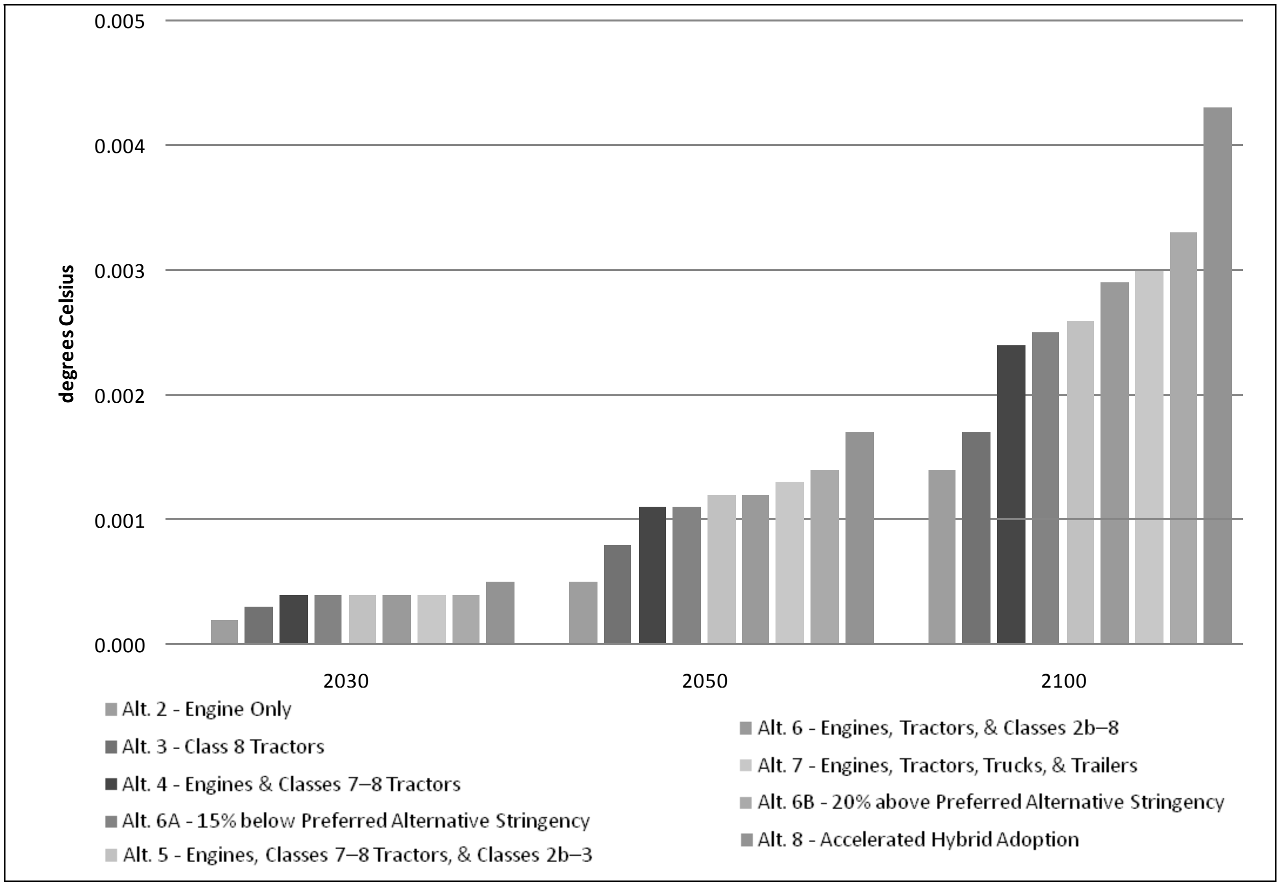


Figure 3.4.4-7. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative a/



a/ The differences in CO_2 concentration in 2030 are less than 0.1 ppm for Alt. 2, Alt. 3, Alt. 4, Alt. 6A, and Alt. 5, and therefore are not visible on the chart.

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



As Figure 3.4.4-7 shows, the reduction in the increases in projected CO_2 concentrations from each action alternative as compared to the No Action Alternative amounts to a small fraction of the projected total increases in CO_2 concentrations. The relative impact of the action alternatives, however, is demonstrated by the reduction in increases of CO_2 concentrations under the range of action alternatives. As shown in Figure 3.4.4-7, the reduction in increase of CO_2 concentrations by 2100 under Alternative 8 is more than twice that of Alternative 2.

3.4.4.3.2 Temperature

Table 3.4.4-5 above lists MAGICC simulations of mean global surface air temperature increases. Under the No Action Alternative, the global surface air temperature increase is projected to increase from 1990 levels by 0.88 °C (1.58 °F) by 2030, 1.52 °C (2.74 °F) by 2050, and 3.06 °C (5.51 °F) by 2100.[85] The differences among alternatives are small. For 2100, the reduction in temperature increase as compared to the No Action Alternative ranges from 0.001 °C (0.002 °F) under Alternative 2 to 0.004 °C (0.007 °F) under Alternative 8.

[85] 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. The actual increase in surface temperature lags the commitment due primarily to the time required to heat the ocean to the level committed by the concentrations of the greenhouse gases.

As Figure 3.4.4-8 shows, reductions in the growth of projected global mean surface temperature from each action alternative as compared to the No Action Alternative are small. The *relative* impacts of the action alternatives in comparison to one another, however, can be seen by comparing the reductions in the increases in global mean surface temperature projected to occur under Alternatives 2 and 8. As shown in Figure 3.4.4-8, the reduction in the projected growth in global temperature under Alternative 8 is more than twice that under Alternative 2.

Table 3.4.4-6 summarizes the regional changes in warming and seasonal temperatures presented in the IPCC Fourth Assessment Report. At this time, quantifying the changes in regional climate as a result of the action alternatives is not possible due to the limitations of existing climate models, but the alternatives would be expected to reduce the regional impacts in proportion to reduction in global mean surface temperature.

Table 3.4.4-6

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	*Likely* larger than global mean throughout continent and in all seasons	
	East Africa	*Likely* larger than global mean throughout continent and in all seasons	
Mediterranean and Europe	Northern Europe	*Likely* to increase more than the global mean with largest warming in winter	
	Southern and Central Europe	*Likely* to increase more than the global mean with largest warming in winter	Maximum summer temperatures *likely* to increase more than the average
	Mediterranean area	*Likely* to increase more than the global mean with largest warming in winter	
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	

Table 3.4.4-6 (continued)

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
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
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	
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	

3.4.4.3.3 Precipitation

In some areas, the increase in energy available to the hydrologic cycle might increase precipitation. Increases in precipitation result from higher temperatures causing greater water evaporation, which causes more water vapor to be available for precipitation (EPA 2009). Increased evaporation leads to increased precipitation in areas where surface water is sufficient, such as over oceans and lakes. In drier areas, the increased evaporation can actually accelerate surface drying, which can lead to drought conditions (EPA 2009). Overall, according to IPCC (Meehl *et al.* 2007a), global mean precipitation is expected to increase under all climate scenarios. Spatial and seasonal variations, however, will be considerable. Generally, precipitation increases are *very likely* to occur in high latitudes, and decreases are *likely* to occur in the sub-tropics (EPA 2009).

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 in Section 3.4.3, MAGICC does not directly simulate changes in precipitation, and undertaking precipitation modeling with a full Atmospheric-Ocean General Circulation Model was not feasible 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 (expressed 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 3.4.4-7. 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 GCAM reference scenario in this analysis because MAGICC does not directly estimate changes in global mean precipitation.[86]

Table 3.4.4-7

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. The action alternatives slightly reduce temperature increases as well as predicted increases in precipitation in relation to the No Action Alternative, as shown in Table 3.4.4-8 (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 periods between rainfall events would be longer. The mid-continental areas tend to dry during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than 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, primarily due to the lack of available AOGCMs required to estimate these changes. These models typically are 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 (such as those resulting from the action alternatives considered here) would produce results that would be difficult to resolve among scenarios. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but inconsistent in others.

[86] Although MAGICC does not estimate changes in precipitation, SCENGEN does. SCENGEN (Scenario Generator) is an added component to MAGICC 5.3v2; it scales regional results of AOGCM models based on global mean surface temperature change and regional aerosol emissions from MAGICC.

Table 3.4.4-8

Global Mean Precipitation (Percent Change) Based on RCP GCAM 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 GCAM reference Scenario and Alternative HD Standards b/			
1 No Action	0.600	1.675	2.760
2 Engine Only	0.599	1.675	2.759
3 Class 8 Tractors	0.599	1.674	2.759
4 Engines & Classes 7–8 Tractors	0.599	1.674	2.758
6A 15% below Preferred Alternative Stringency	0.599	1.674	2.758
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.599	1.674	2.758
6 Engines, Tractors, & Classes 2b–8: Preferred	0.599	1.674	2.758
7 Engines, Tractors, Trucks, & Trailers	0.599	1.674	2.758
6B 20% above Preferred Alternative Stringency	0.599	1.674	2.757
8 Accelerated Hybrid Adoption	0.599	1.673	2.757
Reduction in Global Temperature (K) for Alternative HD Standards, Mid-level Results (Compared to No Action Alternative)			
2 Engine Only	0.000	0.001	0.001
3 Class 8 Tractors	0.000	0.001	0.002
4 Engines & Classes 7–8 Tractors	0.000	0.001	0.002
6A 15% below Preferred Alternative Stringency	0.000	0.001	0.002
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.000	0.001	0.002
6 Engines, Tractors, & Classes 2b–8: Preferred	0.000	0.002	0.003
7 Engines, Tractors, Trucks, & Trailers	0.000	0.002	0.003
6B 20% above Preferred Alternative Stringency	0.000	0.002	0.003
8 Accelerated Hybrid Adoption	0.000	0.002	0.004
Global Mean Precipitation Change (%)			
1 No Action	0.87%	2.53%	4.50%
2 Engine Only	0.87%	2.53%	4.50%
3 Class 8 Tractors	0.87%	2.53%	4.50%
4 Engines & Classes 7–8 Tractors	0.87%	2.53%	4.50%
6A 15% below Preferred Alternative Stringency	0.87%	2.53%	4.50%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.87%	2.53%	4.50%
6 Engines, Tractors, & Classes 2b–8: Preferred	0.87%	2.53%	4.50%
7 Engines, Tractors, Trucks, & Trailers	0.87%	2.53%	4.50%
6B 20% above Preferred Alternative Stringency	0.87%	2.53%	4.49%
8 Accelerated Hybrid Adoption	0.87%	2.53%	4.49%
Reduction in Global Mean Precipitation Change for Alternative HD Standards (% Compared to No Action Alternative)			
2 Engine Only	0.00%	0.00%	0.00%
3 Class 8 Tractors	0.00%	0.00%	0.00%
4 Engines & Classes 7–8 Tractors	0.00%	0.00%	0.00%
6A 15% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.00%	0.00%	0.00%
6 Engines, Tractors, & Classes 2b–8: Preferred	0.00%	0.00%	0.00%
7 Engines, Tractors, Trucks, & Trailers	0.00%	0.00%	0.00%
6B 20% above Preferred Alternative Stringency	0.00%	0.00%	0.00%
8 Accelerated Hybrid Adoption	0.00%	0.00%	0.01%

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.

b/ These numbers differ slightly from those in Table 3.4.4-4 because the increases in temperature in Table 3.4.4-4 are relative to the global mean surface temperature in 1990 and those in this table represent increases relative to average temperature in the interval 1990–1999.

Table 3.4.4-9 summarizes, in qualitative terms, the regional changes in precipitation from the IPCC Fourth Assessment Report. Quantifying the changes in regional climate from the action alternatives is not possible at present, but the alternatives would be expected to reduce the relative precipitation changes in proportion to the reduction in global mean surface temperature.

Table 3.4.4-9

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		*Likely* to decrease.
	Mediterranean area	*Very likely* to decrease and precipitation days are *very likely* to decrease	*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	

Table 3.4.4-9 (continued)

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
Asia (cont'd)	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	Snow season length and snow depth are *very likely* to decrease
	Northeast USA	Annual mean precipitation is *very likely* to increase	Snow season length and snow depth are *very likely* to decrease
	Southern Canada		Snow season length and snow depth are *very likely* to decrease
	Canada	Annual mean precipitation is *very likely* to increase	Snow season length and snow depth are *very likely* to decrease
	Northernmost part of Canada		Snow season length and snow depth are *likely* to increase
Central and 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	
	New Zealand, South Island	Precipitation is *likely* to increase in the west	
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	

3.4.4.3.4 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 2009). 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 by projected temperature increases.

The state of science reflected as of the publication of the IPCC Fourth Assessment Report projects a sea-level rise of 18–59 centimeters (0.6–1.9 feet) by 2090 to 2099 (EPA 2009). This projection does not include all changes in ice-sheet flow or the potential for rapid acceleration in ice loss (Pew citing Alley *et al.* 2005, Gregory and Huybrechts 2006, and Hansen 2005). 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 Celsius of warming, and a projected sea-level rise of 0.5–1.4 meters (1.6–4.6 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 3.4.4-5 above lists the impacts on sea-level rise under the RCP GCAM Reference scenario and shows sea-level rise in 2100 ranging from 37.40 centimeters (14.72 inches) under the No Action Alternative to 37.36 centimeters (14.71 inches) under Alternative 8, for a maximum reduction of 0.04 centimeters (0.016 inches) by 2100 under Alternative 8 as compared to 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 GCAM reference scenario.[87] 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.

3.4.4.3.5 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

[87] 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.

Alternative (Alternative 6) with the GCAM reference scenario. Table 3.4.4-10 lists the results from the sensitivity analysis, which included climate sensitivities of 1.5, 2.0, 2.5, 3.0, 4.5, and 6.0 °C for a doubling of CO_2 climate sensitivity.

Table 3.4.4-10

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

HD Alternative	Climate Sensitivity (°C for 2xCO_2)	CO_2 Concentration (ppm) 2030	2050	2100	Global Mean Surface Temperature Increase (°C) 2030	2050	2100	Sea-level Rise (cm) 2100
Alternative 1 (No Action)								
	1.5	441.253	512.77	757.689	0.538	0.912	1.761	15.30
	2.0	442.152	515.091	767.457	0.669	1.140	2.240	28.27
	2.5	442.933	517.145	776.500	0.782	1.340	2.673	33.10
	3.0	443.618	518.972	784.869	0.880	1.516	3.064	37.40
	4.5	445.237	523.397	806.468	1.111	1.936	4.037	47.81
	6.0	446.403	526.678	823.758	1.275	2.240	4.780	72.89
Alternative 6 (Engines, Tractors, & Classes 2b–8) b/								
	1.5	441.183	512.537	757.003	0.538	0.911	1.759	15.28
	2.0	442.082	514.857	766.758	0.669	1.139	2.238	28.25
	2.5	442.863	516.909	775.788	0.781	1.339	2.670	33.08
	3.0	443.548	518.735	784.146	0.880	1.515	3.061	37.37
	4.5	445.167	523.158	805.716	1.110	1.934	4.033	47.78
	6.0	446.332	526.436	822.982	1.274	2.238	4.776	72.85
Reduction Compared to No Action								
	1.5	0.070	0.233	0.686	0.000	0.001	0.002	0.02
	2.0	0.070	0.234	0.699	0.000	0.001	0.002	0.02
	2.5	0.070	0.236	0.712	0.000	0.001	0.002	0.02
	3.0	0.070	0.237	0.723	0.000	0.001	0.003	0.03
	4.5	0.070	0.239	0.752	0.000	0.001	0.004	0.03
	6.0	0.071	0.242	0.776	0.000	0.002	0.004	0.04

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b/ Preferred Alternative

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 estimated warming but also estimated sea-level rise and CO_2 concentration. Sea level is influenced by temperature. CO_2 concentrations are affected by temperature-dependent effects of ocean carbon storage (higher temperatures result in lower aqueous solubility of CO_2).

As shown in Table 3.4.4-10, simulated atmospheric CO_2 concentrations in 2030, 2050, and 2100 are a function of changes in climate sensitivity. The small changes in concentration are due primarily to small changes in the aqueous solubility of CO_2 in ocean water: slightly warmer air and sea surface temperatures lead to less CO_2 being dissolved in the ocean and slightly higher atmospheric concentrations.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, as shown in Table 3.4.4-10. In 2030, the impact is low due primarily to the limited 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 larger change in emissions. In 2100, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative ranges from 0.002 °C (0.004 °F) for the 1.5 °C (2.7 °F) climate sensitivity to 0.004 °C (0.007 °F) for the 6.0 °C (10.8 °F) climate sensitivity, as listed in Table 3.4.4-10. 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 3.4.4-10. Scenarios with lower climate sensitivities show generally smaller increases in sea-level rise; at the same time, the reduction in the increase in sea-level rise is lower under the Preferred Alternative than under the No Action Alternative. Conversely, scenarios with higher climate sensitivities have higher sea-level rise; again, however, 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 0.02–0.04 centimeter (0.008–0.016 inch), depending on the climate sensitivity.

3.5 OTHER POTENTIALLY AFFECTED RESOURCE AREAS

This section describes the environmental resource areas that may be impacted by the proposed action and alternatives–water resources (Section 3.5.1), biological resources (Section 3.5.2), safety and other impacts to human health (Section 3.5.3), hazardous materials and regulated wastes (Section 3.5.4), noise (Section 3.5.5), and environmental justice (Section 3.5.6). The discussions of the resource areas that follow include a discussion of the affected environment (the current threats to that resource area from non-global climate change impacts relevant to the proposed standards) and environmental consequences of the proposed standards on these resource areas (primarily qualitative assessments of any potential consequences of the alternatives, positive or negative).

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. This section and 3.5.1.2 describe existing and projected future threats to these resources from non-global climate change impacts related to the proposed action. 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 have come from a number of sources during recent decades, including increased water demand for human and agricultural use, pollution from point and nonpoint 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.

Oil refineries, which produce gasoline and diesel fuel, and the motor vehicles that combust petroleum-based fuels are major sources of air pollutants that contribute to the formation of acid rain and can harm surface water (*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 showed evidence of 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 extraction, 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" during 1973 to 2000, as defined under the CAA, 83.8 percent was deposited in internal or headland waters and within 3 miles of shore, with 17.5 percent spilled from pipelines, often in inland areas (EPA 2004). The environmental impacts on and recovery time for individual water bodies vary based on a number of factors (*e.g.*, salinity, water movement, wind, temperature), with faster moving waters and warm waters recovering more quickly (EPA 2008).

The primary waste product of oil extraction is a highly saline liquid called "produced water," which can contain metals and other potentially toxic components. Produced water and other oil extraction wastes are most commonly disposed of by reinjecting them into the oil 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). *See* Section 3.5.4.1.1 for more on produced water.

In April 2010, an explosion on the Deepwater Horizon drill rig in the Gulf of Mexico caused the largest marine oil spill in U.S. history approximately 41 miles off the coast of Louisiana. Clean-up efforts are ongoing and the full extent of the environmental and economic damages is uncertain but could be significant. This event, although severe, is relatively rare in offshore drilling. According to EIA, offshore drilling in the Gulf of Mexico accounts for 23.5 percent of U.S. oil production. This event could have an impact on the future rate of oil production in the Gulf of Mexico, as noted in Section 3.2.1.

3.5.1.2 Environmental Consequences

Each of the nine action alternatives considered in this EIS is expected to reduce fuel consumption as compared to the No Action Alternative. As a result, the extraction, refining, and combustion of oil should also decline. This decline might result in less water pollution due to oil and other chemical spills.

As discussed in Section 3.3, although emissions of some air pollutants, including PM, NO_x, and CO increase in some model years for some alternatives, each action alternative is generally expected to decrease the amount of SO_2, NO_x (except Alternative 2 in 2030 and 2050) and other air pollutants in relation to the No Action Alternative (Alternative 1) levels. Reductions in these pollutant levels would be the result of lower petroleum fuel consumption for HD vehicles. NHTSA expects that lower emissions of SO_2 and NO_x would lead to a decrease in 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 fresh water by decreasing acidification.

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 recognize species of concern to which they have assigned additional protections. As discussed below, the production and combustion of fossil fuels are identified as the relevant source of impacts to biological resources including threatened or endangered species. 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 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. As the authors of one study noted, "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" (O'Rourke and Connolly 2003 citing Borasin *et al.* 2002).

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. 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.

As noted above, the process of oil extraction and the combustion of fuel during motor vehicle operation result in air emissions that affect air quality and can contribute to acid rain. These effects can result in negative impacts on plants and animals. Once present in surface waters, air pollutants can cause acidification of water bodies, affecting the function of freshwater ecosystems.

Acid rain has also been shown to affect forest ecosystems negatively, both directly and indirectly. 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 led 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 nitrogen in these systems is a major cause of eutrophication[88] in freshwater and marine water bodies. Eutrophication can ultimately result in the death of fish and other aquatic animals, as well as harmful algal blooms. Acid rain enhances eutrophication of aquatic systems through the deposition of additional nitrogen (Lindberg 2007).

3.5.2.2 Environmental Consequences

Reductions in the rate of fuel consumption under all of the action alternatives (except Alternative 2 in 2030 and 2050) would lead to decreases in the release of SO_2 and NO_x as compared to the No Action Alternative. Reductions in acid rain and anthropogenic nutrient deposition could lower levels of eutrophication in surface waters and could slow direct impacts to ecosystems and soil leaching.

3.5.3 Safety and Other Impacts to Human Health

NHTSA has analyzed how future improvements in fuel efficiency in the HD sector 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.

NHTSA and EPA have been considering the effect of vehicle weight on vehicle safety for the past several years in the context of our Joint Rulemaking for light-duty vehicle CAFE and GHG standards, consistent with NHTSA's long-standing consideration of safety effects in setting CAFE

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[88] 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, 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 (August 26, 2010).

standards. The latest analysis by NHTSA for the MYs 2012–2016 Final Rule found that reducing the weight of heavier light trucks had a positive overall effect on safety, reducing fatalities.[89]

In the context of the current rulemaking for the HD fuel consumption and GHG standards, one would expect that reducing the weight of HD vehicles similarly would, if anything, have a positive impact on safety. Given the large difference in weight between light-duty vehicles and HD vehicles, and even larger difference between light-duty vehicles and HD vehicles with loads, however, the agencies believe that the impact of weight reductions of HD vehicles would not have a noticeable impact on safety for any of these classes of vehicles.

The agencies recognize that conducting further study and research on the interaction of mass, size, and safety is important to assist future rulemakings, and we expect that the collaborative interagency work currently ongoing to address this issue for the light-duty vehicle context might also inform our evaluation of safety effects for the final HD vehicle rule.

3.5.4 Hazardous Materials and Regulated Wastes

3.5.4.1 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 the purpose 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. Batteries, such as those used in hybrid vehicles, are considered universal wastes by EPA (40 CFR Part 273) and, therefore, can be collected under the streamlined collection standards that facilitate environmentally sound collection and proper recycling and treatment.

3.5.4.1.1 Wastes Produced during the Extraction Phase of Oil Production

As noted above, 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 2000). 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). Besides produced water, 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 (American Petroleum Institute 2000, EPA 2000).

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

[89] “Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2012 - MY 2016 Passenger Cars and Light Trucks” NHTSA, March 2010 (Docket No. NHTSA-2009-0059-0344.1).

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 2000).

3.5.4.1.2 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 1995). 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 1995). EPA reports that 9 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 ethylbenzene (EPA 1995). 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 methyl tert-butyl ether [MTBE]), and chemical feedstocks (propylene, ethylene, and naphthalene) (EPA 1995). Spent sulfuric acid is by far the most commonly produced toxic substance; it is generally reclaimed, however, rather than being released or transferred for disposal (EPA 1995).

Wastes released during the oil-refining process can cause environmental impacts on 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 1995). 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 1995). Ammonia is a form of nitrogen that can contribute to eutrophication in surface waters.

3.5.4.1.3 HD Vehicle Production, Assembly, and Decommissioning

HD vehicles and equipment, and businesses engaged in the manufacture and assembly of HD vehicles, 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 1995). These solvents are used to clean metal and also are used in the vehicle-finishing process during assembly and painting (EPA 1995). Other industry wastes include metal paint and component-part scrap.

In addition, HD vehicles may incorporate hybrid power trains and on-board energy storage systems; the range of commercial electrochemical battery types that are either currently available or under development for use in HD Hybrid Electric Vehicles (HEVs) involve different environmental considerations vis-à-vis potential releases of component materials. Examples include advanced lead-acid (PbA), conventional nickel cadmium (NiCd) and nickel metal hydride (NiMH), and sodium nickel chloride (NaNiCl) batteries, and multiple options for emerging lighter and higher capacity lithium ion (Li-ion) batteries. These battery types encompass a broad range of potential battery chemistries, with diverse performance, safety, and toxicity tradeoffs.

Beyond these vehicle body materials, the standards could induce increases in production and use of electrochemical batteries for HD HEVs.[90] Although the agencies expect that proposed standards could be met without increases in the production of HEVs, the proposed standards provide credit for the production of HEVs, and could thus result in some increased HEV production. The agencies have not estimated the extent to which this increased production might occur, or which battery types and chemistries might be utilized by HD HEV models.

As mentioned above, batteries such as those used in HEVs are considered universal wastes by EPA under 40 CFR Part 273, and therefore can be collected under streamlined collection standards that facilitate environmentally sound collection and proper recycling and treatment. A report by the Electric Power Research Institute (EPRI) stated that, at the end of their life, HEV batteries can, depending on design, be nearly fully recycled and transformed into new batteries, or can have secondary uses in stationary applications (EPRI 2001, 2004). The DOE National Renewable Energy Laboratory (NREL) has also recently initiated a three-year study of potential secondary uses of Li-ion vehicle batteries, to help improve their cost effectiveness (NREL 2010). Because there is uncertainty regarding the outlook for different battery types, there is corresponding uncertainty regarding any projected future environmental impacts of battery production, use, secondary reuse and recycling, or end-of-life landfill disposal.

Life-cycle analysis of materials resource, energy intensiveness, and the environmental issues associated with the production, operation and disposal of automotive batteries are active areas of research, especially for advanced Li-ion chemistries for hybrid and electric vehicles. For example, recent studies have developed methodologies to characterize and quantify the environmental benefits of plug-in HEVs (PHEVs) for a range of battery types, weights, and charging patterns (Shiau *et al.* 2009). As another example, emerging Li-ion automotive battery designs for HD applications include such variants as lithium ion cobalt oxide, lithium iron phosphate, and lithium manganese oxide, as well as other variants such as lithium titanium oxide and lithium salt with nickel cobalt aluminum for the cathode with a graphite anode (Calstart 2010). The materials resource and recyclability issues associated with advanced battery chemistries such as these for HEVs were recently summarized in studies by Argonne National Laboratory (Argonne 2009, Gaines and Nelson 2010). Further, a recent life-cycle assessment of different types of traction batteries for hybrid and battery-electric vehicles in the EU context has assigned environmental scores to different battery chemistries. This study indicated that NiMH and Li-ion batteries have much lower life-cycle environmental burden than other battery types considered by the authors (Matheys *et al.* 2008).

It is possible that adverse environmental effects of increased HEV battery utilization could be mitigated through good battery design, production, recycling, and disposal practices. Currently, about 99 percent of automotive lead acid batteries in the United States are voluntarily recycled, as are the rechargeable NiMH batteries currently used in hybrid cars (Birth of Industry 2009). Some types of Li-ion batteries have more benign compositions, using less toxic heavy metals, and corrosive acids and electrolytes, and are therefore safer for landfill disposal. Furthermore, as Li-ion battery technology continues to develop and mature, the materials handling industry is developing corresponding recycling and disposal processes: for example, Toxco reports using cryogenic chilling (to slow chemical reactions involving lithium) and remote process control to maintain safety for personnel involved in recycling of Li-ion batteries (Toxco 2003).

Some international practices for battery production, operation and recycling, or end-of-life disposal that minimize potentially adverse environmental impacts, could serve as models for handling

[90] In addition to electrochemical batteries, other energy storage technologies not considered here could be applied to hybridize HD powertrains. Examples include ultracapacitors, high-speed flywheels, and hydraulic accumulators.

future HD vehicle batteries in the United States. For instance, in 2006 the EU approved a directive on batteries and accumulators waste (ECE 2010) and adopted subsequent requirements to ensure standardized collection and recyclability of batteries and to prevent or minimize adverse impacts of toxic chemicals in batteries disposed in landfills.

The United States recently has undertaken a range of technology development and demonstration partnership efforts to foster the minimization of any waste issues related to electrochemical batteries for use in hybrid-electric highway vehicles. The EPA Design for the Environment Program has recently initiated a partnership with industry on "Assessing Life Cycle Impacts of Lithium Ion batteries" (EPA 2010a, 2010b). Vehicles and technologies with reduced environmental footprints are also being pursued through ongoing DOE research, development, and demonstration partnerships with industry, such as:

- The DOE Applied Battery Research Program,[91] a broad-based effort led by the DOE National Laboratories to address barriers to commercialization of lithium ion batteries, including designs for improved performance, durability, manufacturability, and recyclability;
- The 21st Century Truck Partnership[92] under the DOE Vehicle Technologies Program;
- The U.S. Advanced Battery Consortium,[93] a component of the United States Council for Automotive Research (USCAR) industry partnership;
- The USCAR Vehicle Recycling Partnership[94] developing "green" materials and separator technology advances to enable vehicle End-of-Life recycling; and
- The DOE FreedomCAR and Fuel Partnership[95] within the DOE Advanced Vehicles Technologies and Fuels programs includes major research thrusts on battery and powertrain for energy management optimization in HD vehicles.

3.5.4.2 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. These effects would likely be small if they occurred, however, because of the limited overall effect of the proposed action and alternatives on these areas.

All of the alternatives could lead to the use of some lighter weight materials in HD vehicles, depending on the mix of methods manufacturers use to meet the proposed HD fuel efficiency requirements, economic demands from consumers and manufacturers, and technological developments. If manufacturers pursued vehicle downweighting in response to the standards, a net increase in the waste stream could occur, as discussed above. Uncertainty is still substantial, however, regarding how manufacturers would choose to implement the standards, including whether they would use lighter weight materials. Therefore, we decline to quantify the effects on waste produced during the refining process due to downweighting.

[91] DOE (2008).
[92] *See* details related to HD goals, including advanced batteries, in DOE (2007).
[93] USABC (2006).
[94] VRP (2006).
[95] Partnership activities include batteries and other electrochemical energy storage technology development, and demonstration.

3.5.5 Noise

3.5.5.1 Affected Environment

Excessive amounts of noise, which is measured in decibels, can present a disturbance and a hazard to human health at certain levels. 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.

3.5.5.2 Environmental Consequences

NHTSA predicts that vehicle use will increase under all of the alternatives which would result in increases in vehicle road noise. 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. Location-specific analysis of noise impacts, however, is not possible based on available data.

All of the alternatives could lead to an increase in use of hybrid technologies, depending on the methods manufacturers use to meet the new requirements, economic demands from consumers and manufacturers, and technological developments. An increased percentage of hybrid technologies could result in reduced road noise, potentially offsetting some of the increase in road noise predicted to result from increased VMT. Uncertainty is substantial, however, regarding how manufacturers would choose to implement the standards, including whether they would use hybrid technologies. Therefore, we decline to quantify the effects on noise due to hybridization.

3.5.6 Environmental Justice

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 as defined by the U.S. Census Bureau. The term “environmental justice populations” refers to the group comprising minorities and low-income communities as defined.

3.5.6.1 Affected Environment

Federal agencies must identify and address disproportionately high and adverse impacts on 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 are the identified relevant sources of impact on environmental justice populations for this analysis. In addition, for a discussion of the effects of climate change on environmental justice populations, *see* Section 4.6.

Potential impacts of the oil exploration and extraction processes 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 on culturally or economically important plants and animals as a result of a spill or hazardous-material release (O'Rourke and Connolly 2003, Kharaka and Otton 2003).

Research studies indicate that minority and low-income populations often disproportionately reside near high-risk polluting facilities, such as oil refineries (Pastor *et al.* 2001, Graham *et al.* 1999, O'Rourke and Connolly 2003), and "mobile" sources of air toxins and pollutants, as in the case of populations residing near highways (Morello-Frosch 2002, Jerrett *et al.* 2001, O'Neill *et al.* 2003). Populations near refineries could be disproportionately affected by exposure to potentially dangerous petroleum and by-products of the refining process, such as benzene (Borasin *et al.* 2002). Exposure to the toxic chemicals associated with refineries, primarily by refinery workers, has been shown to be related to increases in certain diseases and types of cancer (Pukkala 1998, Chan *et al.* 2006); the precise nature and severity of these health impacts are still under debate. Pollutants emitted primarily by transportation sources, such as NO_x and CO, are often found in higher concentrations near roadways and other emission sources (Zhou and Levy 2007). These pollutants have been reported in higher concentrations in areas with high proportions of disadvantaged populations, such as minorities and low-income groups (Jerret *et al.* 2001, Morello-Frosch 2002). Recent reviews by health and medical researchers indicate a consensus that proximity to high-traffic roadways could result in adverse cardiovascular and respiratory effects, among other possible impacts (HEI 2010, Heinrich and Wichmann 2004, Salam *et al.* 2008, Adar and Kaufman 2007). The exact nature of the relationship between these health impacts, traffic-related emissions, and the influence of confounding factors or modifying factors such as traffic noise are not fully understood at this time (Samet 2007, HEI 2010).

3.5.6.2 Environmental Consequences

As discussed in Section 3.3, the decrease in emissions predicted to occur as a result of the proposed action (as compared to the No Action Alternative) is not evenly distributed due to the increase in VMT from the rebound effect and regional changes in upstream emissions. As a result, emissions of some criteria and toxic air pollutants, such as $PM_{2.5}$ and DPM (pollutants associated with negative health effects and economic impacts) are predicted to increase in some air quality nonattainment areas where HD vehicle traffic is more prevalent. Specifically, large nonattainment areas like Los Angeles, California could have large increases in $PM_{2.5}$ and DPM. Tables 3.3.3-8 and D1-1 through D1-33 in Appendix D to this document present information about emission changes for nonattainment areas.

In a 2009 report to EPA examining air emissions associated with goods movement, the National Environmental Justice Advisory Council stated that, "across the country, there are many communities near goods movement infrastructure that consist of large populations of low-income and minority residents. These environmental justice communities tend to have greater exposure to poor air quality as a result of diesel emissions from transportation facilities with high traffic density" (NEJAC 2009). For example, a Connecticut Department of Environmental Protection truck stop electrification project completed in September 2010 stated that 16 of the 19 planned project sites were within or immediately adjacent to environmental justice communities (CTDEP 2009). Therefore, environmental justice populations could be disproportionately affected due to their disproportionately close proximity to truck stops and highways.

3.6 UNAVOIDABLE IMPACTS AND IRREVERSIBLE AND IRRETRIEVABLE RESOURCE COMMITMENT

3.6.1 Unavoidable Adverse Impacts

The NHTSA proposed action is to implement an HD Fuel Efficiency Improvement Program for MYs 2016–2018 for most HD regulatory categories, with voluntary compliance standards for MYs 2014–2015. Under Alternative 1 (No Action), neither NHTSA nor EPA would issue a rule regarding fuel-efficiency improvement or GHG emissions for MYs 2014–2018. Each of the nine action alternatives (Alternatives 2 through 8) would result in a decrease in CO_2 emissions and associated climate change effects and a decrease in energy consumption as compared to the No Action Alternative. Total energy consumption and CO_2 emissions by HD vehicles in the United States, however, are projected to continue to increase under all of the alternatives as a result of continued economic and population growth (EIA 2010).

Based on NHTSA's current understanding of global climate change, certain effects are likely to occur as a consequence of accumulated total GHG emissions in Earth's atmosphere. Neither the proposed action nor the alternatives would prevent these effects. As described in Section 3.4.4.1, each action alternative could contribute to reductions in global GHG emissions from the levels that would occur if average fuel efficiency were to continue at its current levels (the No Action Alternative), thus diminishing these anticipated changes in the global climate.

Emissions of SO_x and VOCs would decrease 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 the emissions would have no unavoidable adverse impacts. Emissions of CO, NO_x, acetaldehyde, acrolein, benzene, and formaldehyde would increase (except for NOx and benzene in 2018) under Alternative 2, but would decrease for all other action alternatives and analysis years as compared to their levels under the No Action Alternative. Any adverse health impacts associated with these emissions would similarly increase under Alternative 2 but are expected to be reduced under Alternatives 3 through 8. These emissions would have no unavoidable adverse impacts under Alternatives 3 through 8.

According to NHTSA's analysis, emissions of $PM_{2.5}$, 1,3-butadiene, and DPM also could increase under certain alternatives and for certain years from the levels that are projected under the No Action Alternative. Thus, the potential for unavoidable impacts depends on the alternative selected by the decisionmaker. The maximum projected increases in emissions compared to the No Action Alternative are 0.3 percent for CO (under Alternative 2 in 2050), 0.2 percent for NO_x (under Alternative 2 in 2050), 2.3 percent for $PM_{2.5}$ (under Alternative 3 in 2050), 0.6 percent for acetaldehyde (under Alternative 2 in 2050), 0.6 percent for acrolein (under Alternative 2 in 2050), 0.2 percent for benzene (under Alternative 2 in 2050), 0.5 percent for 1,3-butadiene (under Alternative 2 in 2030), 3.0 percent for DPM (under Alternative 3 in 2050), and 0.5 percent for formaldehyde (under Alternative 2 in 2050). Under the Preferred Alternative (Alternative 6), the increases in emissions in 2030 compared to the No Action Alternative would be 369 tons (1.0 percent) for $PM_{2.5}$, 0.5 tons (0.1 percent) for 1,3-butadiene, and 301 tons (1.1 percent) for DPM.

Increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the proposed HD Fuel Efficiency Improvement Program under the action alternatives, due to increases in VMT. These increases would represent a slight decline in the rate of reductions being achieved by implementation of CAA standards.

3.6.2 Short-term Uses and Long-term Productivity

The nine action alternatives (Alternatives 2 through 8) 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 HD vehicles to meet the proposed HD fuel consumption standards under the action alternatives. NHTSA cannot predict the specific technologies manufacturers would apply to meet the proposed fuel consumption standards under any of the nine action alternatives; NHTSA estimates that existing technologies and existing vehicle production facilities, however, could be utilized to meet the proposed fuel consumption standards under the action alternatives. Some vehicle manufacturers may need to commit additional resources to existing, redeveloped, or new production facilities to meet the proposed standards. Such short-term uses of resources by vehicle manufacturers to meet the proposed 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 through 3.2.3-4 (*see* Section 3.2 of this EIS) summarize fuel consumption under each alternative. For the Preferred Alternative (Alternative 6: Engines, Tractors, & Class 2b–8 Vehicles), the fuel savings[96] over the No Action Alternative in 2050 would be 8.94 billion gallons for the HD vehicle fleet.

As discussed in Section 3.6.2, manufacturers would need to apply various technologies to the production of HD vehicles to meet the proposed HD fuel consumption standards. NHTSA cannot predict which specific technologies manufacturers would apply to meet the standards under any of the nine action alternatives. Again, although NHTSA expects that existing technologies and existing vehicle production facilities could be utilized to meet the proposed fuel efficiency standards under each of the nine action alternatives, some vehicle manufacturers, may 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) that manufacturers would expend in meeting the proposed standards would depend on the methods and technologies manufacturers select. Commitment of resources for manufacturers to comply with the standards would tend to be offset by the fuel savings from implementing the standards.

[96] Fuel savings is expressed as the sum of the gallons of diesel fuel and gasoline without adjustment for the energy content per gallon of each fuel.

Chapter 4 Cumulative Impacts

4.1 INTRODUCTION

The Council on Environmental Quality (CEQ) regulations implementing the National Environmental Policy Act (NEPA) identify environmental and other impacts that Federal agencies must address and consider to satisfy the requirements of NEPA. These include permanent, short-term impacts as well as long-term direct, indirect, and cumulative impacts.

CEQ's regulations implementing NEPA 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." 40 CFR § 1508.7. 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 (CEQ 1997):

- 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.

NHTSA uses the Energy information Administrations (EIA) Annual Energy Outlook 2010 (EIA 2010) Reference Case forecast of increases in the average fuel efficiency (in miles per gallon [mpg]) of "light commercial trucks" (8,500–10,000 pounds gross vehicle weight rating [GVWR]) and "freight trucks" (greater than 10,000 pounds GVWR). These projections reflect a combination of anticipated future actions by producers, purchasers, and operators of these vehicles that result in continuing fuel efficiency gains through the AEO 2010 forecast horizon of 2035. Specifically, the AEO 2010 forecasts of fuel economy reflect the influence of changes in the availability, cost, and effectiveness of technologies to increase truck's fuel efficiency, as well as projected fuel prices and patterns of vehicle use. The forecasts incorporate the effects of previously adopted emisisons standards for MD and HD vehicles but do *not* reflect the provision of the Energy Independence and Security Act of 2007 (EISA) requiring NHTSA to develop fuel economy standards for meduim- and heavy-duty vehicles, because NHTSA had not yet taken action with respect to that provision at the time of publication of the AEO 2010 forecast.[1] The current proposal represents NHTSA's response to that requirement. NHTSA believes the AEO forecast

[1] The AEO 2010 forecasts assume that the fuel economy of Class 2b trucks will increase at the same rate as smaller gasoline light trucks, which are subject to previously adopted CAFE standards. However, the recently-adopted light truck CAFE standards apply only to model years 2012-2016, and thus do not affect the AEO 2010 forecast of growth in Class 2b fuel economy for model years 2019 and beyond.

represents a reasonable proxy of foreseeable actions regarding increases in fuel efficiency in the HD sector.

Chapter 4 addresses areas of the quantitative analyses presented in Chapter 3, with particular attention to energy, air quality, and climate, and describes the indirect cumulative effects of climate change on a global scale. The alternatives in the tables and figures in this chapter are arranged in ascending order of fuel savings, to aid in the environmental analysis and the comparison of alternatives. Consequently, the alternatives appear out of numerical sequence.

The discussion of indirect cumulative effects of climate change presented in Section 4.5 of this EIS summarizes the comprehensive qualitative analysis presented in Chapter 4.5 of NHTSA's EIS for MYs 2012–2016 CAFE standards for passenger cars and light trucks, issued April 1, 2010.[2] In addition, the discussion in Chapter 4.5 of this EIS presents relevant developments in climate change science published since this most recent CAFE EIS.

4.1.1 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 encompass past, present, and reasonably foreseeable future actions that might affect the environmental resources of concern. The time frame for this cumulative impacts analysis is the same as Chapter 3; it extends through 2050 for the energy and air quality analysis and through 2100 for climate change. The timeframes are based on the reasonable ability to model fuel consumption and emissions of the heavy duty (HD) sector. As was also the case in Chapter 3, the inherently long-term nature of the effects of increasing GHG accumulations on global climate requires that fuel consumption and GHG emissions for the proposed alternatives be estimated over a longer time span.

The cumulative impacts analyzed in this chapter include those attributable to actions occurring both prior and subsequent to the current action. The analysis considers these potential cumulative impacts on a national as well as a global basis.

4.1.2 Reasonably Foreseeable Future Actions

The analysis in Chapter 4 is broader than the analysis in Chapter 3 because it addresses the effects of the HD Fuel Efficiency Improvement Program together with those of reasonably foreseeable future actions, consistent with NEPA's requirement to consider such actions as part of the analysis of cumulative impacts. Specifically, NHTSA's analysis of cumulative impacts reported in this chapter reflects the effects of continuing increases in HD vehicle fuel efficiency for model years after 2018 under both the No Action Alternative and each action alternative, which the agency believes meets the NEPA definition of a "reasonably foreseeable action." This differs from a key assumption underlying the analysis previously reported in Chapter 3, namely that the fuel efficiency of new HD vehicles under the No Action Alternative as well as each action alternative would remain constant at its 2018 level during all subsequent model years.

The analysis reported in Chapter 3 was intentionally structured to reflect only the impacts of alternative fuel efficiency requirements for MYs 2014–2018 under the various action alternatives, because that analysis was intended to isolate the direct and indirect effects of the proposed action alone. Thus the analysis reported in Chapter 3 did not show the environmental effects of fuel efficiency

[2] *See* NHTSA 2010. A complete version of NHTSA's EIS for the MYs 2012–2016 CAFE standards is available online at http://www.nhtsa.gov/fuel-economy.

improvements beyond those anticipated to result from the proposed action; instead, it assumed that all new vehicles added to the fleet after 2018 would have the same fuel efficiency as the proposed rule would require MY 2018 vehicles to attain. In contrast, the analysis of cumulative impacts reported in Chapter 4 reflects the same estimates of increases in fuel efficiency for MYs 2014–2018 that were projected to occur under each action alternative in Chapter 3, together with the additional impacts of continuing increases in HD vehicle fuel efficiency projected for model years after 2018.

As noted above, the gains in HD vehicle fuel efficiency for 2019 and beyond are derived from the Energy Information Administration's (EIA) Annual Energy Outlook 2010 (EIA 2010) Reference Case forecast of increases in the average fuel efficiency (in miles per gallon [mpg]) of "light commercial trucks" (8,500–10,000 pounds gross vehicle weight rating [GVWR]) and "freight trucks" (greater than 10,000 pounds GVWR).

The AEO "light commercial truck" category is comparable to the Class 2b segment of the HD pickups and vans category employed in this EIS, while the AEO "freight truck" category is comparable to the vocational vehicle and tractor segments of the HD vehicle market in this EIS. Therefore, the analysis of cumulative impacts reported in this chapter for HD pickups and vans reflects the AEO 2010 forecast of technology- and market-driven gains in the fuel efficiency of "light commercial" trucks after 2018. Similarly, the cumulative impacts reported in this chapter for tractors and vocational vehicles reflect the AEO forecast percentage gains in the fuel efficiency of "freight trucks" after 2018, which reflect continuing technological innovations and market forces.

Table 4.1.2-1 shows the projected gains in fuel efficiency after 2018 that are reflected in the cumulative impacts analysis reported in this chapter but were not reflected in the impacts of the proposed action alone reported previously in Chapter 3. Based on the AEO forecast for "light commercial truck" fuel efficiency gains, Table 4.1.2-1 shows that the overall fuel efficiency of HD pickups and vans is

Table 4.1.2-1

Cumulative Percent Increase in HD Vehicle Average Fuel Efficiency vs. 2018

Calendar Year	HD Pickups and Vans (Class 2b-3)	Vocational Vehicles (Class 2b-8) and Tractors (Class 7-8)
2019	1.48%	0.95%
2020	2.96%	1.81%
2021	4.38%	2.60%
2022	5.73%	3.30%
2023	7.01%	3.92%
2024	8.21%	4.46%
2025	9.34%	4.96%
2026	10.38%	5.40%
2027	11.35%	5.81%
2028	12.27%	6.18%
2029	13.13%	6.53%
2030	13.95%	6.83%
2031	14.72%	7.11%
2032	15.46%	7.38%
2033	16.15%	7.65%
2034	16.81%	7.88%
2035	17.45%	8.09%
2036 through 2050	17.45%	8.09%

forecast to be 1.48 percent higher in 2019 than in 2018, while by 2035 the overall fuel efficiency of HD pickups and vans is forecast to be 17.45 percent higher than in 2018. Similarly, based on the AEO forecast for "freight truck" fuel efficiency gains, Table 4.1.2-1 shows that the overall fuel efficiency of vocational vehicles and tractors is forecast to be 0.95 percent higher in 2019 than in 2018, and 8.09 percent higher by 2035 than in 2018. The cumulative impacts reported in this chapter also assume that the cumulative percentage gains in fleet-wide fuel efficiency relative to 2018 for both HD pickups and vans and vocational vehicles and tractors remain the same for each year from 2036 through 2050 as those projected to occur in 2035, the last year of the AEO forecast horizon.

The analysis of cumulative impacts in the NHTSA EIS for MYs 2012–2016 CAFE standards for passenger cars and light trucks[3] also reflected AEO projections for ongoing increases in light vehicle fuel efficiency (after 2016), but the methodology used in the CAFE analysis differed from that used in this analysis of cumulative impacts, reflecting differences in how the AEO measures fuel efficiency in its projections for light vehicles versus HD vehicles.

AEO projections of light vehicle fuel efficiency apply to the average mpg of new light-duty vehicles produced during each model year. In the cumulative impacts analysis for the CAFE EIS, these AEO mpg projections were reflected as inputs to the NHTSA/Volpe CAFE compliance model. The Volpe model then calculated fuel use and VMT associated with the combined effect of increases in CAFE levels projected to occur through MY 2016 under each action alternative plus the effect of continuing increases in fuel economy after MY 2016 projected by AEO 2010. The Volpe model also reflected the replacement of older light vehicles over time, so the average fleet-wide MPG of the entire light vehicle fleet continued to increase during each calendar year through 2050, as newer vehicles with higher model year mpg accounted for an increasing proportion of the overall vehicle stock over time.

In contrast, AEO forecasts for "freight truck" and for " commercial light truck" fuel efficiency do not apply to new vehicles produced during each model year, but instead to the overall average mpg for the entire fleet of HD vehicles in use, which includes both new vehicles and those produced during many previous model years. Therefore, AEO projections for cumulative gains in average mpg after 2018, shown in Table 4.1.2-1, reflect the combined effect of gains in new vehicle mpg and continuing increases in the shares of the HD vehicle fleet and total HD vehicle use that are represented by newer vehicles with higher mpg levels.

Thus the methodology used in this analysis of the cumulative impacts of HD vehicle fuel consumption standards first calculates the average mpg projected to occur for the entire HD vehicle stock in use during each calendar year after 2018 under each alternative, exactly as in Chapter 3. Next, that average mpg is increased for each future year by the cumulative percentage gains in fuel efficiency shown previously in Table 4.1.2-1. This methodology involves the following analytical steps:

- The average mpg for the entire stock of HD pickups and vans in use under each alternative for every year after 2018 is calculated by dividing total VMT of commercial light trucks projected in AEO 2010 by their total fuel consumption.

- The corresponding average mpg for the entire stock of HD pickups and vans in use under each alternative analyzed in this chapter, is calculated by adjusting the average mpg for every year after 2018 to reflect the cumulative percentage fuel efficiency gains shown in Table 4.1.2-1. For example, the calculated average mpg for the entire stock of HD pickups and vans in use under each alternative in Chapter 3 in each year from 2035 through 2050 is

[3] *See* NHTSA 2010. A complete version of NHTSA's EIS for the MYs 2012–2016 CAFE standards is available online at http://www.nhtsa.gov/fuel-economy.

multiplied by 1.1745 to calculate the average mpg in this chapter for the corresponding year and alternative.

- The average mpg for the entire stock of vocational vehicles and tractors in use under each alternative for every year after 2018 is calculated by dividing total VMT of freight trucks projected in AEO 2010 by their total fuel consumption.

- For every year after 2018, the corresponding average mpg for the entire stock of vocational vehicles and tractors in use under each alternative considered in this chapter, is calculated by adjusting the corresponding average mpg in 2018 to reflect the cumulative percentage fuel efficiency gains shown in Table 4.1.2-1. For example, the calculated average mpg for the entire stock of vocational vehicles and tractors in use under each alternative in Chapter 3 in each year from 2035 through 2050 is multiplied by 1.0809 to calculate the average mpg in this chapter for the corresponding year and alternative.

- In effect, no further increases in fuel efficiency are assumed to occur after 2035 for each regulatory class.

The change in fuel consumption associated with these projected increases in average fuel efficiency is also affected by the VMT rebound effect, which partially offsets the fuel savings associated with an increase in fuel efficiency. For the purposes of this analysis, NHTSA assumes that the rebound effect is different for different segments of the HD vehicle market. As discussed in Section 3.1, this EIS assumes a VMT rebound effect of 5 percent for tractors, 10 percent for HD pickups and vans, and 15 percent for vocational vehicles. Fuel savings associated with increased fuel efficiency in each of these market segments are offset by these rebound effects. For example:

- A 10-percent increase in tractor fuel efficiency would result in a VMT increase of 0.5 percent, thus reducing the fuel savings that this increase in fuel efficiency would otherwise be expected to produce from 10 percent to 9.5 percent;

- Similarly, a 10-percent increase in HD pickup and van fuel efficiency would result in a VMT increase of 1.0 percent, thereby lowering the expected reduction in fuel consumption from 10 percent to 9 percent; and

- Finally, a 10-percent increase in the fuel efficiency of vocational vehicles would result in a VMT increase of 1.5 percent, thus lowering the expected reduction in fuel consumption from 10 percent to 8.5 percent.

These rebound effects are reflected in estimates of reductions in fuel consumption and other impacts reported in Chapter 3 for action alternatives that increase fuel efficiency during MYs 2014–2018 relative to the No Action Alernative. The analysis of cumulative impacts reported in this chapter also incorporates the rebound effects associated with the projected gains in efficiency after 2018 shown above in Table 4.1.2-1. Thusthe cumulative impacts reported in this chapter reflect the fuel efficiency gains through 2050 shown in Table 4.1.2-1 and the changes in fuel consumption and VMT associated with those gains in fuel efficiency. The changes in VMT reflect the responses to increases in fuel efficiency summarized by the specific rebound effects applicable to each of the tractor, HD pickup and van, and vocational vehicle segments of the HD vehicle market.

4.2 ENERGY

A NEPA analysis must consider the cumulative impacts of the proposed action. For this EIS, such considerations include evaluating the cumulative impacts of fuel consumption of the HD vehicle fleet for the proposed HD Fuel Efficiency Improvement Program.

4.2.1 Affected Environment

Diesel consumption from HD vehicles made up 17 percent of energy consumption in the U.S. transportation sector in 2008, and is projected to increase to 20 percent of energy consumption in the U.S. transportation sector by 2035.[4] EIA projections include renewable fuels and biofuels, but fuel use in transportation remains largely petroleum based despite efforts to increase the use of non-fossil fuels.[5] In both 2007 and 2008, finished motor gasoline and on-road diesel constituted 89 percent of all finished petroleum products consumed for transportation in the United States. In 2018, this proportion is expected to decline to 83 percent and eventually to 79 percent by 2035.[6] According to AEO projections, the biofuels (*e.g.*, ethanol used in E85, ethanol used in gasoline blending, biodiesel used in distillate blending, liquids from biomass) share of energy consumption in the transportation sector will rise to 3.92 quads,[7] approximately 12 percent of all energy consumed in the U.S. transportation sector by 2035.[8]

The analysis of fuel consumption in this EIS assumes that fuel consumed by HD vehicles will consist predominantly of diesel and gasoline fuel derived from petroleum for the foreseeable future. The estimates of gasoline consumption in this analysis include ethanol used as a gasoline additive to increase its oxygen content (as in E10), while the estimates of diesel fuel consumption include biodiesel used as a blending agent.[9]

Statistics demonstrate that lowered imports of petroleum products and crude oil into the US signify either decreased or displaced consumption of petroleum products in various US economic sectors. Statistics demonstrate this trend with regard to petroleum imports. In 2006, 2.30 percent of finished motor gasoline and 1.76 percent of distillate fuel oil supplied to the U.S. economy – mostly to the transportation sector – were imported. By 2007 and 2008, these numbers had dropped to 2 and 1.55 percent of motor gasoline and 1.47 and 1.09 percent of distillate fuel oil supplied to the U.S. economy, respectively.

By 2009, petroleum imports are estimated to equal 63 percent of total petroleum liquids supplied to the U.S. economy.[10] Crude oil imports had declined from 10 million barrels per day from 2005 through 2008 to an estimated 9 million barrels per day in 2009,[11] albeit some of this decline could be attributed to the economic recession which gained momentum during the latter part of 2008 rather than fuel efficiency and increased consumption of biofuels. According to EIA, imports of crude oil – due to factors such as

[4] EIA (2010). "Table 2 – Energy Consumption by Sector and Source."
[5] EIA (2010). "Pg. 75 – Liquid Fuels Supply."
[6] EIA (2010). "Pg. 75 – Liquid Fuels Supply."
[7] Quads – quadrillion British thermal units
[8] EIA (2010). "Table 17 – Renewable Energy Consumption by Sector and Source (quadrillion Btu)" and "Table 2 – Energy Consumption by Sector and Source."
[9] EIA data indicate that in 2008, ethanol accounted for approximately 3.3 and 5.0 percent of the energy content of fuel labeled at retail as gasoline, while biodiesel accounted for about 1.0 and 1.5 percent of the energy content of fuel sold at retail as diesel. Computed from information reported in: EIA (2010). "Table 17 – Renewable Energy Consumption by Sector and Source (quadrillion Btu)" and "Table 2 – Energy Consumption by Sector and Source."
[10] EIA (2009). "Table 5.3 – Petroleum Imports by Type, 1948-2009 (Excel version)" and "Table 5.11 – Petroleum Products Supplied by Type, 1949-2009 (Excel version)."
[11] EIA (2009). "Table 5.3 – Petroleum Imports by Type, 1948-2009 (Excel version)."

improvements in fuel efficiency required by the changes in CAFE standards for passenger cars and light trucks, substitution of biofuels, high prices– and lift of ban on drilling in various U.S. offshore areas from July 2008 to May 2010 while onshore domestic production continued to increase – will fall from 20 to roughly 19 quads (138 billion gallons) over the period 2009–2035. Petroleum product imports are expected to grow slightly during this period, increasing from 5.61 (41 billion gallons) quads to 6.08 quads (44 billion gallons) from 2009 to 2035, an average growth of 0.3 percent per year. We note, however, that these projections were made before the oil spill in the U.S. Gulf of Mexico in 2010, and the effect of the spill is difficult to predict at this time. For example, the growth of domestic offshore production might be lower than anticipated.

4.2.2 Methodology

NHTSA analyzed the cumulative energy resource impacts of the action alternatives by calculating the fuel consumption from HD vehicles that would occur under each alternative, and then calculating the reductions in fuel consumption of each action alternative when compared to the No Action Alternative. The methodology used to estimate total fuel consumption for the cumulative impacts analysis is described in Section 4.1. The cumulative analysis includes, as a reasonably foreseeable action, increases in fuel efficiency of the HD vehicle fleet beyond 2018 based on AEO projections until 2050. The methodology for calculating the expected reductions in fuel consumption as a result of each alternative is the same as that described in Section 3.3.2.

4.2.3 Environmental Consequences

Table 4.2.3-1 shows the cumulative impact of the proposed alternatives on annual fuel consumption for all HD vehicles from 2018 through 2050, when the entire HD vehicle fleet is likely to be composed of MY 2018 or later vehicles. This table reports total cumulative fuel consumption, both gasoline and diesel, for HD pickups and vans, vocational vehicles, and combination tractors, under the No Action Alternative (Alternative 1) and each of the nine action alternatives described in Section 2.3.

Table 4.2.3-1

Cumulative HD Vehicle Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	52.06	51.20	50.79	50.31	50.33	50.26	50.13	49.96	49.80	49.50
2030	57.03	54.47	53.89	52.52	52.41	52.20	51.84	51.53	50.98	49.51
2050	80.88	76.76	76.38	74.02	73.78	73.47	72.71	72.28	71.29	68.19
Fuel Savings Compared to No Action										
2018	--	0.86	1.27	1.75	1.72	1.79	1.93	2.09	2.26	2.56
2030	--	2.57	3.14	4.51	4.63	4.83	5.19	5.51	6.06	7.52
2050	--	4.11	4.49	6.86	7.09	7.41	8.16	8.60	9.58	12.68

a/ Preferred Alternative

Fuel consumption under the No Action Alternative is 80.88 billion gallons in 2050. Fuel consumption ranges from 76.76 billion gallons under Alternative 2 (Engine Only) to 68.19 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). Fuel consumption in 2050 is 72.71 billion gallons under the Preferred Alternative. Fuel consumption is less than under the No Action Alternative for all action alternatives, resulting in 2050 cumulative fuel savings ranging from 4.11 billion gallons under Alternative 2 (Engine Only) to 12.68 billion gallons under Alternative 8 (Accelerated Hybrid Adoption). In 2050, fuel savings under the Preferred Alternative (Alternative 6) amounts to 8.16 billion gallons.

Fuel consumption under every alternative in Table 4.2.3-1 is less than the fuel consumption shown for the same alternative and year in Chapter 3 (*see* Table 3.2.3-1) because the cumulative impacts reported in Table 4.2.3-1 reflect continuing increases in HD vehicle fuel efficiency for years after 2018 (based on AEO projections, as described in Section 4.1.2). Fuel savings compared to the No Action Alternative in Table 4.2.3-1 are also less than those shown for the same alternative and year in Chapter 3 (*see* Table 3.2.3-1). This is because the continuing increases in HD vehicle fuel efficiency after 2018 are applied to all alternatives including the No Action Alternative.

Table 4.2.3-2 shows the cumulative impact on annual fuel consumption, both gasoline and diesel, for HD pickups and vans (Classes 2b–3) under the No Action Alternative (Alternative 1) and each of the nine action alternatives. Diesel fuel accounts for just over half of all HD pickup and van fuel consumption (the gasoline share varies from 46 percent to 48 percent from 2018 to 2050 across all alternatives).

Table 4.2.3-2

HD Pickup and Van (Classes 2b–3) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors, & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	9.71	9.59	9.71	9.59	9.58	9.55	9.55	9.55	9.52	9.40
2030	7.86	7.48	7.86	7.48	7.28	7.16	7.16	7.16	7.04	6.51
2050	9.82	9.21	9.82	9.21	8.86	8.66	8.66	8.66	8.46	7.58
Fuel Savings Compared to No Action										
2018	--	0.12	0.00	0.12	0.13	0.17	0.17	0.17	0.20	0.32
2030	--	0.38	0.00	0.38	0.57	0.69	0.69	0.69	0.81	1.34
2050	--	0.61	0.00	0.61	0.96	1.15	1.15	1.15	1.35	2.24

a/ Preferred Alternative

As shown in Table 4.2.3-2, HD pickup and van fuel consumption is 9.82 billion gallons in 2050 under the No Action Alternative and under Alternative 3 because HD pickups and vans would not be regulated under Alternative 3. HD pickup and van fuel consumption is 9.21 billion gallons in 2050 under Alternative 2 and under Alternative 4 because both of these action alternatives regulate only the engine of HD pickup and vans. Fuel consumption is 8.86 billion gallons in 2050 under Alternative 6A. Fuel consumption is 8.66 billion gallons in 2050 under Alternative 5, Alternative 6 (the Preferred Alternative) and Alternative 7, because each of these alternatives requires the same fuel-efficiency standards for HD pickups and vans. Fuel consumption in 2050 is 8.46 billion gallons under Alternative 6B and 7.58 billion gallons under Alternative 8, reflecting the higher fuel-efficiency standards for HD pickups and vans under these alternatives.

There are no HD pickup and van fuel savings in 2050 under Alternative 3 relative to the No Action Alternative because Alternative 3 does not regulate HD pickups and vans. HD pickup and van fuel savings in 2050 are 0.61 billion gallons under Alternative 2 and Alternative 4. Fuel savings in 2050 are 0.96 billion gallons under Alternative 6A. Fuel savings in 2050 are 1.15 billion gallons under the Preferred Alternative (Alternative 6) and under Alternatives 5 and 7. HD pickup and van fuel savings in 2050 relative to the No Action Alternative are 1.35 billion gallons under Alternative 6B, and 2.24 billion gallons under Alternative 8.

Table 4.2.3-3 shows the cumulative impact on annual fuel consumption, both gasoline and diesel, for HD vocational vehicles (Classes 2b–8) under the No Action Alternative (Alternative 1) and each of the nine action alternatives. The diesel fuel share of total vocational vehicle fuel consumption is expected to increase from 90 percent in 2018 to 93 percent in 2050.

Table 4.2.3-3

HD Vocational Vehicle(Classes 2b–8) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 – 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	9.81	9.64	9.81	9.64	9.64	9.64	9.51	9.51	9.46	9.19
2030	12.65	12.12	12.65	12.12	12.12	12.12	11.76	11.76	11.54	10.39
2050	23.38	22.28	23.38	22.28	22.28	22.28	21.52	21.52	21.04	18.52
Fuel Savings Compared to No Action										
2018	--	0.17	0.00	0.17	0.17	0.17	0.31	0.31	0.35	0.62
2030	--	0.53	0.00	0.53	0.53	0.53	0.89	0.89	1.11	2.26
2050	--	1.10	0.00	1.10	1.10	1.10	1.86	1.86	2.33	4.86

a/ Preferred Alternative

HD vocational vehicle fuel consumption is 23.38 billion gallons in 2050 under the No Action Alternative and under Alternative 3 because Alternative 3 does not regulate HD vocational vehicles. HD vocational vehicle fuel consumption is 22.28 billion gallons in 2050 under Alternative 2 and under Alternatives 4, 6A and 5 because these alternatives regulate only the engine of HD vocational vehicles. Fuel consumption is 21.52 billion gallons in 2050 under Alternative 6 (the Preferred Alternative) and Alternative 7, because Alternatives 6 and 7 require the same fuel-efficiency standards for HD vocational vehicles. Fuel consumption in 2050 is 21.04 billion gallons in 2050 under the Alternative 6B, and 18.52 billion gallons under the Alternative 8, reflecting higher fuel-efficiency standards for HD vocational vehicles under these alternatives.

There are no HD vocational vehicle fuel savings in 2050 under Alternative 3 relative to the No Action Alternative because Alternative 3 does not regulate vocational vehicles. HD vocational vehicle fuel savings in 2050 are 1.1 billion gallons under Alternatives 2, 4, 6A, and 5. Fuel savings in 2050 are 1.86 billion gallons under Alternative 6 (the Preferred Alternative) and Alternative 7. HD vocational vehicle fuel savings in 2050 are 2.33 billion gallons under Alternative 6B, and 4.86 billion gallons under Alternative 8, relative to the No Action Alternative.

Table 4.2.3-4 shows the cumulative impact on annual fuel consumption for HD tractors (Classes 7–8) under the No Action Alternative and each of the nine action alternatives. Diesel fuel is expected to account for 100 percent of HD tractors fuel consumption after 2018.

Table 4.2.3-4

HD Tractor (Classes 7–8) Annual Fuel Consumption and Fuel Savings by Alternative (calendar year billion gallons)

	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b–8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Fuel Consumption										
2018	32.53	31.97	31.27	31.08	31.12	31.08	31.08	30.91	30.82	30.91
2030	36.53	34.87	33.39	32.92	33.01	32.92	32.92	32.61	32.39	32.61
2050	47.68	45.28	43.19	42.53	42.65	42.53	42.53	42.09	41.79	42.09
Fuel Savings Compared to No Action										
2018	--	0.56	1.27	1.45	1.41	1.45	1.45	1.62	1.71	1.62
2030	--	1.66	3.14	3.60	3.52	3.60	3.60	3.92	4.13	3.92
2050	--	2.41	4.49	5.15	5.04	5.15	5.15	5.59	5.90	5.59

a/ Preferred Alternative

HD tractor fuel consumption in 2050 is 47.68 billion gallons under the No Action Alternative, 45.28 billion gallons under Alternative 2, 43.19 billion gallons under Alternative 3, and 42.65 billion gallons under Alternative 6A. Combination tractor fuel consumption is 42.53 billion gallons in 2050 under Alternatives 4, 5, and 6 (the Preferred Alternative) because each of these alternatives requires the same fuel efficiency standards for combination tractors. Fuel consumption is 42.09 billion gallons in 2050 under Alternatives 7 and 8, and 41.79 billion gallons under Alternative 6B, reflecting higher fuel efficiency standards for for combination tractors under these alternatives. Fuel consumption is the same under Alternatives 7 and 8 because these alternatives reflect accelerated hybrid adoption in the HD pickup truck and van and vocational vehicle segments of the HD vehicle market, but not in the combination tractor segment.

Combination tractor fuel savings in 2050 relative to the No Action Alternative are 2.41 billion gallons under Alternative 2, and 4.49 billion gallons under Alternative 3, and 5.04 billion gallons under Alternative 6A. Fuel savings in 2050 are 5.15 billion gallons under Alternatives 4, 5, and 6 (the Preferred Alternative). Fuel savings in 2050 are 5.59 billion gallons under Alternative 7 and under Alternative 8, and 5.90 billion gallons under Alternative 6B.

4.3 AIR QUALITY

4.3.1 Affected Environment

Section 3.3.1 describes the air quality affected environment.

4.3.2 Methodology

NHTSA analyzed the cumulative air quality impacts of the action alternatives by calculating the emissions from medium- and heavy-duty vehicles that would occur under each alternative, and then calculating the reductions in emissions of each action alternative when compared to the No Action Alternative. The methodology used to estimate total emissions for the cumulative impacts analysis is described in Section 4.1.3. The cumulative analysis includes, as a reasonably foreseeable action, increases in fuel efficiency of the HD vehicle fleet beyond 2018 based on AEO projections until 2050. The methodologies for the air quality and human health outcomes analysis of the cumulative air emissions for each action alternative are the same as those described in Section 3.3.2.

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. Incomplete or unavailable information with respect to cumulative impacts is treated as described in Section 3.3.2.

4.3.3 Environmental Consequences

4.3.3.1 Results of Cumulative Emissions Analysis

As discussed in Section 3.3.1, most criteria pollutant emissions from vehicles have been declining since 1970 as a result of the U.S. Environmental Protection Agency's (EPA) emissions regulations under the Clean Air Act (CAA), and EPA projects that they will continue to decline. As future trends show, however, 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 HD Fuel Efficiency Improvement Program standards.

The cumulative analysis in this section shows that the action alternatives considered in this analysis will have varying impacts on emissions from HD vehicles when measured against projected trends without the proposed fuel consumption standards, with the reductions or increases in emissions varying by pollutant, calendar year, and action alternative. The more stringent or comprehensive action alternatives generally would result in greater emissions reductions compared to the No Action Alternative. This trend is similar to the trend shown in the analysis of direct and indirect effects in Section 3.3.3. The following sections provide an overview of the results. Sections 4.3.3.2 through 4.3.3.9 discuss the results in detail for each alternative.

4.3.3.1.1 Criteria Pollutants Overview

Table 4.3.3-1 summarizes the total national emissions of criteria pollutants from HD vehicles under the No Action Alternative and the nine action alternatives. Figure 4.3.3-1 illustrates this information by alternative for 2030, the mid-term forecast year. NHTSA chose to report air quality results for the following years: 2018, to show the immediate effect of the rule; 2030 to show an intermediate effect of the rule when a large portion of the HD vehicle fleet will be MY 2014 or newer; and 2050, to show the effect of the rule when almost all of the HD vehicle fleet will be MY 2014 or newer. Table 4.3.3-1 presents the alternatives from left to right in order of decreasing fuel consumption

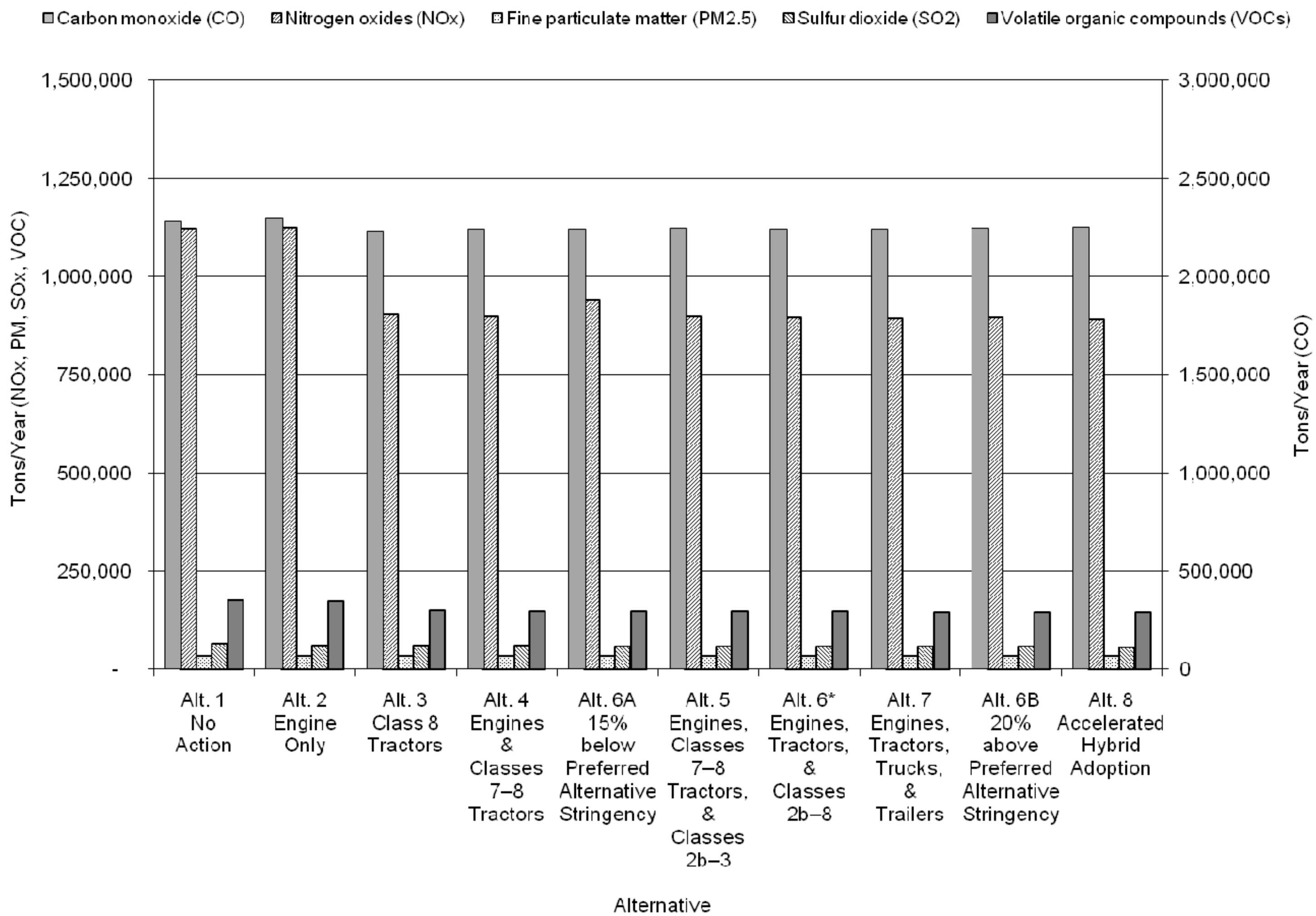
Table 4.3.3-1

Cumulative Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles by Alternative

Poll. and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
2018	3,073,944	3,074,884	3,047,782	3,048,367	3,049,049	3,048,979	3,048,691	3,048,464	3,048,358	3,048,027
2030	2,285,310	2,295,773	2,228,091	2,237,354	2,240,215	2,241,641	2,240,831	2,240,554	2,242,148	2,250,171
2050	2,650,619	2,659,711	2,570,497	2,578,221	2,578,125	2,577,938	2,576,467	2,576,059	2,575,695	2,573,864
Nitrogen oxides (NO_x)										
2018	2,023,599	2,023,367	1,924,671	1,921,698	1,940,878	1,921,877	1,921,188	1,919,241	1,920,212	1,917,958
2030	1,121,567	1,124,949	903,040	898,906	941,562	899,158	897,778	893,747	896,767	892,423
2050	1,409,231	1,411,928	1,103,828	1,096,918	1,155,426	1,096,059	1,093,192	1,087,552	1,090,892	1,080,970
Particulate matter ($PM_{2.5}$)										
2018	80,890	80,556	80,975	80,819	80,839	80,807	80,755	80,667	80,610	80,476
2030	34,147	33,681	34,897	34,718	34,705	34,656	34,588	34,486	34,399	34,061
2050	43,190	42,423	44,193	43,851	44,093	43,731	43,587	43,443	43,540	42,540
Sulfur dioxide (SO_2)										
2018	104,791	103,016	102,092	101,118	101,182	101,046	100,770	100,412	100,079	99,504
2030	65,344	62,402	61,712	60,140	60,017	59,787	59,371	59,007	58,376	56,706
2050	91,912	87,233	86,762	84,074	83,822	83,468	82,604	82,107	80,993	77,484
Volatile organic compounds (VOC)										
2018	290,586	289,661	279,649	278,812	278,831	278,686	278,551	278,384	277,956	277,688
2030	174,503	172,526	150,517	148,736	148,325	147,917	147,621	147,393	146,678	145,152
2050	211,920	208,579	178,433	175,464	174,557	173,826	173,257	172,945	171,757	168,403

a/ Preferred Alternative

Figure 4.3.3-1. Cumulative Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

requirements. In the case of carbon monoxide (CO) and nitrogen oxides (NO_x), Alternative 2 produces slightly higher emissions than does the No Action Alternative (except for NO_x in 2018). Emissions of CO and NO_x under Alternatives 3 through 8 are lower than under the No Action Alternative, and generally decline or remain largely unchanged from alternative to alternative, when emissions increase relative to the less stringent alternative; the exceptions are CO under Alternative 4 (all years), Alternative 6A (2018 and 2030), Alternative 5 (2030 only), Alternative 6B (2030 only), and Alternative 8 (2030 only); and NO_x under Alternatives 6A and 6B (all years). In the case of particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), emissions under Alternative 2 are lower than under the No Action Alternative. Emissions under Alternative 3 are higher than under the No Action Alternative. Emissions then decline unevenly across Alternatives 4 through 8. In the case of sulfur dioxide (SO_2) and volatile organic compounds (VOC), the No Action Alternative results in the highest emissions, and emissions of SO_2 and VOC decline consistently across Alternatives 4 through 8, with the exception of Alternative 6A in 2018. Overall, as shown in Table 4.3.3-1, many of the differences in national emissions of criteria air pollutants, particularly those between Alternatives 1 and 2 and those among Alternatives 3 through 8, are only slight. Consequently, such differences might not lead to measurable changes in ambient concentrations of criteria pollutants.

Total emissions have eight components, consisting of tailpipe emissions and upstream emissions for each of four vehicle classes: Classes 2b–3 HD pickups and vans, Classes 3 through 8 vocational vehicles, day cab combination unit tractors (or trailers), and sleeper cab combination unit tractors (or trailers). To show the relationship among these eight components for criteria pollutants, Table 4.3.3-2 breaks down the total emissions of criteria pollutants by component for calendar year 2030.

Table 4.3.3-3 lists the net changes in nationwide cumulative emissions from HD vehicles as compared to the No Action Alternative for each criteria pollutant and analysis year. After the No Action Alternative (Alternative 1), the table presents the action alternatives (Alternatives 2 through 8) left to right, roughly in order of increasingly more stringent fuel consumption requirements. As discussed above, trends in the reductions in nationwide cumulative emissions under the action alternatives, as compared to the No Action Alternative, vary broadly by pollutant. Variations are due to the complex interaction of VMT, fuel efficiency, and the specific technological improvements that increase fuel efficiency. In many – but not all – cases, the action alternatives reduce nationwide emissions compared to the No Action Alternative. Alternative 2 produces some increases in emissions relative to the No Action Alternative for CO and NO_x. The differences in CO and NO_x emissions among Alternatives 3 through 8 are slight, except under Alternative 6A, where reductions in NOx emissions are less due to an increase in downstream emissions from sleeper cab combination vehicles. Emissions of $PM_{2.5}$ increase under Alternative 3 in 2018 and under Alternatives 3 through 6B in 2030 and 2050, compared to the No Action Alternative. The peak in $PM_{2.5}$ emissions under Alternative 3 is due to EPA's assumption that tractor trailers would use auxiliary power units (APUs) that have relatively high PM emission rates during extended idling. Under Alternatives 3 through 8, the $PM_{2.5}$ emission contribution from APUs approximately offsets the reductions due to the regulation of vehicle and engine classes other than Class 8. Emissions of SO_2 and VOCs decline relatively smoothly across all alternatives because reductions in upstream emissions are greater than the increases due to the VMT rebound effect.

Table 4.3.3-4 summarizes the cumulative criteria air pollutant results by nonattainment area. Tables in Appendix D present the emission changes for each nonattainment area. Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions. Emissions of criteria pollutants vary due to interrelations among upstream emissions and increases in VMT. The reductions in upstream emissions, however, 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

Table 4.3.3-2

Cumulative Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
Class 2b-3 Work Trucks Tailpipe	1,760,672	1,768,838	1,760,672	1,768,838	1,768,840	1,768,840	1,768,840	1,768,840	1,768,840	1,768,840
Class 2b-3 Work Trucks Upstream	5,094	4,772	5,094	4,772	4,590	4,487	4,487	4,487	4,384	3,926
Class 3-8 Vocational Trucks Tailpipe	580,300	581,776	580,300	581,776	581,776	581,776	580,722	580,722	580,724	580,740
Class 3-8 Vocational Trucks Upstream	12,797	12,195	12,797	12,195	12,195	12,195	11,779	11,779	11,515	10,127
Class 7-8 Day Cab Combination Unit Tailpipe	44,424	44,663	44,533	44,564	44,571	44,564	44,564	44,457	44,564	44,457
Class 7-8 Day Cab Combination Unit Upstream	10,107	9,591	9,456	9,207	9,223	9,207	9,207	9,068	9,075	9,068
Class 7-8 Sleeper Cab Combination Unit Tailpipe	221,101	222,560	143,341	142,679	142,691	142,679	142,679	142,617	142,679	142,617
Class 7-8 Sleeper Cab Combination Unit Upstream	16,124	15,315	14,305	14,189	14,238	14,189	14,189	14,088	13,913	14,088
Total	2,650,619	2,659,711	2,570,497	2,578,221	2,578,125	2,577,938	2,576,467	2,576,059	2,575,695	2,573,864
Nitrogen oxides (NO_x)										
Class 2b-3 Work Trucks Tailpipe	286,221	288,808	286,221	288,808	288,808	288,808	288,808	288,808	288,808	288,808
Class 2b-3 Work Trucks Upstream	15,344	14,381	15,344	14,381	13,832	13,522	13,522	13,522	13,212	11,832
Class 3-8 Vocational Trucks Tailpipe	261,598	263,231	261,598	263,231	263,231	263,231	261,598	261,598	261,599	261,607
Class 3-8 Vocational Trucks Upstream	38,011	36,225	38,011	36,225	36,225	36,225	34,991	34,991	34,209	30,090
Class 7-8 Day Cab Combination Unit Tailpipe	148,516	149,558	146,185	145,606	145,832	145,606	145,606	142,483	145,606	142,483
Class 7-8 Day Cab Combination Unit Upstream	29,986	28,454	28,055	27,315	27,364	27,315	27,315	26,903	26,923	26,903
Class 7-8 Sleeper Cab Combination Unit Tailpipe	581,717	585,833	285,975	279,255	337,894	279,255	279,255	277,449	279,256	277,449
Class 7-8 Sleeper Cab Combination Unit Upstream	47,838	45,438	42,438	42,097	42,241	42,097	42,097	41,797	41,278	41,797
Total	1,409,231	1,411,928	1,103,828	1,096,918	1,155,426	1,096,059	1,093,192	1,087,552	1,090,892	1,080,970

Table 4.3.3-2 (continued)

Cumulative Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Particulate matter ($PM_{2.5}$)										
Class 2b-3 Work Trucks Tailpipe	2,838	2,862	2,838	2,862	2,860	2,860	2,860	2,860	2,860	2,860
Class 2b-3 Work Trucks Upstream	2,116	1,983	2,116	1,983	1,935	1,865	1,865	1,865	1,849	1,632
Class 3-8 Vocational Trucks Tailpipe	8,658	8,711	8,658	8,711	8,711	8,711	8,736	8,736	8,736	8,736
Class 3-8 Vocational Trucks Upstream	5,216	4,971	5,217	4,972	5,103	4,972	4,803	4,803	4,819	4,130
Class 7-8 Day Cab Combination Unit Tailpipe	4,479	4,505	4,464	4,465	4,467	4,465	4,465	4,444	4,465	4,444
Class 7-8 Day Cab Combination Unit Upstream	4,174	3,960	3,905	3,803	3,857	3,803	3,803	3,744	3,795	3,745
Class 7-8 Sleeper Cab Combination Unit Tailpipe	9,052	9,107	11,088	11,197	11,205	11,197	11,197	11,175	11,197	11,175
Class 7-8 Sleeper Cab Combination Unit Upstream	6,658	6,325	5,907	5,859	5,954	5,859	5,859	5,818	5,819	5,819
Total	43,190	42,423	44,193	43,851	44,093	43,731	43,587	43,443	43,540	42,540
Sulfur dioxide (SO_2)										
Class 2b-3 Work Trucks Tailpipe	1,017	959	1,017	959	925	904	904	904	883	791
Class 2b-3 Work Trucks Upstream	9,820	9,200	9,820	9,200	8,847	8,649	8,649	8,649	8,451	7,568
Class 3-8 Vocational Trucks Tailpipe	1,855	1,768	1,855	1,768	1,768	1,768	1,709	1,709	1,673	1,478
Class 3-8 Vocational Trucks Upstream	24,761	23,597	24,761	23,597	23,597	23,597	22,792	22,792	22,282	19,594
Class 7-8 Day Cab Combination Unit Tailpipe	1,406	1,334	1,315	1,281	1,283	1,281	1,281	1,261	1,262	1,261
Class 7-8 Day Cab Combination Unit Upstream	19,564	18,564	18,304	17,821	17,852	17,821	17,821	17,552	17,565	17,552
Class 7-8 Sleeper Cab Combination Unit Tailpipe	2,279	2,166	2,002	1,984	1,991	1,984	1,984	1,970	1,946	1,970
Class 7-8 Sleeper Cab Combination Unit Upstream	31,211	29,645	27,688	27,464	27,559	27,464	27,464	27,270	26,931	27,270
Total	91,912	87,233	86,762	84,074	83,822	83,468	82,604	82,107	80,993	77,484

Table 4.3.3-2 (continued)

Cumulative Nationwide Criteria Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type by Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Volatile organic compounds (VOC)										
Class 2b-3 Work Trucks Tailpipe	45,975	46,209	45,975	46,209	46,136	46,093	46,093	46,093	46,050	46,093
Class 2b-3 Work Trucks Upstream	29,753	28,459	29,753	28,459	27,538	26,937	26,937	26,937	26,337	23,570
Class 3-8 Vocational Trucks Tailpipe	30,111	29,856	30,111	29,856	29,856	29,856	29,617	29,617	29,492	29,618
Class 3-8 Vocational Trucks Upstream	14,466	13,804	14,466	13,804	13,804	13,804	13,473	13,473	13,286	12,297
Class 7-8 Day Cab Combination Unit Tailpipe	10,587	10,306	10,221	10,079	10,088	10,079	10,079	9,999	9,999	9,999
Class 7-8 Day Cab Combination Unit Upstream	7,194	6,827	6,731	6,554	6,566	6,554	6,554	6,455	6,459	6,455
Class 7-8 Sleeper Cab Combination Unit Tailpipe	62,356	62,217	30,994	30,403	30,434	30,403	30,403	30,342	30,230	30,342
Class 7-8 Sleeper Cab Combination Unit Upstream	11,478	10,902	10,183	10,100	10,135	10,100	10,100	10,028	9,904	10,028
Total	211,920	208,579	178,433	175,464	174,557	173,826	173,257	172,945	171,757	168,403

a/ Preferred Alternative

Table 4.3.3-3

Cumulative Nationwide Changes in Criteria Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Pollutant and Year	Alt. 1 No Action d/	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon monoxide (CO)										
2018	0	940.04	-26,162	-25,577	-24,895	-24,965	-25,252	-25,480	-25,585	-25,917
2030	0	10,463	-57,219	-47,956	-45,095	-43,669	-44,479	-44,756	-43,162	-35,139
2050	0	9,092	-80,122	-72,399	-72,495	-72,682	-74,152	-74,561	-74,924	-76,755
Nitrogen oxides (NO_x)										
2018	0	-231.34	-98,928	-101,900	-82,720	-101,721	-102,410	-104,358	-103,386	-105,641
2030	0	3,382	-218,527	-222,661	-180,005	-222,409	-223,789	-227,820	-224,800	-229,145
2050	0	2,697	-305,404	-312,313	-253,805	-313,172	-316,039	-321,679	-318,340	-328,262
Particulate matter ($PM_{2.5}$)										
2018	0	-333.98	86	-70	-51	-82	-135	-223	-280	-414
2030	0	-466	750	572	559	510	442	339	253	-86
2050	0	-767	1,003	662	904	542	398	254	350	-650
Sulfur dioxide (SO_2)										
2018	0	-1775.11	-2,698	-3,673	-3,608	-3,745	-4,021	-4,379	-4,712	-5,287
2030	0	-2,943	-3,632	-5,205	-5,328	-5,557	-5,974	-6,338	-6,968	-8,638
2050	0	-4,679	-5,151	-7,838	-8,090	-8,444	-9,308	-9,805	-10,919	-14,428
Volatile organic compounds (VOC)										
2018	0	-924.52	-10,936	-11,773	-11,754	-11,899	-12,035	-12,201	-12,630	-12,897
2030	0	-1,977	-23,986	-25,768	-26,178	-26,586	-26,882	-27,110	-27,825	-29,351
2050	0	-3,341	-33,487	-36,455	-37,363	-38,093	-38,663	-38,975	-40,163	-43,517

a/ Emission changes have been rounded to the nearest whole number.
b/ Negative emission changes indicate reductions; positive emission changes are increases.
c/ Preferred Alternative
d/ Emission changes are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.

Table 4.3.3-4

Cumulative Criteria Pollutant Emissions from HD Vehicles, Maximum Changes by Nonattainment Area and Alternative a/

Criteria Pollutant	Maximum Increase/ Decrease	Change (tons per year)	Year	Alt. Number	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	1,438	2030	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-9,472	2050	Alt. 3	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	988	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-37,574	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Particulate matter ($PM_{2.5}$)	Maximum Increase	209	2050	Alt. 6A	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-237	2050	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Sulfur dioxide (SO_2)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,107	2050	Alt. 8	Chicago-Gary-Lake County, IL-IN, TX (Ozone, $PM_{2.5}$)
Volatile organic compounds (VOC)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-4,094	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)

a/ Emission changes have been rounded to the nearest whole number.

has none. Net emission reductions can occur if the reduction in upstream emissions in the nonattainment area more than offsets the increase due to the rebound effect. For CO, NO_x, and $PM_{2.5}$ emissions some nonattainment areas would experience increases while others would experience decreases. For SO_2 and VOC emissions, all nonattainment areas would experience decreases.

4.3.3.1.2 Toxic Air Pollutants Overview

Table 4.3.3-5 summarizes the cumulative national toxic air pollutant emissions from HD vehicles by alternative for each pollutant and analysis year. Table 4.3.3-5 presents the alternatives from left to right in order of increasing fuel-efficiency requirements. Figure 4.3.3-2 illustrates this information by alternative for 2030, the mid-term forecast year. Under Alternative 2, emissions are highest for acetaldehyde, acrolein, benzene (except in 2018), and formaldeyhde; emissions of diesel particulate matter (DPM) are highest under Alternative 3; and emissions of 1,3-butadiene are highest under Alternatives 1 and 2, except in 2030 when they are highest under Alternative 8. Emissions of benzene in 2018 are highest under the No Action Alternative. Emissions of toxic air pollutants would generally decrease under Alternatives 3 through 8 as compared to the No Action Alternative, except for 1,3-butadiene and DPM. These trends are accounted for by the classes of the HD vehicle fleet that would be affected by each proposed alternative and the fuel-efficiency requirements for those vehicle classes (due to the fuel-efficiency requirements, the overall average fuel efficiency increases across successive years). Overall, the differences in national emissions of toxic air pollutants between Alternatives 1 and 2 are only slight and consequently might not lead to measurable changes in ambient concentrations. The same is true of the differences in national emissions among Alternatives 3 through 8.

Decreases in toxic air pollutant emissions vary depending on year and alternative, in relation to the No Action Alternative emission levels. The magnitude of the decrease generally becomes larger from 2018 to 2030 to 2050. For instance, decreases in formaldehyde emissions in 2018 under Alternatives 3 through 8 are approximately 15 percent relative to the No Action Alternative, compared to decreases of between 46 and 47 percent in 2050 for those same alternatives. Some exceptions occur, however, whereby the magnitude of the decrease is less or the direction of the emission change shifts from a decrease to an increase from 2018 to 2030 to 2050. The exceptions are benzene under Alternative 2, for which emissions decrease in 2018 but increase in 2030 and 2050; 1,3-butadiene under Alternatives 2 through 8, for which the emission changes are approximately equivalent from 2018 to 2030 to 2050; DPM under Alternatives 4 through 7 , for which emissions decrease in 2018 but increase in 2030 and 2050; and DPM under Alternative 8, for which the emission decrease in 2030 is less than that in 2018 or 2050. Increases in toxic air pollutant emissions would be relatively small (less than 4 percent in all cases), with increases relative to the No Action Alternative of less than 1 percent for acetaldehyde, acrolein, benzene, and formaldehyde under Alternative 2; increases of 0.1 to 3 percent for DPM depending on the year and alternative; and almost no emission increase for 1,3-butadiene.

To show the relationship among the eight components for total air toxic pollutant emissions (described above in Section 4.3.3.1.1), Table 4.3.3-6 breaks down the total emissions by component for calendar year 2030. The mid-term forecast year of 2030 was selected because, by this point, a large proportion of HD vehicle VMT would be accounted for by vehicles that meet the MYs 2014–2018 standards.

Table 4.3.3-7 lists the net change from the No Action Alternative in nationwide toxic air pollutant emissions from HD vehicles for each toxic air pollutant and analysis year. The table presents the alternatives from left to right in order of increasing fuel efficiency requirements. In Table 4.3.3-7, the changes in nationwide emissions are reductions in acetaldehyde, acrolein, benzene, and formaldehyde (except for Alternative 2, which generally increases relative to the No Action Alternative for all these

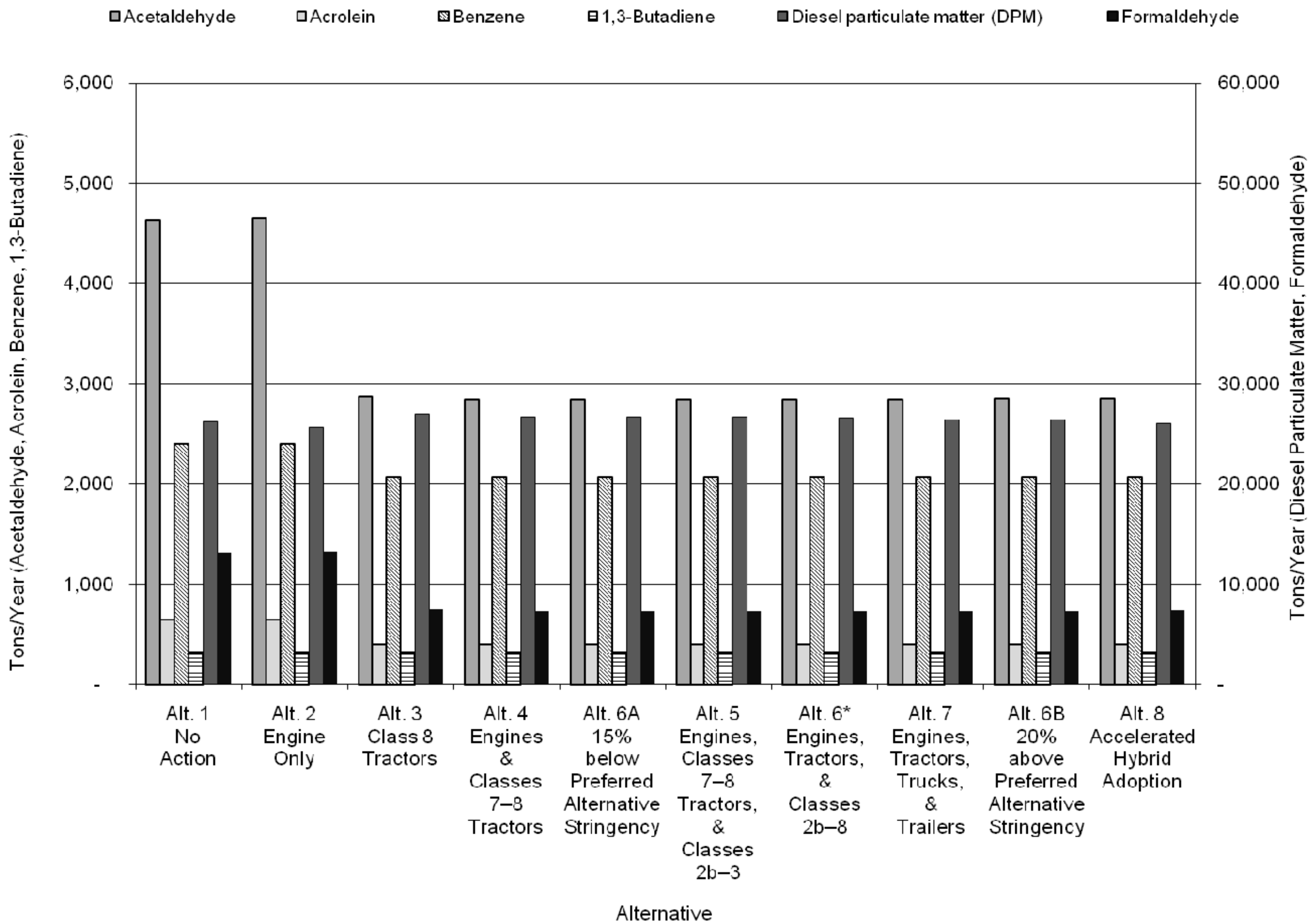
Table 4.3.3-5

Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative

Pollutant and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
2018	6,954	6,964	6,173	6,158	6,158	6,158	6,158	6,158	6,158	6,158
2030	4,624	4,654	2,873	2,844	2,845	2,845	2,845	2,846	2,847	2,852
2050	5,894	5,931	3,453	3,410	3,409	3,409	3,409	3,408	3,408	3,406
Acrolein										
2018	1,059	1,060	952	950	950	950	950	950	950	950
2030	639	643	398	395	395	395	395	395	395	396
2050	805	810	469	464	464	464	464	464	464	463
Benzene										
2018	4,147	4,145	3,999	3,993	3,995	3,994	3,994	3,993	3,991	3,989
2030	2,390	2,397	2,062	2,062	2,064	2,064	2,063	2,062	2,061	2,062
2050	2,782	2,787	2,325	2,320	2,318	2,317	2,314	2,313	2,309	2,297
1,3-Butadiene										
2018	741	741	739	739	739	739	739	739	739	738
2030	317	319	316	318	319	319	319	319	319	320
2050	333	333	330	332	332	332	331	331	331	331
Diesel particulate matter (DPM)										
2018	74,823	74,462	74,896	74,727	74,746	74,713	74,650	74,552	74,503	74,360
2030	26,170	25,645	26,900	26,685	26,674	26,621	26,528	26,406	26,336	25,967
2050	31,623	30,756	32,590	32,184	32,147	32,063	31,867	31,695	31,544	30,772
Formaldehyde										
2018	16,945	16,971	14,384	14,328	14,329	14,329	14,329	14,328	14,326	14,325
2030	13,152	13,232	7,418	7,301	7,304	7,305	7,304	7,304	7,304	7,311
2050	17,358	17,451	9,364	9,198	9,196	9,195	9,192	9,191	9,187	9,175

a/ Preferred Alternative

Figure 4.3.3-2. Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative



* Preferred Alternative

Table 4.3.3-6

Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 – 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
Class 2b-3 Work Trucks Tailpipe	867	873	867	873	873	873	873	873	873	873
Class 2b-3 Work Trucks Upstream	5	5	5	5	4	4	4	4	4	4
Class 3-8 Vocational Trucks Tailpipe	1,209	1,215	1,209	1,215	1,215	1,215	1,214	1,214	1,214	1,214
Class 3-8 Vocational Trucks Upstream	12	11	12	11	11	11	11	11	11	9
Class 7-8 Day Cab Combination Unit Tailpipe	312	314	314	315	315	315	315	315	315	315
Class 7-8 Day Cab Combination Unit Upstream	9	9	9	8	8	8	8	8	8	8
Class 7-8 Sleeper Cab Combination Unit Tailpipe	3,464	3,488	1,023	969	969	969	969	969	969	969
Class 7-8 Sleeper Cab Combination Unit Upstream	16	15	14	14	14	14	14	13	13	13
Total	5,894	5,931	3,453	3,410	3,409	3,409	3,409	3,408	3,408	3,406
Acrolein										
Class 2b-3 Work Trucks Tailpipe	77	78	77	78	78	78	78	78	78	78
Class 2b-3 Work Trucks Upstream	1	1	1	1	1	1	1	1	1	1
Class 3-8 Vocational Trucks Tailpipe	174	174	174	174	174	174	174	174	174	174
Class 3-8 Vocational Trucks Upstream	2	2	2	2	2	2	2	2	2	1
Class 7-8 Day Cab Combination Unit Tailpipe	45	45	45	45	45	45	45	45	45	45
Class 7-8 Day Cab Combination Unit Upstream	1	1	1	1	1	1	1	1	1	1
Class 7-8 Sleeper Cab Combination Unit Tailpipe	504	508	168	161	161	161	161	161	161	161
Class 7-8 Sleeper Cab Combination Unit Upstream	2	2	2	2	2	2	2	2	2	2
Total	805	810	469	464	464	464	464	464	464	463

Table 4.3.3-6 (continued)

Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Benzene										
Class 2b-3 Work Trucks Tailpipe	1,385	1,397	1,385	1,397	1,397	1,397	1,397	1,397	1,396	1,397
Class 2b-3 Work Trucks Upstream	68	65	68	65	62	62	62	62	60	54
Class 3-8 Vocational Trucks Tailpipe	417	419	417	419	419	419	418	418	418	418
Class 3-8 Vocational Trucks Upstream	72	68	72	68	68	68	66	66	65	58
Class 7-8 Day Cab Combination Unit Tailpipe	58	59	59	59	59	59	59	59	59	59
Class 7-8 Day Cab Combination Unit Upstream	50	47	46	45	45	45	45	44	44	44
Class 7-8 Sleeper Cab Combination Unit Tailpipe	653	657	208	198	198	198	198	198	198	198
Class 7-8 Sleeper Cab Combination Unit Upstream	78	75	70	69	69	69	69	69	68	69
Total	2,782	2,787	2,325	2,320	2,318	2,317	2,314	2,313	2,309	2,297
1,3-Butadiene										
Class 2b-3 Work Trucks Tailpipe	223	225	223	225	225	225	225	225	225	225
Class 2b-3 Work Trucks Upstream	2	1	2	1	1	1	1	1	1	1
Class 3-8 Vocational Trucks Tailpipe	46	46	46	46	46	46	46	46	46	46
Class 3-8 Vocational Trucks Upstream	4	3	4	3	3	3	3	3	3	3
Class 7-8 Day Cab Combination Unit Tailpipe	3	3	3	3	3	3	3	3	3	3
Class 7-8 Day Cab Combination Unit Upstream	3	3	3	3	3	3	3	3	3	3
Class 7-8 Sleeper Cab Combination Unit Tailpipe	48	49	47	47	47	47	47	47	47	47
Class 7-8 Sleeper Cab Combination Unit Upstream	5	4	4	4	4	4	4	4	4	4
Total	333	333	330	332	332	332	331	331	331	331

Table 4.3.3-6 (continued)

Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) in 2030 from HD Vehicles, by Vehicle Type and Alternative

Pollutant and Vehicle Class	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b–3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Diesel particulate matter (DPM)										
Class 2b-3 Work Trucks Tailpipe	877	883	877	883	882	881	881	881	881	881
Class 2b-3 Work Trucks Upstream	2,130	1,996	2,130	1,996	1,920	1,876	1,876	1,876	1,833	1,642
Class 3-8 Vocational Trucks Tailpipe	3,543	3,561	3,543	3,561	3,561	3,561	3,538	3,538	3,538	3,539
Class 3-8 Vocational Trucks Upstream	5,336	5,086	5,336	5,086	5,086	5,086	4,912	4,912	4,802	4,224
Class 7-8 Day Cab Combination Unit Tailpipe	2,638	2,651	2,595	2,592	2,594	2,592	2,592	2,550	2,592	2,550
Class 7-8 Day Cab Combination Unit Upstream	4,214	3,999	3,942	3,839	3,845	3,839	3,839	3,781	3,783	3,781
Class 7-8 Sleeper Cab Combination Unit Tailpipe	6,161	6,195	8,201	8,312	8,323	8,312	8,312	8,282	8,312	8,282
Class 7-8 Sleeper Cab Combination Unit Upstream	6,723	6,385	5,964	5,916	5,936	5,916	5,916	5,874	5,801	5,874
Total	31,623	30,756	32,590	32,184	32,147	32,063	31,867	31,695	31,544	30,772
Formaldehyde										
Class 2b-3 Work Trucks Tailpipe	1,694	1,704	1,694	1,704	1,704	1,704	1,704	1,704	1,704	1,704
Class 2b-3 Work Trucks Upstream	39	36	39	36	35	34	34	34	33	30
Class 3-8 Vocational Trucks Tailpipe	3,638	3,655	3,638	3,655	3,655	3,655	3,654	3,654	3,654	3,655
Class 3-8 Vocational Trucks Upstream	93	88	93	88	88	88	86	86	84	74
Class 7-8 Day Cab Combination Unit Tailpipe	980	986	985	987	987	987	987	988	987	988
Class 7-8 Day Cab Combination Unit Upstream	73	69	68	66	66	66	66	66	66	66
Class 7-8 Sleeper Cab Combination Unit Tailpipe	10,726	10,801	2,743	2,558	2,558	2,558	2,558	2,558	2,558	2,558
Class 7-8 Sleeper Cab Combination Unit Upstream	116	111	103	102	102	102	102	102	101	102
Total	17,358	17,451	9,364	9,198	9,196	9,195	9,192	9,191	9,187	9,175

a/ Preferred Alternative

Table 4.3.3-7

Cumulative Nationwide Changes in Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Poll. and Year	Alt. 1 No Action d/	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Acetaldehyde										
2018	0	10	-781	-796	-796	-796	-796	-795	-796	-795
2030	0	29	-1,752	-1,781	-1,779	-1,779	-1,779	-1,779	-1,778	-1,772
2050	0	37	-2,441	-2,484	-2,485	-2,485	-2,485	-2,486	-2,486	-2,488
Acrolein										
2018	0	1	-107	-109	-109	-109	-109	-109	-109	-109
2030	0	4	-241	-244	-244	-244	-244	-244	-244	-243
2050	0	5	-336	-341	-341	-341	-341	-341	-341	-342
Benzene										
2018	0	-2	-148	-154	-152	-153	-153	-154	-156	-158
2030	0	7	-328	-328	-326	-326	-328	-328	-329	-328
2050	0	5	-457	-462	-464	-465	-468	-469	-473	-485
1,3-Butadiene										
2018	0	-1	-3	-2	-2	-2	-2	-2	-2	-3
2030	0	2	-1	1	2	2	2	2	2	3
2050	0	0	-3	-2	-2	-2	-2	-2	-2	-2
Diesel particulate matter (DPM)										
2018	0	-360	73	-96	-77	-110	-172	-271	-319	-463
2030	0	-525	730	515	504	451	358	236	166	-203
2050	0	-867	967	561	524	440	244	72	-79	-851
Formaldehyde										
2018	0	26	-2,561	-2,617	-2,616	-2,616	-2,616	-2,618	-2,619	-2,621
2030	0	79	-5,735	-5,851	-5,848	-5,847	-5,848	-5,848	-5,849	-5,842
2050	0	93	-7,995	-8,160	-8,162	-8,163	-8,166	-8,167	-8,172	-8,183

a/ Emission changes have been rounded to the nearest whole number.
b/ Negative emission changes indicate reductions; positive emission changes are increases.
c/ Preferred Alternative
d/ Emission 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.

pollutants); decreases in DPM emissions under Alternative 2; and increases in DPM emissions in most cases under Alternatives 3 through 8, compared to the No Action Alternative. There is almost no change in emissions of 1,3-butadiene. The changes in total emissions reflect the changes in VMT and emissions by individual vehicle classes projected to occur with the decreasing fuelconsumption requirements across the alternatives.

Table 4.3.3-8 summarizes the air toxic results by nonattainment area. Tables in Appendix D list emission changes for each nonattainment area. As with criteria pollutants, toxic pollutant emissions in individual nonattainment areas might follow patterns that differ from nationwide emissions (*see* Section 4.3.3.1.1). For all toxic air pollutant emissions, some nonattainment areas would experience increases while others would experience decreases. The net emission increases in nonattainment areas would occur when the downstream emissions from additional VMT due to the rebound effect exceed the reductions in upstream emissions due to lower fuel production levels resulting from decreased fuel consumption.

Cumulative toxic air pollutant emissions would be equal to or lower than direct and indirect emissions for air toxics under all alternatives and in all years.

Most changes (compared to the No Action Alternative) in toxic air pollutant emissions as shown by the cumulative analysis (see Table 4.3.3-7) would be the same as or greater than the corresponding emission changes shown by the direct and indirect analysis (see Table 3.3.3-7) for most toxic air pollutants. The exceptions are acetaldehyde, benzene, and formaldehyde in 2050 under Alternative 2; DPM in 2030 under Alternative 3; and DPM in 2050 under Alternatives 3 through 5 (including Alternative 6A).

4.3.3.1.3 Health Effects and Monetized Health Benefits Overview

Table 4.3.3-9 presents the potential net changes in health outcomes due to nationwide cumulative emissions in each analysis year, compared to the No Action Alternative. The table lists the alternatives left to right in order of decreasing fuel consumption requirements. Adverse health effects would be reduced nationwide (*i.e.*, the benefits would increase) in each analysis year and with increasing stringency of the alternatives.

Table 4.3.3-10 presents the corresponding nationwide monetized health benefits under the action alternatives compared to the No Action Alternative. 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 decreasing fuel consumption requirements. The monetized health benefits would increase with each analysis year and with decreasing fuel consumption requirements.

4.3.3.2 Alternative 1: No Action

4.3.3.2.1 Criteria Pollutants

Under the No Action Alternative, the average fuel efficiency for HD vehicles would increase only as would be expected from prevailing trends in vehicle markets. Average fuel efficiency of HD vehicles is assumed to increase from 2014 through 2050 due to a projected rise in demand for fuel efficiency, consistent with AEO 2010 (EIA 2010) projections (*see* Section 4.1.3). Current trends in the levels of criteria pollutant emissions from vehicles would continue, with emissions continuing to decline due to tightening EPA emission standards, despite a growth in total VMT from 2018 to 2030. By 2050, however, VMT growth would more than offset decreases due to emission standards, and total emissions would increase. The No Action Alternative would not impose any fuel consumption standards; therefore, any change in criteria pollutant emissions throughout the United States would be attributable to current

Table 4.3.3-8

Cumulative Changes in Toxic Air Pollutant Emissions from HD Vehicles, Maximum Changes by Nonattainment Area and Alternative a/

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons per year)	Year	Alt. No.	Nonattainment Area
Acetaldehyde	Maximum Increase	5	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-300	2050	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Acrolein	Maximum Increase	0.6	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-41	2050	Alt. 6 b/	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Benzene	Maximum Increase	2	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-54	2050	Alt. 3	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	0.4	2030	Alt. 8	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-0.9	2018	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Diesel particulate matter (DPM)	Maximum Increase	200	2050	Alt. 6A	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-239	2050	Alt. 8	Houston-Galveston-Brazoria, TX (Ozone)
Formaldehyde	Maximum Increase	13	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-982	2050	Alt. 6B	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)

a/ Emission changes have been rounded to the nearest whole number except to present values greater than zero but less than one.
b/ Preferred Alternative

Table 4.3.3-9

Cumulative Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions (cases per year) from HD Vehicles by Alternative a/

Outcome and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Mortality (ages 30 and older), Pope *et al.* (2002)										
2018	0	-15	-62	-71	-59	-72	-74	-79	-81	-88
2030	0	-23	-137	-150	-122	-154	-158	-166	-169	-189
2050	0	-44	-220	-248	-194	-256	-267	-279	-278	-337
Mortality (ages 30 and older), Laden *et al.* (2006)										
2018	0	-38	-160	-183	-152	-184	-191	-203	-208	-226
2030	0	-58	-349	-385	-311	-393	-405	-424	-431	-483
2050	0	-113	-562	-634	-496	-654	-682	-713	-710	-860
Chronic bronchitis										
2018	0	-10	-45	-51	-42	-51	-53	-56	-58	-62
2030	0	-15	-95	-104	-83	-106	-109	-114	-116	-129
2050	0	-28	-147	-165	-129	-170	-177	-184	-184	-221
Emergency room visits for asthma										
2018	0	-15	-52	-61	-51	-61	-64	-68	-70	-76
2030	0	-22	-103	-116	-96	-119	-123	-130	-133	-151
2050	0	-41	-158	-183	-145	-190	-199	-209	-208	-259
Work-loss days										
2018	0	-1,906	-8,614	-9,781	-8,101	-9,838	-10,191	-10,819	-11,076	-11,982
2030	0	-2,641	-17,127	-18,749	-15,096	-19,120	-19,668	-20,595	-20,904	-23,306
2050	0	-4,784	-25,424	-28,496	-22,296	-29,356	-30,564	-31,924	-31,768	-38,262

a/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the other alternatives are compared.
b/ Preferred Alternative
c/ Negative changes indicate fewer health impacts; positive changes indicate additional health impacts.

Table 4.3.3-10

Cumulative Nationwide Monetized Health Benefits (U.S. million dollars per year) from Criteria Pollutant Emissions from HD Vehicles by Alternative a/

Rate and Year	Alt. 1 b/ No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7–8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7–8 Tractors & Classes 2b 3	Alt. 6 a/ Engines, Tractors, & Classes 2b 8	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
3-Percent Discount Rate										
Pope *et al.*(2002)										
2018	0	-126	-535	-611	-509	-615	-638	-679	-696	-755
2030	0	-203	-1,218	-1,340	-1,083	-1,368	-1,409	-1,477	-1,503	-1,682
2050	0	-399	-1,995	-2,248	-1,761	-2,319	-2,418	-2,528	-2,517	-3,049
Laden *et al.* (2006)										
2018	0	-310	-1,308	-1,496	-1,245	-1,505	-1,562	-1,661	-1,704	-1,848
2030	0	-497	-2,978	-3,278	-2,648	-3,347	-3,448	-3,614	-3,676	-4,116
2050	0	-978	-4,880	-5,500	-4,307	-5,674	-5,916	-6,185	-6,158	-7,463
7-Percent Discount Rate										
Pope *et al.* (2002)										
2018	0	-115	-485	-555	-462	-558	-579	-616	-632	-685
2030	0	-184	-1,105	-1,216	-982	-1,241	-1,279	-1,340	-1,363	-1,526
2050	0	-362	-1,810	-2,039	-1,597	-2,103	-2,193	-2,293	-2,283	-2,766
Laden *et al.* (2006)										
2018	0	-280	-1,182	-1,351	-1,125	-1,360	-1,411	-1,501	-1,539	-1,669
2030	0	-449	-2,690	-2,961	-2,392	-3,024	-3,115	-3,265	-3,321	-3,718
2050	0	-883	-4,408	-4,968	-3,891	-5,125	-5,344	-5,586	-5,562	-6,741

a/ Negative changes indicate fewer health impacts; positive changes indicate additional health impacts.
b/ Changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the other alternatives are compared.
c/ Preferred Alternative

emission regulatory programs, growth in VMT, and the assumed future trends in fuel-efficiency increases in accordance with the AEO 2010 projections.

4.3.3.2.2 Toxic Air Pollutants

Under Alternative 1 (No Action), the average fuel efficiency for HD vehicles would increase gradually above the MY 2018 level in future years due to market forces. EPA regulates toxic air pollutants from motor vehicles through vehicle emission standards and fuel quality standards, as discussed in Section 3.3.1. 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 emission standards, despite a growth in total VMT from 2018 to 2030, but increasing from 2030 to 2050 due to growth in total VMT during that period. The No Action Alternative would impose no fuel consumption standards and therefore would result in no change in toxic air pollutant emissions nationally or in nonattainment and maintenance areas beyond those changes projected to result from current and future trends in emissions and VMT.

4.3.3.2.3 Health Outcomes and Monetized Benefits

As with criteria and toxic air pollutants, under Alternative 1 (No Action), HD vehicle fuel efficiency would increase due to prevailing market trends. The human health-related impacts and monetized health impacts that are expected to occur under current trends would continue. The No Action Alternative would result in no other increase or decrease in human health effects throughout the United States.

4.3.3.3 Alternative 2: Engine Only

4.3.3.3.1 Criteria Pollutants

Under Alternative 2, as presented in Table 4.3.3-3, nationwide emissions of CO would increase slightly in all years and NO_x emissions would increase slightly in 2030 and 2050, compared to the No Action Alternative. These increases are due to the rebound effect, which more than offsets the decrease in upstream emissions due to reduced fuel production. CO emissions would increase by 0.03 percent in 2018, 0.5 percent in 2030, and 0.3 percent in 2050. NO_x emissions would increase by 0.3 percent in 2030 and 0.2 percent in 2050. Decreases in emissions of $PM_{2.5}$, SO_2, and VOCs would occur in all years compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would decrease by between 0.4 percent (in 2018) and 1.8 percent (in 2050). SO_2 emissions would decrease by between 1.7 percent (in 2018) and 5.1 percent (in 2050), and VOC emissions would decrease by 0.3 percent (in 2018) to 1.6 percent (in 2050), compared to the No Action Alternative.

Criteria pollutant emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Table 4.3.3-4 in Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of SO_2 and VOCs under Alternative 2 would decrease in all nonattainment areas. Emissions of CO, NO_x, and $PM_{2.5}$ would increase in most nonattainment areas. The net emission increases in nonattainment areas occur when the downstream emissions from additional VMT due to the rebound effect exceed the reductions in upstream emissions due to lower fuel production levels resulting from greater fuel efficiency.

4.3.3.3.2 Toxic Air Pollutants

Nationwide cumulative emissions of acetaldehyde, acrolein, benzene, and formaldehyde would generally be slightly higher, emissions of DPM would be lower, and emissions of 1,3-butadiene would be almost unchanged, under Alternative 2 compared to the No Action Alternative in all analysis years. Emissions of benzene in 2018 are an exception because they decrease slightly under Alternative 2 compared to the No Action Alternative. Cumulative emissions of toxic air pollutants would be lower than direct and indirect emissions for the same combinations of pollutant and year.

Compared to Alternatives 3 through 8 (including Alternatives 6A and 6B), Alternative 2 would result in higher emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, in all analysis years. Alternative 2 would result in slightly lower emissions of DPM compared to Alternatives 3 through 8 in all analysis years except under Alternative 8 in 2018.

Emission changes (compared to the No Action Alternative) under the Alternative 2 cumulative analysis would be the same as or less than the corresponding changes under the Alternative 2 direct and indirect analysis of emissions for all toxic air pollutants.

As with criteria pollutants, toxic pollutant emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Under Alternative 2, most nonattainment areas would experience net increases in emissions of one or more toxic air pollutants in all analysis years (*see* Appendix D). The net emission increases in nonattainment areas occur when the downstream emissions from additional VMT due to the rebound effect exceed the reductions in upstream emissions due to lower fuel production levels resulting from greater fuel efficiency. The sizes of the emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.3.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide adverse health effects would be reduced under Alternative 2 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 2 would reduce the number premature mortality cases by 23 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 58 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 2,641.

These health benefits increase greatly in 2050. Premature mortality would be reduced by 44 cases using the Pope *et al.* values compared to the No Action Alternative (113 cases under Laden *et al.*), and the number of work-loss days would be reduced by 4,784.

Similarly, Alternative 2 results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 2 would be $184 million in 2030, increasing to $362 million in 2050. Under the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits would increase to $497 million in 2030 and $978 million in 2050.

Health and monetized health benefits generally increase with each alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 2 are greater than those of the No Action Alternative but less than those of the remaining alternatives.

4.3.3.4 Alternative 3: Class 8 Tractors

4.3.3.4.1 Criteria Pollutants

Under Alternative 3, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced, due to reduced fuel production and consumption. Nationwide emissions of $PM_{2.5}$ would increase. Compared to the No Action Alternative, CO emissions would be reduced 0.9 percent (in 2018) to 3.0 percent (in 2050); NO_x emissions would be reduced 4.9 percent (in 2018) to 21.7 percent (in 2050); $PM_{2.5}$ emissions would be increased 0.1 percent (in 2018) to 2.3 percent (in 2050); SO_2 emissions would be reduced 2.6 percent (in 2018) to 5.6 percent (in 2050); and VOC emissions would be reduced 3.8 percent (in 2018) to 15.8 percent (in 2050). For CO, reductions under Alternative 3 are greater than under any other alternative. For NO_x, SO_2, and VOCs, reductions under Alternative 3 are greater than under Alternative 2, but less than under Alternatives 4 through 8, with the exception of NO_x under Alternative 6A. NO_x emissions are higher under that alternative due to an increase in downstream emissions from sleeper cab combination vehicles. Under Alternative 3, emissions of $PM_{2.5}$ are higher than under the No Action Alternative and all other alternatives. The increase in $PM_{2.5}$ emissions is attributable to the assumed expansion of the use of APUs to replace extended idling. APUs are more fuel-efficient than the tractor main engines but are regulated as non-road engines, which are subject to less stringent PM standards than highway engines and thus have higher $PM_{2.5}$ emission rates.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 3 would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.4.2 Toxic Air Pollutants

Compared to the No Action Alternative, Alternative 3 would reduce emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and would have almost equivalent emissions of 1,3-butadiene, in all years. For DPM, Alternative 3 would increase emissions compared to the No Action Alternative in all analysis years. Compared to Alternatives 4 through 8 (including Alternatives 6A and 6B), Alternative 3 would generally have approximately equivalent or slightly higher emissions of acetaldehyde, acrolein, benzene, and formaldehyde; slightly lower or approximately equivalent emissions of 1,3-butadiene; and higher or slightly higher emissions of DPM for all analysis years.

Under Alternative 3, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants. Emission changes (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be the same as or less than the corresponding emission changes under the Alternative 3 direct and indirect analysis for all toxic air pollutants.

At the national level, emissions of toxic air pollutants (except DPM) could decrease because the reduction in sleeper cab tailpipe emissions more than offsets the increase in VMT and emissions due to the rebound effect. The increase in DPM emissions is attributable to the assumed expansion of the use of APUs to replace extended idling. APUs are more fuel-efficient than the tractor main engines but are regulated as non-road engines, which have less stringent PM standards than highway engines, and thus have higher DPM emission rates.

As with criteria pollutants, toxic pollutant emissions in individual nonattainment areas might follow patterns that differ from those for nationwide emissions (*see* Section 4.3.3.1.1). As with Alternative 2, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 3, all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would decrease in some nonattainment areas in all analysis years. The emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.4.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide reductions in adverse health effects would occur under Alternative 3 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative the cumulative impact of Alternative 3 would reduce the number of cases of premature mortality by 137 in 2030 using the Pope *et al.* values (using the Laden *et al.* values, premature mortality would be reduced by 349 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values). In the same year, the number of work-loss days would be reduced by 17,127.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 220 cases compared to the No Action Alternative using the Pope *et al.* values (562 cases under Laden *et al.*), and the number of work-loss days would be reduced by 25,424.

Similarly, Alternative 3 would result in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 3 would be $1.105 billion in 2030, increasing to $1.810 billion in 2050. Under the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits would increase to $2.978 billion in 2030 and $4.880 billion in 2050.

Health and monetized health benefits generally would increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 3 are greater than those of the No Action Alternative and Alternatives 2 and 6A, but less than those of the remaining alternatives.

4.3.3.5 Alternative 4: Engines and Classes 7–8 Tractors

4.3.3.5.1 Criteria Pollutants

Under Alternative 4, nationwide reductions would occur in emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.7 percent (in 2050), NO_x emissions would be reduced 5.0 percent (in 2018) to 22.2 percent (in 2050), SO_2 emissions would be reduced 3.5 percent (in 2018) to 8.5 percent (in 2050), changes in $PM_{2.5}$ emissions would range from 0.1 percent decrease (in 2018) to 1.5 percent increase (in 2030), and VOC emissions would be reduced 4.1 percent (in 2018) to 17.2 percent (in 2050). For SO_2 and VOCs, these reductions are greater than would occur under Alternative 3, but less than or approximately equal to the reductions that would occur under the more stringent alternatives. For NO_x, emission reductions are greater than would occur under Alternative 3 but less than or approximately equal to the reductions under the more stringent alternatives, with the exception of Alternative 6A. Emissions under Alternative 6A are higher due to an increase in downstream emissions from sleeper cab combination vehicles. For CO, emissions would be slightly greater than under Alternative 3, due to the rebound effect, which more than offsets the decreases in upstream emissions due to reduced fuel production. CO emissions under

Alternative 4 would be approximately equal to emissions under the more stringent alternatives in 2018, slightly less than emissions under the more stringent alternatives in 2030, and slightly greater than under the more stringent alternatives in 2050. These trends reflect the complex interactions between fuel efficiency and VMT, as well as the engine and vehicle classes regulated under each action alternative. Under Alternative 4, emissions of $PM_{2.5}$ are lower than under Alternative 3, but slightly higher than or approximately equal to emissions under the more stringent alternatives, except for under Alternative 6A in 2050. Emissions of $PM_{2.5}$ are higher under that alternative due to use of APUs.

Emissions in individual nonattainment areas might follow patterns different from those for nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 4 would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.5.2 Toxic Air Pollutants

Alternative 4 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years compared to the No Action Alternative. Results under Alternative 4 for DPM would be mixed, with higher emissions of DPM in 2030 and 2050, but slightly lower emissions of DPM in 2018, compared to the No Action Alternative. Compared to Alternatives 5 through 8 (including Alternatives 6A and 6B), Alternative 4 would result in slightly higher or approximately equivalent emissions of all toxic air pollutants except for acetaldehyde in 2030.

Under Alternative 4, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants.

Emission changes (compared to the No Action Alternative) under the Alternative 4 cumulative analysis would be the same as or less than the corresponding emission changes under the Alternative 4 direct and indirect analysis, for all toxic air pollutants, except for DPM in 2030.

At the national level, emissions of toxic air pollutants could decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with Alternatives 2 and 3, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 4, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in all analysis years. The sizes of the emission increases, however, would generally be small, as shown in Appendix D. Potential air quality impacts from these increases would be minor, because the VMT and emission increases would be distributed throughout each nonattainment area.

4.3.3.5.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide reductions in adverse health effects would occur under Alternative 4 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative the cumulative impact of Alternative 4 would reduce the number of cases of premature mortality by 150 in 2030 (using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 385 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values). In the same year, the number of work-loss days would be reduced by 18,749.

These potential health benefits increase greatly in 2050. Premature mortality would be reduced by 248 cases compared to the No Action Alternative using the Pope *et al.* values (634 cases under Laden *et al.*), and the number of work-loss days would be reduced by 28,496.

Similarly, Alternative 4 results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7 percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 4 would be $1.216 billion in 2030, increasing to $2.039 billion in 2050. Under more the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.278 billion in 2030 and $5.500 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 4 are greater than those of the No Action Alternative and Alternatives 2, 3, and 6a, but less than those of the remaining alternatives.

4.3.3.6 Alternative 6A: 15 Percent below Preferred Alternative Stringency

4.3.3.6.1 Criteria Pollutants

Under Alternative 6A, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.7 percent (in 2050), NO_x emissions would be reduced 4.1 percent (in 2018) to 18.0 percent (in 2050), SO_2 emissions would be reduced 3.4 percent (in 2018) to 8.8 percent (in 2050), changes in $PM_{2.5}$ emissions would vary between 0.1 percent decrease (in 2018) to 2.1 percent increase (in 2050), and VOC emissions would be reduced 4.0 percent (in 2018) to 17.6 percent (in 2050). For SO_2 and VOCs, reductions would be slightly greater than under Alternative 4 (except in 2018), but slightly less than or equal to reductions under the more stringent alternatives. For CO, emissions would be slightly greater than under Alternative 4 in 2018 and 2030 and slightly less than under Alternative 4 in 2050. Reductions would be slightly less than under the more stringent alternatives in 2018 and 2050, but greater than under the more stringent alternatives in 2030, reflecting the complex interactions between fuel efficiency and VMT as well as the engine and vehicle classes regulated under each action alternative. For NO_x, emission reductions would be less than under Alternative 4 and less than under the more stringent alternatives, because of increases in downstream emissions from sleeper cab combination vehicles under Alternative 6A. For $PM_{2.5}$, emissions are approximately the same as under Alternative 4 and higher than under the more stringent alternatives except in 2050, when emissions are higher than under Alternative 4. Because Alternative 6A assumes the use of APUs that have relatively high PM emission rates for extended idling, this alternative has $PM_{2.5}$ emissions that are higher than under the No Action Alternative.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 6A would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission reductions for each nonattainment area.

4.3.3.6.2 Toxic Air Pollutants

Alternative 6A would result in reduced toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years compared to the No Action Alternative. Results for

DPM would be mixed; emissions of DPM would be higher in 2030 and 2050 but lower in 2018 compared to the No Action Alternative. Compared to Alternatives 5 through 8 (including Alternative 6B), Alternative 6A would result in slightly higher or approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde in all years; and higher or slightly higher emissions DPM in all analysis years.

Under Alternative 6A, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants for all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 6A cumulative analysis would be the same or greater than the corresponding emission changes under the Alternative 6A direct and indirect analysis, for all toxic air pollutants, except for 1,3-butadiene and DPM in 2030.

At the national level, emissions of toxic air pollutants could decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 6A, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in 2030 and 2050 but decrease in 2018. The emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.6.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide adverse health effects would be reduced under Alternative 6A compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 6A would be a reduction in the number of cases of premature mortality by 122 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 311 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 15,096.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 194 cases using the Pope *et al.* values compared to the No Action Alternative (496 cases under Laden *et al.*), and the number of work-loss days would be reduced by 22,296.

Similarly, Alternative 6A would result in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6A would be $982 million in 2030, increasing to $1.597 billion in 2050. Under the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits would increase to $2.648 billion in 2030 and $4.307 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. However, the results of Alternative 6A are an exception to this trend. The health and monetized health benefits under Alternative 6A are less than under all other alternatives except for Alternative 2 and the No Action Alternative.

4.3.3.7 Alternative 5: Engines, Classes 7–8 Tractors, and Classes 2b–3 Trucks

4.3.3.7.1 Criteria Pollutants

Under Alternative 5, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.7 percent (in 2050), NO_x emissions would be reduced 5.0 percent (in 2018) to 22.2 percent (in 2050), SO_2 emissions would be reduced 3.6 percent (in 2018) to 9.2 percent (in 2050), changes in $PM_{2.5}$ emissions would vary between 0.1 percent decrease (in 2018) to 1.4 percent increase (in 2030), and VOC emissions would be reduced 4.1 percent (in 2018) to 18.0 percent (in 2030). For SO_2 and VOCs, reductions would be slightly greater than under Alternative 6A, but slightly less than or equal to reductions under the more stringent alternatives. For CO, emissions would be slightly greater than under Alternative 6A in 2030 and slightly less than under Alternative 6A in 2018 and 2050; and slightly greater than under the more stringent alternatives in all years (except Alternative 6B and Alternative 8 in 2030), reflecting the complex interactions between fuel efficiency and VMT as well as the engine and vehicle classes regulated under each action alternative. For NO_x and $PM_{2.5}$, emissions would be slightly less than under alternative 6A but slightly higher than under the more stringent alternatives in all years.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 5 would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.7.2 Toxic Air Pollutants

Alternative 5 would result in reduced toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, and formaldehyde, and almost no change in emissions of 1,3-butadiene, for all analysis years compared to the No Action Alternative. Results for DPM would be mixed: emissions of DPM would be higher in 2030 and 2050 and slightly lower in 2018 than under the No Action Alternative. Compared to Alternatives 6 through 8 (including Alternative 6B), Alternative 5 would result in slightly higher or approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde and higher or slightly higher emissions of DPM in all years. The exception is acetaldehyde in 2030 under Alternative 8, which results in slightly higher emissions than results under Alternative 5.

Under Alternative 5, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants for all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 5 cumulative analysis would be the same or greater than the corresponding emission changes under the Alternative 5 direct and indirect analysis, for all toxic air pollutants except 1,3-butadiene and DPM in 2030.

At the national level, emissions of toxic air pollutants could decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 5, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in 2030 and 2050 but decrease in 2018. The emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.7.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide adverse health effects would be reduced under Alternative 5 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 5 would be a reduction in the number of cases of premature mortality by 154 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 393 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 19,120.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 256 cases using the Pope *et al.* values compared to the No Action Alternative (654 cases under Laden *et al.*), and the number of work-loss days would be reduced by 29,356.

Similarly, Alternative 5 would result in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 5 would be \$1.241 billion in 2030, increasing to \$2.103 billion in 2050. Under the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits would increase to \$3.347 billion in 2030 and \$5.674 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 5 would be greater than those of Alternatives 1 through 4 and 6A, but less than those of Alternatives 6, 6B, 7, and 8.

4.3.3.8 Alternative 6 (Preferred Alternative): Engines, Tractors, and Classes 2b–8 Trucks

4.3.3.8.1 Criteria Pollutants

Under the Preferred Alternative (Alternative 6), nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.8 percent (in 2050), NO_x emissions would be reduced 5.1 percent (in 2018) to 22.4 percent (in 2050), SO_2 emissions would be reduced 3.8 percent (in 2018) to 10.1 percent (in 2050), changes in $PM_{2.5}$ emissions would range from a 0.2-percent decrease (in 2018) to a 0.9-percent increase (in 2050), and VOC emissions would be reduced 4.1 percent (in 2018) to 18.2 percent (in 2050). For CO, NO_x, SO_2, and VOCs, emission reductions would be slightly greater than under Alternative 5, but slightly less than or equal to reductions under the more stringent alternatives (except for CO in 2030 under Alternative 6B and Alternative 8). Under the Preferred Alternative, emissions of $PM_{2.5}$ would be slightly lower than under Alternative 5, but slightly higher than under the more stringent alternatives.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under the Preferred Alternative would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission reductions for each nonattainment area.

4.3.3.8.2 Toxic Air Pollutants

Alternative 6 would result in reduced toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, and formaldehyde, and almost equivalent emissions for 1,3-butadiene, for all analysis years. Results for DPM would be mixed: under Alternative 6 compared to the No Action Alternative, emissions of DPM would be slightly lower in 2018 but higher in 2030 and 2050. For acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, compared to Alternatives 7, 6B, and 8, emissions under Alternative 6 would be slightly higher or approximately equivalent in in all years. Compared to Alternatives 7, 6B, and 8, emissions of DPM under Alternative 6 would be higher or slightly higher in all analysis years.

Under Alternative 6, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants for all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 6 cumulative analysis would be the same or less than the corresponding emission changes under the Alternative 6 direct and indirect analysis, for all toxic air pollutants in all analysis years, except for 1,3-butadiene in 2030 and DPM in 2030 and 2050.

At the national level, emissions of toxic air pollutants would decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with the other action alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 6, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in 2030 and 2050 but decrease in 2018. The emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.8.3 Health Outcomes and Monetized Benefits

The analysis projects that adverse health effects would be reduced nationwide under Alternative 6 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 6 would be to reduce the number of cases of premature mortality by 158 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 405 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 19,688.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 267 cases using the Pope *et al.* values compared to the No Action Alternative (682 cases under Laden *et al.*), and the number of work-loss days would be reduced by 30,564.

Similarly, Alternative 6 would result in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6 would be $1.279 billion in 2030, increasing to $2.193 billion in 2050. Under more the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.448 billion in 2030 and $5.916 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 6 would be greater than those of the No Action Alternative, Alternatives 2 through 5, and 6A but less than those of Alternatives 6B, 7, and 8.

4.3.3.9 Alternative 7: Engines, Tractors, Trucks, and Trailers

4.3.3.9.1 Criteria Pollutants

Under Alternative 7, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase slightly compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.8 percent (in 2050), NO_x emissions would be reduced 5.2 percent (in 2018) to 22.8 percent (in 2050), SO_2 emissions would be reduced 4.2 percent (in 2018) to 10.7 percent (in 2050), changes in $PM_{2.5}$ emissions would range from a 0.3-percent decrease (in 2018) to a 0.6-percent increase (in 2050), and VOC emissions would be reduced 4.2 percent (in 2018) to 18.4 percent (in 2050). For CO, NO_x, SO_2, and VOCs, emission reductions would be slightly greater than under Alternative 6, but less than or equal to reductions under the more stringent alternatives (except NO_x in 2030). Under Alternative 7, emissions of $PM_{2.5}$ would be slightly lower than under Alternative 6, but slightly higher than under the more stringent alternatives, except under Alternative 6B in 2050.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 7 would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.9.2 Toxic Air Pollutants

Alternative 7 would result in reduced toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, in all analysis years. Results for DPM would be mixed: emissions of DPM would be slightly lower in 2018 but slightly higher in 2030 and 2050. Compared to Alternatives 6B and 8, Alternative 7 would result in slightly higher or approximately equivalent emissions for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde (except for acetalahyde and formaldehyde in 2030 under Alternative 8); and slightly higher emissions of DPM in all analysis years.

Under Alternative 7, cumulative emissions would be less than or approximately equivalent to direct and indirect emissions for all toxic air pollutants for all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 7 cumulative analysis would be the same as or greater than the corresponding emission changes under the Alternative 7 direct and indirect analysis, for all toxic air pollutants, except for 1,3-butadiene in 2030 and DPM in 2030 and 2050.

At the national level, emissions of toxic air pollutants would decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with the other action alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 7, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in

2030 and 2050 but decrease in 2018. The sizes of the emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.9.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide adverse health effects would be reduced under Alternative 7 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 7 would reduce the number of cases of premature mortality by 166 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 424 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 20,595.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 279 cases using the Pope *et al.* values compared to the No Action Alternative (713 cases under Laden *et al.*), and the number of work-loss days would be reduced by 31,924.

Similarly, Alternative 7 results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 7 would be $1.340 billion in 2030, increasing to $2.293 billion in 2050. Under more the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.614 billion in 2030 and $6.185 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 7. The health and monetized health benefits of Alternative 7 would be greater than those of the No Action Alternative, Alternatives 2 through 6, and 6B, but generally less than those of Alternatives 6B and 8. As an exception, benefits of Alternative 7 exceed those of Alternative 6B in year 2050.

4.3.3.10 Alternative 6B: 20 Percent above Preferred Alternative Stringency

4.3.3.10.1 Criteria Pollutants

Under Alternative 6B, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative, due to reduced fuel production and consumption. $PM_{2.5}$ emissions would increase slightly compared to the No Action Alternative, except in 2018, due to the use of APUs to reduce extended idling (*see* Section 4.3.3.4.1). CO emissions would be reduced 0.8 percent (in 2018) to 2.8 percent (in 2050), NO_x emissions would be reduced 5.1 percent (in 2018) to 22.6 percent (in 2050), SO_2 emissions would be reduced 4.5 percent (in 2018) to 11.9 percent (in 2050), changes in $PM_{2.5}$ emissions would range from a 0.3-percent decrease (in 2018) to a 0.8-percent increase (in 2050), and VOC emissions would be reduced 4.3 percent (in 2018) to 19.0 percent (in 2050). For SO_2 and VOC emissions, reductions would be greater than under Alternative 7 but less than under Alternative 8. For CO, reductions would be slightly greater than under Alternative 7 and slightly less than under Alternative 8 in 2018 and 2050, but slightly less than under Alternative 7 and slightly greater than under Alternative 8 in 2030. For NO_x, reductions would be less than under Alternative 7 and less than under Alternative 8 in all years. Under Alternative 6B, emissions of $PM_{2.5}$ would be slightly lower than under Alternative 7, but slightly higher than under Alternative 8, except in 2050.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 6B would decrease in all nonattainment areas.

In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.10.2 Toxic Air Pollutants

Alternative 6B would result in reduced toxic air pollutant emissions compared to the No Action Alternative for acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, in all analysis years. Results for DPM would be mixed: emissions of DPM would be slightly lower in 2018 and 2050 but slightly higher in 2030. Compared to Alternative 8, Alternative 6B would result in slightly higher or approximately equivalent emissions in 2018 and 2050 but slightly lower emissions in 2030 for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde; and slightly higher emissions of DPM in all analysis years.

Under Alternative 6B, cumulative emissions would be less than or approximately equivalent to direct and indirect emissions for all toxic air pollutants for all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 6B cumulative analysis would be the same as or greater than the corresponding emission changes under the Alternative 6B direct and indirect analysis, for all toxic air pollutants, except for 1,3-butadiene and DPM in 2030.

At the national level, emissions of toxic air pollutants would decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with the other action alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 6B, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in some nonattainment areas in 2030 and 2050 but decrease in 2018. The sizes of the emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.10.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide adverse health effects would be reduced under Alternative 6B compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 6B would reduce the number of cases of premature mortality by 169 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 431 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 20,904.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 278 cases using the Pope *et al.* values compared to the No Action Alternative (710 cases under Laden *et al.*), and the number of work-loss days would be reduced by 31,768.

Similarly, Alternative 6B results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 6B would be $1.363 billion in 2030, increasing to $2.283 billion in 2050. Under more the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits increase to $3.676 billion in 2030 and $6.158 billion in 2050.

Health and monetized health benefits generally increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 6B are less than those of Alternative 8, but generally greater than those of the No Action Alternative and Alternatives 2 through 7. As an exception, the benefits of Alternative 6B are less than those of Alternative 7 in year 2050.

4.3.3.11 Alternative 8: Accelerated Hybrid Adoption

4.3.3.11.1 Criteria Pollutants

Under Alternative 8, nationwide reductions in emissions would occur for all criteria pollutants compared to the No Action Alternative, due to reduced fuel production and consumption. CO emissions would be reduced 0.8 percent (in 2018) to 2.9 percent (in 2050), NO_x emissions would be reduced 5.2 percent (in 2018) to 23.3 percent (in 2050), $PM_{2.5}$ emissions would be reduced 0.5 percent (in 2030) to 1.5 percent (in 2050), SO_2 emissions would be reduced 5.0 percent (in 2018) to 15.7 percent (in 2050), and VOC emissions would be reduced 4.4 percent (in 2018) to 20.5 percent (in 2050). For NO_x, SO_2 and VOCs, reductions under Alternative 8 are greater than reductions under any other alternative. For CO, emissions would be slightly greater than under Alternative 6B in 2030 and slightly less than under Alternative 6B in 2018 and 2050. Under Alternative 8, emissions of $PM_{2.5}$ would be slightly lower than under Alternative 6B.

Emissions in individual nonattainment areas might follow patterns that differ from those of nationwide emissions (*see* Section 4.3.3.1.1). Compared to the No Action Alternative, cumulative emissions of CO, NO_x, SO_2, and VOCs under Alternative 8 would decrease in all nonattainment areas. In contrast, $PM_{2.5}$ emissions would increase in almost all nonattainment areas. Tables in Appendix D present the emission changes for each nonattainment area.

4.3.3.11.2 Toxic Air Pollutants

Alternative 8 would result in reduced emissions of acetaldehyde, acrolein, benzene, DPM, and formaldehyde, and slightly reduced emissions of 1,3-butadiene (except in 2030), in all analysis years compared to the No Action Alternative.

Under Alternative 8, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants in all analysis years.

Emission changes (compared to the No Action Alternative) under the Alternative 8 cumulative analysis would be the same as or greater than the corresponding emission changes under the Alternative 8 direct and indirect analysis for all toxic air pollutants in all analysis years, except for 1,3-butadiene in 2030.

At the national level, emissions of toxic air pollutants would decrease because the reductions in emissions more than offset the increase in VMT and emissions due to the rebound effect. As with less stringent alternatives, however, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas (*see* Section 4.3.3.1.1). Under Alternative 8, nearly all nonattainment areas would experience net decreases in emissions of most toxic air pollutants in all analysis years (*see* Appendix D), with the exception of DPM, which would increase in most nonattainment areas in all years, and 1,3-butadiene, which would increase in many nonattainment areas in 2030 and 2050. The emission increases, however, would generally be small, as shown in Appendix D, and emission increases would be distributed throughout each nonattainment area.

4.3.3.11.3 Health Outcomes and Monetized Benefits

The analysis projects that nationwide reductions in adverse health effects would occur under Alternative 8 compared to the No Action Alternative (*see* Table 4.3.3-9). Compared to the No Action Alternative, the cumulative impact of Alternative 8 would reduce the number of cases of premature mortality by 189 in 2030 using the Pope *et al.* values; using the Laden *et al.* values, premature mortality would be reduced by 483 cases, an increase of 155 percent compared to mortality under the Pope *et al.* values. In the same year, the number of work-loss days would be reduced by 23,306.

These health benefits would increase greatly in 2050. Premature mortality would be reduced by 337 cases using the Pope *et al.* values compared to the No Action Alternative (860 cases under Laden *et al.*), and the number of work-loss days would be reduced by 38,262.

Similarly, Alternative 8 results in monetized health benefits in all analysis years (*see* Table 4.3.3-10). Using the most conservative assumptions (7-percent discount rate, Pope *et al.* health outcomes), health-related benefits under Alternative 8 would be $1.526 billion in 2030, increasing to $2.766 billion in 2050. Under the most aggressive assumptions (3-percent discount rate, Laden *et al.* health outcomes), the monetized health benefits would increase to $4.116 billion in 2030 and $7.463 billion in 2050.

Health and monetized health benefits generally would increase with each Alternative from Alternative 2 through Alternative 8. The health and monetized health benefits of Alternative 8 would be greater than those of all other alternatives.

4.4 CLIMATE

As noted in Section 4.1, 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 focuses on the cumulative impacts on climate of the proposed action and alternatives and covers many of the same topics as Section 3.4. The analysis in Chapter 4, however, is broader than the analysis in Chapter 3. Chapter 4 addresses the effects of the HD Fuel Efficiency Improvement Program standards together with those of reasonably foreseeable future actions, consistent with NEPA requirements to consider such actions as part of the analysis of cumulative impacts. The HD vehicle fleet's emission trajectory through 2050 is described in Section 4.1.2. That section includes reasonably foreseeable action increases in fuel efficiency of the HD vehicle fleet from 2018 to 2050 based on AEO projections. The cumulative climate analysis also considers projected GHG emissions for the HD vehicle sector and global GHG emissions from 2050 to 2100 (*see* Section 4.4.3.1).

With the understanding that many readers do not read through an EIS in linear fashion but instead focus on the sections of most interest, this section repeats some of the information in Section 3.4 with modifications to reflect the slightly different scope (*e.g.*, cumulative impacts versus the direct and indirect effects of the proposed action and alternatives). This section also refers the reader to Section 3.4 in many cases, however, to minimize repetition of background information on climate science or modeling methodologies.

4.4.1 Introduction – Greenhouse Gases and Climate Change

Section 3.4.1 provides a discussion of the science of climate change, uncertainty within the frame work of the Intergovernmental Panel on Climate Change (IPCC), and NHTSA's reliance on panel- and peer-reviewed literature for this EIS.

4.4.2 Affected Environment

The affected environment can be characterized in terms of GHG emissions and climate. Section 3.4.2 provides a discussion of both topics, including a description of conditions both in the United States, and across the globe. Many themes in the discussions regarding conditions in the United States reappear in the global discussions. Because there is no distinction between the affected environment for purposes of the analysis of direct and indirect effects and the analysis of cumulative impacts, NHTSA refers readers to Section 3.4.2 for a discussion of this topic.

4.4.3 Methodology

The methodology NHTSA used to characterize the effects of the proposed action and alternatives on climate has three key elements: (1) estimating GHG emissions under each alternative (including the No Action Alternative), (2) estimating the monetized damages associated with carbon dioxide (CO_2) emissions and the reductions in those damages that would be attributable to each regulatory alternative, and (3) analyzing how the estimated GHG emissions might affect the climate system (climate effects). The methodology for estimating GHG emissions is described in Section 4.1.2 and in Section 4.4.3.1, below. The methodology for estimating the social cost of carbon is described in Section 4.4.3.2. The methodologies for analyzing how GHG emissions affect global climate parameters (such as atmospheric CO_2 concentration, surface temperature, precipitation patterns, and sea level) are described in Section

4.4.3.3 and 4.4.3.4. The methods NHTSA used to characterize emissions and climate change impacts involve considerable uncertainty. *See* Section 3.4.3 for a discussion of uncertainty in emissions scenarios, the global climate system, and climate models.

4.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

GHG emissions were estimated by scaling the GHG emissions estimated from the Motor Vehicle Emissions Simulator (MOVES) and Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) models (described in Section 3.1.4) to take into account projected annual gains in fuel efficiency implied in AEO. The methodology for modeling GHG emissions is described in Section 3.4.3.1. The scaling methodology to incorporate projected annual gains in fuel efficiency to 2050 is described in Section 4.1.2. GHG emissions from MYs 2051–2100 HD vehicles were then scaled using Global Change Assessment Model (GCAM) assumptions regarding the growth of U.S. transportation fuel consumption, as described in Section 3.4.3.1.[12] The analysis of cumulative impacts presented in this section includes reasonably foreseeable actions beyond this proposed action. *See* Section 4.4.3.4 below for a detailed description of these additional actions.

4.4.3.2 Social Cost of Carbon

This section describes the methodology used to estimate the monetized damages associated with CO_2 emissions and the reductions in those damages that would be attributable to each alternative including the No Action Alternative. As described in Section 3.4.3.2, NHTSA adopted an approach that relies on estimates of the social cost of carbon (SCC) developed by the Interagency Working Group on Social Cost of Carbon; this approach is consistent with the analysis in the draft RIA for the proposed HD vehicle rule (*See* the "Draft Regulatory Impact Analysis" accompanying the joint rule *available* on docket number NHTSA-2010-0079).

The SCC is an estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions. NHTSA multiplied the estimated value of the SCC for each future year by the emission reductions estimated to result during that year from each alternative analyzed in this EIS to estimate the monetized climate-related benefits associated with each alternative. The description below (which mirrors the discussion in the draft RIA) provides details of this analysis.

The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. The SCC estimates used in this analysis were developed through an interagency process that included the U.S. Department of Transportation (DOT)/NHTSA, EPA, and other executive branch entities. This process was completed in February 2010. These SCC estimates were used previously in the benefits analysis for the final joint EPA/DOT Rulemaking to establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards.[13] The SCC Technical Support Document (TSD) provides a complete discussion of the methods used to develop these SCC estimates.[14]

[12] The last year for which the MOVES model provides estimates of fleet CO_2 emissions is 2050.
[13] For a discussion about the application of the SCC, *see* the preamble to the Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Final Rule, 75 *FR* 25324 (May 7, 2010).
[14] (EPA 2010b) Docket ID EPA-HQ-OAR-2009-0472-114577, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon*, with participation by Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and

The interagency group selected four SCC values for use in regulatory analyses, which NHTSA has applied in this analysis: approximately $5, $22, $36, and $66 per metric ton of CO_2 emissions occurring in 2010, in 2008 dollars.[15] The first three values are based on the average SCC from three integrated assessment models, at discount rates of 5, 3, and 2.5 percent, respectively. SCCs at several discount rates are included because the literature shows that the SCC is quite sensitive to assumptions about the discount rate and because no consensus exists on the appropriate rate to use in an intergenerational context. The fourth value is the 95th percentile of the SCC from all three models at a 3-percent discount rate. This value is included to represent higher-than-expected impacts from temperature change farther out in the tails of the SCC probability distribution. Low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models, as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn leads to higher projections of damages.

The SCC increases over time because incremental increases in emissions are expected to produce progressively larger incremental damages over future years as physical and economic systems become more stressed in response to greater climatic change. The interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual growth rate. This approach helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 4.4.3-1 presents the SCC estimates used in this analysis. Note that the interagency group provided estimates of the SCC only through 2050. Therefore, unlike other elements of the climate change analysis in this EIS, which generally extend to 2100, the SCC analysis covers a shorter time frame.

Table 4.4.3-1

Social Cost of CO_2, 2010–2050 (in 2008 dollars per metric ton)

	Discount Rate and Statistic			
Year	5% Average	3% Average	2.5% Average	3% 95th percentile
2010	$4.80	$21.85	$35.84	$66.26
2015	$5.87	$24.35	$39.21	$74.33
2020	$6.94	$26.85	$42.58	$82.39
2025	$8.45	$30.15	$46.84	$92.25
2030	$9.95	$33.44	$51.10	$102.10
2035	$11.46	$36.73	$55.36	$111.95
2040	$12.97	$40.02	$59.63	$121.81
2045	$14.50	$42.93	$63.00	$130.43
2050	$16.03	$45.84	$66.37	$139.06

Several serious challenges arise when attempting to assess the incremental economic impacts of CO_2 emissions. A recent report from the National Academies (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of GHGs, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into

Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also *available at* http://epa.gov/otaq/climate/regulations.htm.

[15] The SCC estimates were converted from 2007 dollars to 2008 dollars using a gross domestic product (GDP) price deflator (1.021) obtained from the Bureau of Economic Analysis, National Income, and Product Accounts Table 1.1.4, *Price Indexes for Gross Domestic Product* (BEA 2010).

economic damages. As a result, any effort to quantify and monetize the harm associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

The interagency group noted several limitations to the SCC analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes the interagency modeling exercise even more difficult. The interagency group hopes that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. Additional details on these limitations are discussed in the SCC TSD.

Although CO_2 is the most prevalent GHG emitted into the atmosphere, other GHGs, including methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, also contribute to climate change. Because these gases differ in both radiative forcing (the increase in temperature likely to result from increasing atmospheric concentrations of each gas) and their atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer lived gases. Thus, transforming gases into CO_2-equivalents using global warming potential (GWP), and then multiplying the carbon equivalents by the SCC, would result in inaccurate estimates of the social costs of non-CO_2 gases; the SCC estimates used in this analysis therefore account only for the effects of changes in CO_2 emissions.

Although the SCC analysis omits the effects of changes in non-CO_2 GHG emissions, most of the emission reductions for this proposed action are of CO_2. Given the broad range in the values of SCC used in this EIS, the omission of the other GHGs does not pose a barrier to distinguishing among alternatives.

The global SCC estimates, in constant 2008 dollars per metric ton of CO_2 emitted, are presented in Table 4.4.3-1. These values are the average SCCs across all three integrated assessment models used in the interagency group's SCC analysis. The final column in the table indicates the 95th percentile of the SCC at a 3-percent discount rate, averaged across the three models. Annual versions of these values are used in the subsequent calculations in this section. The figures are in 2008 dollars for emissions occurring in the years shown in the table.

4.4.3.3 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: (1) changes in CO_2 concentrations, (2) changes in global 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, in turn, influences each indirect effect, including global mean surface temperature, changes in regional temperature and precipitation patterns, and changes in sea level.

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, and uses increases in global mean surface temperature combined with an approach and coefficients from the IPCC Fourth Assessment Report (IPCC 2007) to estimate changes in global precipitation. NHTSA used the publicly available modeling software Model for Assessment of Greenhouse Gas-induced Climate Change (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, methane (CH_4), nitrous oxide (N_2O), CO, NO_x, SO_2, and

VOCs produced by scaling emissions estimated from the MOVES and GREET models for the Chapter 3 analysis. Sensitivity analyses examine the relationship among the 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 alternatives on direct and indirect climate effects.

Sections 4.4.3.3.1, 4.4.3.3.2, and 4.4.3.3.3, respectively, describe MAGICC, the Reference Case modeling runs, and the sensitivity analysis. The emissions scenarios NHTSA used in the analysis are described in Section 4.4.3.4.

4.4.3.3.1 MAGICC Version 5.3.v2

The selection of MAGICC for this analysis was driven by several factors, as described in Section 3.4.3.3.1. NHTSA assumed that global emissions consistent under the No Action Alternative (Alternative 1) would follow the trajectory provided by the GCAM6.0 scenario. This scenario represents a Reference Case in which future global emissions assume significant global actions to address climate change. Section 4.4.3.4 describes the GCAM scenarios.

4.4.3.3.2 Reference Case Modeling Runs

The approach for the Reference Case modeling runs was based on the approach described in Section 3.4.3.3.2. For this analysis, NHSTA assumed that global emissions under the No Action Alternative (Alternative 1) follow the trajectories provided by the GCAM6.0 scenario, rather than the GCAM reference scenario used in Section 3.4. Section 4.4.4 presents the results of the Reference Case modeling runs.

4.4.3.3.3 Sensitivity Analysis

The approach for the sensitivity analysis was based on the same approach described in Section 3.4.3.3.3. In the Chapter 4 analysis, NHTSA assumed multiple global emissions scenarios including GCAM6.0 (678 ppm as of 2100); RCP4.5 (522 ppm as of 2100); and GCAM reference scenario (785 ppm as of 2100). The Section 3.4 analysis did not assess the sensitivity around different global emissions scenarios. These global emissions scenarios represent various levels of implementation of global GHG emission reduction policies. Section 4.4.4.3.5 presents the results of the sensitivity analysis.

4.4.3.4 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 U.S. Climate Change Science Program (CCSP) effort to develop a set of long-term (2000 to 2100) emissions scenarios that incorporate an update of economic and technology data and use improved scenario development tools compared with the IPCC *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) developed more than a decade ago. *See* Section 3.4.3.3 for background on the development of the CCSP scenarios.

The results in this chapter rely primarily on the GCAM6.0 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 HD Fuel Efficiency Improvement Program alternatives can be measured.[16]

[16] 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

NHTSA chose the GCAM6.0 scenario to represent reasonably foreseeable actions based on the following factors:

- The GCAM6.0 scenario is the GCAM representation of the radiative forcing target (6.0 W/m^2) of the RCP scenarios 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. The GCAM6.0 scenario 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 678 parts per million by volume (ppmv)[17], after accounting for the contributions to radiative forcing from the non-CO_2 GHGs. This scenario therefore represents a plausible future pathway of global emissions in response to significant global action to mitigate climate change.

- GCAM scenarios are more than a decade more recent than the IPCC SRES, and therefore include updated economic and technology data/assumptions. GCAM scenarios also use improved integrated assessment models that account for advances in economics and science over the past 10 years.

The GCAM6.0 scenario assumes a moderate level of global GHG reductions, resulting in a global atmospheric CO_2 concentration of roughly 678 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, the GCAM6.0 scenario can be considered reasonably foreseeable under NEPA.

4.4.3.4.1 Reasonably Foreseeable Actions Related to the Cumulative Impacts Analysis

United States: Regional Actions[18]

- **Regional Greenhouse Gas Initiative (RGGI).** Beginning January 1, 2009, RGGI was 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 emission reduction from the 2015 cap from the power sector by 2018 (RGGI 2009b). Thus, the cap comprises two phases: the first is a stabilization phase from 2009 to 2014, and the second is a reduction phase from 2015 through 2018.

- **Western Climate Initiative (WCI)** – The WCI includes seven partner States (Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington) and four partner

emissions scenario used for the analysis assumes that no significant global controls or large efforts to mitigate the projected continued growth of global GHG emissions are in place. Given that the climate system is nonlinear, 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.

[17] Based on 3.0 °C climate sensitivity.

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

Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec), along with 15 additional observer States or provinces in the United States, Canada, and Mexico (not currently active participants). Set to begin on January 1, 2012, the WCI cap-and-trade program will cover emissions of the six main GHGs (CO_2, CH_4, N_2O, hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], and sulfur hexafluoride [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. Affected 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. Not all WCI States are planning to participate in the first phase, but approximately two-thirds of all jurisdictional emissions are estimated to be covered (WCI 2010). The second phase begins in 2015, when the program expands to include transportation fuels and residential, commercial, and industrial fuels not otherwise covered (WCI 2010). When fully implemented in 2015, the program will cover nearly 90 percent of GHG 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. The Accord will establish GHG-reduction targets and time frames consistent with member States' targets; develop a market-based and multi-sectoral 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

- **NHSTA and EPA Joint Rulemaking on Fuel Efficiency and GHG Emissions Standards for Light-Duty Vehicles.** In a Joint Rulemaking published in April 2010, NHTSA and EPA issued a joint Final Rule establishing a new National Program to regulate MYs 2012–2016 passenger cars and light trucks to improve fuel efficiency and reduce GHG emissions. NHTSA issued CAFE standards for MYs 2012–2016 passenger cars and light trucks under the Energy Policy and Conservation Act (EPCA) and Energy Independence and Security Act (EISA). These standards will yield MY 2016 vehicles with an estimated fleet-wide average of 34.1 mpg. Jointly, EPA issued the first national GHG emissions standards under Section 202(a) of the Clean Air Act. EPA standards will require vehicles to achieve an average of 250 grams per mile of CO_2 in MY 2016. Vehicles covered under this rulemaking are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. The program is intended to reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (NHTSA 2010 citing EPA 2009c).

- **NHTSA and EPA Joint Actions to Develop Model Year 2017 and Beyond Light-Duty Vehicle Standards.** As a continuation to their recent Joint Rulemaking, NHTSA and EPA plan to create more stringent GHG emissions and fuel-efficiency standards for light-duty vehicles built for MY 2017 and beyond. On September 30, 2010, NHTSA and EPA issued a Notice of Intent announcing their plans for setting light-duty vehicle standards for MYs 2017–2025. NHTSA and EPA will work with California to harmonize regulations and create a single set of standards that will meet all Federal and State regulations. This process is intended to lessen the burden on manufacturers and regulators alike while increasing light-duty vehicle efficiency and lowering GHG emissions from the transportation sector.

- **Energy Bills in the 111th Congress.** H.R. 2454, the American Clean Energy and Security Act of 2009 ("Waxman-Markey Bill"), passed in the House on June 26, 2009 (a Senate vote is still pending). The bill would amend the Clean Air Act to require the EPA Administrator to promulgate regulations to cap and reduce GHG emissions, annually, to yield GHG emission reductions from capped sources of 17 percent (below 2005 levels) by 2020, 42 percent by 2030, and 83 percent by 2050; and establish a Federal GHG registry, among other amendments. In the U.S. Senate, S. 1733, Clean Energy Jobs and American Power Act ("Kerry-Boxer Bill"), proposes to cut U.S. GHG emissions by 20 percent by 2020 and 83 percent by 2050 relative to the 2005 baseline. Included in the bill's key elements are: a coordinated approach to geological sequestration of CO_2, new performance standards for coal-fired plants, programs to research furthering of nuclear power use, water-use efficiency programs, and new energy efficiency standards for buildings. The Kerry-Boxer bill passed out of the Senate Environment and Public Works Committee on November 5, 2009 (a Senate vote is still pending). S. 3738, The Clean Energy Technology Leadership Act of 2010 was introduced in August 2010 to provide Federal tax incentives for biofuels and renewable energy production and research; the bill was referred to the Senate Committee on Finance.

- **EPA Prevention of Significant Deterioration (PSD) and Title V Greenhouse Gas Tailoring Rule.** In May 2010, EPA issued rules to address GHG emissions from stationary sources under Clean Air Act permitting programs. Under the first step to phase in this rule, set to start January 2, 2011, only those sources already subject to the PSD program due to their non-GHG emissions (which includes newly constructed facilities or those that are modified to significantly increase non-GHG emissions) are subject to PSD and Title V permitting requirements. During the first step, such facilities that have emissions increases of at least 75,000 tons per year (tpy) of GHGs (based on carbon dioxide equivalent [CO_2e]), and also significantly increase emissions of at least one non-GHG pollutant, will need to implement Best Available Control Technology (BACT). During the first step, no sources are subject to permitting requirements based solely on their GHG emissions. The second step, which begins July 1, 2011, covers all new facilities with the potential to emit at least 100,000 tpy of CO_2e and modifications to existing facilities that result in emissions of at least 100,000 tpy and that increase GHG emissions by at least 75,000 tpy CO_2e . Title V requirements will apply to facilities that emit at least 100,000 tpy CO_2e. Additionally, any modifications of existing facilities that result in increases of GHG emissions of at least 75,000 tpy will be subject to permitting requirements. EPA has also committed to undertake a rulemaking beginning in 2011 and ending no later than July 1, 2012. This rulemaking will consider an additional step (step three) for phasing in rulemaking. This third step would begin by July 1, 2013. EPA will consider in this rulemaking streamlining the permitting procedure and may consider whether smaller sources can be permanently excluded from permitting requirements. EPA has already stated that this third step will not apply to sources with GHG emissions below 50,000 tpy and that the agency will not issue requirements for smaller sources until April 30, 2016.

- **Renewable Fuel Standard 2 (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 2009a), and the renewable fuel standard for 2010 is 8.25 percent (75 *FR* 14670). EPA estimates that the greater volume of biofuel mandated by RFS2 will reduce life-cycle GHG emissions by an annual average of 150 million tons CO_2e (EPA 2009b).

- **United States GHG Emissions Target in Association with the Copenhagen Accord.** Building on the pledge made at the December 2009 U.N. climate change conference in Copenhagen (COP-15), President Obama submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020, in association with the Copenhagen Accord. This target conforms to anticipated U.S. energy and climate legislation, and recognizes that the final target will be reported to the U.N. Secretariat in light of enacted legislation. Initial activities toward this goal include an $80-billion investment in clean energy through the American Recovery and Reinvestment Act of 2009, more stringent energy efficiency standards for commercial and residential appliances, and development of wind energy on the Outer Continental Shelf, among other Federal initiatives. On January 28, 2010, the United States submitted this target to the U.N. Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the [U.N.] in light of enacted legislation" (U.S. Department of State 2010).

International Actions

- **United Nations Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol, and the December 2009 Conference of the Parties (COP)-15.** UNFCCC is an international treaty signed by many countries around the world (including the United States[19]), 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 UNFCCC. The major feature of the Kyoto Protocol is its binding targets for 37 industrialized countries and the European Community for reducing GHG emissions, which covers more than half of the world's GHG emissions. These amount to an average of 5 percent of 1990 levels over the 5-year period 2008 through 2012 (UNFCCC 2005). At COP-15, and for the first time, all major developed and developing countries agreed to pledge specific emission reductions. As of October 14 2010, 139 countries have agreed to the Copenhagen Accord, accounting for the vast majority of global emissions (UNFCCC 2010); the pledges, however, are not legally binding, and much remains to be negotiated.

[19] 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 the Kyoto Protocol has not been submitted 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).

- **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 worldwide (European Union 2009). The aim of the EU ETS is to help European Union member states achieve compliance with their commitments under the Kyoto Protocol (European Union 2005). This trading system does not entail new environmental targets; instead, it allows for less expensive compliance with existing targets under the Kyoto Protocol. The scheme is based on Directive 2003/87/EC, which entered into force on October 25, 2003 (European Union 2009), and covers more than 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, and iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp, and paper (European Union 2005).

- **G8 Declaration – Summit 2010.** During the June 2010 G8 Summit in Canada, the G8 Nations officially reiterated their support of the Copenhagen Accord and urged countries not already signed on to associate themselves with the accord and its goals. The G8 summit officially recognized a goal that the global temperature should not increase by more than 2 °C. A statement was made supporting a fair but binding post-2012 agreement for all countries to reduce their GHG emissions.

- **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 the 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).

Assessing the contributions of each of these policies or initiations to the cumulative total is difficult. However, the GCAM6.0 scenario serves as a useful proxy because it provides a global context for emissions of a full suite of GHGs and ozone precursors for a Reference Case harmonious with implementation of these policies and initiatives. Some inconsistencies exist between the overall assumptions used by GCAM6.0 (Moss et al., 2008; Moss et al., 2010)) to develop global emissions scenarios and the fuel efficiency and VMT assumptions used by EPA in their modeling of GHG emissions from HD vehicles. Because these inconsistencies affect the characterization of each HD Fuel Efficiency Improvement Program alternative in equal proportion, however, the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives.

NHTSA used the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects in the Chapter 4 analysis, but used the RCP4.5 scenario and the GCAM reference emissions scenario (an updated version of the MiniCAM model scenario) to evaluate the sensitivity of the results to alternative emissions scenarios. The GCAM reference emissions scenario assumes that no climate policy would be implemented beyond the current set of policies in place, whereas the GCAM6.0 and RCP4.5 scenarios correspond to total radiative forcing stabilization by 2100 and associated CO_2 concentrations at roughly 678 ppmv and 522 ppmv, respectively, after accounting for the contributions to radiative forcing from the non-CO_2 GHGs.

Separately, each action alternative 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 GCAM6.0 scenario to generate modified global-scale emissions scenarios, which show the effect of the various alternatives on the global emissions path. For example, emissions from HD vehicles in the United States in 2020 under the No Action Alternative are 647 million metric tons of CO_2 ($MMTCO_2$); emissions in 2020 under the Preferred Alternative (Alternative 6) are 618 $MMTCO_2$ (*see* Table 4.4.4-2). The difference of 30 $MMTCO_2$ (rounded) represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global CO_2 emissions for the GCAM6.0 scenario in 2020 are 37,522 $MMTCO_2$, which are assumed to incorporate the level of emissions from HD vehicles in the United States under the No Action Alternative. Global emissions under the Preferred Alternative are thus estimated to be 30 $MMTCO_2$ less than this reference level, or 37,492 $MMTCO_2$ in 2020.

Many of the economic assumptions used in the MOVES model (such as VMT, freight miles, and freight modal shares) are based on the EIA AEO 2010 (EIA 2010a) and International Energy Outlook (IEO) 2010 (EIA 2010b), which forecast energy supply and demand in the United States and globally to 2035. Appendix C includes a discussion of 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 GCAM6.0 and RCP4.5 scenarios and the GCAM reference scenario.

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 GCAM assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the emission estimates for the U.S. transportation sector provided by the MOVES 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.

4.4.3.5 Tipping Points and Abrupt Climate Change

Tipping points and abrupt climate change are discussed in Section 3.4.3.5 and the same conclusions drawn in that section apply to this cumulative impact analysis. A qualitative survey of the current state of climate science on tipping points and abrupt climate change is presented in Section 4.5.9.

4.4.4 Environmental Consequences

This section describes the consequences of the proposed action and alternatives, and other reasonably foreseeable future actions, in relation to GHG emissions and the consequences of global climate change.

4.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from the HD Fuel Efficiency Improvement Program, NHTSA uses the MOVES and GREET models (*see* Section 3.1.4 for descriptions of the models) and scaled the estimates using projected annual gains in fuel efficiency implied from AEO. The methodology for modeling GHG emissions is described in Section 3.4.3.1. The scaling methodology to incorporate projected annual gains in fuel efficiency to 2050 is described in Section 4.1.2. GHG emissions from MYs

2051–2100 HD vehicles were then scaled using GCAM assumptions regarding the growth of U.S. transportation fuel consumption, as described in Section 3.4.3.1.[20]

The change in fuel use projected to result from each alternative determines the resulting impacts on total energy and petroleum energy use, which in turn affects the amount of CO_2 emissions. These CO_2 emission 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 GHGs 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 efficiency.[21]

Cumulative emission reductions from each action alternative increase as fuel consumption decreases across alternatives, with Alternative 2 (Engine Only) having the lowest cumulative emission reductions and Alternative 8 (Accelerated Hybrid Option) having the highest cumulative emission reductions. Emission reductions represent the differences in total annual emissions by all HD vehicles in use between their estimated future levels under the No Action Alternative (baseline) and under each action alternative.

Table 4.4.4-1 shows total GHG emissions and emission reductions from new HD vehicles from 2014–2100 under each action alternative. Projections of emission reductions over 2014 to 2100 due to the MYs 2014–2018 HD Fuel Efficiency Improvement Program standards and other reasonably foreseeable future actions ranged from 3,500 to 10,600 $MMTCO_2$. Compared to cumulative global

Table 4.4.4-1

Cumulative Effects of Emissions and Emission Reductions ($MMTCO_2$) from 2014 to 2100 by Alternative a/

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative	Emissions Reductions Compared to No Action Alternative (%)
1 No Action	74,600	0	
2 Engine Only	71,100	3,500	5%
3 Class 8 Tractors	70,700	3,900	5%
4 Engines & Classes 7–8 Tractors	68,700	5,900	8%
6A 15% below Preferred Alternative Stringency	68,600	6,100	8%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	68,300	6,300	8%
6 Engines, Tractors, & Classes 2b–8	67,700	6,900	9%
7 Engines, Tractors, Trucks, & Trailers	67,300	7,300	10%
6B 20% above Preferred Alternative Stringency	66,500	8,200	11%
8 Accelerated Hybrid Adoption	64,000	10,600	14%

a/ Note: The numbers in this table have been rounded for presentation purposes. As a result, the reductions do not reflect the exact differences of the values.
b/ Preferred Alternative

[20] The last year for which the MOVES model provides estimates of fleet CO_2 emissions is 2050.
[21] Although this section includes only a discussion of CO_2 emissions, the climate modeling discussion in Section 4.4.4.4 assesses the direct and indirect effects associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.

emissions of 4,294,482 $MMTCO_2$ over this period (projected by the GCAM6.0 scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.1 to 0.2 percent from their projected levels under the No Action Alternative.

To illustrate the relative impact of these reductions, it can be helpful to consider the magnitude of emissions from HD vehicles as a whole and to compare them against emissions projections from the United States and to the expected or stated goals from existing programs designed to reduce CO_2 emissions. As mentioned previously, HD vehicles in the United States currently account for approximately 6.9 percent of U.S. CO_2 emissions. With the action alternatives reducing U.S. HD vehicle CO_2 emissions by 5–14 percent over 2014–2100, the proposed action 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 GCAM6.0 scenario of 4,401 $MMTCO_2$ (Clarke *et al.* 2007), the action alternatives would reduce total U.S. CO_2 emissions by 1.0 to 3.1 percent in 2100. Figure 4.4.4-1 shows projected annual emissions from HD vehicles for MYs 2014–2018 and other reasonably foreseeable future actions.

As Table 4.4.4-2 shows, total CO_2 emissions from the HD vehicle fleet in the United States are projected to increase substantially from their levels in 2014 under the No Action Alternative, which assumes increases in both the number of HD vehicles and in VMT per vehicle. The table also shows that each action alternative would reduce total HD vehicle 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 through 2080, due to decreased fuel consumption of the fleet as vehicles turnover

Under all of the alternatives, growth in the number of HD vehicles 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 HD VMT. As a result, despite increases in fuel efficiency, total fuel consumption and CO_2 emissions by HD vehicles in the United States is projected to increase under each action alternative, as shown in the Figure 4.4.4-1. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from HD vehicles.

Emissions of CO_2, the primary gas that drives climate effects, from the U.S. HD vehicle fleet represented about 1.2 percent of total global emissions of CO_2 in 2005 (EPA 2010a, WRI 2010).[22] Although substantial, this source is still a small percentage of global emissions. The relative contribution of CO_2 emissions from U.S. HD vehicles is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are, in turn, due in part to growth in global transportation sector emissions). These conclusions are not meant to be interpreted as expressing NHTSA views that the U.S. vehicle fleet's contribution to global CO_2 emissions is not an area of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] *of the proposed action*." 42 U.S.C. § 4332(2)(C)(i) (emphasis added). The analysis in this EIS fulfills NHTSA obligations in this regard.

These emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the WCI to develop regional strategies to address climate change. WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent during 2009 to 2020 (WCI 2007). By comparison, this rulemaking is expected to reduce CO_2 emissions by 51 to 145 $MMTCO_2$ between 2014 and 2020. In the Northeast and Mid-Atlantic, nine States have formed RGGI to reduce CO_2 emissions from power plants. The program

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

Figure 4.4.4-1. Cumulative Annual Emissions Under the MYs 2014–2018 Standards and Other Reasonably Foreseeable Future Actions ($MMTCO_2$)

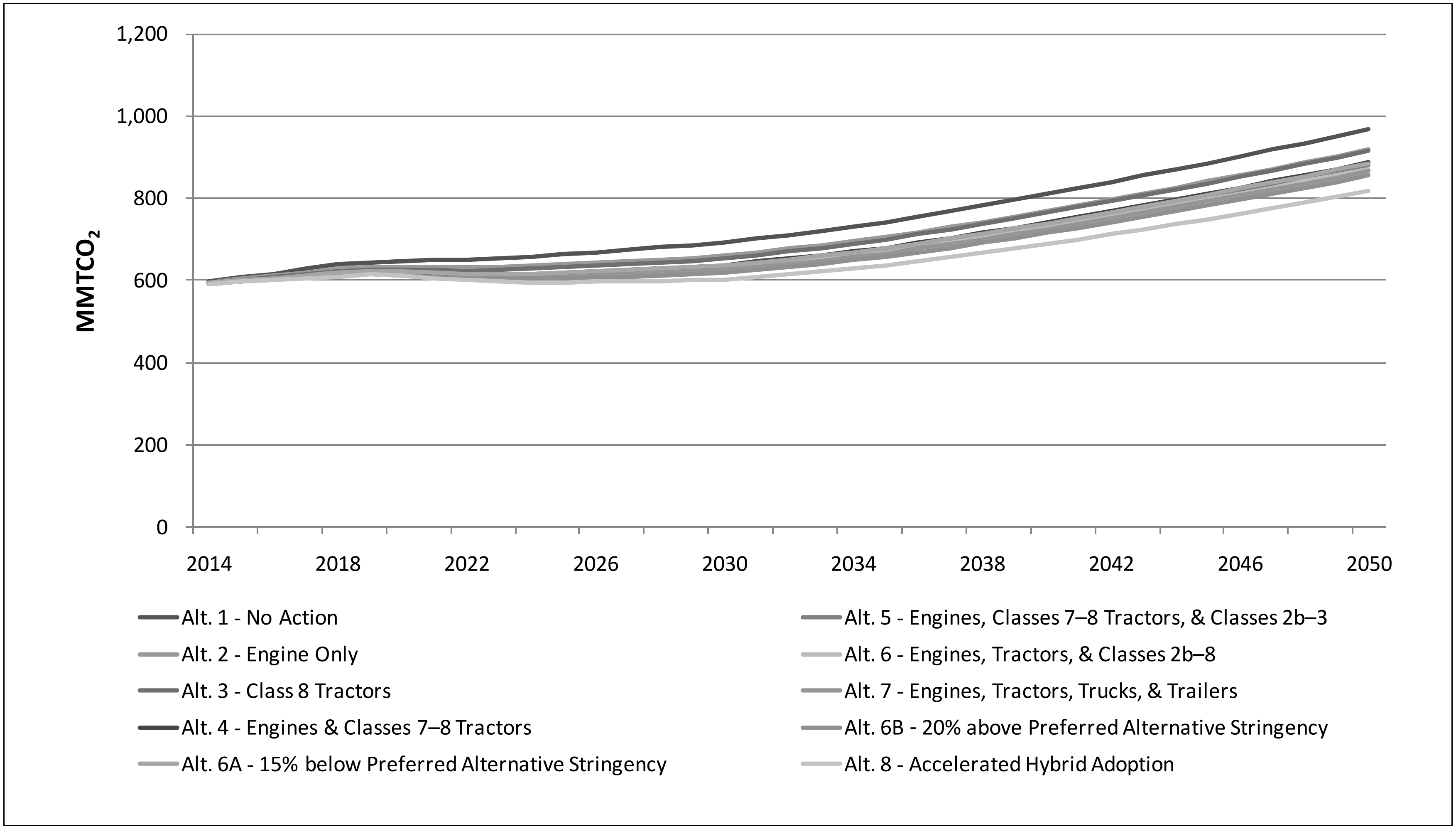


Table 4.4.4-2

Cumulative Effects of Nationwide Emissions of Greenhouse Gases (MMTCO$_2$e per year) from HD Vehicles by Alternative

GHG and Year	Alt. 1 No Action	Alt. 2 Engine Only	Alt. 3 Class 8 Tractors	Alt. 4 Engines & Classes 7 8 Tractors	Alt. 6A 15% below Preferred Alternative Stringency	Alt. 5 Engines, Classes 7 8 Tractors, & Classes 2b–3	Alt. 6 Engines, Tractors, & Classes 2b–8 a/	Alt. 7 Engines, Tractors, Trucks, & Trailers	Alt. 6B 20% above Preferred Alternative Stringency	Alt. 8 Accelerated Hybrid Adoption
Carbon dioxide (CO_2)										
2014	597	595	594	593	593	593	593	592	592	592
2020	647	634	626	620	621	619	618	615	613	612
2030	692	661	653	637	636	633	629	625	619	602
2050	968	919	915	887	885	881	872	866	855	818
2080	957	908	904	876	874	870	861	856	844	808
2100	890	844	841	815	813	809	801	796	785	751
Methane (CH_4)										
2014	18.67	18.60	18.56	18.53	18.53	18.52	18.51	18.50	18.49	18.46
2020	20.03	19.68	19.43	19.27	19.34	19.25	19.22	19.15	19.12	19.12
2030	17.96	17.15	16.94	16.52	16.50	16.43	16.32	16.22	16.06	15.63
2050	22.96	21.80	21.69	21.02	20.95	20.87	20.65	20.53	20.25	19.37
2080	22.68	21.53	21.42	20.76	20.70	20.61	20.40	20.28	20.00	19.14
2100	21.10	20.03	19.93	19.31	19.25	19.17	18.97	18.86	18.60	17.80
Nitrous oxide (N_2O)										
2014	2.21	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
2020	1.69	1.69	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
2030	1.18	1.16	1.15	1.14	1.14	1.13	1.13	1.13	1.12	1.11
2050	1.40	1.37	1.37	1.35	1.35	1.34	1.34	1.33	1.32	1.30
2080	1.39	1.35	1.35	1.33	1.33	1.33	1.32	1.32	1.31	1.28
2100	1.29	1.26	1.25	1.24	1.24	1.23	1.23	1.22	1.22	1.19

a/ Preferred Alternative

is projected to reduce emissions by 268 $MMTCO_2$ from 2006 to 2024 (RGGI 2006).[23] By comparison, NHTSA forecasts that this rulemaking will reduce CO_2 emissions by 128 to 354 $MMTCO_2$ over the 2014 to 2024 period.

Two features of these comparisons are 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, although emissions from HD vehicles are projected to increase under all alternatives for this rulemaking due to increases in vehicle ownership and use. Second, these projections are estimates, and the scope of these climate programs differs from that in this rulemaking in terms of geography, sector, and purpose.

In this case, the comparison of emission reductions from the action alternatives to emission 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 emission reductions that are on a scale similar to many of the most progressive and ambitious GHG emission reduction programs underway in the United States. Due to projected increases in VMT, however, increases attributed to the HD Fuel Efficiency Improvement Program are not projected to provide absolute emission reductions from today's levels of HD vehicle emissions, whereas some regional programs do predict such absolute reductions.

4.4.4.2 Social Cost of Carbon

Table 4.4.4-3 presents the benefits of the HD Fuel Efficiency Improvement Program along with other foreseeable policy changes, in terms of reduced monetized damages. By applying each future year's SCC estimate to the estimated reductions in CO_2 emissions during that year for each policy scenario, discounting the resulting figure to its present value, and summing those estimates for each year from 2014 to 2050, NHTSA derived the net present value of the benefits in 2014 (Table 4.4.4-3). For

Table 4.4.4-3

Reduced Monetized Damages of Climate Change for each Regulatory Alternative
Net Present Value in 2011 of CO_2 emission reductions between 2014 and 2050
(in millions of 2008 dollars)

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2	$ 3,552	$19,152	$ 32,735	$ 58,333
3	$ 4,301	$22,968	$ 39,179	$ 69,977
4	$ 6,210	$33,306	$ 56,864	$101,460
6A	$ 6,314	$33,912	$ 57,914	$103,298
5	$ 6,618	$35,531	$ 60,676	$108,234
6	$ 7,152	$38,456	$ 65,691	$117,140
7	$ 7,607	$40,866	$ 69,795	$124,482
6B	$ 8,381	$45,071	$ 76,991	$137,285
8	$10,345	$55,957	$ 95,702	$170,412

internal consistency, the annual benefits are discounted to net present value terms using the same discount rate as each SCC estimate (*i.e.,* 5 percent, 3 percent, and 2.5 percent), rather than the 3-percent and 7-

[23] 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.

percent discount rates applied to other future benefits.[24] Consistent with the SCC table in Section 4.4.3.2 (Table 4.4.3-1) these estimates show increasing benefits with decreasing discount rates (and higher damage estimates). The estimated net present value for a given alternative varies by approximately an order of magnitude across the discount rates. The estimated net present value computed using a single discount rate differs by roughly a factor of three across alternatives.

4.4.4.3 Cumulative Effects on Climate Change

The approach to estimating the cumulative effects of climate change from the MYs 2014–2018 HD Fuel Efficiency Improvement Program combined with other reasonably foreseeable future actions mirrors that used to estimate the direct and indirect effects of the proposed action and alternatives, with the exception of assumptions on continuation of fuel efficiency improvements and the global emissions scenario used.

NHTSA assumes that the overall fuel efficiency of new vehicles continues to improve until 2035 at a pace consistent with AEO 2010 (*see* Section 4.1.2). NHTSA also assumes fuel-efficiency increases consistent with the AEO projections under the No Action Alternative.

The HD Fuel Efficiency Improvement Program will apply to new vehicles, therefore this assumption results in emission reductions and fuel savings that continue to grow after 2035 as new vehicles meeting the increased fuel consumption requirements are added to the fleet in each subsequent year. Overall, the emission reductions for the HD Fuel Efficiency Improvement Program have a small impact on climate change. Despite this, these emission reductions 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 4.4.4.3.1 through 4.4.4.3.4 describe cumulative effects of the alternatives on climate change in terms of atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise.

4.4.4.3.1 Atmospheric Carbon Dioxide 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. *See* Section 3.4.6.2.1 for a comparison of MAGICC 5.3v2 results and reported results from the IPCC Fourth Assessment Report.

The GCAM6.0 scenario, which is a radiative forcing stabilization scenario with a corresponding CO_2 concentration level of roughly 678 ppmv in 2100, was used to represent the No Action Alternative (Alternative 1) in the MAGICC runs for this EIS. 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 nine 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 concentration and temperature is a small fraction of the total growth in CO_2 concentrations and global mean surface temperature. The relative impact of the action alternatives, however, is illustrated by the reduction in growth of both CO_2 concentrations and temperature.

[24] Other benefits or costs of proposed regulations unrelated to CO_2 emissions could be discounted at rates that differ from those used to develop the SCC estimates.

Table 4.4.4-4

Cumulative Effects on CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAM6.0) by Alternative a/

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)			Sea-level Rise (cm)		
Alternative	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Totals Under Alternative HD Fuel Efficiency Improvement Program Standards									
1 No Action	440.1	506.5	677.8	0.838	1.397	2.564	7.9	14.15	33.42
2 Engine Only	440.0	506.4	677.5	0.838	1.397	2.562	7.9	14.14	33.41
3 Class 8 Tractors	440.0	506.4	677.5	0.838	1.396	2.562	7.9	14.14	33.41
4 Engines & Classes 7-8 Tractors	440.0	506.3	677.3	0.838	1.396	2.561	7.9	14.14	33.40
6A 15% below Preferred Alternative Stringency	440.0	506.3	677.3	0.838	1.396	2.561	7.9	14.14	33.40
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	440.0	506.3	677.2	0.838	1.396	2.561	7.9	14.14	33.40
6 Engines, Tractors, & Classes 2b–8 b/	440.0	506.3	677.2	0.838	1.396	2.561	7.9	14.14	33.40
7 Engines, Tractors, Trucks, & Trailers	440.0	506.3	677.1	0.838	1.396	2.561	7.9	14.14	33.40
6B 20% above Preferred Alternative Stringency	440.0	506.3	677.1	0.838	1.396	2.560	7.9	14.14	33.39
8 Accelerated Hybrid Adoption	440.0	506.2	676.8	0.838	1.396	2.559	7.9	14.14	33.39
Reductions Under Alternative HD Fuel Efficiency Improvement Program Standards									
2 Engine Only	0.1	0.1	0.3	0.000	0.000	0.001	0.00	0.01	0.01
3 Class 8 Tractors	0.1	0.1	0.3	0.000	0.001	0.002	0.00	0.01	0.01
4 Engines & Classes 7–8 Tractors	0.1	0.2	0.5	0.000	0.001	0.002	0.00	0.01	0.02
6A 15% below Preferred Alternative Stringency	0.1	0.2	0.6	0.000	0.001	0.002	0.00	0.01	0.02
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.1	0.2	0.6	0.000	0.001	0.002	0.00	0.01	0.02
6 Engines, Tractors, & Classes 2b–8 b/	0.1	0.2	0.6	0.001	0.001	0.003	0.00	0.01	0.02
7 Engines, Tractors, Trucks, & Trailers	0.1	0.2	0.7	0.001	0.001	0.003	0.00	0.01	0.02
6B 20% above Preferred Alternative Stringency	0.1	0.3	0.7	0.001	0.001	0.003	0.00	0.01	0.03
8 Accelerated Hybrid Adoption	0.1	0.3	1.0	0.001	0.002	0.004	0.00	0.01	0.03

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

Figure 4.4.4-2. Cumulative Effects on CO_2 Concentrations

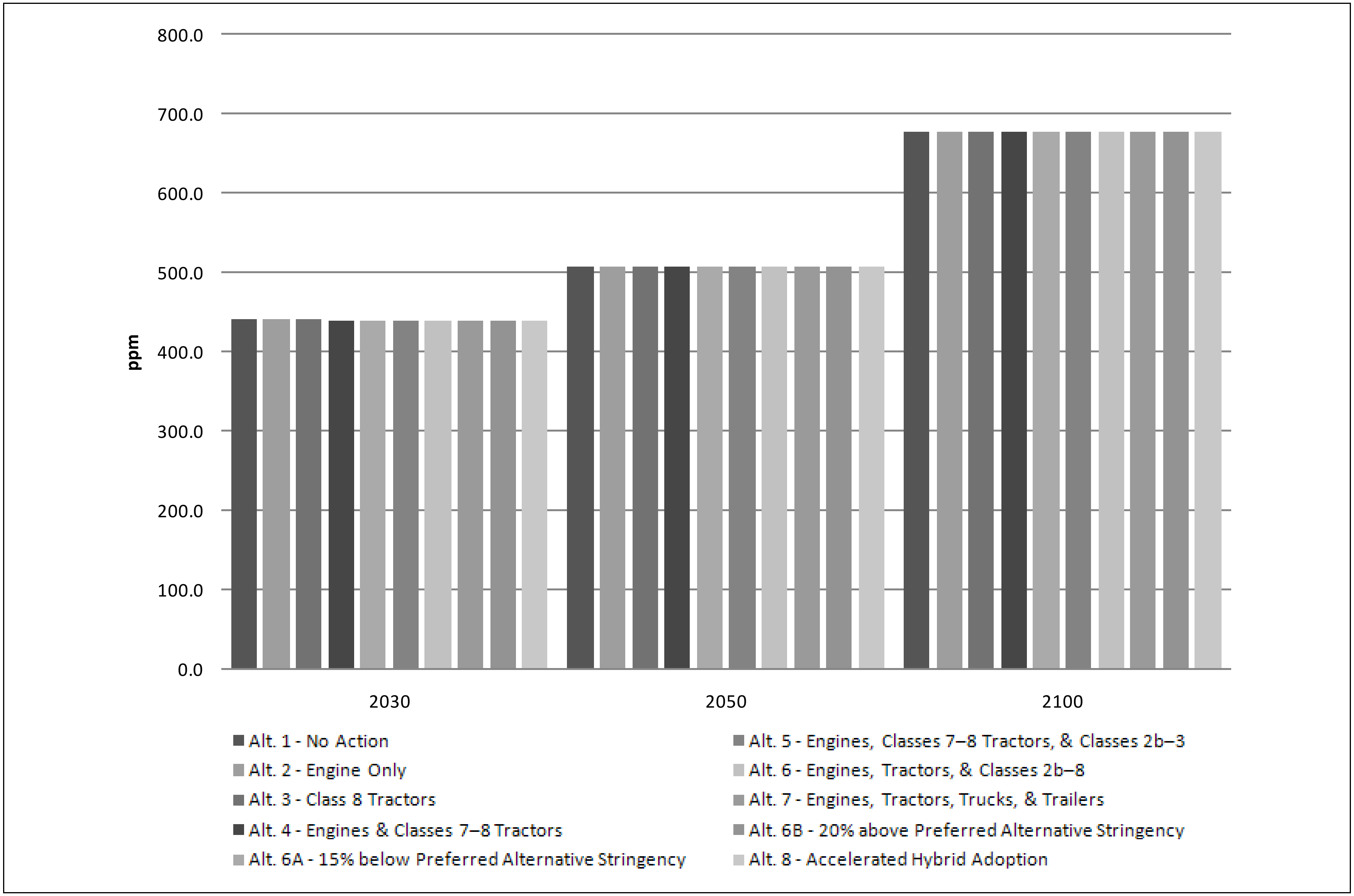


Figure 4.4.4-3. Cumulative Effects on Global Mean Surface Temperature Increase

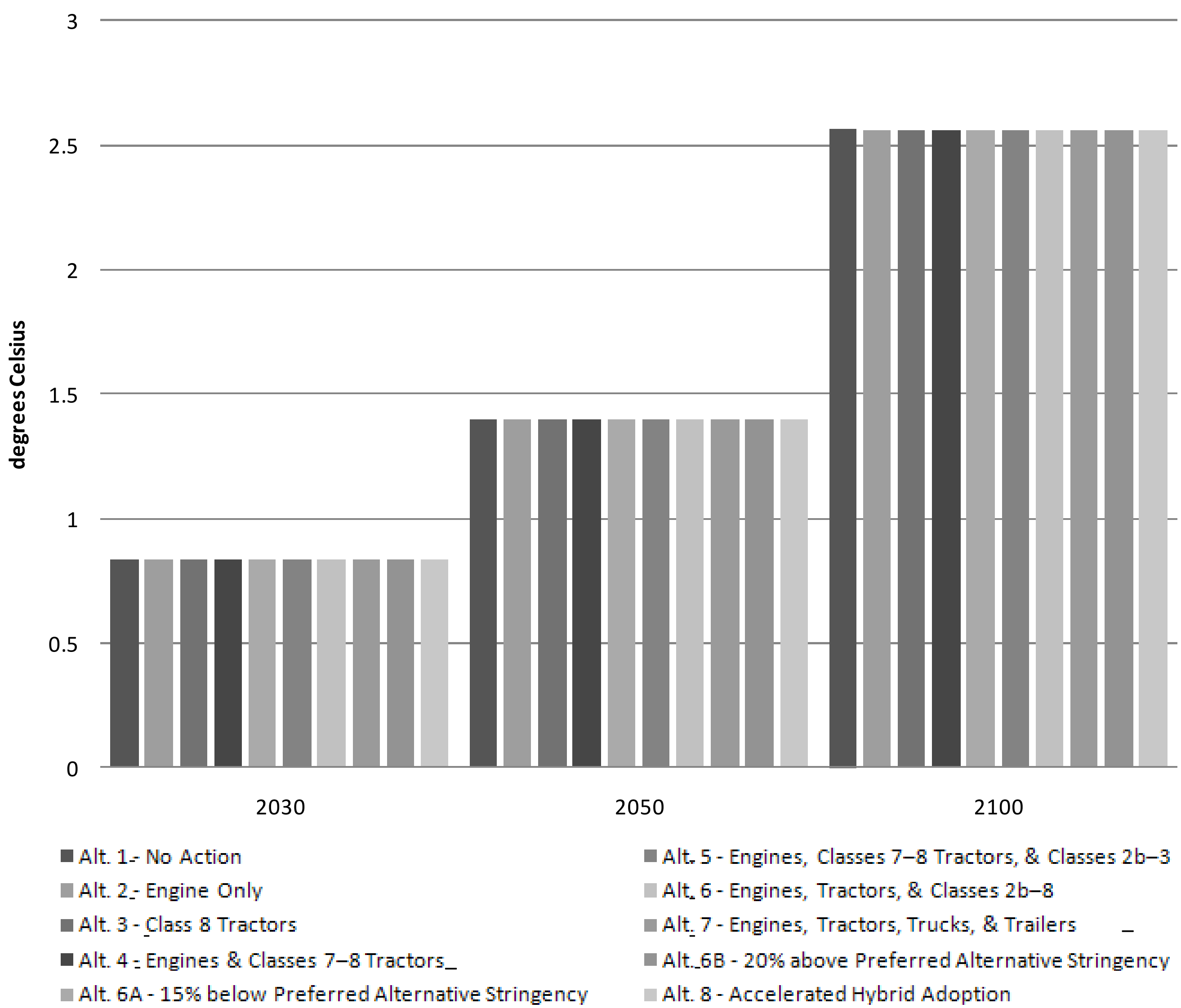


Figure 4.4.4-4. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

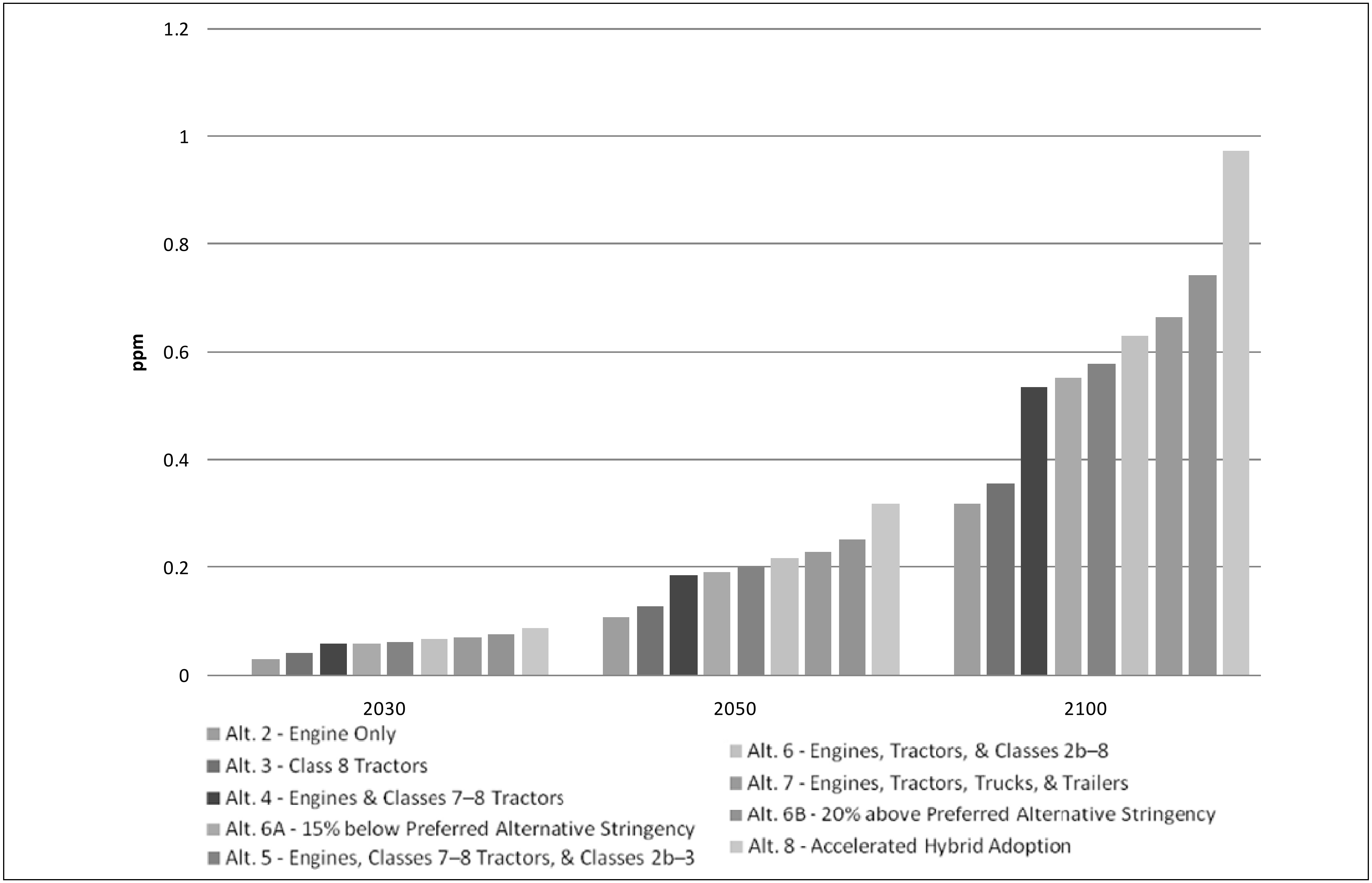
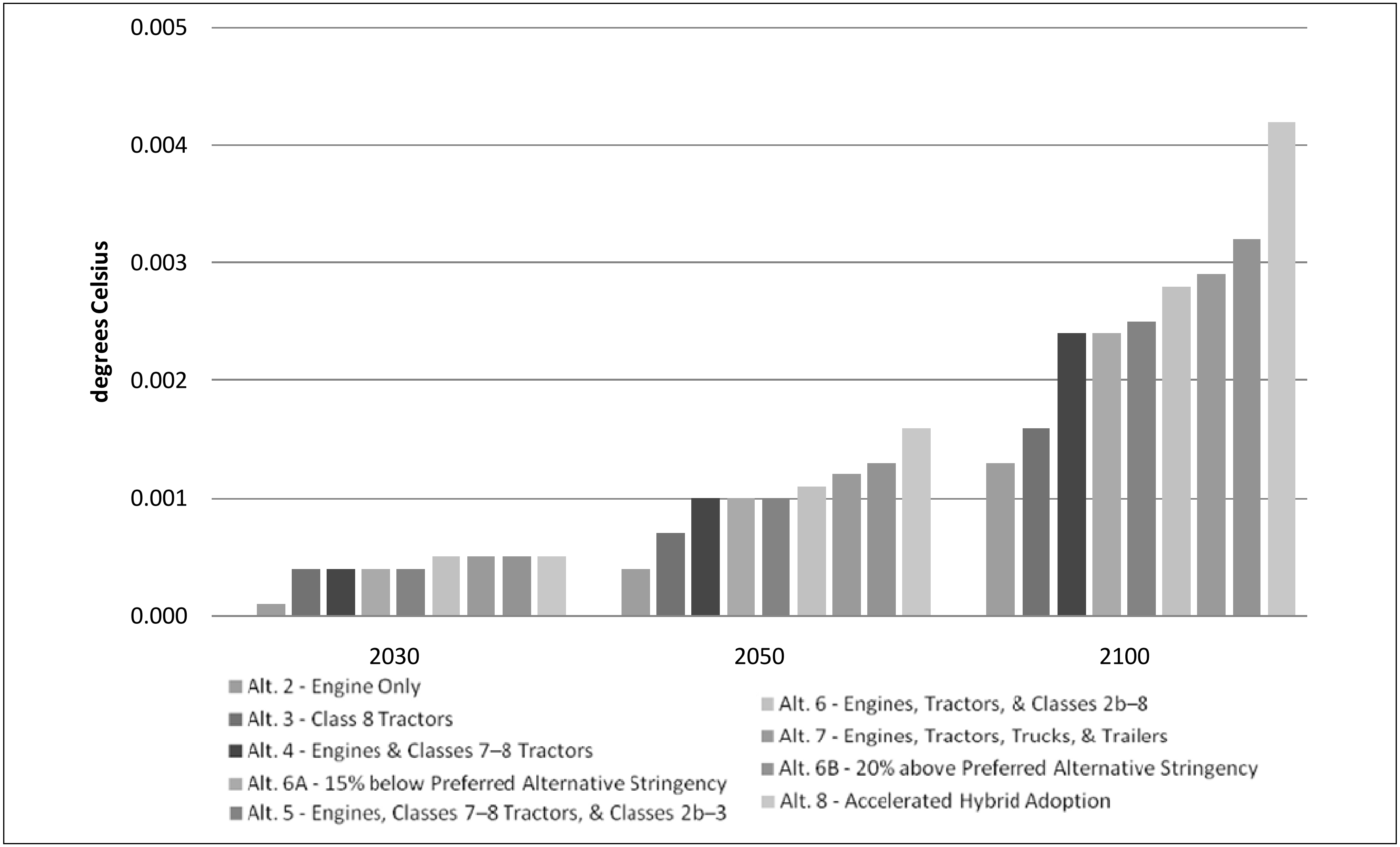


Figure 4.4.4-5. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)



As shown in the Table 4.4.4-4 and Figures 4.4.4-2 through 4.4.4-5, the band of estimated CO_2 concentrations as of 2100 is fairly narrow, from 676.8 ppm under Alternative 8 to 677.8 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 all other climate effects, the small changes in CO_2 would lead to small differences in climate effects. Although these effects are small, they occur on a global scale and are long-lived.

4.4.4.3.1 Temperature

MAGICC simulations of mean global surface air temperature increases are shown in Table 4.4.4-4. For all alternatives, the cumulative global mean surface temperature increase is projected to increase about 0.84 °C (1.51 °F) by 2030; 1.40 °C (2.52 °F) by 2050; and 2.56 °C (4.61 °F) by 2100.[25] 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 approximately 0.001 °C (0.002 °F) under Alternative 2 to 0.004 °C (0.007 °F) under Alternative 8. Although these effects are small, they occur on a global scale and are long- lived.

Quantifying the changes to regional climate from the proposed action and alternatives is not possible at this point due to the limitations of existing climate models. The alternatives, however, would be expected to reduce the changes in relation to the reduction in global mean surface temperature. Regional changes to warming and seasonal temperatures as described by the IPCC Fourth Assessment Report are summarized in Table 3.4.4-5 in Section 3.4.4.3.2.

4.4.4.3.2 Precipitation

The effects of higher temperatures on the amount of precipitation and the intensity of precipitation events, as well as the IPCC scaling factors to estimate global mean precipitation change, are discussed in Section 3.4.4.3.3. Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the action alternatives would reduce temperature increases slightly in relation to the No Action Alternative, they also would reduce predicted increases in precipitation slightly, as shown in Table 4.4.4-5 (again, based on the A1B [medium] scenario).

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This inability is due primarily to the lack of availability of atmospheric-ocean general circulation models (AOGCMs) required to estimate these changes. AOGCMs are typically used to provide results among scenarios having very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles produce results that would be difficult to resolve among scenarios having relatively small changes in emissions. Also, the multiple AOGCMs produce results that are regionally consistent in some cases but are inconsistent in others.

Quantifying the changes in regional climate from the action alternatives is not possible at this point, but the action alternatives would reduce the changes in relation to the reduction in global mean surface temperature. Regional changes to precipitation as described by the IPCC Fourth Assessment Report are summarized in Table 3.4.4-9 in Section 3.4.4.3.3.

[25] 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. The actual increase in surface temperature lags the commitment due primarily to the time required to heat the ocean to the level committed by the concentrations of the greenhouse gases.

Table 4.4.4-5

Cumulative Effects on Global Mean Precipitation (Percent Change) Based on GCAM6.0 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 GCAM6.0 Scenario and by Alternative			
1 No Action	0.583	1.533	2.386
2 Engine Only	0.583	1.532	2.385
3 Class 8 Tractors	0.583	1.532	2.385
4 Engines & Classes 7–8 Tractors	0.583	1.532	2.384
6A 15% below Preferred Alternative Stringency	0.583	1.532	2.384
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.583	1.532	2.384
6 Engines, Tractors, & Classes 2b–8 b/	0.583	1.532	2.384
7 Engines, Tractors, Trucks, & Trailers	0.583	1.532	2.383
6B 20% above Preferred Alternative Stringency	0.583	1.531	2.383
8 Accelerated Hybrid Adoption	0.583	1.531	2.382
Reduction in Global Temperature (K) by Alternative, Mid-level Results (Compared to No Action Alternative)			
2 Engine Only	0.000	0.000	0.001
3 Class 8 Tractors	0.000	0.001	0.002
4 Engines & Classes 7–8 Tractors	0.000	0.001	0.002
6A 15% below Preferred Alternative Stringency	0.000	0.001	0.002
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.000	0.001	0.002
6 Engines, Tractors, & Classes 2b–8 b/	0.000	0.001	0.002
7 Engines, Tractors, Trucks, & Trailers	0.000	0.001	0.003
6B 20% above Preferred Alternative Stringency	0.000	0.001	0.003
8 Accelerated Hybrid Adoption	0.000	0.002	0.004
Global Mean Precipitation Change (%)			
1 No Action	0.85%	2.31%	3.89%
2 Engine Only	0.85%	2.31%	3.89%
3 Class 8 Tractors	0.85%	2.31%	3.89%
4 Engines & Classes 7–8 Tractors	0.85%	2.31%	3.89%
6A 15% below Preferred Alternative Stringency	0.85%	2.31%	3.89%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.85%	2.31%	3.89%
6 Engines, Tractors, & Classes 2b–8 b/	0.85%	2.31%	3.89%
7 Engines, Tractors, Trucks, & Trailers	0.85%	2.31%	3.88%
6B 20% above Preferred Alternative Stringency	0.85%	2.31%	3.88%
8 Accelerated Hybrid Adoption	0.85%	2.31%	3.88%

Table 4.4.4-5 (continued)

Cumulative Effects on Global Mean Precipitation (Percent Change) Based on GCAM6.0 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 by Alternative (% Compared to No Action Alternative)			
2 Engine Only	0.00%	0.00%	0.00%
3 Class 8 Tractors	0.00%	0.00%	0.00%
4 Engines & Classes 7–8 Tractors	0.00%	0.00%	0.00%
6A 15% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
5 Engines, Classes 7–8 Tractors, & Classes 2b–3	0.00%	0.00%	0.00%
6 Engines, Tractors, & Classes 2b–8 b/	0.00%	0.00%	0.00%
7 Engines, Tractors, Trucks, & Trailers	0.00%	0.00%	0.00%
6B 20% above Preferred Alternative Stringency	0.00%	0.00%	0.00%
8 Accelerated Hybrid Adoption	0.00%	0.00%	0.01%

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.
b/ Preferred Alternative

4.4.4.3.3 Sea-level Rise

The components of sea-level rise, MAGICC 5.3.v2 treatment of these components, and recent scientific assessments are discussed in Section 3.4.4.3.4. Table 4.4.4-4 presents the impact on sea-level rise from the scenarios and show sea-level rise in 2100 ranging from 33.42 centimeters (13.16 inches) under the No Action Alternative to 33.39 centimeters (13.15 inches) under Alternative 8, for a maximum reduction of 0.03 centimeter (0.01 inch) by 2100.

In summary, the impacts of the proposed action and alternatives and other reasonably foreseeable future actions on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the GCAM scenarios[26] – primarily due 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.

4.4.4.3.4 Climate Sensitivity Variations

NHTSA examined the sensitivity of climate effects on key assumptions used in the analysis. This examination reviewed the impact of various climate sensitivities and global emissions scenarios on the climate effects under the No Action Alternative and the Preferred Alternative (Alternative 6). Table 4.4.4-6 presents the results from the sensitivity analysis.

The use of alternative global emissions scenarios can influence the results in several ways. Emission reductions can lead to larger reductions in the CO_2 concentrations in later years because more of the anthropogenic emissions are 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) could

[26] These conclusions are not meant to be interpreted as expressing NHTSA's view 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.

affect not only warming but also indirectly affect sea-level rise and CO_2 concentration. Sea level is influenced by temperature. CO_2 concentration is affected by temperature-dependent effects of ocean carbon storage (higher temperature results in lower aqueous solubility of CO_2).

As shown in Table 4.4.4-6, the sensitivity of simulated CO_2 emissions in 2030, 2050, and 2100 to assumptions of global emissions and climate sensitivity is low; stated simply, CO_2 concentration differences 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 6) has the greatest impact in the global emissions scenario with the highest CO_2

Table 4.4.4-6

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

HD Fuel Efficiency Improvement Program 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
Emissions Scenario: RCP4.5								
Totals								
1 No Action	1.5	432.976	480.890	505.173	0.490	0.766	0.981	10.39
	2.0	433.836	482.949	511.118	0.611	0.965	1.284	20.71
	2.5	434.586	484.779	516.684	0.717	1.141	1.568	24.43
	3.0	435.244	486.413	521.879	0.809	1.296	1.831	27.77
	4.5	436.804	490.384	535.431	1.027	1.670	2.512	36.00
	6.0	437.930	493.339	546.401	1.183	1.945	3.053	56.89
6 Engines, Tractors, & Classes 2b–8 b/	1.5	432.913	480.679	504.621	0.489	0.765	0.979	10.38
	2.0	433.773	482.737	510.556	0.611	0.964	1.282	20.69
	2.5	434.523	484.566	516.112	0.717	1.140	1.565	24.40
	3.0	435.181	486.198	521.298	0.809	1.295	1.828	27.74
	4.5	436.741	490.167	534.827	1.027	1.669	2.508	35.97
	6.0	437.866	493.120	545.778	1.183	1.943	3.048	56.84
Reduction Compared to No Action								
	1.5	0.063	0.211	0.552	0.000	0.001	0.002	0.01
	2.0	0.063	0.212	0.562	0.000	0.001	0.002	0.02
	2.5	0.063	0.213	0.572	0.000	0.001	0.003	0.03
	3.0	0.063	0.215	0.581	0.000	0.001	0.003	0.03
	4.5	0.063	0.217	0.604	0.000	0.001	0.004	0.03
	6.0	0.064	0.219	0.623	0.000	0.002	0.005	0.05
Emissions Scenario: GCAM6.0								
Totals								
1 No Action	1.5	437.772	500.695	655.075	0.510	0.834	1.443	13.31
	2.0	438.647	502.871	663.231	0.635	1.046	1.852	25.17
	2.5	439.409	504.801	670.796	0.744	1.233	2.224	29.53
	3.0	440.077	506.520	677.811	0.838	1.397	2.564	33.42
	4.5	441.658	510.690	695.946	1.061	1.791	3.417	42.91
	6.0	442.798	513.788	710.493	1.220	2.078	4.077	66.16

Table 4.4.4-6

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

HD Fuel Efficiency Improvement Program 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
6 Engines, Tractors, & Classes 2b–8 b/	1.5	437.708	500.484	654.480	0.510	0.833	1.442	13.30
	2.0	438.583	502.658	662.623	0.635	1.045	1.850	25.15
	2.5	439.344	504.586	670.178	0.743	1.232	2.222	29.51
	3.0	440.012	506.304	677.182	0.838	1.396	2.561	33.40
	4.5	441.593	510.472	695.292	1.061	1.790	3.413	42.88
	6.0	442.733	513.567	709.818	1.220	2.077	4.072	66.12
Reduction Compared to No Action								
	1.5	0.064	0.211	0.595	0.000	0.001	0.002	0.01
	2.0	0.064	0.213	0.608	0.000	0.001	0.002	0.02
	2.5	0.065	0.215	0.618	0.001	0.001	0.002	0.02
	3.0	0.065	0.216	0.629	0.001	0.001	0.003	0.02
	4.5	0.065	0.218	0.654	0.000	0.001	0.004	0.03
	6.0	0.065	0.221	0.675	0.001	0.002	0.004	0.04
Emissions Scenario: GCAM Reference								
Totals								
1 No Action	1.5	441.253	512.770	757.689	0.538	0.912	1.761	15.30
	2.0	442.152	515.091	767.457	0.669	1.140	2.240	28.27
	2.5	442.933	517.145	776.500	0.782	1.340	2.673	33.10
	3.0	443.618	518.972	784.869	0.880	1.516	3.064	37.40
	4.5	445.237	523.397	806.468	1.111	1.936	4.037	47.81
	6.0	446.403	526.678	823.758	1.275	2.240	4.780	72.89
6 Engines, Tractors, & Classes 2b–8 b/	1.5	441.183	512.537	757.003	0.538	0.911	1.759	15.28
	2.0	442.082	514.857	766.758	0.669	1.139	2.238	28.25
	2.5	442.864	516.910	775.788	0.781	1.339	2.670	33.08
	3.0	443.548	518.736	784.146	0.880	1.515	3.061	37.37
	4.5	445.167	523.158	805.717	1.110	1.934	4.033	47.78
	6.0	446.332	526.436	822.983	1.274	2.239	4.776	72.85
Reduction Compared to No Action								
	1.5	0.070	0.233	0.686	0.000	0.001	0.002	0.02
	2.0	0.070	0.234	0.699	0.000	0.001	0.002	0.02
	2.5	0.069	0.235	0.712	0.000	0.001	0.002	0.02
	3.0	0.070	0.236	0.723	0.000	0.001	0.003	0.03
	4.5	0.070	0.239	0.751	0.000	0.001	0.004	0.03
	6.0	0.071	0.242	0.775	0.000	0.002	0.004	0.04

emissions (GCAM reference scenario) and the least impact in the scenario with the lowest CO_2 emissions (RCP4.5). The total range of the impact of the Preferred Alternative on CO_2 concentrations in 2100 is roughly 0.6–0.8 ppm. The Preferred Alternative using the GCAM6.0 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of 0.7-ppm reduction compared to the No Action scenario.

The sensitivity of the simulated global mean surface temperatures for 2030, 2050, and 2100 varies, is shown in Table 4.4.4-6. In 2030, the impact is low due primarily to the rate at which global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is large due to climate sensitivity as well as change in emissions. In 2030, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative (Alternative 6) is 0.000 to 0.001 °C (0.000 to 0.002 °F) across the climate sensitivities and global emissions scenarios, as shown in Table 4.4.4-6. The impact on global mean surface temperature due to assumptions concerning global emissions of GHGs is also important. The scenarios with the higher global emissions of GHGs, such as the GCAM reference scenario, 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 nonlinear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are high; therefore, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

The sensitivity of simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Table 4.4.4-6. Scenarios with lower climate sensitivities have lower increases in sea-level rise; the increase in sea-level rise is lower under the Preferred Alternative (Alternative 6) 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 (Alternative 6) than it would be under scenarios with lower climate sensitivities. Higher global GHG emissions scenarios 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, although 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

This section incorporates by reference Section 4.5 of the *Final Environmental Impact Statement for the Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2012-2016* (NHTSA 2010). The CEQ NEPA implementing regulations recommend incorporating material by reference when the effect is to reduce excessive paperwork without impeding agency or public review. According to 40 CFR § 1502.21, material incorporated by reference must be briefly described and the full material must be reasonably available for inspection. Section 4.5 of the MYs 2012–2016 CAFE Standards Final Environmental Impact Statement (FEIS) can be accessed on the NHTSA CAFE website at http://www.nhtsa.gov/fuel-economy; on the Federal government's online docket, http://www.regulations.gov (Docket No. NHTSA-2009-0059-0140); and at the DOT Library.

4.5.1 Introduction to Sector Summaries

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 on 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 on the following key natural and human resources:

- Freshwater resources (the availability, resource management practices, and vulnerabilities of fresh water 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 among 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 climate change could affect);
- 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 climate change might affect these elements); and
- Human health (how a changing climate might affect human mortality and morbidity).

Each of the following sections is divided into three parts. First, each section begins with a summary of the corresponding Section 4.5 of the MYs 2012–2016 CAFE Standards FEIS. The summary provides an overview of the specific resource area within the United States and globally, and addresses the consequences and observed changes of climate change on that resource. It also summarizes both the beneficial and adverse projected consequences of climate change on that resource, as detailed in the MYs 2012–2016 CAFE Standards FEIS. The reader is directed to MYs 2012–2016 CAFE Standards FEIS for scientific references to supporting documents. 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, a key source for much of the information presented in this section. Notably, these categories do not follow the classification of resources typically found in an EIS, such as biological resources, water resources, land use, or socioeconomics, although these resources are discussed.

Second, each section includes a summary of recent findings of the consequences of observed and projected climate change on each resource since the publication of the MYs 2012–2016 CAFE Standards FEIS. This subsection draws from recent reports summarizing existing peer-reviewed information and recent peer-reviewed literature not reflected in the MYs 2012–2016 CAFE Standards FEIS.

Third, each section also provides a brief discussion of adaptation for that particular resource area.

As shown in Section 4.4, although the action alternatives NHTSA is considering would decrease the growth in 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 otherwise projected to occur under the No Action Alternative. NHTSA's assumption is that these reductions in climate effects would be reflected in reduced impacts on affected resources. However, the magnitude of the changes in climate effects that the alternatives would produce – about 1 ppm of CO_2, less than one-hundredth of a degree Fahrenheit difference in temperature, one hundredth of one percent change in the rate of precipitation increase, and less than one-half millimeter 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 alternatives; rather it provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.[27]

4.5.2 Methodology

Each sector-specific discussion opens with a summary of information presented in the MYs 2012–2016 CAFE Standards FEIS, broken down into "Observed Impacts and Vulnerabilities" (*e.g.*, observed current impacts of climate change on that sector) and "Projected Impacts of Climate Change" (*e.g.*, future impacts of climate change on that sector). That FEIS draws primarily upon panel-reviewed synthesis and assessment reports from the IPCC, CCSP, and U.S. Global Change Research Program (GCRP). Each also draws from EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009), which, in turn, heavily relied on the IPCC and GCRP panel reports. NHTSA similarly relies on panel reports because they have assessed numerous individual studies to draw general conclusions about the state of science and have been reviewed and formally accepted by, commissioned by, or in some cases authored by U.S. government agencies and individual government scientists. This material has been well vetted, both by the climate change research community and by the U.S. Government. In many cases, it reflects the consensus conclusions of expert authors.

The MYs 2012–2016 CAFE Standards FEIS also refers to peer-reviewed literature that has not been assessed or synthesized by an expert panel. This literature supplements but does not supersede the findings of the panel-reviewed reports.

[27] *See* 42 U.S.C. § 4332 (requiring Federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited Aug. 12, 2010) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

Following the summary of information from the MYs 2012–2016 CAFE Standards FEIS, the discussion of each sector continues with a brief review of "recent findings" drawn from a variety of panel reviewed reports published since the completion of the FEIS. NHTSA's consideration of more recent studies responds to previous public comments received on the scoping document and the prior CAFE EISs, as well as the Ninth Circuit's decision in *CBD v. NHTSA*, 538 F.3d 1172 (9th Cir. 2008). The level of detail provided in this EIS regarding the science of climate change is intended to inform the public and the decisionmaker of the potential impacts of climate change on health, society, and the environment, consistent with the agency's approach in the prior EISs for the MY 2011 and MYs 2012–2016 CAFE standards.

The discussion for each sector concludes with a brief review of the potential to adapt to climate change, and the extent to which adaptation could reduce climate change risks.

To reflect the likelihood of climate change impacts accurately for each sector, NHTSA references the IPCC uncertainty guidelines (*see* Section 4.4.1). This approach provides 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 IPCC (2007b).

4.5.3 Freshwater Resources

This section provides an overview of the observed and projected impacts of climate change on freshwater resources within the United States and globally, as they are represented in the literature.

4.5.3.1 Summary

Section 4.5.3 (*Freshwater Resources*) of the MYs 2012–2016 CAFE Standards FEIS discusses the observed and projected impacts of climate change on freshwater resources. This section summarizes that information.

4.5.3.1.1 Observed Impacts and Vulnerabilities

In recent decades, there has been increasing evidence that freshwater resources are threatened by both non-climate-related and climate-related drivers. The non-climate threats include population growth and economic development such as changes in land use and land cover, which create increasing demands for water from the residential, industrial, municipal, and agricultural sectors. The observed impacts of climate change on freshwater resources are discussed below by theme.

<u>Precipitation and Streamflow</u>: In the snowmelt-dominated western mountains of the United States, the fraction of annual precipitation falling as rain rather than snow increased from 1949 to 2004. Streamflow records indicate that 200 of the world's largest ocean-discharging rivers showed significant downward trends in annual stream flow in low- and mid-altitude regions over the period 1948 through 2004. Annual discharge into the Arctic Ocean, however, showed a large upward trend. In the world's rain-dominated basins, higher flows are occurring in the peak-flow season, and lower flows or extended dry periods are evident during the low-flow season. In snowmelt dominated regions, the fraction of annual precipitation falling as rain rather than snow also increased. As a result, winter stream flows have increased, summer flows have decreased, and spring peak flows are occurring earlier. Affected regions include the European Alps, the Himalayas, western North America, central North America, eastern North America, Russia, Scandinavia, and the Baltic region.

Snow and Ice Cover: Both temperature and precipitation affect mountain snowpack, with the nature of impacts dependent on factors such as elevation. At high elevations that remain below freezing in winter, increased snowpack has been associated with precipitation increases. Warmer temperatures at mid-elevations result in decreased snowpack and earlier snowmelt, even when associated with precipitation increases. Snow water equivalent (*i.e.*, the amount of water that would result from melting of the snowpack), measured annually in April, has declined 15 to 30 percent since 1950, particularly at lower elevations; this decline is primarily due to warming rather than changes in precipitation. In the Arctic, since the late 1960s snow cover has declined about 10 percent, spring peak flows are occurring earlier, and river discharge to the ocean has increased. In the mountainous regions of the western United States, snowpack declined over the second half of the twentieth century, especially at lower elevations and in locations where average winter temperatures are close to or above 0 degrees Celsius (° C) or 32 degrees Fahrenheit (°F). In North America, the breakup of river and lake ice occurred as much as 13 days earlier over the past century. The world's glaciers are decreasing in areal extent worldwide, except at the highest elevations. Glaciers in Alaska are showing the greatest losses, followed by Himalayan and European glaciers. Glacial loss is considered particularly important in Central Asia and the South American Andes, where glacier melt sustains river flows during the dry summer months. Permafrost is thawing globally.

Groundwater: The available literature suggests that groundwater systems generally respond more slowly to climate change than do surface waters. Groundwater flows and water levels correlate with recharge rates, so changes in precipitation or evapotranspiration (which increases with warmer temperatures, thus reducing recharge) influence these aquifer characteristics. Groundwater flows from areas of higher to lower hydraulic head (*i.e.*, in the direction of the steepest slope of the potentiometric surface). In some cases, coastal areas are experiencing saltwater intrusion into freshwater aquifers due to a flattening in the coastward hydraulic gradient. This intrusion is most prevalent in areas where high groundwater withdrawals or reduced recharge are resulting in lower freshwater levels in the aquifer, but it might also be influenced by an increase in relative sea level.

Water Quality: Higher water temperatures, increased precipitation intensity, and longer periods of low flows as a result of climate change are likely to make existing U.S. water quality goals more difficult to achieve. Negative impacts on water quality from changes in water quantity include resuspension of bottom sediments, increased suspended solids (turbidity) and pollutant introduction, and reduced pollutant dilution. Negative impacts observed to correlate with higher water temperature include increased algal blooms and microbial concentrations.

Extreme Events – Floods and Droughts: Increased precipitation intensity and variability are raising the risks of floods and droughts in many areas. In the United States, the frequency of heavy precipitation events was relatively low in the 1920s and 1930s, increasing during most of the rest of the twentieth century. In the West and Southwest, there is evidence of long-term drying and an increase in drought severity and duration, which are thought to result from a combination of decadal-scale climate variability and long-term climate change.

4.5.3.1.2 Projected Impacts of Climate Change

Although climate models project 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 non-climate stressors, such as increases in population growth, economic activity, land-use change, and urbanization. The following describes the projected impacts of climate change on freshwater resources.

Precipitation, Runoff, and Surface Waters: By 2050, average annual river runoff and water availability are projected to 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 (Mediterranean, southern Africa, western United States, northern Mexico) and in the dry tropics. The United States is projected to continue to experience increases in runoff in the eastern part of the country and substantial decreases in annual runoff in the interior West (Colorado and the Great Basin). In mountainous snowmelt-dominated watersheds, projections suggest continuing advances in the timing of snowmelt runoff, increases in winter and early spring flows (raising flooding potential), and substantially decreased summer flows.

Snow and Ice Cover: Projections for the western mountains of the United States suggest that continued warming and changes in the form, timing, and amount of precipitation will lead to earlier melting and significant reductions in snowpack by the middle of the twenty-first century. Snow cover in Alaska is expected to decrease 10 to 20 percent by the 2070s. Projections for the Arctic region suggest a substantial shortening of the snow season, resulting in decreases in snow and ice cover that are expected to last for many centuries. Over the next five years, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it did from 1950 to 1979 and maximum ice cover is expected to be 20 to 40 percent thinner. Loss in mass of glaciers will continue worldwide.

Groundwater: Global hydrologic models project that globally averaged groundwater recharge will increase less than total runoff (2 percent compared to 9 percent) in the 2050s compared to recharge and runoff rates from 1961 to 1990. In northeastern Brazil, 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. Projected impacts on individual aquifers are expected to be very site-specific.

Water Quality: Higher water temperatures and runoff variations are projected to have negative impacts on water quality. Simulations of precipitation and streamflow in the midwestern United States predict that low flows could decrease by more than 60 percent with a 25-percent decrease in mean precipitation. Considering the additional effect of irrigation demand, the effective decline is projected to reach 100 percent. Low streamflows can result in increased pollutant concentrations and decreased water quality.

Extreme Events – Floods and Droughts: Globally, the proportion of total rainfall from heavy precipitation events is expected 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. More floods are projected for northern and northeastern Europe, while more droughts are projected for southern and southeastern Europe. At mid- and high latitudes in the United States, the intensity and mean amount of precipitation and flood risk are projected to increase. 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.

4.5.3.2 Recent Findings

This section provides new information about observed and projected climate change impacts on freshwater resources published after the MYs 2012–2016 CAFE Standards FEIS. Three recent synthesis reports discuss the impacts of climate change on freshwater resources, and corroborate the findings and discussions presented in the MYs 2012–2016 CAFE Standards FEIS. These reports include the National Resource Council's (NRC's) *America's Climate Choices* (2010a), NRC's *Climate Stabilization Targets*

(2010b), and *The Copenhagen Diagnosis* (Allison *et al*. 2009); they draw from much of the same literature used to inform the MYs 2012-2016 CAFE Standards FEIS. Because there is so much agreement between these synthesis reports and the ones cited in the MYs 2012–2016 CAFE Standards FEIS, and summarizing most of their key points would be repetitive, this section only includes information from the synthesis reports in cases where they diverge from the previous summary section.

In addition, findings provided by newly released peer-reviewed journal articles are also included in this section. Overall, these new studies confirm previous results and add to the growing body of modeling results and field observations indicating substantial impacts on freshwater resources as a result of climate change.

<u>Precipitation, Runoff, and Surface Waters</u>: A new report confirms the trends in precipitation discussed in the MYs 2012–2016 CAFE Standards FEIS, showing that over the past century average precipitation increased both in the United States and globally (EPA 2010). The new trends indicate that since 1901, average precipitation increased more than 6 percent per century in the contiguous United States and almost 2 percent per century worldwide. Precipitation declines were observed in some parts of the United States, including Hawaii and the Southwest, as a result of shifting weather patterns (EPA 2010).

With regard to future climate change impacts, new research provides projections of hydroclimatology over the northeastern United States under a scenario of high emissions to demonstrate that changes in precipitation will vary within regions because of local differences in topography, vegetation, and other factors. Modeling by Anderson *et al*. (2010) predicted that summer precipitation will decrease across the central Northeast, but increase in the most northern and southern parts of the region. Evaporation is predicted to increase throughout the Northeast. The combined effect of these precipitation and evaporation changes is a projected 10-millimeter (mm) decrease in soil moisture content in summer across most of the Northeast and a 10-mm per month increase in summertime soil-moisture depletion.

<u>Snow and Ice Cover</u>: Existing scientific consensus indicates that snow cover around the globe has diminished in response to warming temperatures; new research supports this consensus by quantifying this observed impact at several locations. EPA (2010) found that although snow cover extended across 3.43 million square miles of North America during the 1970s, the area declined to 3.18 million square miles over the past decade. During the second half of the twentieth century, the depth of snow cover in early spring decreased at most measurement sites in the western United States and Canada, declining by more than 75 percent in some areas. In the northern United States, lake ice is forming later and thawing earlier than observed during the 1800s and early 1900s. The length of time that lakes remain frozen has declined by an average 1 to 2 days per decade (EPA 2010).

A new study by Choi *et al*. (2010) focused on spatial and temporal patterns in the onset and duration of the snow season across the Northern Hemisphere continents over the period 1967 to 2008. The data showed that the duration of the snow season decreased by 5 to 25 days in Western Europe, Central and East Asia, and the mountainous western United States. Snow cover disappeared progressively earlier and its disappearance advanced poleward at a rate of 5.5 days per decade.

Lawrence and Slater (2010) simulated climate effects on northern high-latitude snow conditions for the one of the IPCC global GHG emission scenarios, the Special Report on Emissions Scenarios (SRES) A1B scenario. Simulation of the twentieth and twenty-first centuries corroborated previous findings and indicated increased winter snowfall (+10 to 40 percent), altered maximum snow depth (-5 ± 6 cm), and a shortened snow-season (-14 ± 7 days in spring, $+20 \pm 9$ days in autumn).

With regard to projected impacts on glaciers, there is increasing evidence that climate change is contributing to worldwide reductions in glacier mass, but new studies suggest that the effects of melting glaciers on river flows will vary among river basins. Previously, a general conclusion was that melting glaciers in the Himalayas, Hindukush, and other high mountain ranges in Central Asia in response to global warming will lead to significant declines in seasonal flows in the region's major river basins. Results of recent modeling by Immerzeel *et al*. (2010) suggest, however, that effects will be more complex. Their modeling results indicated that the Indus and the Brahmaputra basins, which the researchers concluded are the most vulnerable to reductions in flow among the large river basins of Southeast Asia, will experience a period of increased flows due to accelerated glacial melt; this increased flow period would be followed by ongoing reductions in late spring and summer discharges around the mid-century that will threaten downstream water supplies and food security for millions of people.

EPA (2010) recently examined long-term monitoring measurements for glaciers worldwide to determine any trends in mass balance (the net gain or loss of snow and ice over the year). EPA's evaluation of the cumulative change in glacier volume worldwide indicates a significant negative trend since 1960, when most of the monitoring studies began. During that time, glaciers worldwide have lost more than 2,000 cubic miles of water. The data also indicated the rate at which glaciers are losing volume has increased over the past decade. All three of the U.S. Geological Survey "benchmark" glaciers in the United States (the South Cascade Glacier in Washington, the Wolverine Glacier near Alaska's southern coast, and the Gulkana Glacier in Alaska's interior) have shown an overall decline in mass since the 1950s and 1960s.

New studies are also available that quantify the observed mass loss of glaciers around the globe. In a recent analysis of satellite observations, Matsuo and Heki (2010) estimated that from 2003 to 2009 mass loss from the Himalayas, Karakoram, and the Tibetan Plateau averaged 47 billion metric tons per year. A new study by Immerzeel *et al*. (2010) of five major Southeast Asia river basins (the Indus; the Ganges and the Brahmaputra in India, Pakistan, and Bangladesh; and the Yellow and Yangtze rivers in China) found that the relative importance of glacial melt varied among basins depending upon several basin-specific factors. Meltwater is most important for the Indus (151 percent of the discharge is supplied by lowland rainfall), followed by the Brahmaputra (27 percent), the Ganges (10 percent), and the Yangtze and Yellow rivers (8 percent each). Huss *et al*. (2010) examined 30 100-year records of glaciers in the Swiss Alps, an exceptionally long time series, and found that all glaciers showed a decrease in ice mass throughout the twentieth century, consistent with global trends. Although rates of loss varied among individual glaciers due to differences in factors such as elevation and slope, all glaciers experienced a period of moderate mass loss followed by rapid loss over the past 40 years, coinciding with trends globally. The researchers determined that melt rates are the dominant factor in the glacial mass fluctuations, but also found that mass loss was negatively correlated with natural climate variability resulting from the Atlantic Multidecadal Oscillation (AMO), a periodic rise and fall of North Atlantic sea surface temperatures.

<u>Water Quality</u>: A novel new study has documented rising water temperatures in streams and rivers throughout the United States, finding statistically significant warming in 20 major U.S. streams and rivers, including prominent rivers such as the Colorado, Potomac, Delaware, and Hudson. Annual mean water temperatures for streams in the United States increased by 0.009°C (0.016°F) to 0.077°C (0.14°F) per year across observational records of twenty-four to a hundred years. Rates of warming were highest in urban areas, which the researchers suggest may reflect an urban "heat island" effect in addition to increasing air temperatures (Kaushal *et al*. 2010).

<u>Extreme Events – Floods and Droughts</u>: New findings of storm intensity and heavy precipitation have become available, in comparison to studies cited in the MYs 2012–2016 CAFE Standards FEIS, which focused simply on the severity and frequency of drought in response to changes in climate. A

recent analysis by EPA (2010) found that extreme precipitation events have been increasing, with 8 of the top 10 years of extreme 1-day precipitation events observed since 1990. EPA also found a high incidence of drought in some areas. From 2001 through 2009, for example, 30 to 60 percent of land area in the United States experienced drought conditions at any given time (EPA 2010).

With regard to projected impacts, new research reinforces the results of previous studies indicating that storm intensity might increase in some areas as the climate changes, even though storm frequency could decline. For example, one recent study predicted that the number of strong storms in the western Atlantic could double by the end of the twenty-first century, despite a drop in the overall number of storms. Using the ensemble-mean of 18 general circulation models (GCMs) and 4 regional models, the researchers assessed the climatic response to the IPCC "business as usual" scenario and used a hurricane model to simulate storm development in response to projected warming. Simulation results predicted an 81-percent increase in the number of storms in the Atlantic Ocean of Category 4 (210–249 kilometers per hour [km/hr]) and Category 5 (greater than 250 km/hr) by 2100. The number of storms with winds exceeding 234 km/hr was projected to increase by 250 percent (NRC 2010a citing Bender *et al*. 2010).

An important new finding is that even if future GHG emissions decreased dramatically, the responses of hydrologic systems could significantly lag. A 2010 study modeled the effects on floods and droughts of an increase in CO_2 concentrations to 1,000 ppm followed by a decrease to 280 ppm. The study projected that increases in floods and droughts would continue to occur for decades, even after global temperatures were stabilized, indicating that even though CO_2 decline would reduce temperatures, it would not have an immediate effect on floods and droughts. The researchers concluded that relationships between precipitation and warming could significantly underestimate precipitation changes during GHG stabilization or reduction, which should be taken into account when assessing the implications of mitigation options and adaptation strategies (Wu *et al*. 2010).

4.5.3.3 Adaptation

Climate change impacts on freshwater resources will have significant effects on the quantity and quality of water needed to support ecosystem services, including water for residential, municipal, industrial, and agricultural needs. Water is considered one of the most important sectors to address with adaptation, both domestically (*e.g.,* CCSP 2008a) and internationally (*e.g.,* UNFCCC 2010).

In many cases, climate change impacts on water resources can be addressed in the context of existing stressors. For example, many international organizations are considering climate change risks in the context of ongoing management of natural disasters (*e.g.,* the United National International Strategy for Disaster Risk Reduction. Drinking water and wastewater utilities, both in the United States (*e.g.,* CUWA 2007) and internationally (*e.g.,* Australia) also recognize that climate change risks to water resources can best be managed within ongoing planning and operational frameworks that already take into account variations in water supply. At the same time, there is broad recognition that past trends are no longer good predictors of future water resource changes (NRC 2010c citing Milly *et al*. 2008). In the United States, adaptation needs are particularly acute in the West and Southwest, and efforts are already underway to develop adaptation options, including demand management (NRC 2010c citing Brekke *et al*. 2009; Overpeck and Udall 2010). The National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and EPA are among several Federal agencies that are leading water resource adaptation efforts in the United States. A number of State agencies have also developed or are developing water resource adaptation programs (*e.g.*, the California Energy Commission's Climate Change Program).

4.5.4 Terrestrial and Freshwater Ecosystems

This section provides an overview of the observed and projected impacts of climate change on terrestrial and freshwater ecosystems within the United States and globally, as they are represented in the literature.

4.5.4.1 Summary

Section 4.5.4 (*Terrestrial and Freshwater Ecosystems*) of the MYs 2012–2016 CAFE Standards FEIS discusses the observed and projected impacts of climate change on these ecosystems. Ecosystems addressed in this section include terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra; aquatic communities, such as rivers, lakes, and ponds; and freshwater wetlands, including marshes, swamps, and bogs.

4.5.4.1.1 Observed Impacts and Vulnerabilities

Terrestrial and freshwater ecosystems in the United States and around the world are experiencing rapid and clearly observable changes. Steadily warming temperatures and rising CO_2 concentrations, as well as changing precipitation patterns, are already leading to shifting species ranges and earlier spring migrations and are threatening the ability of existing habitats to thrive. Climate change is also affecting the relative timing of species life-cycle events, referred to as *phenology*, which can upset existing species interactions, dependencies, and predator-prey interactions. Terrestrial and freshwater ecosystems are also affected by wildfires, insect outbreaks, and changes in human activity such as land-use change, hydrologic modification, and pollution.

Phenology: 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. 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 past 30 to 50 years. Increasing regional temperatures are also associated with earlier calling and mating and shorter time to maturity of amphibians. The seasonal timing of bird migration and egg-laying has also changed, associated with the increase of temperature in breeding grounds and migration routes. Several species of birds no longer migrate out of Europe in the winter as the temperature continues to rise.

Species' Range and Ecosystem Shifts: Changes in the distribution of species have occurred across a wide range of taxonomic groups and geographical locations. Over the past several decades, a poleward extension of various species' ranges has been observed that is probably attributable to increases in temperature. Many Arctic and tundra communities have been replaced by trees and dwarf shrubs. In some mountainous areas of the Northern Hemisphere, including in Alaska, tree lines have shifted to higher altitudes over the past century. Previously uncommon species of fish, such as Pacific salmon, have been observed in aquatic systems of the Canadian Arctic in recent years as a result of expanded ranges from warming waters.

Species Morphology, Reproduction, or Genetics: Changes in morphology and reproductive rates have been attributed to climate change. For example, the egg sizes of many bird species are changing with increasing regional temperatures. Several studies conducted in Asia and Europe found that some birds and mammals are experiencing increases in body size on a regional scale as temperatures increase, most likely due to the increasing availability of food. Many northern insects have a two-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 for its survival. The reproductive success of polar bears has been compromised in response to melting Arctic sea ice.

Local/Regional Extirpation or Global Extinction: Decreases in the size of a species' range, the density of individuals within the range, and the abundance of its preferred habitat factors can reduce population sizes and potentially increase the risk of global disappearance of a species ("extinction") or local extinction of a species ("extirpation"). Examples of climate change-driven declines in populations and subsequent extinction or extirpation are found for amphibians around the world, as well as for some insects (e.g., extirpation of the Edith's checkerspot butterfly in the southwestern United States). Several populations of the pika, a mountain-dwelling rodent in the Rocky Mountain region, appear to have been extirpated as of the 1990s, at least in part due to changes in climate.

4.5.4.1.2 Projected Impacts of Climate Change

The United States is projected to experience even more rapid and pronounced changes in average temperature and precipitation over the twenty-first century than in the previous century. Alaska and the western continental United States are anticipated to experience particularly large temperature increases – as much as 5 °C (41 °F) by the end of the century. The country as a whole could be subject to more frequent hot days and nights, heavier precipitation events, more rain than snow, and declining snow cover and water reservoir levels. The threat of sea-level rise is also significant to the health of existing ecosystems. The projected sea-level rise for the northeastern United States is greater than the projected global average of 0.8 to 2.0 meters; such a rise would have a significant impact on existing ecosystems at elevations below 2.0 to 3.0 meters.

These anticipated changes could have a profound impact on terrestrial and freshwater resources such as 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. Global average temperature increases in excess of 1.5 to 2.5 °C (2.7 to 4.5 °F) are *likely* to threaten 20 to 30 percent of plant and animal species, globally, with extinction by 2100. As species and their habitats shift, a mismatch between species and their food sources could occur, potentially accelerating species global extinction and local or regional extirpation. Migrating species such as birds and butterflies are particularly vulnerable to this risk. Cold-weather animals such as polar bears and cold-water fish are also among the most vulnerable to a warming climate. Globally, scientists predict increased ecosystem disturbance from floods, drought, wildfires, insects, ocean acidification, and other drivers of global change; they also predict declines in keystone species, which could result in ecological cascade effects. Some of the impacts projected to affect ecosystems in the United States include the following.

Phenology: Growing seasons are likely to continue lengthening. 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. Shifts in migration ranges could result in diseases entering new areas; for example, avian malaria in Hawaii could move upslope as climate changes.

Species' Range and Ecosystem Shifts: Over the next century, many species are projected to move northward and to higher elevations. Coldwater fish, aquatic invertebrates, and waterfowl are among the species groups expected to move north as the climate warms, with the potential for some extinctions or extirpations of fish species that are already at the northern limits of their range. Vegetation types might shift or decline in size in response to a changing climate. 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. The area of drought-limited ecosystems is projected to expand in the United

States by 11 percent for every 1 °C rise in average temperature. Closed-canopy forest ecosystems could be converted to savanna ecosystems, woodlands, or grasslands, measurably increasing the threat of fire occurrence.

Species Morphology, Reproduction, or Genetics: 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 and other surface waters. The production of their eggs is also highly dependent on temperature and moisture availability. 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 mechanism for such impacts.

Local/Regional Extirpation or Global Extinction: Declines in keystone species populations are hypothesized to be the primary cause of *ecological cascades*, during which species extinctions or extirpations occur due to disruption in processes or the loss of a primary or key ecosystem species. More than half of the wild trout populations of the southern Appalachian Mountains are projected to disappear as streams warm. Climate change in response to a doubling of CO_2 concentrations in the atmosphere could affect the amount of suitable habitat for coldwater and cool water fishes in U.S. lakes, causing declines of 45 and 30 percent, respectively. By 2050, coldwater stream fish habitat is projected to decline by 20 percent in the United States as a whole and 50 percent in the Rocky Mountain region. In locations where fish are unable to migrate northward, such as the desert Southwest and the southern Great Plains, it is expected that many native fish species could become extinct with a few degrees of warming. Models of Pacific Northwest salmon populations project losses of 20 to 40 percent by 2050. Seasonal migrations of wetland species will be disrupted, with reduced survival and possible extinctions of some species. Boreal peatlands are considered particularly vulnerable. 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. As sea-ice loss continues, two-thirds of polar bears could be gone from Alaska by the middle of this century.

Also worth noting is that 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. Crossing over a threshold, an ecosystem makes a well-defined break from previous trends in the system's behaviors and overall characteristics. An example that illustrates this effect is the observed impact to grasslands as a result of interactions between drought and livestock overgrazing. As one study described, when a component critical to the wellbeing of the grassland ecosystem failed, that failure triggered runaway desertification, a cascade of instability that affected the remaining components of the ecosystem in a profoundly negative way. Another example is that of the previously cited rapid die-off of forests in the southwestern United States. Another study demonstrated that the primary trigger to runaway changes – sudden tree mortality from the combined stressors of drought and bark beetles – led to other nonlinear changes in the ecosystem, such as erosion and the increased incidence of forest fires.

4.5.4.2 Recent Findings

The latest science on changes in climate and the associated impacts on terrestrial and freshwater ecosystems largely affirms the threats and predictions identified in Section 4.5.4 of the MYs 2012–2016 CAFE Standards FEIS. Three recently released synthesis reports discuss the impacts of climate change on terrestrial and freshwater ecosystems: NRC's *America's Climate Choices: Advancing the Science of Climate Change* (2010a), NRC's *Climate Stabilization Targets* (2010b), and EPA's *Climate Change Indicators in the United States* (2010). These reports largely draw from similar literature used to inform the MYs 2012-2016 CAFE Standards FEIS and affirm much of the findings. To reduce redundancy with the information already provided in the MYs 2012–2016 CAFE Standards FEIS, these reports are not discussed in this section as they do not provide new information or interpretations. Hence, the recent findings presented here draw from newly released individual peer-reviewed studies.

The topics synthesized in this report are addressed in the recent findings below. The major theme emerging from recent peer-reviewed literature is that climate change does not affect species in isolation. Impacts on a single species affect its interactions with others and can set off a cascade of ecosystem changes.

A number of other reports and articles based on original research have confirmed that impacts of climate change are being observed in the planet's terrestrial and freshwater ecosystems, with impacts becoming increasingly pronounced in recent years. Updated climate science indicates that climate is changing more rapidly than suggested by previous IPCC projections. Research in the past year has built on previous predictions that climate change will result in species' life-cycle shifts, changes in species interactions, and impacts on the ecosystem services on which humans depend. In addition, new research has focused on the combined impacts of climate change and human activity on future ecosystem services (Strayer and Dudgeon 2010, Nelson *et al*. 2009). Much of the latest research has focused on improved understanding of complex ecosystem interactions to better predict the full impacts of climate change (Woodward *et al*. 2010, Mulholland *et al*. 2009, Nelson *et al*. 2009, Morin and Thuiller 2009). Studies over the past year have also revealed more specific climate change impact predictions.

Species' Range and Ecosystem Shifts: New findings are consistent with the general trend of species movement poleward and to higher elevations in response to rising temperatures discussed in the summary section above. Plant and animal species ranges in the Northern Hemisphere are shifting to the north and west and to higher elevations (Montoya and Rafaelli 2010), affecting their interactions with new ecosystems and species. One recent publication indicated that half of the 28 mammal species first studied a century ago in Yosemite National Park, California, moved approximately 500 meters upward in elevation since the initial study. This is apparently consistent with the observed increase in local minimum temperatures of 3 °C (37 °F) (Pimm 2009 citing Moritz *et al.* 2008). Another study –of moths in Borneo – found that two-thirds of the 102 species studied had moved upward in elevation. In a 42-year period, the average increase in elevation for species was observed to be 67 meters (Pimm 2009 citing Chen *et al.* 2009). A third recent study of 171 plant species in Europe found that two-thirds of the plants were moving upward, at an average rate of 29 meters per decade (Pimm 2009 citing Lenoir *et al.* 2008). For some habitats, such as those native to mountaintops, upward shifts have not been possible due to restrictions in mobility. In these cases, range shrinkage has been observed (Pimm 2009).

Regarding projected changes, the Greater Himalayas are highly sensitive to climate change, and the rate of glacial retreat has increased in recent years. Continuation of this trend could result in reduced water supply to 1.3 billion people and the 10 largest rivers in Asia. Reduced water availability due to warmer temperatures and climate change would affect river flows; groundwater recharge; biodiversity; and ecosystem composition, structure, and function (Xu *et al*. 2009). In addition, changes in minimum temperatures over the coming century might have a direct impact on the survival and migration of plant species. In the Great Lakes region of the United States, it is projected that the U.S. Department of Agriculture (USDA) Plant Hardiness Zone designation of 5b (plant hardiness minimum temperatures of -23 °C to -26 °C (73 °F to -15 °F)) will shift to a designation of Zone 6a (plant hardiness minimum temperatures of -23 °C to -21 °C (-9 °F to -5 °F)). Under a higher emission scenario, the region could fit in to Zone 7a (plant hardiness minimum temperatures of -18 °C to -15 °C (0 °F to 5 °F)). This would mean that by 2100, the southwestern Lake Michigan region would be similar in climate to the hardiness zone that currently exists in northern Alabama (Hellmann *et al*. 2010).

Local/Regional Extirpation or Global Extinction: New findings demonstrate that global forests are currently displaying some effects of climate change. These findings enhance current understanding of observed extinction or local/regional extirpation in species discussed in the summary section above. Forests in 2010 have higher background mortality rates as a result of changes in climate, such as higher temperatures and reduced precipitation rates (Allen *et al*. 2010). This high mortality rate makes trees, forests, and the species that live in them increasingly vulnerable to climate-related heat stress, insect outbreaks, and fires, among other impacts (Allen *et al*. 2010). In North America, several examples of forest die-offs include a loss of more than a million hectares of multiple spruce species in Alaska (Allen *et al.* 2010 citing Berg *et al*. 2006) and a loss of more than 10 million hectares of *Pinus contorta* in British Columbia, Canada (Allen *et al*. 2010 citing Kurz *et al*. 2008). Farther east in the United States, similar increases in tree mortality have been observed. In particular, declines in oaks, especially red oaks, that are related to long-term droughts have been observed from Missouri to South Carolina (Allen *et al*. 2010 citing Voelker *et al*. 2008 and Clinton *et al*. 1993). Climate change-induced tree death also fosters a positive feedback loop, whereby dead trees release their stored carbon into the atmosphere and might further exacerbate climate change.

A study published in 2009 supports predictions that migration constraints such as human land use will have a large impact on species extinction rates (Morin and Thuiller 2009). The study used a niche-based model to compare results of previous process-based model approaches. Not only would species extinction rates likely be augmented by these anthropogenic stressors, but also impacted by the disruption of ecosystem relationships. For example, there will likely be greater-than-previously predicted increases in bird mortality worldwide. A new study examined the relative rates of response to climate change by birds and the woody plants they depend on for survival. Trees and other woody plants have much slower response rates to climate variables, and the study predicts a mismatch between birds and their food sources as the climate warms. The losses might be even more drastic for highly specialized bird-plant associations (Kissling *et al*. 2010).

Trophic Interactions: Scientists have long understood that changes to any level of an ecosystem or food chain will have rippling effects throughout; research investigating how climate change could impact these trophic dynamics, however, is only recently available. One new study found that higher CO_2 concentrations can change the nutrient ratios of detritus, which can significantly change basic feeding rates and nutrition at the base of the food web (Woodward *et al*. 2010). This would have rippling effects upward through the ecosystem.

Several new studies also contribute to the knowledge of climate change impacts on ecosystem interactions and *trophic cascades*, during which the abundance of particular species of predators, associated with climate change, overwhelms populations of their prey and therefore enables the prey of their prey (two or more levels down the chain) to greatly expand their populations (Knight *et al*. 2005). In one study investigating ecosystem interactions, the authors used the atypical 2007 spring freeze in the eastern United States as a case study of how these interactions might unfold. They found that the spring freeze, expected to occur more often due to climate change, stunted leaf growth and led to increased light saturation, which in turn led to abnormally high gross primary production rates and lower water nutrient levels (Mulholland *et al*. 2009). The study shows that climate change impacts, seemingly separate from a given ecosystem, can still ultimately affect multiple trophic levels of an ecosystem (Mulholland *et al*. 2009).

New research continues to support the understanding of ecological thresholds. Recent findings show that even if global GHG emissions dropped to zero by 2030, there would be a 25-percent chance of a global mean temperature increase greater than 2 °C (3.6 °F), a widely accepted threshold for critical change (Allison *et al*. 2009). The IPCC predicts that if such warming were to happen, 20 to 30 percent of plant and animal species would be at a very high risk of extinction (Mooney *et al*. 2009 citing Fischlin *et* *al*. 2007). These recent findings fully support those discussed in the projected impacts of climate change section above.

4.5.4.3 Adaptation

Human activities will also play a role in determining the degree to which climate change affects terrestrial and freshwater ecosystems. For example, human responses to climate change, such as engineering measures and land-use changes, can threaten freshwater ecosystems (Strayer and Dudgeon 2010). A study of urbanization and climate change impacts on streams found that both have large impacts on their own, and both can work in synergy to further impact stream ecosystems (Nelson *et al*. 2009). Urbanization alone depressed growth of more than 20 percent of species, while climate change negatively affected 75 percent of species. Combined, the study predicts "considerable" alterations in stream fish composition and diversity loss (Nelson *et al*. 2009). Overall, human factors combine with climate change as major drivers of ecosystem change. These changes in turn could ultimately depress the ecosystem services on which humans and other animals depend (Mooney *et al*. 2009), increasing the imperative to adapt to climate change.

The ability or inability of ecosystems to adapt to change is referred to as adaptive capacity. There could be notable regional differences in the adaptive capacity of ecosystems, and adaptive capacity is moderated by anthropogenic influences and capabilities. The ultimate impact of climate change on ecosystems depends on the speed and extent to which these systems can adapt to a changing climate. Adaptation occurs naturally in a biological system to varying degrees, but it can also be a planned human response to anticipated challenges (CCSP 2008b).

In the future, facing changes in precipitation, temperature, and sea level, ecosystem composition and function will change. Therefore, managers of ecosystem resources will likely have to modify their goals to accommodate these changes. For example, fostering the growth of more resilient components of ecosystems could be necessary, 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. More detail about ecological and climatological tipping points is included in Section 4.5.9, *Tipping Points and Abrupt Climate Change*.

In addition, ecosystem managers can improve the resilience of ecosystems (*i.e.*, their ability to cope with the impacts of climate change) by "proactively alter[ing] the context in which ecosystems develop" (Fischlin *et al*. 2007). One strategy proposed for mitigating some of the loss of ecosystem biodiversity calls for moving species out of their native ranges into less threatened zones. Because this strategy exacerbates problems posed by some invasive species, such "assisted colonization" is advisable only in situations and for species that are deemed low risk for overwhelming populations of prey or otherwise disrupting critical ecosystem balance (Hoegh-Guldberg *et al*. 2007).

Because the effectiveness of specific adaptation strategies is uncertain, an approach consisting of practical adaptation options that account for current, known stressors along with the more uncertain future stressors (CCSP 2008b) is typically sought by ecosystem managers. For example, invasive species pose a known threat to many ecosystems. Future climate change is likely to exacerbate this stressor, so an adaptation strategy to tackle current invasive species problems could also address projected impacts of more serious, future invasive species challenges (CCSP 2008b). Another example of dual-purpose adaptation strategies lies with the construction of *riparian buffer strips*, which are vegetative barriers or zones at the edges of rivers and land that help protect land from flooding and erosion. These areas also reduce agricultural runoff into freshwater systems and establish protective barriers against potential increases in both pollution and sediment loadings due to climate change in the future (CCSP 2008b).

4.5.5 Marine, Coastal, and Low-lying Areas

This section provides an overview of the observed and projected impacts of climate change on marine, coastal, and low-lying areas within the United States and globally, as well as adaptation options to address these impacts.

4.5.5.1 Summary

This section presents a summary of the information presented in Section 4.5.5 of the MYs 2012–2016 CAFE Standards FEIS regarding observed and projected climate change impacts on marine, coastal, and low-lying areas.

4.5.5.1.1 Observed Impacts and Vulnerabilities

A large portion of marine[28] and coastal[29] ecosystems around the globe has been substantially degraded or lost altogether. Despite the lack of high-quality data available to quantify changes in these ecosystems, it is safe to assume that an increase in human population in coastal zones has created environmental pressures (*e.g.*, physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species) that threaten the very resources that make the coastal zones desirable. Moreover, climate change has the potential to compound these pressures, leaving these systems particularly vulnerable to warming water temperatures, sea-level rise, melting of freshwater ice, storm events, and water acidification.

Anthropogenic Pressures: According to EPA research, overall coastal condition of the United States is considered to be fair.[30] Marine and coastal ecosystems are being pressured by overfishing, pollution, and other human-induced stressors that have caused increases in habitat loss, impacts on species, occurrences of hypoxia, penetration of invasive species, harmful algal blooms, and other ecological damages.

Sea Level: There is strong evidence that temperature increases have caused a rise in global sea level during the twentieth century. The change in sea level is attributed to thermal expansion of ocean water, thawing of permafrost, and the melting of mountain glaciers, ice caps, and land ice. Sea-level rise was found to be non-uniform around the world, which might result from variations in thermal expansion; exchanges of water, ocean, and atmospheric circulation; and geologic processes. Furthermore, although it is uncertain whether it is part of a long-term trend or decadal-scale variability, data show an accelerated rate of sea-level rise in the past two decades. Increases in sea level have significant impacts on coastal

[28] Marine zones are varied and are 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, no one universal definition is applicable to establishing the sub-boundaries 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 2009).

[29] Coastal zones, commonly included as part of the marine intertidal and neritic zones, are unique environments where land and water meet. Although 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) define coastal zones as the "intertidal and subtidal areas on and above the continental shelf (to a depth of about 200 m (650 feet)) – areas routinely inundated by saltwater – and immediately adjacent lands."

[30] In a 2005 study, EPA assessed five indicators of ecological health to determine this rating: water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants. For each indicator, a score of "good," "fair," or "poor" was assigned to each coastal region of the United States. Indicator ratings were then averaged regionally and nationally (Summers *et al.* 2005).

areas. For example, there is evidence that where ecosystems are squeezed between natural and artificial landward boundaries and rising sea levels, coastal wetland loss is occurring. Furthermore, regional sea-level rise has contributed to amplified storm-surge impacts and an increased risk of flooding in certain low-lying areas, affecting the growing populations along the coasts.

Hypoxia and Acidification: Excess amounts of decaying plankton and elevated dissolved CO_2 concentrations (in response to the ocean's absorbing more CO_2) can cause and expand hypoxic (low-oxygen) zones, or oceanic dead zones, which physiologically stress marine animals. Furthermore, as the oceans absorb CO_2, they become more acidic and threaten coral reef ecosystems (*see* Section 4.7 for additional information on ocean acidification).

Salinity: In general, as ice melts and precipitation increases at varying degrees around the globe, fresh water enters the ocean system, which causes a decrease in salinity. Less saline surface waters interfere with the distribution of nutrients due to the reduced vertical mixing of ocean waters. Lower surface salinity in polar regions can also lead to a reduction in the poleward transport of heat; this is due to a reduction in deep mixing. While most areas have been found to experience freshening, others are experiencing increases in salinity, potentially due to increased evaporation.

Productivity: Recent studies linking the changes in temperature to ocean productivity show that trends in chlorophyll productivity closely follow changes in temperature. In general, phytoplankton biomass and growth decline as surface waters warm. Impacts on marine and coastal ecosystems are expected to continue due to climate and non-climate stressors, particularly where coastal populations increase and demand more land area and resources. Climatic changes are projected to significantly impact coastal and marine ecosystems through events such as submergence and erosion of lands, flooding due to storm surges, and salinity changes in estuaries and groundwater.

4.5.5.1.2 Projected Impacts of Climate Change

Anthropogenic Pressures: Projected population increases are expected to compound the anticipated adverse effects of climate change on coastal communities, placing heavier demand on already stressed ecosystems. In addition to population, increases in other non-climate stressors, such as deforestation, invasive species, resource extraction, and pollutant discharge, could have significant implications for natural systems around the world. Moreover, other anthropogenic pressures might cause marine and coastal systems to become more vulnerable to climate stressors, thereby exacerbating cumulative impacts.

Sea Level: Sea-level rise is expected to be one of the most damaging effects of climate change. In the twenty-first century, sea-level is expected to exceed that of past years. The effects of sea-level rise on some coastal communities could be devastating due to increased flooding and erosion, where a rise will further cause sandy shorelines to retreat; barrier-islands to erode; and tidal wetlands, estuarine beaches, marshes, and deltas to flood. In addition, 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.

Some of the most devastating sea-level impacts are associated with storm surge, where the frequency and intensity of storms and the height of storm surges are projected to increase concurrently with sea levels and sea surface temperatures. Of further concern is the possible effect on ocean circulation and sea-level rise dynamics by the melting of the Greenland ice sheet.

Displacement of coastal populations due to sea-level rise, flooding, and increased intensity and frequency of storms remains a concern. Furthermore, the loss or degradation of coastal ecosystems has a direct impact on societies that depend on coastal-related goods and services such as fresh water and fisheries and has the potential to impact hundreds of millions of people.

Ecological: Rising water temperatures and other climate-driven changes (*e.g.*, salinity, dissolved oxygen levels, and ocean circulation) will impact the distribution and movement of coastal and marine species, causing changes in food webs and commercial and subsistence fisheries. In addition, increasing water temperatures are likely to cause further coral bleaching and mortality unless corals demonstrate thermal adaptation.

Freshwater: Freshwater resources are also at risk given the likely intrusion of saltwater into groundwater supplies, adversely affecting water quality and salinization rates (*see* Section 4.5.3 on *Freshwater Resources* for more information).

4.5.5.2 Recent Findings

This section provides updates to the MYs 2012–2016 CAFE Standards FEIS discussion of marine, coastal, and low-lying areas. Two new synthesis reports, NRC's *Climate Stabilization Targets* (2010b), and the United Nations Environmental Programme's (UNEP) *Climate Change Science Compendium* (2009) address climate impacts on marine, coastal, and low-lying areas. These reports are largely based on the same body of literature presented in the MYs 2012–2016 CAFE Standards FEIS, and thereby largely corroborate the findings discussed in the summary section above. To avoid repetition, the areas where these synthesis reports mirror the findings already presented in the MYs 2012-106 CAFE Standards FEIS are not discussed here. This section does, however, discuss areas in which these reports provide new information or interpretations. In addition to these recent synthesis reports, results from several other reports and articles based on original research are discussed below. The new information reported in this section is consistent with the findings summarized in the previous section.

Anthropogenic Pressures: Consistent with previous findings discussed in the MYs 2012–2016 CAFE Standards FEIS, NRC (2010b) notes that with rapid coastal development, infrastructure and populations in low-lying areas are increasingly at risk due to rising seas. This is particularly important due to the fact that, in 2010, 21 of 31 "mega-cities" were located on the coast. Other human activities, including underground water mining, irrigation, urbanization, and deforestation, exacerbate subsidence and increase relative sea-level rise on coasts already susceptible to sea-level rise impacts (Nicholls and Cazenave 2010).

Evidence continues to accumulate regarding the impacts caused jointly by climate change and anthropogenic activities on marine ecosystems. Most of the world's marine ecosystems are changing rapidly and face an increasing risk of sudden, nonlinear changes due to the impacts of anthropogenic climate change (Hoegh-Guldberg and Bruno 2010). In particular, the threat of weakening coral reefs, due to the combined impacts of ocean acidification from increased atmospheric CO_2 levels, warming, pollution, and physical destruction, persists. There is concern that coral reefs might reach a point where they cannot provide "fish nursery services" at the rates required to sustain ecosystem health (UNEP 2009 citing Hoegh-Guldberg *et al*. 2009). These findings continue to support the many studies highlighting projected and observed threats to coral reefs.

Sea level: Recent reports indicate that sea-level rise may be occurring at a rate greater than previously thought. A new study suggests that since the beginning of satellite measurements in the early 1990s, sea level has risen at a rate of 3.4 millimeters (0.13 inches) per year (Rahmstorf 2010 citing Cazenave and Llovel 2010), as compared to the average rate for the twentieth century of 1.7 millimeters (0.07 inches) per year (IPCC 2007b). Cazenave and Llovel (2010) indicate that, for the period 1993 through 2007, approximately 30 percent of the observed rate of sea-level rise is due to thermal expansion and approximately 55 percent results from melting land ice.

The most recent projections linking sea level to temperature observations estimate a range of sea level rise from 0.97 to 1.56 meters (3.2 to 5.1 feet) above 1990 levels by 2100 (Vermeer and Rahmstorf 2009).[31] Although the NRC notes that this higher range "cannot be ruled out" (NRC 2010b citing Vermeer and Rahmstorf 2009), its more modest projections estimate that sea levels could rise from 0.5 to 1.0 meter (1.6 to 3.3 feet) by 2100 (NRC 2010b). This estimate is higher than the end-of-century rise of 0.18 to 0.59 meter (0.6 to 2.0 feet) relative to 1980–1999 suggested by EPA (2009) and IPCC (2007a) and provided in the MYs 2012–2016 CAFE Standards FEIS. *The Copenhagen Diagnosis* also supports revising earlier estimates of sea level rise, suggesting that sea level rise could be more than twice the projections provided by the IPCC (Allison *et al*. 2009).

With regard to projected climate impacts, new research indicates that even if hurricane intensities do not increase (*e.g.*, in response to warming oceans), rising sea levels exacerbate storm surges and flooding (NRC 2010b). Longer term impacts include increased coastal erosion and saltwater intrusion into groundwater. Additionally, coastal wetlands, including salt marshes and mangroves, are at risk when they are sediment starved or otherwise cannot keep pace with sea-level rise (Nicholls and Cazenave 2010). UNEP (2009) reports that for every 0.20 m (0.7 feet) of sea-level rise the frequency of any extreme sea level of a given height increases by a factor of about 10. According to this relationship, by 2100 a rise of sea level of 0.5 m (1.6 feet) would produce events every day that now occur once a year, and extreme events expected once during the whole of the twentieth century will occur several times every year by the end of the twenty-first century (UNEP 2009 citing Hunter 2009).

Hypoxia and Acidification: CO_2-driven ocean acidification continues to be considered a serious threat to marine ecosystems, as described more fully in Section 4.7 of this EIS. A new study supports concerns of previous findings discussed in the MYs 2012–2016 CAFE Standards FEIS suggesting ocean acidification is expected to track future CO_2 emissions and has been linked to a 19-percent decrease in growth of corals in the Great Barrier Reef (Richardson *et al.* 2009). If emissions increase "unchecked," ecosystem impacts driven by the resulting change in ocean acidity could be irreversible (Richardson *et al.* 2009 citing Solomon *et al*. 2009). Another concern from mounting new evidence is hypoxia, where warmer waters are projected to reduce subsurface dissolved oxygen levels and alter ocean circulation, which would lead to an expansion of "dead zones" (NRC 2010b citing Keeling *et al*. 2010, Rabalais *et al*. 2010, and Levin *et al*. 2009). *The Copenhagen Diagnosis* reports that there is new evidence for a continuing decrease in dissolved oxygen concentrations in the global oceans (Allison *et al.* 2009 citing Oschlies et al. 2008), and for the first time significant evidence shows that the large equatorial oxygen minimum zones are expanding (Allison *et al.* 2009 citing Stramma et al. 2008).

Ecological: Of particular concern to marine ecology, global ocean surface temperatures continue to warm. The second warmest January on record was January 2010, and ocean surface temperatures during the summer of 2009 (June through August) reached 0.58 °C (33 °F) above the average global temperature recorded for the twentieth century (Hoegh-Guldberg and Bruno 2010). New studies support the previous findings outlined in the MYs 2012–2016 CAFE Standards FEIS that discuss the adverse impacts of rising ocean temperatures on marine ecosystems. Recent experiments have shown that higher temperatures reduce both total food web biomass and the ratio of plant-to-animal biomass (O'Connor *et al*. 2009). Similar temperature-food web relationships have been documented in large-scale field studies of plankton in the North Atlantic (Morán *et al*. 2010). Furthermore, increased sea-surface temperatures

[31] Projections from Vermeer and Rahmstorf (2009) use a 2.3 (4.1) to 4.3 °C (7.7 °F) temperature increase by 2100 based on a moderate emission scenario.

have been related to the decline of phytoplankton biomass concentrations in 8 of 10 ocean regions over the past century (Boyce *et al*. 2010).

New studies provide additional evidence of the impact of reduced subsurface dissolved oxygen levels on marine ecology. Hypoxia can lead to habitat degradation and fish and invertebrate mortality (NRC 2010b citing Keeling *et al*. 2010, Rabalais *et al*. 2010, and Levin *et al*. 2009). Moreover, melting ice sheets might increase the amount of chemical pollutants introduced into the marine food web by releasing chemicals currently bound to the ice (Richardson et al. 2009).

Salinity: Researchers have documented the increases in fresh water entering the ocean system around the globe, and new research shows salinity freshening in the subtropical thermocline of the northern Pacific Ocean. Subsurface and surface salinity freshening began in the mid-1980s and early 1990s, respectively, and continues into the 2000s (Ren and Riser 2010).

Productivity: Further new findings continue to support the observed relationship between the reduction in primary productivity and the warming of surface waters discussed in the MYs 2012–2016 CAFE Standards FEIS. While a climate signal related to changes in primary production could be difficult to discern from background natural variability for "many decades," some models project decreases in low-latitude primary productivity tied to climate warming (NRC 2010b citing Boyd *et al*. 2008 and Henson *et al*. 2010). Additionally, satellite data have shown that the lowest productivity zones in the subtropics have expanded over the past 10 years (NRC 2010b citing Sarmiento *et al*. 2004, Polovina *et al*. 2008, and Steinacher *et al*. 2010).

4.5.5.3 Adaptation

In some circumstances, the potential effects of climate change and sea-level rise on coastal systems and low-lying areas can be reduced through widespread adaptation (Nicholls *et al*. 2007). The IPCC cited modeling results of flood risk associated with rising sea level and storm surges projected to 2080; the model found substantial benefit associated with upgrading coastline defenses (*e.g.*, sand dune restoration, dikes, and seawalls) (Nicholls *et al*. 2007). Without adaptation, the results suggest more than 100 million people could experience coastal flooding due to sea-level rise every year by 2080 (Nicholls *et al*. 2007). In addition, curtailing anthropogenic activities such as deforestation, fertilizer use, dredging, sand mining, fish harvesting, and sea-wall construction would provide a more robust coastal system resistant to extreme water levels during storms.

SAP 4.4 (National Science and Technology Council 2008 citing CCSP 2008b) outlines seven approaches to adaptation: (1) protecting key ecosystem features; (2) reducing anthropogenic stresses; (3) representation (maintaining species diversity); (4) replication of ecosystems to maintain species diversity and habitable lands; (5) restoration of disturbed ecosystems; (6) refugia (using less affected areas to "seed" new areas); and (7) relocation.

Some examples of possible adaptation strategies in the United States include: (1) shifting populations and infrastructure from coastal communities along the East and Gulf Coasts and mid-Atlantic region farther inland (National Science and Technology Council 2008 citing Nicholls *et al*. 2007); (2) elevating infrastructure and introducing barriers such as levees and dams to hold off storm surges (Epstein *et al*. 2006); (3) reducing fertilizer and pesticide use in near-shore coastal communities (Epstein *et al*. 2006); (4) preserving contiguous interconnected water systems (including mangrove stands, spawning lagoons, upland forest and watershed systems, and coastal wetlands) (Epstein *et al*. 2006); and (5) constructing watertight containment for essential equipment (NY City DEP 2008). In its 2007 Technical Summary, the IPCC found that the costs of adaptation are *virtually certain* to be less than those of inaction (Parry *et al*. 2007).

Small islands in the Indian and Pacific Oceans and the Caribbean have much of their infrastructure in coastal locations (Parry *et al*. 2007). Under projected levels of sea-level rise, some infrastructure is likely to be at risk from inundation and flooding (Mimura *et al*. 2007). Small island populations have limited choices in adaptation to sea-level rise and the impacts of climate change on coastal areas.

4.5.6 Food, Fiber, and Forest Products

This section provides an overview of the observed and projected impacts of climate change on food, fiber, and forest products within the United States and globally, as they are represented in the literature.

4.5.6.1 Summary

This section presents a summary of the information presented in Section 4.5.6 of the MYs 2012–2016 CAFE FEIS regarding observed and projected climate change impacts on food, fiber, and forest products. As outlined below, 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. The world's food crops, forests, and fisheries have evolved along 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. Climate change will alter these dynamics, potentially threatening forest, cropland, and fishery productivity.

4.5.6.1.1 Observed Vulnerability and Impacts of Climate Change

Exposure to existing stressors, along with sensitivity to changes in climate, increases the vulnerability of the forest, food, and fiber systems to climate change-induced damages. Non-climate stressors such as soil erosion, overgrazing, loss of biodiversity, decreased availability of water resources, and increased economic competition among regions increase overall sensitivity to the climate and thus exacerbate the adverse effects of climate change.

<u>Forests</u>: In the United States and globally, forests have begun responding to climate change through altered distribution, growth, and disturbance dynamics. 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. Climate change has also increased the frequency and intensity of wildfire events in some areas, limiting forest productivity. 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. Finally, forest composition and distribution across the United States are changing in response to new climate patterns. Certain forest habitats are migrating into higher latitudes or higher elevations, while others are transitioning to grassland.

<u>Fisheries</u>: Freshwater fisheries are sensitive to changes in water temperature and to changes in river flows and lake levels caused by changes in surface water. The effects of temperature increases have caused northward shifts of fisheries systems, which is expected to continue in the future. For example, Pacific salmon species have been recently appearing in Arctic rivers.

4.5.6.1.2 Projected Impacts of Climate Change

Forests: Climate change is projected to impact the ability of forests to provide key services and commodities in several ways. Overall, forest productivity could increase because of three factors: (1) the CO_2 fertilization effect, (2) the warming of colder climates associated with increased CO_2 concentrations, and (3) increased precipitation, especially in arid regions. Globally, commercially grown forests for timber production are expected to increase modestly in the short term, depending on geographic region. Over the long term, however, the expected productivity benefits from increased CO_2 concentrations could be counteracted by water shortages and drought.

Under future climate-warming scenarios, plant and animal species are expected to shift to higher elevations and latitudes, thus redistributing ecosystems. Due to the projected pace of climate change, some species could have trouble migrating and adapting quickly enough to tolerate the changing climate regimes. For example, pollen records demonstrate that tree migration[32] rates in the past have been roughly 20 to 40 kilometers (12 to 25 miles) per century. To keep up with the projected climate changes in the future, tree migration rates would require migration rates of roughly 300 to 500 kilometers (186 to 310 miles) per century.

One key impact of climate change on forests is the extended risk and increased burn area of forest fires coupled with pathogenic stressors that damage fragile forest systems. The increasing occurrence of forest fires, which is likely to continue with projected warming temperatures, would impact ecosystem services, might reduce the potential for carbon storage via forest management, and could increase habitat for invasive species and insect outbreaks. Because invasive species and pests are generally not constrained by the need for pollinators or seed spreaders, these species are more adaptable to the warming climate. The poleward movement of weed species, especially invasive weeds, is likely to be a result of higher projected temperatures and increased atmospheric CO_2 concentration.

Agriculture and Croplands: The vulnerability of agriculture is a function of the sensitivity of crop species to changes in climate variables, such as increased temperature, and the exposure of crop species to climate impacts, such as decreased soil moisture. Elevated CO_2 levels and temperatures may initially increase crop yield for certain crop species, such as grain species in the United States. As temperatures continue to rise, however, sensitivity of these crops could increase. In addition to the positive effects of elevated CO_2, climate changes such as decreased rainfall, increased evaporation from higher temperatures, and longer growing seasons can all increase irrigation needs. Agriculture could also be affected by the impact of climate change on pests and weeds. Warming trends have led, in some cases, to earlier spring activity and proliferation of some species, leading to decreases in agricultural yields.

Crops are also vulnerable to extreme weather events, particularly flooding and droughts. Projected increases in intensity of rainfall events will cause crop losses via soil compaction and increased susceptibility to root diseases. More intense and longer drought periods can extend risk and increase burn area of forest fires.

Livestock: The livestock production infrastructure in the United States is likely to be influenced by 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.

[32] Tree migration is the process whereby the geographic distribution of tree-dominated communities changes over time. These plant communities are specifically suited to certain ranges of temperature, precipitation, and soil types. As local climates shift, plants colonize new areas that have newly favorable climate characteristics.

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. Although fisheries in cold freshwater regions are expected to be adversely affected, fisheries in warm freshwater regions could benefit from climate change. The effects of temperature increases have caused northward shifts of fisheries systems, which is expected to continue in the future. Overall, the aquaculture and fisheries sectors are expected to experience negative impacts as a result of the regional changes in the distribution and proliferation of various marine species. As the distribution of certain fish species continues to change, there is the potential for notable extinctions or extirpations in the fisheries system, especially in freshwater species, in temperature ranges at the margin.

4.5.6.2 Recent Findings

The following is a summary of updated information on observed and projected climate change impacts on food, fiber, and forest products that have become available since the MYs 2012-2016 CAFE Standards FEIS. Two recently released synthesis reports addressing climate impacts on food, fiber, and forest products – NRC's *Climate Stabilization Targets* (2010b), and EPA's *Climate Change Indicators in the United States* (2010) – are based on much of the same literature as the earlier synthesis reports used to inform the MYs 2012–2016 CAFE Standards FEIS, and as such, do not introduce new climate change impacts, but broadly affirm the findings discussed in the summary section above. To reduce redundancy, areas in which these reports overlap with the information provided in the MYs 2012–2016 CAFE Standards FEIS are not discussed here. However, new findings or interpretations captured in these synthesis reports, as well as peer-reviewed articles that have been published since the MYs 2012–2016 CAFE Standards FEIS are provided here by topic category.

Forests: Recently published studies provide further evidence of increased forest productivity under observed and projected climatic conditions. The response of forests to climate change depends on complex interactions among many processes including water and nutrient availability, increased temperatures, rising atmospheric CO_2, the ability of species to adapt to new growing conditions, and the location of tree species relative to their thermal boundaries (Way and Oren 2010). In areas where forest is not currently experiencing an optimal temperature for growth, higher temperatures and higher atmospheric CO_2 have both been shown to increase biomass accumulation under conditions where water and resources are not limiting factors (McMahon *et al*. 2010). Elevated CO_2 in isolation from other factors can enable tree biomass accumulation by increasing photosynthesis rates and higher water use efficiency, but the effect is mediated through local conditions. Recent evidence suggests that climate change is already accelerating biomass accumulation in certain forests. For example, McMahon *et al.* (2010) found recent, accelerated biomass accumulation in temperate, deciduous forests in Maryland. The high biomass accumulation rate is most likely the result of local increases in temperature, growing season, and atmospheric CO_2 as these three factors affect tree stand growth dynamics. The extent to which these climate impacts positively affect forest growth is highly contested in the research community, and research into forest impacts is ongoing (*see* for example, Foster *et al.* 2010).

Although historically warmer growing seasons have been correlated with greater tree growth in northern forests, there is evidence that tree species have a thermal optimum for growth; temperatures above or below the optimum will limit tree growth (Way and Oren 2010). Way and Oren (2010) performed a regression analysis on tree species and predicted that, with an average global temperature increase of 3.4 °C (38 °F) by 2100, evergreens would show little change, while deciduous species would experience increased growth. The study found generally that, although trees in northern latitudes could experience higher growth rates due to initial temperature increases, tropical tree growth might decline with increasing temperature. This finding supports previous studies documenting that tree growth at lower latitudes is often negatively correlated with minimum daily temperatures (Way and Oren 2010 citing Clark *et al*. 2003 and 2010 and Feeley *et al*. 2007), and studies indicating that tropical tree species might already be near a high-temperature threshold, beyond which growth would be greatly reduced (Way and Oren 2010 citing Doughty and Goulden 2008).

Additional research supports previous findings in the MYs 2012–2016 CAFE Standards FEIS that the risk and extent of forest fires might increase under projected climatic conditions. Warming temperatures in combination with changed precipitation patterns are projected to increase areas burned during wildfires in parts of Australia, western Canada, Eurasia, and the United States (NRC 2010b). In the United States, the Pacific Northwest and forested regions of the Rockies and Sierra Madre will be particularly vulnerable to increases in wildfires. A warming of 1 °C (1.8 °F) (relative to 1950 through 2003) could double the area burned during wildfires. Over time, however, extensive warming and associated wildfires could exhaust the fuel for fire in some regions, gradually creating negative feedback to reduce wildfire severity (NRC 2010b).

New research introduces potential adverse economic reactions of northeastern forest assets to climate change. Huntington *et al*. (2009) predicted that projected increases in drought frequency in northeastern forests could impact maple syrup production and the coloration of autumn foliage, with potentially profound economic consequences for the northeastern United States.

New research indicates that climate change impacts on disturbances such as forest fire frequency, insect outbreaks, and extreme weather events are likely to affect forest species composition and distribution. For example, a recent simulation model study found that rising summer temperatures could significantly accelerate the succession of northern European birch-dominated forests into coniferous forests by enhancing the damage from defoliating insects (Netherer and Schopf 2010 citing Wolf *et al*. 2008).

Agriculture and Croplands: It has long been understood that crop yield responds to an array of environmental variables that interact in complex patterns. Soil moisture, temperature, atmospheric CO_2, nitrogen availability, ozone, and the timing of short-term heat and flooding events can all impact crop yield – both directly and indirectly. In addition, the particular variables that limit crop yield vary across the landscape and are extremely challenging to model, increasing the difficulty of predicting how specific cropland areas will respond to climate change (Challinor *et al*. 2009).

New research of models that simultaneously include both CO_2 and temperature impacts on crop yield have found that C_3 crops[33] in temperate regions might not experience any net yield impacts for up to 2 to 3 °C (3.6 to 5.4 °F) of local warming due to the interactive effects of elevated CO_2 and increased temperature on yield. C_4 plants, however, could experience decreased yields under milder climate change conditions. For example, high temperatures combined with low soil moisture during the flowering stage of maize can inhibit formation of kernels, thereby damaging crop yield (NRC 2010b). It is difficult to generalize the response of crops to climate change, because responses are strongly dependent on local conditions.

New research indicates that areas with subsistence agriculture and existing poverty, such as sub-Saharan Africa, are likely to be particularly vulnerable to the interaction between new climate stressors

[33] Plants differ in their methods of photosynthesis as well as their uptake and treatment of CO_2. The two main variations are classified as C_3 plants and C_4 plants. C_3 plants rely on an enzyme called ribulose-1,5-bisphosphate carboxylase oxygenase (RuBisCO) to intake CO_2 from the atmosphere. Because RuBisCO activity is not saturated at current atmospheric CO_2 concentrations, elevated CO_2 directly stimulates photosynthesis in C_3 crops, such as wheat, rice, and soybean. C_4 plants, such as maize, sugarcane, and sorghum rely on a specialized pathway that increases the concentration of CO_2 at the RuBisCO active site. Therefore, RuBisCO in C_4 plants is already saturated with CO_2 at current atmospheric conditions, and C_4 plants generally do not respond positively to elevated CO_2 concentrations (Ainsworth and McGrath 2010).

and the rapidly growing global demand for food. For example, a recent modeling study based on the historical responses of crop yield in sub-Saharan Africa to weather shocks predicts that maize, sorghum, millet, and groundnut will experience total production decreases of around 20 percent by 2050, not accounting for the CO_2 fertilization effect. Because maize, sorghum, and millet are all C_4 crops, they are expected to have a reduced fertilization response to CO_2 (Schlenker and Lobell 2010). Similarly, several studies in the United States have also predicted yield decreases for maize and soybean in the United States because these crops prefer cooler and wetter summers, which support prior findings (NRC 2010b). The response of these crops to climate change would vary regionally, however, depending on the crop's location relative to its thermal optimum and other factors.

Most current models of crop yield do not model crop yield response to climate impacts such as possible changes in weed, insect, and pathogen dynamics; ozone levels; and changes in the frequency and intensity of extreme heat, flooding, and storm events (NRC 2010b). Warming temperature due to climate change, however, could increase the severity of crop disease epidemics and alter crop yield dynamics (Butterworth *et al*. 2010 citing Evans *et al*. 2008). For example, a recent study of oilseed rape yield in England and Scotland found that the crop productivity would shift northward due to both changes in climate and the impacts of climate change on a fungal pest species (Butterworth *et al*. 2010).

Recent studies have provided additional evidence that, over the past 50 years, certain crop plants have begun flowering and maturing earlier in the season. Observations indicate that the average length of the agricultural growing season in the lower 48 States has increased by approximately 2 weeks since the early 1900s and most of that increase occurred over the past 30 years (EPA 2010 citing Kunkel 2009). For example, winter wheat grown on the Great Plains has flowered 0.8 to 1.8 days earlier per decade since 1950 (Craufurd and Wheeler 2009 citing Hu *et al*. 2005). Concurrently, the final spring frost is now occurring earlier than at any point since 1900 and the first fall frosts are arriving earlier. Since 1985, the last spring frost has arrived an average of four days earlier than the long-term average; and the first fall frost arrives about three days later (EPA 2010 citing Kunkel 2009). These observations on the length of the growing season apply not only to crops, but also to natural ecosystems, as discussed earlier in Section 4.5.4.

<u>Fisheries</u>: New research further investigates the climate impacts to freshwater, marine, and estuarine systems that support the world's fisheries. These include increased water temperatures, changes in the timing and volume of freshwater drainage, and changes in stratification patterns. Climate change affects fish stocks both directly, through impacts on physiology and distribution, and indirectly, by impacting the productivity and composition of ecosystems that fish depend on for food (Brander 2010). These climate impacts would occur in the context of existing stressors on global fisheries, including overfishing, pollution, habitat destruction, and invasive species and pathogens (Brander 2010).

In marine fisheries, the combination of climate impacts and existing vulnerabilities might reduce the general fitness of native species, and could impact the ability of species to survive existing stressors (Marques *et al*. 2010). One recent study found that warming temperatures could induce commercial species to migrate away from the tropics, increasing the catch potential by 30 to 70 percent in high latitudes and decreasing the catch potential by up to 40 percent in the tropics (NRC 2010b citing Cheung *et al*. 2010).

Freshwater fisheries are particularly vulnerable to climate change because many freshwater habitats are fragmented, species are sensitive to water temperature and availability, and many freshwater systems are already exposed to numerous stressors (Woodward *et al*. 2010). New studies have explored the impact of climate change on freshwater fish species. For example, a recent study of the Muskegon River system in Michigan predicted that the habitat ranges of game fish would change substantially by 2100 resulting in a change from predominantly coldwater fish to cool and warmwater fish. The study predicted declines in Coho salmon and brook, brown, and rainbow trout, but suggested that climate impacts on species would vary spatially within the Muskegon River system (Woodward *et al*. 2010). Another study, examining the effects of warming in Lake Washington in Washington State, found that spring thermal stratification occurs approximately 21 days earlier now than in the 1960s and that the associated phytoplankton bloom has shifted accordingly. The zooplankton that feed on the phytoplankton have not adapted, however, to the earlier bloom, suggesting that climate change can create timing issues (phenology problems, as discussed in Section 4.5.4), possibly weakening trophic interactions on which freshwater fisheries depend (Woodward *et al*. 2010 citing Winder and Schindler 2004).

Disease, Pathogens, Insects, and Weed Species: Scientific consensus holds that climate change has already impacted the temporal and spatial dynamics of insect herbivores, directly through changed dispersal, reproduction, and development patterns and indirectly through altered plant nutritional quality, resistance, and community interactions (Netherer and Schopf 2010). New research indicates that warming temperatures and a longer growing season have begun impacting insect phenology, ability to overwinter, and distributions. For example, warmer temperatures in northwestern North America have halved the time required by the spruce beetle for reproduction and have contributed to the resulting damage to spruce forests (Robinet and Roques 2010 citing Berg *et al*. 2006). Insect species across the world are also developing the ability to produce multiple generations within a single season (Netherer and Schopl 2010).

A new study enhances the current understanding of climate change on pest species. Warming temperatures and longer growing seasons impact insect development, consumption patterns, ability to overwinter, and phenology. Research suggests that when temperature increases remain within the constraints of insect development, positive direct responses of insects to warmer temperatures can be expected. For example, certain insects will benefit from accelerated development in response to warmer temperatures that enables earlier life cycles and even the establishment of multiple generations within a single season. Because cold weather temperatures in northern and high-elevation areas have often historically limited the distribution of pest species such as defoliating insects and bark beetles, these areas are likely to experience increased pest population densities. Warmer temperatures and drought might also result, however, in range contractions because southern areas (such as southern and continental Europe) will be less suitable for heat-susceptible pest species (Netherer and Schopf 2010).

Similarly, in the United States, Dukes *et al*. (2009) project with high confidence that the forest pest hemlock woolly adelgid will expand its range northward because its northern range is currently limited by cold temperatures; this finding is consistent with research summarized in the MYs 2012–2016 CAFE Standards FEIS. This forest pest is an introduced species from Asia that attacks eastern hemlock along the eastern coast of the United States. Expanded infestation would threaten to nearly eliminate this economically and ecologically important tree species. Although many pest species like the hemlock woolly adelgid are sensitive to harsh winter temperatures, the study found that predicting climate change impacts on pest species with high confidence is extremely difficult.

Mountain pine beetle outbreaks are currently occurring throughout the distribution of high-elevation whitebark pine forests in the western United States. Although episodic outbreaks of the beetle in lodgepole pines have been common historically, the colder climate of the whitebark pine forests has usually prevented large-scale outbreaks. Recent research indicates that warmer temperatures are enabling mountain pine beetles to survive the winter at all life-cycle stages and to complete an entire life cycle in one year, resulting in increased disturbance to whitebark pine forests (Logan *et al*. 2010).

Additionally, new research indicates that warming temperatures have very likely contributed to recent epidemics of mountain pine beetle in British Columbia (Dukes *et al*. 2009 citing Regniere and Bentz 2007 and Raffa *et al*. 2008) and the processionary moth in Europe (Dukes *et al*. 2009 citing Battisti *et al*. 2005 and 2006). Kudzu, an invasive weed species that flourishes under high CO_2 concentrations and warm winters, has also expanded its range dramatically over the past few decades (NRC 2010b citing Ziska *et al*. 2010).

Livestock: As discussed in the MYs 2012–2016 CAFE Standards FEIS, elevated CO_2 can increase crop yields in certain circumstances and might also reduce grain quality. For example, one recent study found decreases of 10 to 14 percent in protein content and 15 to 30 percent in concentration of minerals such as iron and zinc in non-leguminous grain crops. A decrease in grain quality could negatively impact livestock health. Livestock suffering from malnutrition exhibit decreased fertility and productivity, suggesting that if livestock owners cannot supplement feed, production of animal-based products might decrease under conditions of elevated CO_2 (Ainsworth and McGrath 2010 citing Fisher 2008).

4.5.6.3 Adaptation

Adaptive practices in the forestry sector include cultivar selection, replanting tree species that are appropriate for the new climate regime, and utilizing dying timber (CCSP 2000). Active forest management, including the adjustment of rotation schedules and harvesting patterns of forests (for example, preemptive harvesting of tree strands that are most vulnerable) can dampen the effects of climate change (Malmsheimer *et al*. 2008 citing Easterling *et al*. 2007). To ensure forest fitness and diversity, the prevention of forest fragmentation is also a key adaptation strategy (Malmsheimer *et al*. 2008 citing Noss 2001).

Adaptation strategies in the agricultural sector include migrating croplands to more suitable areas; substituting new crop species and cultivars that are better adapted to future conditions; diversifying the types of crops being planted; and improving irrigation, soil management regimes, and other agricultural inputs (Campbell *et al*. 2008). Historically, the agricultural sector has successfully selected crops for characteristics related to life-cycle duration and phenology to maximize yield. Future plant breeding and technological advancements could produce crop cultivars that are better adapted to future conditions, thereby partially mitigating projected decreases in crop yields (Challinor *et al*. 2009). Although agricultural intensification and technology improvements have increased crop yield, however, these practices have also accelerated problems such as soil erosion and eutrophication that could ultimately undermine the resiliency of the sector (Campbell *et al*. 2008).

Because the adaptive capacity, sensitivity, and exposure of crop systems varies globally, models of the global food economy indicate that trade could be an important adaptation strategy to mitigate regional yield decreases (NRC 2010b citing Easterling *et al*. 2007).

For livestock, modifying facilities to compensate for the increased temperatures that are affecting stress levels and productivity might help to maintain production levels. There is also the potential to select for livestock species that are more adaptable to the changing climate; this adaptation strategy, however, is arguably high risk and high cost (GCRP 2009).

There is evidence that land management strategies, such as conserving forested areas and limiting urbanization and agriculture near streams, can mitigate the impacts of climate change on freshwater fisheries. In addition, dam removal can help keep water temperatures lower and also maintain and expand salmon populations (Steen *et al*. 2010).

4.5.7 Industries, Settlements, and Societies

This section provides an overview of the observed and projected impacts of climate change on industries, settlements, and societies within the United States and globally, as they are represented in the literature.

4.5.7.1 Summary

This section presents a summary of the information presented in Section 4.5.7 of the MYs 2012–2016 CAFE Standards FEIS regarding observed and projected climate change impacts on industries, settlements, and societies.

4.5.7.1.1 Observed Vulnerability and Impacts of Climate Change

The industries, settlements, and societies discussion in the MYs 2012–2016 CAFE Standards FEIS includes a broad range of resources and human activities that are vulnerable, in varying degrees, to the impacts of climate change. Throughout history, this sector has been resilient to fluctuations in environmental conditions, but is most vulnerable when environmental changes are extreme or persistent, as are many predicted changes in climate. Adopting the organization used by the IPCC, this sector is broken down into five categories.

Industry: Industry, including manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities; this category is mainly susceptible to physical damage from increased extreme weather events, heavy precipitation, and heat stress.

Services/Economic: Services, including trade, retail, and commercial services; tourism; and risk financing or insurance; this category is also vulnerable to interruptions due to extreme weather events.

Utilities and Infrastructure: Utilities and infrastructure, including physical infrastructure such as water, transportation, energy, and communication systems, as well as institutional infrastructure such as shelters, public healthcare systems, and police, fire, and emergency services. In general, physical assets tend to be less resilient to predicted climate change impacts than institutional infrastructure.

Human Settlements: Human settlements represent population centers or any areas where people reside. Settlements are mainly vulnerable to flood risks from sea-level rise (coastal communities) and changes to water supplies from sea-level rise and changes in precipitation patterns.

Social Issues: Social issues include risks to cultural and traditional groups of people, and socioeconomic issues relating to developed versus developing areas and rich versus poor populations; some disadvantaged populations face difficulties that might be exacerbated by climate change impacts.

4.5.7.1.2 Projected Impacts of Climate Change

In general, the nature of climate change impacts expected in the United States and the rest of the world is similar. In terms of the severity of the impacts, research indicates that developing countries will be more vulnerable to climate change impacts than developed countries. In particular, income constraints and less well-developed physical and social infrastructures might make adaptation for developing countries more difficult.

Industry: To some extent, all forms of transportation are vulnerable to climate change impacts arising from temperature changes, sea-level rise, changes in precipitation, and extreme weather events.

For example, predicted increases in very hot days and heat waves could increase the cost of transportation construction, operations, and maintenance. Sea-level rise is virtually certain to occur, and could subject coastal transportation infrastructure to frequent, severe, or permanent inundation. Additionally, scientists predict increases in intense precipitation events, which could disrupt transportation services, safety, and reliability, and cause physical damage to infrastructure through flooding. Overall, climate change is likely to increase costs for the construction and maintenance of transportation infrastructure, impact safety through reduced visibility during storms and physical damage from extreme weather events, and disrupt transportation networks with flooding and physical damage. Temperature changes could also require changes in the kinds of materials used for transportation construction. All of these effects would have substantial economic impacts associated with increased costs, delays, and service interruptions.

Services/Economic: Trade, retail, and commercial services; tourism; and insurance are all particularly vulnerable to climate change impacts, which in turn could have rippling economic effects across communities or countries. These sectors are all vulnerable to extreme weather events and physical damage, both directly and indirectly through damage to transportation infrastructure. The insurance sector is notably vulnerable to increases in risks associated with climate change, and as a result might withdraw or limit coverage in many vulnerable areas, especially along the coast.

Utilities and Infrastructure: All major energy sources are subject to a variety of climate change effects, including changes in temperature, wind, humidity, precipitation, and extreme weather events. The principal impacts on energy systems are reduced total energy demand for space heating and increased total energy demand for space cooling, while the net effects on energy use would vary by region. In addition, temperature increases will increase peak electricity demand and higher temperatures also reduce power generation efficiency. Some coastal facilities might be vulnerable to sea-level rise and extreme weather events, and hydropower production could be directly and substantially affected.

Human Settlements: The impacts of climate change on human settlements are expected to be substantial. They include increased stress due to higher summer temperatures, decreased stress due to warmer winter weather, changes in water availability due to precipitation fluctuations, and flooding and physical damage from sea-level rise and extreme weather events. Human impacts, many of which are more fully discussed in Section 4.5.8 on Human Health, include increased respiratory and cardiovascular problems and damages or disruptions to services associated with urban infrastructure such as sanitation, electricity, and communications as a result of flooding, storms, or increased demand. Vulnerable populations such as the poor, elderly, ill, disabled, those living alone, and recent migrants are expected to be at greater risk to these effects.

Around the world, preserved historic sites are vulnerable to damage from climate change. The damage could be caused by increased salt mobilization from heavy rainfall or increased temperature and humidity in some areas, which would damage historic exteriors. In addition, pest migration could accelerate decay of organic building materials such as wood, while flooding or increases in precipitation could foster growth of damaging molds and fungi.

National Security: Climate change has profound implications for America's national security, both domestically and abroad. Climatic changes including sea-level rise, greater storm surge, and extreme weather events, and changes in temperature and precipitation threaten global stability. These projected changes are potential catalysts for instability in already-volatile regions of the world, such as parts of Asia, Africa, and the Middle East. Further, climate change acts as a threat multiplier[34] for instability in volatile regions of the world. Climate change-driven conflicts could begin around the world,

[34] "Threat multiplier" refers to an action that further intensifies the instability of a system that poses a security concern.

representing an economic and military burden to the United States and other historically stable countries, decreasing their ability to defend their national borders.

Some of the climate change-related drivers of conflict could include: increased conflict over resources, stemming from changes in agricultural productivity and water availability; risk of economic damage to coastal cities and critical infrastructure from sea-level rise and an increase in natural disasters; loss of territory and border disputes due to sea-level rise; environmentally-induced migration from loss of coastal land, desertification, and a decreased availability of resources due to climate change; potential for tension and instability over energy supplies; increasing pressure on international governance, stemming from the potential resentment by nations or peoples impacted most severely by climate change towards those they consider responsible; and limits in domestic resources due to climate refugee populations and immigrants. These areas of conflict could add political and social tension, as well as an economic burden, to the United States and other stable countries, for example, if such countries were to accept large immigrant and refugee populations. In addition, the U.S. military could become overextended as it responds to extreme weather events and natural disasters, along with current or future national security threats. As a result of these risks, defense experts have expressed concern over the potential geopolitical and national security consequences of climate change.

4.5.7.2 Recent Findings

A variety of reports and papers related to climate change and industries, settlements, and societies has been published since September 2009, when the literature review for the MYs 2012–2016 CAFE Standards FEIS was performed. Three recently released broad-based reports on climate change – NRC's *Climate Stabilization Targets* (2010b), EPA's *Climate Change Indicators* (2010), and *The Copenhagen Diagnosis* (Allison *et al*. 2009) – provide support to the findings and discussions presented in the MYs 2012–2016 CAFE Standards FEIS. This is expected given that much of the literature used to inform these reports was also used to develop the discussions in the MYs 2012–2016 CAFE Standards FEIS. This section does not repeat any information already provided in the MYs 2012-2016 CAFE Standards FEIS. However, new information provided by NRC's *Climate Stabilization Targets* is presented here. This section also includes new information and interpretations provided by individual peer-reviewed studies. Overall, the latest research has not revealed any changes to the vulnerability of industries, settlements, and societies to climate change, but it has (a) reinforced the certainty that these areas are at risk, (b) identified new susceptible areas, and (c) examined specific vulnerabilities in more detail.

<u>Industries</u>: Based on their survey of Canadian mining industry officials, Ford *et al*. (2010) found that Canadian firms are already taking actions to manage impacts from climate change. Their dependence on the natural environment as well as their significant investments in long-lived physical assets places firms in the mining industry at risk from climate variability and extremes. The most significant short-term negative impacts are associated with extreme events such as droughts, severe storms, and flooding.

Transportation systems are vulnerable to climate change for a variety of reasons. One is that materials used in construction of transportation infrastructure were chosen based on historical climate conditions (Nolan 2010). If climate does change, these materials may no longer be suitable for a particular area and might fail (NRC 2010b).

Roadways across the world could experience unexpected material degradation given warmer-than-usual temperatures. Roadways might also be subject to flooding from heavy precipitation, extreme weather events, or sea-level rise, which brings additional damage from saltwater corrosion. If urban areas have insufficient pumping capacity to clear the roadways, energy use by the transportation sector could increase because of delays from congestion and detours in response to flooding (Zimmerman and Faris 2010). All of these impacts will increase maintenance costs for the transportation sector.

Transit systems are also vulnerable to the same predicted climatic changes. Warmer temperatures and more frequent heat waves will increase rail degradation, increase the need for cooling equipment on trains and buses, and increase overall maintenance costs (Zimmerman and Faris 2010). Heavy precipitation and sea-level rise could similarly impair transit, causing flooding and delays, increased emergency stops, increased maintenance needs, and deteriorating equipment from salt water, in the case of sea-level rise (Zimmerman and Faris 2010).

Increased use of rail systems represents a potential GHG mitigation option. Rail systems, however, might be vulnerable to climate change. A recent report reveals that the main anticipated effects of climate change on rail are increased rail buckling due to high temperatures, a severe strain on railway drainage systems because of heavy precipitation, and an increased likelihood of travel disruption due to extreme weather events (Baker *et al*. 2010).

Services/Economic: The insurance industry is actively pursuing options for responding to risks associated with climate change by offering new products such as policies with terms and conditions that are aligned with risk-reducing behavior on the part of the insured and adjusting pricing on homeowners' policies to better reflect climate-related risks (Mills 2009).

Utilities and Infrastructure: The energy sector is projected to experience increases in user demand and peak loads due to high temperatures, which in turn could cause energy shortages, black- or brownouts, and overall reduced system reliability (NRC 2010b, Troccoli *et al*. 2010, Zimmerman and Faris 2010). The precise contribution of temperature to electricity demand is a looming research question. Studies show that residential cooling energy use could increase from 5 to 20 percent per degree Celsius of warming (NRC 2010b), and that temperature-related utility costs currently represent about 7 percent of total consumption (Bansal and Ochoa 2009) – a number that is projected to rise. Higher temperatures could also negatively affect energy transmission, causing sags in overhead lines and increased maintenance requirements, and increasing the potential for underground fires and manhole explosions (Zimmerman and Faris 2010). Thermal powerplant efficiency, both fossil and nuclear, is adversely affected by higher ambient temperatures due to diminished efficiency of facility cooling systems (GCRP 2009).

Precipitation changes, extreme weather events, and sea-level rise all pose additional threats to the energy system, namely through flooding and physical damage risks. New research indicates that flooding, corrosion from seawater, and physical damage to production or transmission equipment would decrease energy reliability and increase maintenance time and costs (Troccoli *et al*. 2010, Zimmerman and Faris 2010). Troccoli *et al*. (2010) also point out a potential impact of climate change on energy production facilities: unexpected conditions could make facilities unable to meet environmental regulations. This could be yet another extra cost to the energy system because of climatic changes.

New results from simulation modeling of energy supply and demand in the Pacific Northwest by Hamlet *et al*. (2010) indicate that substantial seasonal changes in the energy sector are likely as a result of climate change. They conclude that over the next century higher temperatures, changes in precipitation, and population growth in the region will combine to increase demand and potentially decrease the supply of hydropower in summer months while increasing the supply in winter months.

All components of the energy system, including new renewable energy installations, are vulnerable to changes in climate. A recent study sought to determine whether climate changes could damage the effectiveness of wind power, a major renewable energy source. The study found that wind energy is theoretically susceptible to climate change, including changes in wind patterns, but that currently no findings show that climate change could significantly alter wind resources in northern

Europe, the site of most global wind installations (Pryor and Barthelmie 2010). No similar study was found on changing wind energy potentials in the United States or Asia.

Human Settlements: Food security is another climate-related human health risk. Crop yields are expected to decline worldwide because of climate change. The U.S. Corn Belt, which supplies 40 percent of the world's maize, is predicted to lose 11 percent yield per degree of warming, representing a major threat to international food security (NRC 2010b).

National Security: In its recently released Quadrennial Defense Review, the U.S. Department of Defense (DOD) noted that even though climate change is not likely to be a direct cause of conflict, it could indirectly contribute to instability or conflict by "placing a burden to respond on civilian institutions and militaries around the world. In addition, extreme weather events may lead to increased demands for defense support to civil authorities for humanitarian assistance or disaster response both within the United States and overseas" (DOD 2010). Climate change can magnify existing risks to national security by exacerbating conflicts over scarce resources, damaging physical assets, contributing to desertification, adding to tensions over energy supplies, and increasing pressures on international governance structures and resources (DOD 2010).

4.5.7.3 Adaptation

Human industries, settlements, and societies historically have been resilient and flexible in the face of change (Ausubel and Langford 1997). Nevertheless, additional adaptation measures will be necessary to combat the predicted effects of global climate change. With the information available on predicted global change, communities can begin to extend their planning time frames, improve responses to changing energy demand, and diversify energy supplies and technologies to reduce risk. The existing uncertainty about localized climate change impacts makes judgments about many adaptation measures difficult (Wilbanks *et al*. 2007), but the key challenge is to find measures that are robust to various scenarios of change, both for climate and non-climate stressors.

4.5.8 Human Health

This section provides an overview of the observed and projected impacts of climate change on human health within the United States and globally.

4.5.8.1 Summary

This section presents a summary of the information presented in Section 4.5.8 of the MYs 2012–2016 CAFE Standards FEIS regarding the observed and projected climate change impacts on human health.

4.5.8.1.1 Observed Impacts and Vulnerabilities

There is strong likelihood that climate change has contributed to human mortality and morbidity. 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.

Observed impacts on human health in response to climate change include the following.

Heat Events: The number of hot days, hot nights, and heat waves has increased, contributing to human morbidity and mortality directly through heat stress and indirectly though a heightened risk of forest fires, reduced air quality, and increased stress on the electrical grid causing brown- or blackouts.

Cold Events: Cold days, cold nights, and frost days have become less common, generally producing beneficial effects.

Air Quality: Several studies have found increasing levels of ground-level ozone, which can exacerbate respiratory ailments and affect lung efficiency.

Aeroallergens: The spring pollen season has recently been shown to begin earlier than usual in the Northern Hemisphere, with further evidence of the lengthening of the pollen season associated with some plant species. Current findings demonstrate that ragweed pollen production and the length of the ragweed pollen season increase with rising CO_2 concentrations and temperatures. Highly allergenic invasive species, such as ragweed and poison ivy, have been found to be spreading in particular locations around the world.

Water-borne and Food-borne Diseases: Increased temperatures, greater evaporation, and intense rain events have been associated with adverse impacts on drinking water through increased water-borne diseases, algal blooms, and toxins. For example, as the waters of the northern Atlantic have warmed, the concentration of the pathogenic bacteria *Vibrio* has increased. In Peru, higher temperatures have been linked to periods of increased diarrhea incidence experienced by adults and children. The global increase in frequency, intensity, and duration of red tides can be linked to local impacts already associated with climate change, as toxins associated with red tide directly affect the nervous system.

Vector-borne Diseases: The transmission of vector-borne diseases, such as West Nile virus and malaria, depends on the survivability of the vector host, the mosquito. For example, the greatest transmission of the West Nile virus occurred during the 2002 and 2004 summers associated with above-average temperatures. A recent study of malaria in East Africa found that the measurable warming trend the area has experienced since the 1970s is correlated with the potential for disease transmission.

4.5.8.1.2 Projected 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; increased heat wave-, flood-, storm-, and fire-induced mortality; decrease in cold-related deaths; increased diarrheal disease burden; increased levels of ground-level ozone; and altered geographic distribution of some infectious disease vectors. 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. The adverse impacts, however, greatly outweigh the beneficial impacts, particularly after mid-century.

Impacts of climate change on human health in the United States are expected to be less detrimental than in the developing world due to more robust infrastructure and emergency response systems. Wealthier nations, like the United States, have more resources available to fund adaptation measures that prevent or reduce widespread health consequences. Regardless of these advantages, however, the United States is still expected to witness many direct climate change impacts, including the following.

Heat Events: There could be a rise in heat-related morbidity and mortality in the coming decades, due in part to an aging population. In U.S. regions where severe heat waves already occur, these events are projected to intensify in magnitude and duration. Heat waves are anticipated to increase in severity, duration, and frequency, particularly in the Midwest and Northeast.

Air Quality: The northern latitudes of the United States are likely to experience the greatest increase in average temperature and concentrations of many of the airborne pollutants. In urban areas, ground-level ozone concentrations are anticipated to increase in response to higher temperatures and increases in water vapor concentrations. Climate change could further cause stagnant air masses that increase pollution concentrations of ground-level ozone and PM in populated areas. There is debate over which specific areas of the country will experience the worst pollution and temperature increases. The Midwest and Northeast could experience noteworthy increases in PM concentrations while the country as a whole may experience small decreases. The Southeast, Intermountain West, and West are likely to experience an increase in frequency, severity, and duration of forest fires.

Aeroallergens: An increase in allergen concentrations and exacerbated respiratory ailments associated with a spring pollen season expansion could result in response to warmer temperatures and higher CO_2 concentrations.

Water-borne and Food-borne Diseases: Climate change is projected to alter temperature and the hydrologic cycle, potentially affecting water-borne and food-borne diseases, such as salmonellosis, campylobacter, leptospirosis, and pathogenic species of *Vibrio*. 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. The United States is projected to endure an increase in the frequency of droughts and heavy rain events across the country, leading to increased risk of flood. Declining water availability in the West could occur as mountain snowpacks are depleted. These events could have a direct impact on water-borne diseases in the United States.

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, while decreasing the range of tick-borne encephalitis in low latitudes and elevations. 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. Malaria in the United States is unlikely to be affected by climate change given the anticipated governmental response of public intervention and vector control.

Globally, the health impacts of climate change will vary by region. In fact, some areas are anticipated to experience improved health outcomes while others will experience diminished health. Some of the health benefits of climate change might include decreases in cold-related mortality, increased crop yields and nutrition, and beneficial changes in the geographic distribution of diseases. Despite these anticipated benefits, negative health impacts are expected to outweigh the benefits. Negative outcomes include: malnutrition and increased disease susceptibility; increased heat wave-, flood-, storm-, and fire-induced mortality; increased diarrheal disease burden; cholera outbreaks associated with floods; increases in food poisoning associated with high temperatures; increased levels of ground-level ozone; changes in geographic distribution of infectious diseases; and increases in asthma rates associated with smog, dust, and particle buildup due to increases in temperature, humidity, and wildfire.

4.5.8.2 Recent Findings

Updated findings to the MYs 2012–2016 CAFE Standards FEIS are provided here for the human health sector. Three recently released synthesis reports – NRC's *America's Climate Choices: Advancing the Science of Climate Change* (2010a), NRC's *Climate Stabilization Targets* (2010b), and

Environmental Health Perspectives/National Institute of Environmental Health Sciences, *A Human Health Perspective on Climate Change* (Portier *et al*. 2010) – are largely based on the similar literature used to inform the MYs 2012–2016 CAFE Standards FEIS and corroborate the findings discussed in the summary section above. To reduce redundancy, information already provided in the MYs 2012–2016 CAFE Standards FEIS are not repeated here. However, one of the three reports, *A Human Health Perspective on Climate Change,* does provide significant new research that is discussed below. This section also includes new findings of recently released peer-reviewed journal articles. The topics listed above (i.e., heat events, air quality) are discussed below only in instances where new findings are available. In addition, a relatively new area of research, climate change impacts on cancer, is included as a new topic below.

<u>Heat Events</u>: According to a recent study, an estimated 75 percent of all deaths due to natural disasters from 1979 to 2004 were associated with temperature extremes (heat waves/extreme cold) (NRC 2010b citing Thacker *et al*. 2008). Consistent with previous findings cited in the MYs 2012–2016 CAFE FEIS, heat-related mortality nationwide declined from the 1970s to the 1990s due to acclimatization and the increased use of air conditioning systems (NRC 2010b citing Sheridan *et al*. 2009).

A number of recent studies quantify and project the relationship between mortality and temperature metrics representing heat events. A case study of the California heat wave of July 2006 estimates an increase of 9 percent of heat-related mortality for every increase in the apparent temperature of 5.5 °C (10 °F) (NRC 2010b citing Ostro *et al*. 2009). Sherwood and Huber (2010) defined a new metric for investigating heat stress keyed to the annual maximum wet bulb temperature exceeding the average human skin temperature of 35 °C (95 °F). This metric draws from the physiological stress of hyperthermia-associated exposure to heat stress for extended periods of time (*i.e.*, more than a few hours). This study found that habitability of some regions across the globe is threatened due to prolonged heat stress once the global mean warming reaches about 7 °C (12.6 °F).

Within the United States, two recent studies provide city-specific projections of heat-related death due to changes in climate. A recent study concluded that the 1995 Chicago heat wave, responsible for almost 800 heat-related deaths, could occur in Chicago as much as twice per decade by mid-century under a lower emission scenario to five times per decade under a higher emission scenario. By the end of the century, the frequency of an event similar to the 1995 heat wave could increase dramatically, occurring every other year under a lower emission scenario to three times a year under a higher emission scenario (Hayhoe *et al*. 2010). This study also concluded that the heat wave season is projected to lengthen (Hayhoe *et al*. 2010). The acclimatization to higher temperatures, the use of early warning systems, and the alteration of infrastructure to reduce the urban heat island effect,[35] however, was not addressed.

Another new heat-mortality study focused on Washington State projects that Seattle could sustain between 89 and 401 excess deaths in 2045 and between 107 and 988 excess deaths in 2085, with residents older than 65 being more vulnerable (Jackson *et al*. 2010).

<u>Air Quality</u>: A few recent studies estimate the projected increases in tropospheric ozone in response to climate change. The daily 1-hour maximum of summertime (June–August) tropospheric ozone averaged across 50 U.S. cities was estimated to increase by 4.8 ppb from the 1990s to 2050s in response to average summertime local temperatures increasing by 1.6 to 3.2 °C (2.9 to 5.8 °F) (these temperature ranges correspond to conditions driven by a moderately high GHG emission scenario) (NRC 2010b citing Bell *et al*. 2007). Additionally, Jackson *et al*. (2010) project that by mid-century, summertime (May–September) daily 8-hour maximum ozone concentrations will increase by 5.8 ppb in

[35] Pavement and buildings in urban areas absorb solar radiation at a greater rate than trees and grass creating warmer conditions than those experienced in nearby rural or suburban areas.

King County, Washington and 6.1 ppb in Spokane County, Washington, resulting in 63 and 37 additional annual deaths, respectively, compared to 1997 through 2006 conditions. The effects of ozone events could be further compounded by heat events. Mortality associated with simultaneous heat and ozone events suggests a rise in mortality of 175 percent compared to that associated with just an ozone event; this estimate was derived by comparing mortality data in nine locations in France from 1996 to 2003 (NRC 2010a citing Filleul *et al*. 2006).

The incidence of respiratory disease could increase as global airborne dust concentrations increase, in response to increased anticipated periods of drought (Portier *et al*. 2010). In addition, strong inversion layers that trap pollution at the surface are anticipated to increase, causing buildup of dust and other local pollutants such as ozone and particulate matter. Further, airborne dust can contribute to increased cases of diseases such as coccidioidomycosis (Portier *et al*. 2010 citing Vugla *et al*. 2009). Conversely, heavy precipitation events, which are projected to increase, might cause mold and microbial pollution (Portier *et al*. 2010 citing Abraham *et al*. 2005).

<u>Aeroallergens</u>: The summary in Section 4.5.8.1 discusses the extension of the pollen season across the Northern Hemisphere. A recent study in Bordighera (western Liguria) supports this finding and found that from 1981 to 2006, increasing temperatures were responsible for advancing the start date of the pollen season, increasing season duration, and pollen load. This was particularly apparent for *Parietario* (an infesting plant), olive, and cypress (Ariano *et al*. 2010).

<u>Water-borne and Food-borne Diseases</u>: The summary section discusses the increased concentration of Vibrio in the North Atlantic in response to warming temperature. In 2004, a Vibrio outbreak in Alaska occurred and was linked to above-normal ocean temperatures (Portier *et al*. 2010 citing McLaughlin *et al*. 2005). A study in England and Wales investigated the impact of ambient temperature on weekly rates of several food-borne illnesses including food poisoning, campylobacteriosis, and salmonellosis, and found, depending on the type of food-borne illness, a 2.5 to 6 percent relative increase in food-borne illness in response to every degree Centigrade rise in temperature (Portier *et al*. 2010 citing Lake *et al*. 2009). This study supports the anticipated increase in food-borne illnesses in response to projected increases in temperature.

In addition to projected increases in food-borne diseases, new research provides evidence that toxic algal blooms that produce liver toxins and could contaminate drinking water might last longer and occur earlier in the season in response to changes in precipitation and ocean temperatures in environments with excess nutrients (Portier *et al*. 2010 citing Paerl and Huisman 2008; Luber and Prudent 2009). Climate change is also projected to increase drought in certain regions, and could cause corn and nuts to be contaminated by a mold that produces aflatoxin, which might be a factor in liver cancer (Portier *et al*. 2010).

<u>Vector-borne Diseases</u>: Consistent with the projections of pathogen transmissions discussed in the summary section above, the length of pathogen transmission seasons has increased and a northward invasion has been documented in response to warming global temperatures (Reisen 2010). For example, several Blue-tongue virus serotypes have reached northern Europe and the West Nile virus has entered central Canada (Reisen 2010). Gould and Higgs (2009) suggest the emergence of the Blue-tongue virus in northern Europe has been associated, in part, with climate change that has already occurred. The pathogen vector expansion in response to warmer northern temperatures is attributed to pathogen population growth, increased frequency in blood feeding and host-vector contact, and increased efficiency of transmission (Reisen 2010). Mexico has experienced increased cases of dengue that could be related to the increases in rainfall amounts, higher sea-surface temperatures, and increases in weekly minimum temperature (San Martin *et al*. 2010).

Climate change may increase the risk of chronic disease (such as cardiovascular and kidney disease) through increases in air pollution, malnutrition, and extreme weather events (Kjellstrom *et al*. 2010). In addition, recent projections indicate that, although the total incidence of malaria and other infectious diseases might not demonstrate substantial increases, a shift in the geographic location of the affected population will likely occur as a result of climate impacts (NRC 2010b citing Lafferty 2009). Gould and Higgs (2009) conclude that climate change could (1) spread the mosquitoes associated with Chikungunya virus, causing more cases of epidemic outbreaks in Northern Italy (along with the potential for dengue and yellow fever virus that are also transmitted by these mosquitoes) and (2) create new outbreaks of rift valley fever virus in areas with projected increased flooding. The authors, however, recognized that the observed and projected spread of arbovirus diseases is complicated by such factors as genetic mutation, changes in agricultural techniques, transportation, sanitation, insect control programs, and trade. A different study suggests that increasing temperatures might expand the range of the dog tick that carries Rocky Mountain spotted fever (NRC 2010a citing Parola *et al*. 2008).

Cancer: The impact of climate change on cancer is not well understood. Some environmental conditions currently associated with the spread of carcinogens might be adversely impacted by climate change. Heavy precipitation events could increase leaching of toxic chemicals and heavy metals from storage facilities and increase runoff of persistent chemicals responsible for water contamination (Portier *et al*. 2010 citing McAloose and Newton 2009).

4.5.8.3 Adaptation

As discussed above, climate change poses risks to health of populations throughout the world (Ebi *et al*. 2008). Developed societies such as the United States are more likely to implement effective adaptation measures, thus reducing the magnitude of severe health impacts. For example, the risk and impact of floods on a population can be reduced with changes in water management practices, improved infrastructure, and land-use practices (Alcamo 2007 citing EEA 2005). Improvements world-wide in adaptive capacity, however, are needed (IPCC 2007b). Many governments have increased their efforts to cope with extreme climate events by moving from disaster relief to risk management. Efforts in Portugal, Spain, France, the United Kingdom, Italy, and Hungary focus on short-term events such as heat waves (IPCC 2007b citing Pascal *et al*. 2006, Simón *et al*. 2005, Nogueira 2005, Michelozzi *et al*. 2005, NHS 2006, and Kosatsky and Menne 2005), while other efforts have undertaken long-term strategies addressing policies for agriculture, energy, forestry, and transport (IPCC 2007b).

A number of communities, states, national agencies, and other organizations in the United States, such as the Centers for Disease Control and Prevention (CDC) and the National Institute of Health (NIH), work to identify and plan for the prevention of adverse health impacts associated with weather and climate. Recent experiences following extreme weather and vector-borne disease outbreaks demonstrate the need for improvement in the effectiveness of these activities (Ebi *et al*. 2008 citing Confalonieri *et al*. 2007). The regions where an increase in the health impacts of climate change is anticipated are very likely to have a greater proportion of poor, elderly, disabled, and uninsured residents. In addition, the American Academy of Pediatrics has determined children are a vulnerable population, recommending the U.S. government afford children particular attention when developing emergency management and disaster response systems (American Academy of Pediatrics 2007).

Adaptation policies to address human health impacts of climate change include: support and maintenance of public health infrastructure, improvement and dissemination of preventive care, continued use of nationwide surveillance as a tool to track the spread of vector-borne diseases, use of preparedness tools to identify and assist vulnerable populations during extreme events, strengthening of infrastructure to withstand extreme weather events, and improved water management practices and drainage systems (Frumkin 2008). Developing countries are less able to afford these adaptation measures, and thus are anticipated to suffer more health consequences associated with climate change than more developed nations.

4.5.9 Tipping Points and Abrupt Climate Change

This section provides an overview of tipping points and abrupt climate change as it is represented in the literature.

4.5.9.1 Summary

The summary is based on a survey of tipping points and abrupt climate change presented in Section 4.5.9 of the MYs 2012–2016 CAFE Standards FEIS.

4.5.9.1.1 Overview

In the context of climate change and its consequences, the phrase "tipping point" is most typically used to describe situations in which the climate system[36] reaches a point at which there is a disproportionately large or singular response in a climate-affected system as a result of 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 a certain stressor(s) causes a system to cross a threshold and adjust to a new state, could result in abrupt changes in the climate or any part of the system.

Tipping points that lead to either abrupt or unexpected changes in the state or rate of change of a climate-affected system can be reached through a variety of mechanisms. These changes result from the appearance or strengthening of positive feedbacks (*i.e.*, self-reinforcing cycles) and phase transitions in climate-affected systems (*i.e.*, situations where a threshold is crossed).

Tipping points are not restricted to the climate system. The same type of nonlinear responses exists in the physical, environmental, and societal systems that climate affects. Consideration of possible tipping points could thus encompass sharp changes in climate-affected resources and not be restricted to climatic parameters and processes. Although climate models incorporate feedback mechanisms, the magnitude of these effects and the threshold at which the feedback-related tipping points are reached are only roughly known. It is widely held that anthropogenic forcing could increase the risk of abrupt climate change and that (1) the greenhouse effect and other anthropogenic actions could amplify the likelihood of undesirable climatic events; (2) experts' understandings of past changes are not comprehensive and, therefore, current climate models do not accurately depict tipping points in climate systems, and (3) unexpected climate change will occur in the future because of the inherent uncertainty in forecasts and predictions. Uncertainties exist, especially for timing estimates, in all projections where tipping points have been hypothesized or observed from paleoclimatological records, and are at least partly responsible for variation in predictions. Exactly where 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.

4.5.9.1.2 Affected Climate Systems

Experts identified 11 large-scale (*e.g.*, at least subcontinent) systems with elements that could facilitate tipping points in the climate system due to increased CO_2 and temperature levels. These are: Arctic sea ice; the Greenland ice sheet; the West Antarctic ice sheet; Atlantic thermohaline circulation; the El-Niño-Southern Oscillation; the Indian summer monsoon; the Sahara/Sahel and West African

[36] The climate system is composed of the atmosphere, oceans, land, cryosphere, and biosphere.

monsoon; the Amazon rainforest; boreal forest; atmospheric methane; and hydrology. The following section briefly describes each of these 11 systems.

Arctic Sea Ice: Studies have suggested that the summer Arctic will be ice-free within a decade or less, that there is a critical threshold for this sea-ice loss, and that this threshold has been crossed.

Greenland Ice Sheet: The melting of Earth's ice sheets raises concerns of tipping points. Models used to estimate thresholds and effects of these tipping points suggest that the timescale for Greenland ice sheet collapse is on a scale of hundreds of years. Estimates of sea-level rise corresponding to a complete disintegration of the Greenland ice sheet range from 0.18 to 6.55 meters (0.6 to 21 feet).

West Antarctic Ice Sheet: Estimates of the sea-level rise that would be associated with a collapse of the West Antarctic ice sheet vary between 3.3 and 6 meters (11 and 20 feet), but, as is the case for the Greenland ice sheet, complete collapse is not viewed as likely in the next century.

It is important to note that the results of the models used to assess ice sheet melt have limitations and uncertainties. For example, ice sheets and other components of the cryosphere are susceptible to positive feedbacks, which are not included in most models and which amplify ice melt. Because the present generation of models does not capture all these processes, knowing if the recent changes to ice sheets are due to natural variability or caused by anthropogenic climate changes is impossible. Similar changes, however, are expected to occur more often in a warmer climate. Although centuries or millennia could pass before a collapse, the thresholds for ocean and surface atmospheric warming temperature are likely to be crossed this century.

Atlantic Meridional Overturning Circulation (AMOC):[37] Climate change is likely to decrease the strength of the AMOC by around 25 to 30 percent over the next century. Dramatically affecting the AMOC are changes to thermohaline circulation (THC),[38] whereby impacts on global climate and ocean currents will occur if enough fresh water entering the North Atlantic reduces the northward flow of thermal energy in the Gulf Stream or less very cold surface water in high latitudes leads to shallower mixing. Projections show that the AMOC and the Atlantic Ocean's THC are unlikely to undergo a weakened state during the course of the twenty-first century, but the possibility should not be entirely excluded given that more recent modeling (which includes larger freshwater inputs) suggests initial changes could occur this century, with larger and more intense reductions in the overturning circulation persisting for many centuries.

El-Niño-Southern Oscillation (ENSO):[39] ENSO has substantial and large-scale effects on the global climate system.[40] 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

[37] 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, which transports oceanic heat from low to high latitudes.
[38] The term thermohaline circulation refers to the physical driving mechanism of ocean circulation resulting from fluxes of heat and fresh water across the sea surface and subsequent interior mixing of heat and salt. The Meridional Overturning Circulation (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.
[39] 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 element.
[40] ENSO influences patterns of tropical sea-surface temperature and has been implicated in historical episodes of extreme drought, including the "mega-droughts" (900–1600 A.D.).

ENSO conditions, but predictive and paleoclimate modeling studies do not agree on the magnitude, frequency, and direction of these effects.

Indian Summer Monsoon: The Indian summer monsoon is caused by land-to-ocean pressure gradients and advection of moisture from ocean to land. Although disproportionate warming over land strengthens the monsoon, reductions in absorbed solar radiation by the land's surface generally weaken it. The IPCC does not project passing a threshold[41] this century, although there are indications that the monsoon has changed substantially in the past.

West African Monsoon: Sahara/Sahel rainfall depends on the West African monsoon circulation, which is affected by sea-surface temperature. Although some models project GHG forcing to draw more moist oceanic air inland (due to the land warming more than the ocean and causing a greater upward movement of air), thus causing an increase in regional rainfall, other models project a less productive monsoon. The reasons for this inconsistency are unclear.

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 might be linked to a more persistent El Niño and increased global average temperature by 3 to 4 °C (5.4 to 7.2 °F). A critical threshold might exist in canopy cover, which could be caused by changes in land use or precipitation, ENSO variability, and global forcing.

Boreal Forest: The dieback of boreal forest could result from a combination of increased heat 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.

Atmospheric Methane: Although the risk of such a change is difficult to assess due to the uncertainty associated with the processes controlling the production of atmospheric methane, a "catastrophic" release of methane to the atmosphere from clathrate hydrates[42] in the sea bed and permafrost, and from northern high-latitude and tropical wetlands could be a potential cause of abrupt climate change. Methane emissions from these sources will most likely be amplified due to the warming of the climate.

Hydrology: Climate changes resulting from an increase from present day CO_2 levels to a peak of 450 to 600 ppm carry the potential for substantial – and irreversible – decreases in dry-season rainfall and long-term irreversible warming and mean rainfall changes in a number of already-dry areas, including southern Europe, northern and southern Africa, the southwestern United States, eastern South America, and western Australia. There are some estimates that dry-season precipitation changes in southwestern North America will be comparable to the American "dust bowl," with average rainfall decreasing by approximately 10 percent over 10 to 20 years.

[41] An albedo greater than roughly 50 percent is necessary to simulate the collapse of the monsoon in a simple model.
[42] 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.

4.5.9.1.3 Conclusions

Experts 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 (although actions this century could create enough momentum in the climate system to cross the threshold in future centuries). Several other systems (loss of Arctic sea ice, Indian summer monsoon disruption, Sahara/Sahel and West African monsoon changes, drying of the Amazon rainforest, and warming of the boreal forest), however, could reach a tipping threshold within this century. Whether they occur this century or farther into the future, such tipping elements could dramatically intensify the effects described in Sections 4.5.3 through 4.5.8.

4.5.9.2 Recent Findings

Due to the difficult nature of understanding the interrelated complexities of climate change impacts and tipping points, the literature pertaining to this subject is frequently updated as new information is discovered and further research is conducted. Following is a summary of updated information concerning abrupt climate change and tipping points that describes recent findings related to (1) human-environment tipping points, (2) ecological tipping points, (3) low-probability, high-impact events, (4) impacted systems, and (5) adaptation. This information draws from three synthesis reports – *The Copenhagen Diagnosis* (Allison *et al.* 2009), NRC's *America's Climate Choices: Adapting to the Impacts of Climate Change* (2010c), and NRC's *America's Climate Choices: Advancing the Science of Climate Change* (2010a) – and supplemented with new peer-reviewed journal articles. These recently released synthesis reports largely affirm the findings discussed in the summary section above. This section discusses where these reports and new peer-reviewed journal articles diverge from the MYs 2012–2016 CAFE Standards FEIS or provide new information.

Human-Environment Tipping Points: A human-environment tipping point could exist in a variety of forms, such as "the collapse of an economy or political system" (NRC 2010a). An NRC (2010a) report states that "given the complexity of coupled human-environment systems, it is difficult to forecast when a tipping point might be approaching, but the probability of crossing one increases as the climate system moves outside the range of natural variability." Understanding the interactions among these human-environment systems is becoming increasingly important due to inherent synergies, relationships, and complex interactions among different components, where a tipping point reached in one system might cause significant stress (to the magnitude of tipping points) on the other. Furthermore, compounding climate stressors exacerbate these impacts. It is, therefore, essential that scientific understanding is enhanced so that new technologies can be leveraged to facilitate a better understanding of the linkages between human and environmental systems (NRC 2010a) and the effects of multiple stresses and their possible relationship with future climate changes (NRC 2010c).

Using an integrated assessment model (FUND 2.8n), Link and Tol (2010) examined the relationship between non-market and market impacts and the temperature change associated with a failure of the thermohaline circulation. The models results show that, although the temperature change is not likely to cause significant economic shock on a global scale, the likelihood is high that it could cause disproportionate impacts for individual countries, resulting in a GDP decrease on the magnitude of a few percent. The study further concludes that effects across economic sectors are also likely to be quite variable, with water resources, energy consumption, and various health impacts more severely affected (Link and Tol 2010).

Ecological Tipping Points: Ecological responses to climate change, such as changes in the distribution and abundance of species, could increasingly coincide with crossing certain thresholds (or tipping points). These tipping points can either be rapid and difficult to predict or associated with slow, subtle changes. When thresholds are crossed, however, ecological change is accelerated due to nonlinear reactions, positive feedbacks, or synergies among several stressors (Harley and Paine 2009, NRC 2010c). The consequences of reaching a tipping point could be serious as irreversible changes could alter both a system's ability to provide valuable ecosystem services or the distribution of socioeconomically important species (Harley and Paine 2009).

More recently, models are beginning to look at ecological tipping points in the context of climate change. This topic is particularly important because climate change can cause both gradual and abrupt changes and forecasting ecological tipping points can be challenging (Harley and Paine 2009). Harley and Paine (2009) state that "when stressors are biological they are somewhat easier to predict but as climate change creates more unpredictable events and forcing involves physical parameters (*e.g.*, extreme ambient temperatures, wind velocity, wave height) the situation becomes more difficult to manage."

Harley and Paine (2009) are more concerned with unexpected, dramatic tipping points that are caused by the interaction of unrelated stressors, which, in isolation, typically have little to no effect on a system. For example, their study's results show that changes in the distribution of intertidal algae do not occur with steady temperature or sea-level changes but only under extreme circumstances, such as when uncharacteristically high temperatures and still waters occur simultaneously (Harley and Paine 2009). These results emphasize both the importance of accounting for various, compounding elements in ecological response models and the challenge of anticipating, reacting, and adapting to catastrophic changes (Harley and Paine 2009, NRC 2010c).

Low-probability, High-impact Events: More recent literature has begun to focus on another source of future climate change surprise, a "low-probability, high-impact" event, which can be any type of extraordinary natural disaster such as a prolonged drought or a situation where one climate change co-occurs with another change or environmental pressure and results in a severe, unexpected impact (NRC 2010a). Although evidence shows that events such as these have occurred in the past, we lack the scientific capability to predict or analyze their likelihood (NRC 2010a). Some experts express a sense of urgency, encouraging rapid "advances in science and technology" (NRC 2010c), which will allow for more accurate projections of thresholds and potential risks. These advances will facilitate and support more effective assessments of climate targets and adaptation analysis in the face of uncertainty (NRC 2010a, NRC 2010c).

Impacted Systems: The tipping points of greatest concern are those that are the most probable, most impactful, and amplify the impacts of climate change through positive feedbacks (as this amplification increases, the probability increases that thresholds will be reached) (Allison *et al.* 2009). *The Copenhagen Diagnosis* report (2009) provided new insights on impacted systems including arctic sea ice and the Amazon rainforest; and Washington *et al*. (2009) have identified the Bodélé Depression as a potential tipping point system.

Arctic Sea Ice: Acting as particularly strong forcing agents, increases in soot aerosol, declines in sulfate aerosol (Allison *et al*. 2009 citing Shindell and Faluvegi 2009), and increases in short-lived GHGs – methane and tropospheric ozone – together have contributed more to the arctic warming than increases in CO_2 (Allison *et al.* 2009).

Amazon Rainforest: Due to widespread drought, in 2005 the Amazon rainforest transformed from a carbon sink to a source and now emits 0.6–0.8 gigatons carbon per year (Allison *et al*. 2009 citing Phillips *et al*. 2009). *The Copenhagen Diagnosis* report indicates that the transformation of rainforest die-back to savannah "could take a few decades, would have low reversibility, large regional impacts" and distant consequences (Allison *et al.* 2009). The report states that the process is expected to occur with an increase in temperature of more than 4 °C (7.2 °F) (Allison *et al*. citing Kriegler 2009).

The Bodélé Depression: Washington *et al*. (2009) consider dust storms from the Bodélé Depression (in Chad, the southern edge of the Sahara Desert) as a relevant tipping point system. The Bodélé could have a particularly strong influence on the climate because (1) mineral dust influences cloud physics and affects radiative heating impacting various land and oceanic biophysical feedbacks, and (2) it is the world's largest source of mineral dust, producing "approximately half of the Sahara's mineral aerosol loadings" (Washington *et al*. 2009). The Bodélé's dust output is currently limited, but it is sensitive to slight adjustments and might therefore substantially alter the climate given the magnitude of projected atmospheric circulation changes (caused by increased CO_2 concentrations) (Washington *et al*. 2009). Simulations demonstrate the uncertainty associated with this system as predictions in the quantity of future dust production range from significant increases to reductions near zero (Washington *et al*. 2009).

4.5.9.3 Adaptation

Recent literature has begun to discuss tipping points in the context of adaptation. The literature reiterates that despite inherent uncertainty, collecting information about tipping points is important for a number of reasons, including the need to understand how to avoid and adapt to critical thresholds where both human and ecological systems might become unsustainable (NRC 2010a). More specifically, enhanced knowledge about tipping points and these thresholds would allow for more adequate forecasting and monitoring systems and informed decisionmaking. This is particularly useful for developing early warning systems, disaster response mechanisms and plans, and adaptation options. In addition, it will also facilitate understanding the limits of adaptation for a particular system (NRC 2010a).

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." The term "environmental justice populations" refers to the group comprising minorities and low-income communities as defined. For more information on EO 12898 *see* Section 3.5.6.

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.[43]

As described in Section 3.5.6, 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 or truck stops and distribution centers. 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

Oil extraction and refining is a concern for environmental justice populations because these populations are prevalent in coastal communities, such as the Alaskan and Gulf coasts, where offshore oil drilling frequently occurs. Oil spills have been shown to disproportionately affect these sensitive populations (O'Rourke and Connolly 2003). An oil spill could affect human health, subsistence resources, and economic livelihoods such as fisheries and tourism (*see* Section 3.5.6).

Air pollutant emissions are of particular concern for environmental justice populations because of their disproportionate proximity to truck stops, highways, and nonattainment areas. Generally, the action alternatives reduce nationwide emissions compared to the No Action Alternative (*see* Section 4.3).

Trends in the reductions in nationwide cumulative emissions under the action alternatives vary broadly by pollutant when compared to the No Action Alternative. Variations are due to the complex interaction of VMT, the use of APUs instead of truck engines for extended idling, fuel consumption, and the specific technologies that improve fuel efficiency. A technology shift from the use of engines to the use of APUs is projected to cause increases in emissions of some criteria and toxic air pollutants in some air quality nonattainment areas because APUs, although more fuel efficient, have higher PM emission rates compared to truck engines. As a result, emissions of some criteria and toxic air pollutants are predicted to increase in some air quality nonattainment areas where emission increases due to higher VMT more than offset emission decreases at fuel refining and distribution facilities due to lower fuel

[43] *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 (1997) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

production. These pollutants include $PM_{2.5}$ and DPM, both of which have been associated with adverse health effects. Specifically, large nonattainment areas like Los Angeles, California could have large increases in $PM_{2.5}$ and DPM. Tables 4.3.3-8, 4.3.3-10 (in Section 4.3) and D2-1 through D2-33 (in Appendix D) present detailed information about emissions changes for each pollutant in specific nonattainment areas.

4.6.2.1 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 as would be experienced by the U.S. population as a whole described in Sections 4.5.6, 4.5.7, and 4.5.8. The CCSP notes that the general climate change impacts on 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 impacts experienced in developing countries would likely be disproportionately more severe than those experienced in developed nations, such as the United States.

Within the United States, some environmental justice populations are likely to be affected. Citing GCRP (2009), EPA (2009) explains, "climate-related changes will add further stress to an existing host of social problems that cities experience, including neighborhood degradation, traffic congestion, crime, unemployment, poverty, and inequities in health and well-being. Climate change impacts on cities are further compounded by aging infrastructure, buildings, and populations, as well as air pollution and population growth."

The remainder of this section discusses, qualitatively, the most substantial areas of potential disproportionate impacts for environmental justice populations in the United States.

4.6.2.1.1 Human Health

Low-income and minority communities exposed to the direct effects of extremes in climatic conditions might also experience synergistic effects if preexisting health risk factors are present, such as limited availability of preventive 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 are likely to disproportionately affect minority and low-income populations, partially as a result of limited access to air conditioning and high energy costs (CCSP 2008, EPA 2009, O'Neill *et al.* 2005). Urban areas, which often have relatively large environmental justice populations, would likely experience the most substantial temperature increase due to the urban "heat island" effect and could be particularly vulnerable to this type of health impact (CCSP 2008, Knowlton *et al.* 2007).

The IPCC notes that the incidence or prevalence of many human diseases is sensitive to weather. Increasing temperatures could lead to expanded ranges for several 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, disproportionate impacts could result. 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. This observation led 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).

4.6.2.1.2 Land Use

In the United States, two principal types of geographical environmental justice communities are likely to be affected by global climate change: those located in 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 the potential for heat exposure and concurrent health impacts, 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). For example, CCSP 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 experience major impacts to their subsistence economies as a result of climate change. These impacts would result from their partial reliance on arctic animals, such as seals and caribou, for food and the potential destruction of transportation infrastructure due to ground thaw.

As of 2003, about half of the U.S. population lived in the country's 673 coastal counties (EPA 2009). In coastal and floodplain areas prone to flooding because of larger storm surges and generally more extreme weather, increases in flood insurance premiums could disproportionately affect environmental justice populations unable to absorb the additional cost. Lack of sufficient insurance coverage might render these populations more financially vulnerable to severe weather events.

Global climate change has the potential to increase food insecurity, particularly among low-income populations (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 (CCSP 2008 citing Cook and Frank 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 between the atmosphere and water, plants, and soil. CO_2 readily dissolves in water, combining with water molecules to form carbonic acid (H_2CO_3). The amount of CO_2 dissolved in the upper ocean is related to its concentration in the air. About 30 percent of each year's emissions (Canadell *et al.* 2007) dissolves in the ocean by this process; as the atmospheric concentration continues to increase, the amount of CO_2 dissolved will increase. Although this process moderates the increase in the atmospheric concentration of CO_2, it also increases the acidity of the ocean. Increasing CO_2 concentrations in the atmosphere and surface waters will have a global effect on the oceans; by 2100, the average ocean pH could drop by 0.3 to 0.4 units relative to the ocean pH today (Caldeira and Wickett 2005, Feely *et al*. 2009).

Terrestrial plants remove CO_2 from the atmosphere through photosynthesis and use the carbon for plant growth. This uptake by plants can result in an atmospheric CO_2 concentration that is about 3 percent lower in the growing season than in the non-growing season (Perry 1994 citing Schneider and Londer 1984). Increased levels of CO_2 essentially act as a fertilizer, influencing normal annual terrestrial plant growth. Over recent decades, terrestrial uptake has been equivalent to about 30 percent of each year's emissions (Canadell *et al.* 2007); so, this process is about equal to CO_2 dissolution in ocean waters in moderating the effect of increasing CO_2 emissions on atmospheric CO_2 concentrations.

In addition, CO_2 concentrations affect soil microorganisms. Only recently have the relationships between aboveground and belowground components of ecosystems been considered significant; there is increasing awareness that feedbacks between the aboveground and belowground components play a fundamental role in controlling ecosystem processes. For example, plants provide most of the organic carbon required for belowground decomposition. Plants also provide the resources for microorganisms associated with roots (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 belowground 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. The effects of plant community composition on decomposer systems, however, 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).

Terrestrial communities contain as much carbon as the atmosphere. Forest ecosystems, including forest soils, play a key role in storing carbon. The amount of carbon stored in soils of temperate and boreal forests is about four times greater than the carbon stored by vegetation and is "33 percent higher than total carbon storage in tropical forests" (Heath *et al.* 2005). Forest soils are the longest-lived carbon pools in terrestrial ecosystems (King *et al.* 2004). Several experiments involving increases of atmospheric CO_2 resulted in increasing carbon mass in trees, but a reduction of carbon sequestration in soils. This observation is attributable to increased 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). Under climate change, however, the reduction of soil carbon via increased soil respiration could be counterbalanced by an increase in litter on the forest floor due to increased productivity.

4.7.2 Environmental Consequences

NHTSA provides in this EIS a qualitative analysis of the cumulative effects of the proposed action regarding non-climate cumulative impacts of CO_2.[44]

4.7.2.1 Ocean Acidification

Ocean acidification occurs when CO_2 dissolves in seawater, initiating a series of chemical reactions that increases the concentration of hydrogen ions and makes seawater less basic (and therefore more acidic) (Bindoff *et al*. 2007, Menon *et al*. 2007, Doney *et al*. 2009a, Feely *et al*. 2009). 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 re-dissolve in the surrounding seawater, unless the water contains a sufficiently high concentration of carbonate ions (recent reviews by Doney 2009c, Doney *et al*. 2009b, EPA 2009, Fabry *et al*. 2008, Fischlin *et al.* 2007, Guinotte and Fabry 2008, The Royal Society 2005, SCBD 2009).

For many millennia before present, ocean pH changed little. Even during the warm Cretaceous period, about 100 million years ago, when atmospheric CO_2 concentrations were between 3 and 10 times higher than at present, that any significant decrease in ocean pH occurred is considered unlikely. 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, carbonate will be dissolved from sediments, buffering the chemistry of the seawater so that pH changes are lessened (The Royal Society 2005).

As anthropogenic emissions have increased, CO_2 in the atmosphere has accumulated and a net flux of CO_2 from the atmosphere to the oceans has occurred. 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). Ocean pH today is estimated to have declined in relation to the pre-industrial period by 0.1 pH units (on a log scale), representing a 30 percent increase in ocean acidity (Caldeira and Wickett 2003; EPA 2009). Regionally, high-latitude ocean water has exhibited greater reduction in pH due to low buffer capacity, compared to low-latitude ocean water (EPA 2009). Feely *et al.* (2004) predict that as early as 2050, ocean pH could be lower than at any time during the past 20 million years. This rate of change is at least a hundred times greater than during the past hundreds of millennia (The Royal Society 2005). By 2100, depending on the emission scenario modeled, the average ocean pH could decline by another 0.3 to 0.4 pH units from today's levels (Fischlin *et al*. 2007, Doney *et al*. 2009a, EPA 2009, Feely *et al.* 2009). The current atmospheric concentration of CO_2 (387 ppm) is already more than 37 percent higher than pre-industrial levels (Feely *et al*. 2009, Tans 2009). Further increases will have significant consequences for marine life (Doney *et al*. 2009b). In fact, Caldeira *et al*. (2007) estimated that atmospheric CO_2 would need to be stabilized below 500 ppm for the

[44] *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 (1997) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

change in locally measured ocean pH to remain below the limit of 0.2 pH units of human-caused variation established in 1976 under Section 304(a) of the Clean Water Act to protect marine life (EPA 1976). After reviewing the available literature, EPA decided in spring 2010 to develop guidance to help States address the increase in ocean acidification in today's ocean (Nature 2010).

At present, the ocean's surface waters contain enough carbonate ions to sustain marine life. About 42 percent of the ocean volume is saturated with respect to aragonite (Bindoff *et al*. 2007). The saturation horizon (the depth above which super-saturation occurs and within which most of the ocean's marine life occurs) is becoming shallower (Feely *et al*. 2004, 2009). As the ocean absorbs more CO_2 and ocean acidity increases, fewer carbonate ions will be available for organisms to use for calcification.

As the oceans absorb increasing amounts of CO_2, the greatest pH decline in the ocean's surface waters in relation to the global average will occur in polar and subpolar regions. CO_2 dissolves more readily in cold water, which is naturally low in carbonate ion concentration and more acidic than surface waters (Meehl *et al*. 2007). Under one of the six IPCC emission scenario alternatives developed in 1992, the IPCC IS92a "business as usual" scenario (Leggett *et al*. 1992), the multi-model projection of 788 ppm of atmospheric CO_2 by 2100 indicates that as early as 2050, Southern Ocean surface waters would begin to become undersaturated with respect to aragonite; by 2100 all of the Southern Ocean south of 60 degrees south and portions of the Subarctic North Pacific could become undersaturated (Orr *et al*. 2005; EPA 2009). Simulation of the IPCC IS92a scenario predicted wintertime aragonite undersaturation in the Southern Ocean starting between 2030 and 2038 (McNeil and Matear 2008), with 10 percent of the area becoming undersaturated at least one month per year during this decade (Hauri *et al*. 2009). Simulation of the SRES A2 scenario (IPCC 2000) predicts aragonite undersaturation in Arctic surface waters once the atmospheric CO_2 concentration increases above 450 ppm (Steinacher *et al*. 2009). Under this scenario, the ocean volume that is saturated with respect to aragonite 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 (Hauri *et al*. 2009). Hydrographic surveys have found that this differential acidification occurs, for example, when 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, Hauri *et al*. 2009). Seasonal upwelling is also observed in the California Current System and the Humboldt Current System, as well as other eastern boundary upwelling systems (Hauri *et al*. 2009). Measurements of ocean pH off the coast of Washington State over 8 years found that acidity in the region has increased more than 10 times faster than in other areas (Wootton *et al*. 2008). Because measurements in other parts of the ocean will not reflect this regional variability, there is concern that the more immediate vulnerability of marine organisms in upwelling areas might be overlooked (Hauri *et al*. 2009).

4.7.2.1.1 Effects of Ocean Acidification on Marine Life

The results of most laboratory and field studies to date indicate that 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. Studies also suggest that some species could benefit from conditions of low pH, at least during certain life stages. Responses of some groups, such as microbial communities, have received little attention to date, and findings thus far are unclear but potentially significant, given the importance of microbes for ocean biochemistry (Joint *et al*. 2010). A complex picture is emerging, indicating that there will be "winners" and "losers" in acidified oceans (Ries *et al*. 2009). Several important questions remain (NRC 2010). For example, if or how much acclimation or adaptation by marine organisms will occur is not yet known. Observations over sufficient time to determine the potential for genetic adaptation are lacking, and whether responses of individual species in laboratory and mesocosm studies can be extrapolated to populations in natural systems is not known. Also, little information is available on how key variables such as temperature, light, and nutrients might interact with acidification to influence calcification rates. Recent reviews of available studies are provided by Doney 2009c, Doney *et al*. 2009b, EPA 2009, Fabry *et al*. 2008, Guinotte and Fabry 2008, Fischlin *et al*. 2007, The Royal Society 2005, and SCBD 2009. Details on the available literature are presented in Table 1 in Fabry *et al*. (2008), Table 2 in Guinotte and Fabry (2008), and Tables 2 and 3 in SCBD (2009). This section provides representative results, through July 2010, ranging from the individual to ecosystem level, for a variety of marine taxa.

Warmwater Corals. Under the SRES A2 scenario, ocean waters with an aragonite saturation level 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). Models of CO_2 concentrations up to 560 ppm (a doubling of pre-industrial levels), which could occur by mid-century, predicted a 20- to 60-percent decrease in the calcification rates of tropical reef-building corals, depending on the species (Guinotte and Fabry 2008, Hoegh-Guldberg 2007, Kleypas *et al*. 1999). A recent study by Silverman *et al.* (2009) produced even more dramatic results, predicting that existing reefs could stop growing and start to dissolve once atmospheric concentrations reach the 560-ppm level. Other studies indicate that the percent decreases in calcification rates will be species- and life-stage specific (Cohen and Holcomb 2009, Kleypas and Yates 2009). Fine and Tchernov (2007) studied two species of coral that showed complete dissolution of their shells in highly acidified water, but were able to regrow their shells when returned to water of normal pH. Langdon *et al.* (2000) and Leclercq *et al*. (2000) found that saturation state was the primary factor determining calcification rates of coral reef ecosystems grown in a large mesocosm (*i.e.*, an outdoor containment). Krief *et al.* (2010) held fragments of two species of stony coral for 6 to 14 months at pH values of 8.09, 7.49, and 7.19, and found that although all of the coral survived and added new skeleton, skeletal growth and zooxanthellae density decreased, whereas coral tissue biomass and zooxanthellae chlorophyll concentrations increased under low pH. A recent mesocosm study of a subtropical coral reef community found that although the community as a whole showed reduced calcification in acidified waters, some individuals were able to continue calcification at a reduced rate (Andersson *et al*. 2009).

Measurement of the calcification rates of 328 corals from 69 reefs along the Great Barrier Reef showed a decline of 14.2 percent in calcification rates from 1990 to 2005. The researchers hypothesize that the main causes of the continuing decline are increased sea surface temperatures combined with a lower aragonite saturation state (De'ath *et al*. 2009). The combined effects of increased CO_2 and "bleaching" events resulting from elevated sea surface temperatures have heightened concerns about the survival of tropical and subtropical corals worldwide (Hoegh-Guldberg 2007, Kleypas and Yates 2009). 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 episodes in subtropical and tropical coral reefs (EPA 2009, Kleypas and Yates 2009). These bleaching events increase the risk of disease among surviving coral (EPA 2009, Hoegh-Guldberg 2007, Kleypas and Yates 2009). For example, in Virgin Islands National Park, fifty percent of the corals have died from bleaching or subsequent disease outbreaks (EPA 2009). The IPCC concluded that it is *very likely* that a projected future increase in sea surface temperature of 1–3 °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 (Carpenter *et al*. 2008).

The vulnerability of warm water corals to thermal stress will also depend on the severity and extent of additional anthropogenic stressors, such as overfishing, pollution, invasive species, and available nutrients (EPA 2009). For example, a recent analysis of 23 years of Chesapeake Bay water quality data showed significant reductions in oyster biocalcification in relation to a 0.5-unit decline in pH from pollution alone (Waldbusser *et al.* 2010). Cohen and Holcomb (2009) observed that global warming has increased ocean stratification, reduced the depth of the mixed layer, and slowed circulation, all of which reduce nutrient availability and therefore could magnify the adverse effects of ocean acidification. They noted that not only would this combination of effects reduce growth and calcification rates in corals, it could also reduce sexual reproduction and genetic diversity, interfering with adaptation mechanisms. A new field study in Puget Sound showed that acidification combined with excess nutrient runoff from polluted landscapes enhances growth of phytoplankton and zooplankton (Feely *et al*. 2010). Excess nutrients could increase eutrophication in the near term, while also increasing rates of acidification over time as the plankton die and decompose.

Coldwater Corals. As the aragonite saturation horizon (which is the limit between water that is saturated with aragonite and that which is undersaturated) 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 carbonate fragments together. 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).

Although some marine phytoplankton grow well over a wide range of pH, others have growth rates that vary greatly over a 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 showed reduced calcification when grown in water in contact with air at 750 ppm CO_2 (Riebesell *et al.* 2000), although in another study they showed no change (Langer *et al*. 2006). In another laboratory study, photosynthesis and nitrogen fixation in some coccolithophores, prokaryotes, and cyanobacteria showed either no change or increases in water in contact with higher CO_2 (Doney *et al.* 2009a).

Mollusks. Gazeau *et al*. (2007) found that calcification in a mussel species and the Pacific oyster declined by 25 percent and 10 percent, respectively, when grown in seawater in contact with air at 740 ppm CO_2, which is the concentration expected by 2100 under the IPCC IS92a scenario. Two of the largest oyster hatcheries in the Pacific Northwest report an 80-percent decline in production rates since 2005, which could be the result of acidification of surface waters combined with lower pH water in the deeper ocean that is brought to the surface during the upwelling season (Miller *et al*. 2009). A study of the Sydney rock oyster found that fertilization declined significantly from the combined effects of acidification and temperature (Parker *et al*. 2009). Prolonged exposure to these stressors also impaired growth and survival of early developmental stages.

The effects of ocean acidification alone on an intertidal gastropod included slowed development and abnormal growth of early life stages. Within 14 to 35 days, there was significant dissolution in the shells of four species of Antarctic benthic mollusks (two bivalves, one limpet, one brachiopod) held in pH 7.4 seawater (McClintock *et al*. 2009). Barnacles exposed to the same low pH showed a trend of larger basal shell diameters during growth, which researchers suggest could indicate a compensatory response to declining pH (McDonald *et al.* 2009). Nonetheless, dissolution weakened shell walls as the barnacles grew. Shifts in community composition were observed in a mussel-dominated rocky intertidal community experiencing rapid declines in pH (0.4 pH unit over 8 years). Years of low pH were accompanied by declines in calcareous species (*e.g.*, mussels, stalked barnacles) and increases in non-calcareous species (*e.g.*, acorn barnacles, algae) (Wootton *et al*. 2008).

Effects on species at high latitudes will likely be apparent earlier than in other areas, given the more rapid accumulation of acidification in these regions (Fabry *et al*. 2009). Pteropods, small marine snails that are ubiquitous at high latitudes, 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 emission scenario, shell dissolution occurred within 48 hours (Orr *et al*. 2005). A 28-percent reduction in calcification was observed in one species of pteropod in response to pH levels expected by 2100 (Comeau *et al.* 2009). Declines in pteropods are a particular concern in oceans at high latitude, 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). Recent observations in the Gulf of Alaska, for example, show that pteropods are especially vulnerable in Alaska waters, which show higher acidification than elsewhere (Bates and Mathis. 2009). Researchers estimated that a 10-percent decline in pteropod abundance in this region could mean a 20-percent decrease in an adult salmon's body weight.

Echinoderms. Some sea urchins show reduced early development (Kurihara and Shirayama 2004) and shell growth (Shirayama and Thornton 2005) in seawater with elevated CO_2 concentrations. Another study found that fertilization and early development were unaffected by pH declines, apparently because urchin fertilization occurs naturally in low-pH waters (Byrne *et al.* 2010). Urchin embryos were sensitive to elevated temperature.

Crustaceans. Laboratory studies of larval stages of the European lobster found physiological changes in calcification and carapace development in low-pH, high-acidity seawater (Arnold *et al*. 2009). Another study found that North American lobsters, crabs, and shrimp were able to build more shell as acidity increased (Ries *et al*. 2009).

Marine Fish and Marine Mammals. The use of calcium minerals in gravity sensory organs is common in marine species at higher trophic levels. A study of responses to olfactory cues by clownfish larvae found that responses were impaired at pH 7.8 and below, interfering with the ability of the larvae to identify suitable settlement sites on reefs (Munday *et al.* 2010). A study of predator detection by early life stages of another marine fish species found that when eggs and larvae were exposed to low-pH water, larvae at the settlement stage were unable to distinguish between predators and non-predators, and in some cases were actually attracted to the smell of predators (Dixon *et al*. 2010). Cooley and Doney (2009) observed that losses of calcifying organisms at the base of marine food webs will ultimately be transmitted to fish species of high ecological and economic value.

Analogs. Some recent studies have examined geologic and natural analogs to help determine potential effects of ocean acidification on marine life. A period about 55 million years ago known as the Paleocene-Eocene thermal maximum (PETM) is considered the closest geological analog to today's oceans. During this time a massive and rapid input of carbon to the atmosphere and ocean occurred. Marine plankton survived a period of intense warming and acidification, lasting 1,000 to 2,000 years. A new study that compared predicted future levels of ocean acidity with PETM conditions found that under the SRES "business as usual" scenario, the extent and rate of acidification in today's ocean is on track to greatly exceed that during the PETM (Ridgwell and Schmidt 2010). Moy *et al*. (2009) provided direct evidence that ocean acidification is affecting shell formation, finding that the shells of foraminifera in the current Southern Ocean are 30 to 35 percent lighter than shells of the same species in core samples from ocean sediments that predate the Industrial Revolution. Hall-Spencer *et al*. (2008) found that in near-subsurface vents, which have natural, volcanic release of CO_2, stony corals are not present and numbers of calcifying sea urchins, coralline algae, and gastropods are low.

4.7.2.1.2 Changes in the Effectiveness of the Ocean Sink

As CO_2 increases in surface waters and carbonate concentrations decline, the effectiveness of the ocean as a "sink" for CO_2 could decrease (Sabine *et al*. 2004, Le Quėrė *et al*. 2009). In addition, ocean warming also decreases the solubility of CO_2 in seawater (Bindoff *et al*. 2007, Menon *et al*. 2007). Observations and modeling studies indicate that the large regional sinks in the North Atlantic (Lefèvre *et al*. 2004, Schuster and Watson 2009), the Southern Ocean (LeQuéré *et al*. 2007, Lovenduski *et al*. 2008), and the North Sea have declined in recent decades (Fabry *et al.* 2009). Between 2000 and 2008, emissions increased by 29 percent. One study estimated that from 2000 to 2006, the oceans absorbed about 25 percent of anthropogenic CO_2 emissions, representing a decline in the ocean sink from 29 percent absorption in earlier decades (Canadell *et al*. 2007). Recently, Khatiwala *et al*. (2009) reconstructed the history of CO_2 concentrations in the ocean since the beginning of industrialization and estimated that ocean uptake decreased by 10 percent over the industrial era. Tans (2009) suggested that although these findings could be true locally, the available data indicate that they do not apply globally. He concluded that the lack of increase in the rate of uptake of atmospheric CO_2, despite increased emissions, can only be explained if there has been a more effective uptake by the oceanic or terrestrial biosphere. LeQuéré *et al*. (2009) reported that over the past 50 years, the fraction of CO_2 emissions that remains in the atmosphere each year has increased from 40 percent to 45 percent, supporting the conclusion that the decline in the uptake of CO_2 is not keeping up with increasing emissions. Recent modeling suggests that this results from the responses of carbon sinks to both climate change and climate variability (LeQuéré *et al*. 2009).

If climate variability is the primary cause, current trends might be short term and not signals of long-term climate change. Khatiwala *et al.* (2009) reported on measurements indicating that the slowdown in ocean uptake of carbon results from physical and chemical limits on the ocean's ability to absorb carbon. The researchers concluded that the more acidic the oceans become, the less they are able to absorb carbon. Other measurements of actual CO_2 concentrations found that in the Canada Basin in the Arctic in areas where sea ice had melted dramatically, uptake of carbon (measured in units of CO_2 pressure at 120 to 150 micropascals) was well below atmospheric CO_2 pressure (375 micropascals), whereas in ice-free areas offshore, seawater pressure (320 to 360 micropascals) was much closer to atmospheric pressure (Yamamoto-Kawai *et al*. 2009, Cai *et al*. 2010). In the Chukchi Sea during the summertime retreat of sea ice, increased phytoplankton productivity decreases the concentration of CO_2 over the continental shelf, causing aragonite saturation states to increase, while deeper waters become undersaturated (Bates and Mathis 2009).

4.7.2.1.3 IPCC Conclusions about Ocean Acidification

The 2007 IPCC conclusions about ocean acidification are as follows (Menon *et al*. 2007, EPA 2009):

- 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'" (Menon *et al.* 2007). IPCC projects with *medium* confidence that forest growth in North America will likely increase 10−20 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 C_3 crops (*e.g.*, wheat, soybeans, and rice) yielded 10–25 percent more than under current CO_2 conditions, while C_4 crops (*e.g.*, maize) yielded up to 10 percent more (EPA 2009).[45] 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 23–25 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). Because saturation of CO_2 stimulation due to nutrient or other limitations is common (Dukes *et al.* 2005; Körner *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, and 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). One study's results show that the magnitude of increased production was determined primarily by the availability of water and nitrogen, with greater CO_2-induced NPP in environments with plentiful water and nitrogen (McCarthy *et al.* 2010).

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 although 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). Although studies have shown that elevated CO_2 levels resulted in an increase in plant's carbon-to-nitrogen ratio, one experiment found that higher levels actually triggered enhanced photosynthetic nitrogen use efficiency in C_3 plants, which was predominantly caused by improved CO_2 uptake (Leakey *et al.* 2009).

Additionally, some evidence suggests 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

[45] C_3 and C_4 plants are differentiated by the manner through which they use CO_2 for photosynthesis, lending explanation to the differences in plant yield under similar ambient CO_2 conditions.

atmospheric CO_2 concentrations, soil gas is 0.2−0.4 percent CO_2, in areas of observed die-off, CO_2 concentration comprised as much as 20–95 percent of soil gas (EPA 2009). Any CO_2 concentration above 5 percent is likely to adversely impact vegetation, and if concentrations reach 20 percent, CO_2 is observed to have a phytotoxic effect (EPA 2009).

The current annual exchange in CO_2 between the atmosphere and terrestrial ecosystems is estimated at 9−10 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 aboveground/belowground processes and components in terrestrial ecosystems typically sequester carbon.

Recent studies have confirmed that variations in atmospheric CO_2 have impacts not only on the aboveground plant components, but also on the belowground microbial components of these systems.Experiments have shown that elevated CO_2 levels cause an increase in belowground net primary production and fine-root biomass (Jackson *et al.* 2009 citing Fitter *et al.* 1995, Hungate *et al.*1997, Matamala and Schlesinger 2000, King *et al.* 2001, Norby *et al.* 2004, and Finzi *et al.* 2007) with one study showing a 24-percent increase of fine-root biomass in the top 15 centimeters of soil and a doubling of coarse-root biomass in elevated CO_2 (Jackson *et al.* 2009).

In one study, an increase in CO_2 directly resulted in increased soil microbial respiration due to faster outputs and inputs, observed through amplified photosynthesis (Jackson *et al.* 2009 citing Canadell *et al.* 1995, Luo *et al.* 1996, Bernhardt *et al.* 2006, Gill *et al.* 2006, Hoosbeek *et al.* 2007, Wan *et al.*2007). 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), with root biomass, soil respiration, and other variables found to typically peak in midsummer and lessen in winter (Jackson *et al.* 2009). Increased soil respiration and changes in other variables, such as productivity, alters the concentration of CO_2 in soil pore spaces, which impacts weathering of carbonates, silicates, and other soil minerals (Jackson *et al.* 2009 citing Sposito 1989, Jackson *et al.* 2009 citing Andrews and Schlesinger 2001, Pendall *et al.* 2001, Karberg *et al.* 2005). 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 primarily in wood (EPA 2009).

The increase in microbial respiration could, therefore, diminish the carbon sequestration role of terrestrial ecosystems. Because of the number of factors involved in determining soil respiration and carbon sequestration, the threshold for substantial changes in these activities varies spatially and temporally (King *et al.* 2004).

Elevated CO_2 levels were also found to change the functional structure of soil microbial communities, which could have significant impacts on soil carbon and nitrogen dynamics (He *et al.* 2010). More specifically, the study found that when CO_2 levels increased, genes involved in labile carbon degradation, carbon fixation, nitrogen fixation, and phosphorus release also increased. Furthermore, no significant changes were found in the quantity of genes associated in recalcitrant carbon degradation and methane metabolism. Structural and functional alterations, such as these, could potentially modify the way microbial ecosystems regulate changes in CO_2 concentrations (He *et al.* 2010).

Elevated CO_2 concentrations have physiological impacts on plants, which result in further climatic changes, a process referred to as "CO_2-physiological forcing" (Cao *et al.* 2010). Increased CO_2 levels cause plant stomata to open less widely resulting in decreased plant transpiration. A reduction in canopy transpiration causes a decrease in evapotranspiration that triggers adjustments in water vapor, clouds, and surface radiative fluxes. These adjustments ultimately drive macro climatic changes in temperature and the water cycle (Cao *et al.* 2010). One study found that the physiological effects from a doubling of CO_2 on land plants resulted in a 0.42 +/− 0.02 Kelvin (K) increase in air temperature over land and an 8.4 +/− 0.6 percent increase in global runoff (generally caused by reduced evapotranspiration). Furthermore, the study reported that a reduction in plant transpiration caused a decrease in relative humidity over land (Cao *et al.* 2010).

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 differences between the reductions in atmospheric CO_2 concentrations across the action alternatives are substantial is not clear because the damage functions and potential existence of thresholds for CO_2 concentration are not known. It is clear, however, that a reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce the ocean acidification effect and the CO_2 fertilization effect.

Chapter 5 Mitigation

Council on Environmental Quality (CEQ) regulations for implementing the procedural requirements of the National Environmental Policy Act (NEPA) require that the discussion of alternatives in an environmental impact statement (EIS) "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives." 40 CFR § 1502.14(f). In particular, an EIS should discuss the "[m]eans to mitigate adverse environmental impacts." 40 CFR § 1502.16(h). As defined in the CEQ regulations, mitigation includes:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

40 CFR § 1508.20.

Under NEPA, an EIS should contain "a reasonably complete discussion of possible mitigation measures."[1] Essentially, "[t]he mitigation must 'be discussed in sufficient detail to ensure that environmental consequences have been fairly evaluated.'"[2] Under NEPA, an agency does not have to formulate and adopt a complete mitigation plan,[3] but should analyze possible measures that could be adopted. Generally, an agency does not propose mitigation measures for an action resulting in beneficial effects.

5.1 OVERVIEW OF IMPACTS

The proposed action by the National Highway Traffic Safety Administration (NHTSA) is to implement a Heavy-Duty (HD) Fuel Efficiency Improvement Program for model years (MYs) 2016–2018 with voluntary compliance standards for MYs 2014−2015. Under Alternative 1, No Action, neither NHTSA nor the U.S. Environmental Protection Agency (EPA) would issue a rule regarding fuel efficiency improvement or greenhouse gas (GHG) emissions for MYs 2014–2018. Each of the nine action alternatives (Alternatives 2 through 8 and including 6A and 6B) 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.

As described in this EIS, emissions from criteria air pollutants and mobile source air toxics (MSATs) are generally anticipated to decline under the action alternatives when compared to the No Action Alternative. According to the analyses described in Sections 3.3 and 4.3, some emissions would

[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).

increase under some alternatives, while many would demonstrate declines compared to the No Action Alternative (Alternative 1). Emissions of sulfur dioxide (SO_2) and volatile organic compounds (VOCs) would decrease 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. Emissions of carbon monoxide (CO), oxides of nitrogen (NO_x), acetaldehyde, acrolein, benzene, and formaldehyde would increase under Alternative 2, but would decrease for all other action alternatives and analysis years as compared to their levels under the No Action Alternative. Any adverse health impacts associated with these emissions would similarly increase under Alternative 2 but are expected to be reduced under Alternatives 3 through 8.

According to the NHTSA analysis, emissions of particulate matter ($PM_{2.5}$), 1,3-butadiene, and diesel particulate matter (DPM) also could increase under certain alternatives and years from the levels that are projected under the No Action Alternative. The maximum projected increases in emissions, compared to the No Action Alternative, are 0.3 percent for CO (under Alternative 2 in 2050); 0.2 percent for NO_x (under Alternative 2 in 2050); 2.3 percent for $PM_{2.5}$ (under Alternative 3 in 2050); 0.6 percent for acetaldehyde (under Alternative 2 in 2050); 0.6 percent for acrolein (under Alternative 2 in 2050); 0.2 percent for benzene (under Alternative 2 in 2050); 0.5 percent for 1,3-butadiene (under Alternative 2 in 2030); 3.0 percent for DPM (under Alternative 3 in 2050); and 0.5 percent for formaldehyde (under Alternative 2 in 2050). Under the Preferred Alternative (Alternative 6) the increases in emissions in 2030 compared to the No Action Alternative would be 369 tons (1.0 percent) for $PM_{2.5}$; 0.5 tons (0.1 percent) for 1,3-butadiene; and 301 tons (1.1 percent) for DPM.

Increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the proposed HD Fuel Efficiency Improvement Program under the action alternatives, largely due to increases in vehicle miles traveled and assumptions regarding use of anti-idling technologies under the alternatives.

5.2 MITIGATION MEASURES

As noted above, NEPA does not obligate an agency to adopt a mitigation plan. Rather, NEPA requires an agency to discuss possible measures that could be adopted.[4] In accordance with NEPA and CEQ regulations, the following is a discussion of possible measures that could mitigate the effects of the proposed action. These include current and future actions that NHTSA or other Federal agencies could take. Any of these actions would mitigate the environmental impacts associated with some of the action alternatives and provide even greater environmental benefits.

It should be noted that even if emissions of some pollutants show some level of increase, the associated harm might not increase concomitantly. Ambient levels of most pollutants are trending generally downward, owing to the success of regulations governing fuel composition and vehicle emissions as well as stationary sources of emissions (EPA 2009c). Also, vehicle manufacturers can choose which technologies to employ to reach the new HD fuel efficiency requirements. Some of their technology choices result in higher or lower impacts for these emissions. Nevertheless, some air pollutant emissions could increase in some years for some alternatives.

[4] *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).

Beyond these considerations, some increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the HD standards under the action alternatives.

In regard to air quality, Federal transportation funds administered by the Federal Highway Administration (FHWA) could be available to help fund projects for reducing 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, NO_x, $PM_{2.5}$, acetaldehyde, acrolein, benzene, DPM, and formaldehyde (or other emissions eligible under the CMAQ Program, including the criteria pollutants and MSATs analyzed in this EIS), they can apply CMAQ funding to reduce impacts in most areas. Further, EPA has the authority to continue to improve vehicle emission standards under the Clean Air Act, which could result in future reductions as EPA promulgates new regulations.

Each action alternative 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, HD vehicles are a major contributor to energy consumption and GHG emissions in the United States. Although an agency typically does not propose mitigation measures for an action resulting in a net beneficial effect, NHTSA would like to highlight several other Federal programs that, in conjunction with NHTSA HD fuel efficiency standards, can make significant contributions toward further reducing energy consumption and GHG emissions.

The programs discussed below are ongoing and at various stages of completion. All these programs present the potential for future developments and advances that could further increase the net beneficial effect of the environmental impacts identified in this EIS.

Regarding energy consumption, EPA administers Renewable Fuel Standards (RFS2) under Section 211(o) of the Clean Air Act. EPA is required to determine the standard applicable to refiners, importers, and certain blenders of gasoline annually. The RFS2 for 2010 is 8.25 percent.[5] 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 (CO_2e) when measured over a 100-year time frame and discounted at 2 percent. This reduction is equivalent to approximately 150 million tons CO_2e per year. *See* Section 4.4.3.4 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 (HUD), announced six livability principles around which the agencies will coordinate agency policies. One of the principles is focused on increasing transportation options, which aims to decrease energy consumption, improve air quality, and reduce GHG emissions (EPA 2009b). Known as the Federal Sustainable Communities Partnership, this agency coordination establishes a basis upon which DOT, with assistance from EPA and HUD, can embark on future projects and direct existing programs toward further achievements in the areas of energy consumption, air quality, and climate change. Specifically, DOT has a Secretarial goal to reduce VMT.

[5] Final Rule: Regulations of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 *FR* 14670 (March 26, 2010).

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). Similarly, the Smart Growth movement presents great potential for mitigating environmental effects caused by fuel consumption for transportation. EPA provides research, tools, partnerships, case studies, grants, and technical assistance to help communities grow in ways that both expand economic opportunity and protect public health and the environment, further encouraging its growth (EPA 2010a).

In a joint NHTSA and EPA rulemaking published in May 2010, EPA set the first national CO_2 vehicle emission standard under Section 202(a) of the Clean Air Act, which was coordinated and harmonized with NHTSA's CAFE standards.[6] These standards apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles (light-duty vehicles) built in MYs 2012−2016. These vehicle categories are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. Under the NHSTA standards, light-duty vehicles will achieve an estimated fleet-wide average of 34.1 mpg by MY 2016 (EPA 2010b). The agencies estimate that the joint program will reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (EPA 2009d).

In May 2010, EPA issued rules to address GHG emissions from stationary sources under Clean Air Act permitting programs.[7] Under the first step to phase in this rule, set to start January 2, 2011, only those sources currently subject to the Prevention of Significant Deterioration (PSD) program due to their non-GHG emissions (which includes newly constructed facilities or those that are modified to significantly increase non-GHG emissions) are subject to PSD and Title V permitting requirements. During this first step, such facilities that have emission increases of at least 75,000 tons per year (tpy) of GHGs (based on CO_2e), but only if the project also significantly increases emissions of at least one non-GHG pollutant, will need to apply Best Available Control Technology (BACT) for their emissions. During this first step, no sources are subject to permitting requirements based solely on their GHG emissions. The second step, which begins July 1, 2011, covers all new facilities with the potential to emit at least 100,000 tpy of CO_2e, and modifications to existing facilities that have emissions of at least 100,000 tpy and that increase GHG emissions by at least 75,000 tpy CO_2e are subject to PSD permitting requirements. Title V requirements will apply to facilities that emit at least 100,000 tpy CO_2e. Additionally, any modifications of existing facilities that result in increases of GHG emissions of at least 75,000 tpy will also be subject to permitting requirements. EPA has also committed to undertake another rulemaking that will begin in 2011 and will end no later than July 1, 2012. This rulemaking will consider an additional step (step three) for phasing in rulemaking. Phase 3 would begin by July 1, 2013. EPA will consider in this rulemaking streamlining the permitting procedure and may consider whether smaller sources can be permanently excluded from permitting requirements. EPA has already stated that step three will not apply to sources with GHG emissions below 50,000 tpy and it will not issue requirements for smaller sources until April 30, 2016.

DOT and other Federal agencies are currently working to implement Executive Order (EO) 13514 issued by President Obama.[8] This EO on Federal Sustainability sets measurable environmental performance goals for Federal agencies and focuses on making improvements in their environmental, energy, and economic performance. EO 13514 required each Federal agency to submit a 2020 GHG

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[6] Final Rule: Light-Duty Vehicle Greenhouse Gas Emission Standards and Cooperate Average Fuel Economy Standards, 75 *FR* 25324 (May 7, 2010).
[7] Final Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 *FR* 31514 (June 3, 2010).
[8] Federal Leadership in Environmental, Energy, and Economic Performance, Exec. Order No. 13514, 74 *FR* 52117 (Oct. 8, 2009).

emission reduction target from its estimated 2008 baseline to CEQ and to the Office of Management and Budget by January 4, 2010. On January 28, 2010, President Obama announced that the Federal government would reduce its GHG emissions by 28 percent by 2020.[9] This Federal target is the aggregate of 35 Federal agency self-reported targets. Because the Federal government is the single largest energy consumer in the U.S. economy, the White House estimates that achieving the Federal agency GHG emission reduction target will reduce Federal energy use by the equivalent of 646 trillion British thermal units. This amount is equal to 205 million barrels of oil, or the equivalent of taking 17 million cars off the road for one year. In accordance with EO 13514, CEQ issued draft guidance for Federal GHG reporting and accounting on July 14, 2010, establishing government-wide procedures for calculating and reporting GHG emissions associated with Federal agency operations.[10]

DOT is also one of more than a dozen agency members of the U.S. Climate Change Technology Program, led by the Department of Energy (DOE), which aims to develop and adopt 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.[11] 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.

The DOT high-speed rail initiative will provide a travel alternative that will reduce U.S. GHG emissions. The overall strategy involves two parts: improving existing rail lines to make current train service faster and identifying potential corridors for the creation of high-speed rail. In furtherance of these goals, on January 28, 2010, President Obama announced the DOT American Recovery and Reinvestment Act High-speed and Inter-city Passenger Rail grants.[12] With 31 States and the District of Columbia receiving awards, these grants are jump-starting high-speed rail development in the United States.

The FTA is actively supporting the DOT Livability Initiative and the Federal Sustainable Communities Partnership with its programs to expand mass transit, another travel alternative that will reduce U.S. GHG emissions (FTA 2010a). The FTA works with public transportation providers and other key stakeholders to implement strategies that reduce GHG emissions from the transportation sector. FTA grants, technical assistance, research, and policy leadership all play a role in the agency's efforts to address climate change (FTA 2010b). For example, the FTA grant programs support purchases of fuel efficient and alternative fuel transit vehicles.

Also within DOT, the Federal Aviation Administration (FAA) is a sponsor of the Commercial Aviation Alternative Fuels Initiative (CAAFI), which is a coalition of the U.S. commercial aviation community that acts as a focal point for engaging the emerging alternative fuels industry (FAA 2009). The CAAFI seeks to enhance energy security, and thereby reduce GHG emissions, in the transportation sector by promoting the development of alternative fuel options for use in aviation. Similarly, the Maritime Administration is exploring alternative fuels for ferries and other vessels via workshops with key stakeholders.

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[9] *See* http://www.whitehouse.gov/the-press-office/president-obama-sets-greenhouse-gas-emissions-reduction-target-federal-operations (last accessed Aug. 25, 2010).
[10] *See* http://www.whitehouse.gov/sites/default/files/microsites/ceq/Draft-GHG-Accounting-and-Reporting-Guidance-6-30-10.pdf (last accessed Aug. 25, 2010).
[11] 42 U.S.C. § 13385(b).
[12] *See* http://www.whitehouse.gov/blog/2010/01/28/president-obama-delivers-american-high-speed-rail (last accessed Aug. 25, 2010).

Regarding carbon emissions, DOE administers programs designed to provide consumers and industries information to help them make environmentally conscious decisions. Specifically, the DOE Clean Cities program develops government-industry partnerships designed to reduce petroleum consumption (DOE 2009a). The focus on urbanized areas overlaps with some of the nonattainment areas identified in Sections 3.3.2 and 4.3.2. Also, DOE administers the Vehicle Technologies Program, which creates public-private partnerships that enhance energy efficiency and productivity and bring clean technologies to the marketplace (DOE 2009c).

As NHTSA notes throughout this EIS, HD vehicle GHG emissions will continue to increase regardless of the level at which NHTSA sets fuel efficiency standards. NHTSA's setting of fuel efficiency standards will reduce the rate at which these emissions will increase. *See* Figure 2.6-3. NHTSA recognizes the importance of mitigating GHG emissions in this sector, and in the transportation sector more generally. Mitigation of emissions in the transportation sector can be discussed only in the context of larger national emission reductions policies and strategies. GHG emission reductions of the order of magnitude necessary to mitigate climate change will require concurrent efforts from many different international entities, from both the public and private sectors. For this reason, mitigation of global GHG emissions presents a unique set of challenges far beyond this rulemaking.

Nevertheless, in the HD vehicle sector, policies that could be explored to contribute to this sector's GHG mitigation, and to reductions in emissions of criteria and toxic air pollutants, include truck stop electrification, incentive programs to deter VMT growth, and setting lower speed limits. Truck stop electrification offers a viable alternative to auxiliary power units and their emissions (particularly $PM_{2.5}$ and DPM) as a solution to eliminate overnight idling of heavy-duty trucks at truck stops. These systems supply electricity, heating, and cooling directly to the cab from an external source. EPA oversees verification of truck-stop electrification products for emission reductions through its SmartWay program. Some barriers to wider implementation of truck-stop electrification, however, include infrastructure installation costs, reluctance of truckers to use the systems, and difficulty in enforcing anti-idling policies. Funding is available from some States for truck-stop electrification projects. A truck stop electrification infrastructure deployment project, administered by the Department of Energy with funding from the American Recovery and Reinvestment Act of 2009, is currently underway.

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Chapter 8 Distribution List

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) (40 Code of Federal Regulations 1501.19) specify requirements for circulating an Environmental Impact Statement (EIS). In accordance with those requirements, NHTSA is mailing this EIS to the agencies, officials, and other interested persons listed in this chapter.

8.1 FEDERAL AGENCIES

- Advisory Council on Historic Preservation, Office of Federal Agency Programs
- Executive Office of the President, Council on Environmental Quality
- Government of Canada, The Department of Natural Resources, Natural Resources Canada
- Office of the Federal Coordinator, Alaska Natural Gas Transportation Projects
- U.S. Department of Energy, Federal Energy Regulatory Commission, Office of Energy Market Regulation, Pipeline Regulation
- U.S. Department of Energy, Federal Energy Regulatory Commission, Office of Energy Projects, Hydropower Licensing
- U.S. Department of Energy, Federal Energy Regulatory Commission, Office of Energy Projects, Divison of Gas Environment and Engineering
- U.S. Department of Agriculture, Agricultural Research Service
- U.S. Department of Agriculture, Animal and Plant H ealth Inspection Service, Environmental Services
- U.S. Department of Agriculture, Farm Service Agency
- U.S. Department of Agriculture, National Institute of Food and Agriculture, Natural Resources and Environmental Unit
- U.S. Department of Agriculture, Natural Resources Conservation Service, Ecological Services Division
- U.S. Department of Agriculture, Rural Business Cooperative Service
- U.S. Department of Agriculture, Rural Housing Service
- U.S. Department of Agriculture, Rural Utilities Service
- U.S. Department of Agriculture, U.S. Forest Service, Ecosystem Management Coordination
- U.S. Department of Commerce, Economic Development Administration
- U.S. Department of Commerce, National Marine Fisheries Service

- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Program Planning and Integration Office, NEPA Policy & Compliance
- U.S. Department of Commerce, National Telecommunications and Information Administration
- U.S. Department of Commerce, Office of Administrative Services, Office of Real Estate Policy and Major Programs, Environmental Planning Division
- U.S. Department of Defense, Army Corps of Engineers, Planning and Policy Division, Office of Water Project Review
- U.S. Department of Defense, Office of Deputy Undersecretary Defense (Installations and Environment)
- U.S. Department of Energy, Bonneville Power Administration
- U.S. Department of Energy, Office of the General Counsel, Office of NEPA Policy and Compliance
- U.S. Department of Energy, Western Area Power Administration
- U.S. Department of Health & Human Services, Centers for Disease Control and Prevention
- U.S. Department of Health and Human Services, Centers for Disease Control, National Center for Environmental Health
- U.S. Department of Health and Human Services, Food and Drug Administration, Office of the Commissioner, Office of the Chief Scientist
- U.S. Department of Health and Human Services, National Institutes of Health
- U.S. Department of Health and Human Services, National Institutes of Health, Division of Environmental Protection
- U.S. Department of Health and Human Services, Office for Facilities Management and Policy, Division of Programs, Environmental Quality Program
- U.S. Department of Homeland Security
- U.S. Department of Homeland Security, Federal Emergency Management Agency, Office of Environmental Planning and Historic Preservation
- U.S. Department of Homeland Security, U.S. Coast Guard
- U.S. Department of Housing and Urban Development, Office of Environment and Energy
- U.S. Department of Interior, Bureau of Indian Affairs, Division of Environmental and Cultural Resources Management

- U.S. Department of Interior, Bureau of Land Management, Division of Decision Support, Planning, and NEPA
- U.S. Department of Interior, Bureau of Reclamation, Office of Program and Policy Services, Water & Environmental Resources Office
- U.S. Department of Interior, Minerals Management Service
- U.S. Department of Interior, National Park Service, Environmental Quality Division
- U.S. Department of Interior, Office of Environmental Policy and Compliance
- U.S. Department of Interior, U.S. Fish and Wildlife Service
- U.S. Department of Interior, U.S. Geological Survey, Environmental Management Branch
- 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, Directorate of Evaluation and Analysis, Office of Program Review
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs, Office of Environmental Policy
- U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy (AEE-200)
- U.S. Department of Transportation, Federal Highway Administration, Office of Project Development and Environmental Review
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Office of the Chief Counsel
- U.S. Department of Transportation, Federal Railroad Administration, Office of Railroad Development
- U.S. Department of Transportation, Federal Railroad Administration, Office of Policy and Development
- U.S. Department of Transportation, Federal Transit Administration, Office of Planning & Environment
- U.S. Department of Transportation, Maritime Administration, Office of Environmental Activities
- U.S. Department of Transportation, Office of the Secretary, Office of Assistant Secretary for Transportation Policy

- U.S. Department of Transportation, Pipeline & Hazardous Materials Safety Administration, Office of the Chief Counsel
- U.S. Department of Transportation, Research and Innovative Technology Administration, Office of Planning and Policy Analysis
- U.S. Department of Transportation, Research and Innovative Technology Administration, Volpe Center, Environmental Engineering Division
- U.S. Department of Transportation, Surface Transportation Board
- U.S. Environmental Protection Agency, Office of Federal Activities
- U.S. Federal Maritime Commission, Office of the Secretary
- U.S. Federal Motor Carrier Safety Administration

8.2 STATE AND LOCAL GOVERNMENT ORGANIZATIONS

- American Samoa Office of Grants Policy/Office of the Governor, Department of Commerce, American Samoa Government
- Arkansas Office of Intergovernmental Services, Department of Finance and Administration
- California Attorney General's Office
- Connecticut Department of Environmental Protection, Bureau of Air Management, Planning and Standards Division
- Delaware Office of Management and Budget, Budget Development, Planning & Administration
- Delaware River Basin Commission
- Denali Commission
- Department of Administration, Nevada State Clearinghouse, Coordinator/SPOC
- District of Columbia Office of the City Administrator
- Federal Assistance Clearinghouse, Missouri Office of Administration, Commissioner's Office
- Florida State Clearinghouse, Florida Dept. of Environmental Protection
- Georgia State Clearinghouse
- Governor's Office of Budget and Planning
- Grants Coordination, California State Clearinghouse, Office of Planning and Research

- Guam State Clearinghouse, Office of I Segundo na Maga'lahen Guahan, Office of the Governor
- Iowa Department of Management
- Maine State Planning Office
- Maryland State Clearinghouse for Intergovernmental Assistance
- Massachusetts Office of the Attorney General
- Missouri Department of Natural Resources
- National Association of Attorneys General
- National Governors Association, Environment, Energy & Transportation Division
- National League of Cities
- New Hampshire Office of Energy and Planning, Attn: Intergovernmental Review Process
- North Dakota Department of Commerce
- North Mariana Islands Office of Management and Budget, Office of the Governor
- Oregon Department of Environmental Quality
- Puerto Rico Planning Board, Federal Proposals Review Office
- Rhode Island Division of Planning
- South Carolina Department of Transportation
- South Carolina Office of State Budget
- South Dakota Department of Environment and Natural Resources
- Southeast Michigan Council of Governments
- Southern States Energy Board
- State of Connecticut, Department of Environmental Protection
- State of Connecticut, Department of Transportation
- State of Tennessee, Department of Transportation
- Tennessee Valley Authority, Environmental Policy and Planning
- The Kentucky Governor's Office for Local Development

- The United States Conference of Mayors
- Utah State Clearinghouse, Governor's Office of Planning and Budget Utah State
- West Virginia Department of Transportation
- West Virginia Development Office
- Western Governors' Association
- Western Interstate Energy Board
- Western Regional Air Partnership

8.3 ELECTED OFFICIALS

- The Honorable Adrian Fenty, Mayor of the District of Columbia
- The Honorable Arnold Schwarzenegger, Governor of California
- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable Bev Perdue, Governor of North Carolina
- The Honorable Bill Richardson, Governor of New Mexico
- The Honorable Bill Ritter, Governor of Colorado
- The Honorable Bob McDonnell, Governor of Virginia
- The Honorable Bob Riley, Governor of Alabama
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable Brad Henry, Governor of Oklahoma
- The Honorable Brian Schweitzer, Governor of Montana
- The Honorable C.L. "Butch" Otter, Governor of Idaho
- The Honorable Charlie Crist, Governor of Florida
- The Honorable Chet Culver, Governor of Iowa
- The Honorable Chris Christie, Governor of New Jersey
- The Honorable Chris Gregoire, Governor of Washington
- The Honorable Dave Freudenthal, Governor of Wyoming

- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable David A. Paterson, Governor of New York
- The Honorable Deval Patrick, Governor of Massachusetts
- The Honorable Donald L. Carcieri, Governor of Rhode Island
- The Honorable Edward G. Rendell, Governor of Pennsylvania
- The Honorable Felix P. Camacho, Governor of Guam
- The Honorable Gary Herbert, Governor of Utah
- The Honorable Haley Barbour, Governor of Mississippi
- The Honorable Jack Markell, Governor of Delaware
- The Honorable Jan Brewer, Governor of Arizona
- The Honorable Jay Nixon, Governor of Missouri
- The Honorable Jennifer M. Granholm, Governor of Michigan
- The Honorable Jim Douglas, Governor of Vermont
- The Honorable Jim Doyle, Governor of Wisconsin
- The Honorable Jim Gibbons, Governor of Nevada
- The Honorable Joe Manchin, Governor of West Virginia
- The Honorable John E. Baldacci, Governor of Maine
- The Honorable John Hoeven, Governor of North Dakota
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable John P. deJongh, Jr., Governor of the United States Virgin Islands
- The Honorable Linda Lingle, Governor of Hawaii
- The Honorable Luis G. Fortuño, Governor of Puerto Rico
- The Honorable M. Jodi Rell, Governor of Connecticut
- The Honorable Mark Parkinson, Governor of Kansas
- The Honorable Mark Sanford, Governor of South Carolina

- The Honorable Martin O'Malley, Governor of Maryland
- The Honorable Mike Beebe, Governor of Arkansas
- The Honorable Mike Rounds, Governor of South Dakota
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Pat Quinn, Governor of Illinois
- The Honorable Phil Bredesen, Governor of Tennessee
- The Honorable Rick Perry, Governor of Texas
- The Honorable Sean Parnell, Governor of Alaska
- The Honorable Sonny Perdue, Governor of Georgia
- The Honorable Steve Beshear, Governor of Kentucky
- The Honorable Ted Kulongoski, Governor of Oregon
- The Honorable Ted Strickland, Governor of Ohio
- The Honorable Tim Pawlenty, Governor of Minnesota
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa

8.4 NATIVE AMERICAN TRIBES

- American Indian Science and Engineering Society
- Buena Vista Rancheria
- California Valley Miwok Tribe
- Chickasaw Nation
- Council of Energy Resource Tribes
- Fond du Lac Reservation
- Galena Village
- Hydaburg Cooperative Association
- Inaja-Cosmit Band of Mission Indians
- Intertribal Council on Utility Policy

- Intertribal Timber Council
- Intertribal Transportation Association
- Kokhanok Village Council
- Leech Lake Reservation Business Committee
- National Congress of American Indians
- National Indian Health Board
- National Tribal Air Association
- National Tribal Environmental Council
- Native American Fish & Wildlife Society
- Native Village of Goodnews Bay
- Native Village of Marshall
- Northwestern Band of Shoshone Nation
- Peoria Tribe of Indians of Oklahoma
- Ruby Tribal Council
- Santa Clara Pueblo
- Single Springs Rancheria, Band of Miwok Indians
- Skull Valley Band of Goshute Indians General Council

8.5 STAKEHOLDERS

- Allison Transmission, Inc.
- American Bus Association
- American Council for an Energy-Efficient Economy
- American Jewish Committee
- American Powersports Mfg. Co. Inc.
- American Trucking Associations
- Argonne National Laboratory

- Auto Research Center LLC
- Center for Biological Diversity
- Cummins, Inc.
- Cummins, Inc., Product Environmental Management
- DAF Trucks
- Daimler Trucks North America
- Daimler Vans USA LLC
- Eaton Corporation, Eaton Vehicle Group
- Engine Manufacturers Association
- Environmental Defense Fund
- Ford Motor Company
- Internatinal Boundary and Water Commission, U.S. Section, Engineering Department
- Kenworth Truck Company
- Mack and Volvo Trucks
- Marine Mammal Commission
- Michigan Tech University, ME-EM Department
- Michilen North America, Inc.
- National Automobile Dealers Association, Legal & Regulatory Group
- National Groundwater Association
- National Science Foundation, Office of the General Counsel
- National Truck Equipment Association
- Navistar, Inc.
- Oak Ridge National Laboratory
- Owner-Operator Indpendent Drivers Association, Inc.
- PACCAR Inc.

- PACCAR Technical Center
- Peterbilt Motors Company
- Presidio Trust, NEPA Compliance
- Road Safe America
- Rocky Mountain Institute
- Rubber Manufacturers Association
- Sentech, Inc.
- Sierra Club
- Small Business Administration, Office of General Counsel, Department of Litigation and Claims
- Small Business Administration, Office of Management & Administration, Office of the Associate Administrator
- The Aluminum Association
- The Aluminum Association, Inc., Aluminum Transportation Group
- The Heavy-Duty Fuel Efficiency Leadership Group
- TIAX LLC
- Truck Trailer Manufacturers Association
- U.S. Chamber of Commerce
- Union of Concerned Scientists, Clean Vehicles Program
- Valles Caldera Trust
- Volvo Group, Volvo Powertrain
- Volvo Powertrain
- West Virginia University
- West Virginia University, College of Engineering & Mineral Resources, Center for Alternative Fuels, Engines & Emissions

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