Medium- and Heavy-Duty Fuel Efficiency Improvement Program

Final Environmental Impact Statement

June 2011

NHTSA

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Medium- and Heavy-Duty Fuel Efficiency Improvement Program
Final Environmental Impact Statement

RESPONSIBLE AGENCY:

National Highway Traffic Safety Administration (NHTSA)

COOPERATING AGENCIES:

U.S. Environmental Protection Agency (EPA) and Federal Motor Carrier Safety Administration (FMCSA)

TITLE:

Medium- and Heavy-Duty Fuel Efficiency Improvement Program – Final Environmental Impact Statement

ABSTRACT:

This Final Environmental Impact Statement (FEIS) analyzes the environmental impacts of fuel consumption standards and reasonable alternative standards for model years 2014-2018 commercial medium- and heavy duty on-highway vehicles and work trucks ("HD vehicles") that NHTSA has proposed under the Energy Independence and Security Act of 2007 (EISA). Environmental impacts analyzed in this EIS include those related to fuel and energy use, air quality, and climate change. In developing these proposed standards and alternatives, NHTSA was guided by EISA, which requires that the program 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. The 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. The joint proposed rulemaking is consistent with the President's May 2010 directive to improve the fuel efficiency of and reduce GHG pollution from HD vehicles through coordinated Federal standards.

TIMING OF AGENCY ACTION:

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

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FINAL ENVIRONMENTAL IMPACT STATEMENT

MEDIUM- AND HEAVY-DUTY FUEL EFFICIENCY IMPROVEMENT PROGRAM

JUNE 2011

LEAD AGENCY:
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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

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List of Acronyms and Abbreviations

+/−	plus or minus
°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
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.
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.
Highway vehicle	A self-propelled vehicle, or any trailer or semitrailer, designed to perform a function of transporting a load over public highways, whether or not also designed to perform other functions. Highway vehicles include cars, light-duty trucks, and medium- and heavy-duty vehicles, but do not include vehicles designed to be operated primarily off-road, such as construction, mining, and agricultural equipment.
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.
NEPA scoping process	An early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.

Term	Definition
Nonattainment area	Regions where concentrations of criteria pollutants exceed federal standards. Nonattainment areas are required to develop and implement plans to comply with the National Ambient Air Quality Standards within specified time periods.
Ocean acidification	A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.
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.

Term	Definition
Turbidity	A decrease in the clarity of water due to the presence of suspended sediment.
Vehicle miles traveled	Total number of miles driven.

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 vehicle fuel economy.

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

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[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 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

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's proposal would include mandatory standards that begin in model year (MY) 2016 and 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. Consistent with EISA, the HD vehicle rulemaking is being conducted jointly with the U.S. Environmental Protection Agency (EPA) and in consultation with 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 no fewer than four model years of regulatory lead time and three model years of regulatory stability. In considering these requirements, NHTSA also accounts 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.[12] 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 President requested that, before promulgating a final rule, the Administrators of EPA and NHTSA "[p]ropose 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

On November 30, 2010, NHTSA and EPA announced in the *Federal Register* the proposed rules to establish Greenhouse Gas Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.[13] The proposed rules would together comprise a coordinated and comprehensive HD National Program and would result in substantial improvements in fuel efficiency and reductions in

Vehicles, "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles."

[11] 49 U.S.C. § 32902(k)(3).

[12] 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).

[13] 75 FR 74152 (Nov. 30, 2010).

GHG emissions from HD vehicles, 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 makes 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 of an action if the agency implements, funds, or permits or otherwise approves a proposed Federal 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 preferred alternative and other 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 proposed standards represent the first time that NHTSA and EPA would regulate the HD vehicle sector for fuel consumption and GHG emissions. NHTSA and EPA proposed 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 NO_x and 99 percent less PM than similar vehicles did 20 years ago.[17] The most recent EPA regulations,

[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.
[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.

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 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 2010). 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 used the Light-Duty National Program as a model for the 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 proposed standards and compliance structures, although for this current Rule each agency has proposed 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

[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).

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 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 general universe of HD vehicles that is the focus of the proposed rulemaking – all highway vehicles that are not light-duty, medium-duty passenger vehicles (MDPVs), or motorcycles. In developing the proposal, the agencies carefully evaluated the research supporting this report and its conclusions.

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 proposed coordinated and harmonized fuel consumption[21] and GHG emission standards for HD vehicles to be built in MYs 2014–2018. Under NHTSA's proposal, the agency would set 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

The agency's proposed standards would apply to all highway vehicles and engines that are not regulated by the light-duty vehicle, light-duty truck, and medium-duty passenger vehicle CAFE and GHG standards issued for MYs 2012–2016. Thus, in this 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

[20] 49 U.S.C. § 32902(k)(2).

[21] NHTSA's proposed action is 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.

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

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 covered 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 have proposed deferring the proposed GHG 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 proposed 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, 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.

[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]).

[24] Payload is determined by a tractor's GVWR and GCWR relative to the weight of the tractor, trailer, fuel, driver, and equipment.

- **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 have proposed 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 have proposed 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.

Table 1.3-1 outlines how GVWR classes correspond to the HD vehicle categories of pickups and vans, vocational vehicles, and tractors.

Table 1.3-1

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

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

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 has proposed to include recreational on-highway vehicles within its rulemaking.

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

[25] 49 U.S.C. § 32902(k)(2).

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 also accounts 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. The EPA environmental analysis of the proposed rulemaking is summarized in the draft Regulatory Impact Analysis (RIA), *available at* http://www.epa.gov/oms/climate/regulations/420d10901.pdf (Accessed: June 13, 2011).

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)[28] that are the subject of the proposed regulations. 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 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.

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[26] 40 CFR §1502.13.
[27] 49 U.S.C. § 32902(k)(2).
[28] Note that FMCSA's definition of CMV differs from the population of vehicles included in this rulemaking.

- 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.[29] The NOI described the statutory requirements for the standards, provided initial information about the NEPA process, and initiated scoping[30] 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.[31] Scoping should "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[32] 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

- 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.

NHTSA submitted to EPA the DEIS that disclosed and analyzed the potential environmental impacts of new HD Fuel Efficiency standards and reasonable alternative standards pursuant to CEQ

[29] *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).
[30] 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.
[31] *See* 40 CFR §§ 1500.4(g) and 1501.7(a).
[32] 40 CFR § 1500.4(g).

NEPA implementing regulations, DOT Order 5610.1C, and NHTSA's regulations.[33] On October 29, 2010, EPA issued its Notice of Availability for the DEIS, triggering a public comment period.[34] The public was invited to submit written comments on the DEIS until January 3, 2011. NHTSA and EPA held two hearings on the rule and the EIS, the first on November 15, 2010 in Chicago, Illinois, and the second on November 18, 2010 in Cambridge, Massachusetts.

1.6.1 Comments

NHTSA received 37 responses to its scoping notice. The scoping comments are summarized in Chapter 1 of the DEIS. NHTSA also received 3,048 comments to the DEIS and the NPRM. Comments to the DEIS are addressed in Chapter 6 of this document. As described in Chapter 6, comments that raised issues central to the rule or the rulemaking process will be addressed by the forthcoming final rule and the associated documents. In response to comments received by NHTSA, the agency has attempted to streamline this EIS to increase readability and ensure that the document is concise and clear (s*ee* 40 CFR § 1502.1). Where possible, NHTSA has reduced redundant language and has provided cross-references to explanations elsewhere in this EIS.

[33] Under Section 309 of the CAA, EPA is required to review and publicly comment on the environmental impacts of major federal actions including actions that are the subject of EISs. If EPA determines that the action is environmentally unsatisfactory, it is required by Section 309 to refer the matter to CEQ. This is done by the Office of Federal Activities.
[34] Environmental Impact Statements; Notice of Availability, 75 *FR* 66756 (Oct. 29, 2010); NHTSA also published a separate Notice of Availability describing the program in greater detail, 75 *FR* 68312 (Nov. 5, 2010).

Chapter 2 Proposed Action and Alternatives

2.1 INTRODUCTION

The National Environmental Policy Act[1] (NEPA) requires an agency to evaluate the environmental impacts of its proposed action and alternatives to that action. 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]

As noted in Chapter 1, in developing the new proposed HD vehicle fuel consumption standards[4] 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.[5]

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 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.[6] 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

HD vehicles often vary widely in configuration (*i.e.,* are composed of different vehicle parts combined in different ways). Because of this complexity, in the DEIS we recognized that the question of how to regulate HD vehicles had to be answered to know how stringent the standards should be (or put differently, how much fuel consumption and greenhouse gas reductions can be required of the HD industry). In order to answer this question, the agencies evaluated a range of alternatives that would

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[1] 42 U.S.C. § 4332(2)(C). NEPA is codified at 42 U.S.C. § 4321, *et seq.*
[2] 40 CFR §§ 1502.14(a), (d).
[3] 40 CFR § 1502.13. *See Vermont Yankee Nuclear Power Corp. v. Natural Res. Def. Council*, 435 U.S. 519, 551 (1978); *City of Alexandria v. Slater*, 198 F.3d 862, 867-69 (D.C. Cir. 1999), *cert. denied sub nom.*, 531 U.S. 820 (2000).
[4] 49 U.S.C. § 32902(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.
[5] 49 U.S.C. §§ 32902(k)(2), (3).
[6] 49 U.S.C. § 32902(k)(2).

separately regulate segments of the HD vehicle fleet. Specifically, in recognition of the many different types of HD vehicles, the agencies proposed 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.

In the DEIS, NHTSA analyzed several alternatives that applied only to specific components and/or segments of the HD vehicle fleet. The DEIS also included several alternatives that applied to the entire HD vehicle fleet, but varied in stringency. Finally, the DEIS included an alternative that applied to all vehicle classes but also regulated trailers and assumed widespread use of hybrid technologies.

Many commenters urged the agency to consider alternatives that applied to the entire HD vehicle fleet, reasoning that such an approach would be more consistent with EISA requirements. After careful consideration, NHTSA has decided that those alternatives that would set standards for the whole fleet—that is, the engine as well as the entire vehicle for pickup trucks and vans, vocational vehicles, and tractors – best meet the purpose and need for this action. As noted above, the purpose and need for NHTSA's action is the EISA requirement that the agency establish a fuel efficiency improvement program for HD vehicles that is "designed to achieve the maximum feasible improvement" and that must be appropriate, cost-effective, and technologically feasible for HD vehicles.[7]

NHTSA believes that setting vehicle standards as well as engine standards for each HD vehicle class covered by the proposed regulation meets these requirements. It also allows for the achievement of the "maximum feasible improvement" in HD fuel efficiency. For this reason, NHTSA has eliminated from this analysis those DEIS alternatives that regulated fewer vehicle segments (for example, alternatives that would have regulated only engines, or only a portion of the industry). This FEIS examines impacts associated with four of the action alternatives analyzed in the DEIS — labeled in that document as alternatives 6A, 6, 6B, and 8. For readability, the action alternatives in this FEIS have been renumbered as Alternatives 2 through 5, in order of increasing stringency. The FEIS analysis of these alternatives reflects updated economic and modeling assumptions,[8] but the stringencies of FEIS Alternatives 2 through 5 are directly comparable to DEIS alternatives 6A, 6, 6B, and 8.[9] This encompasses the same range of impacts in the DEIS, but in a context that highlights variations in stringencies for all HD vehicles and engines.

2.2.1 STANDARDS FOR ENGINES AND VEHICLES

In view of the complexity of the HD vehicle fleet, the applicability of differing fuel saving 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 tractors), NHTSA has retained the general approach to standard-setting laid out in the NPRM in that each of the alternatives addressed in this EIS would require separate standards for each covered vehicle category.

[7] 49 U.S.C. §§ 32902(k)(2), (3).

[8] For example, the MOVES2010a model version was used for the FEIS versus MOVES 2009-December-21 for the DEIS; vehicle sales and VMT inputs were updated using AEO2011 Early Release projections; and freight hauling and vehicle technology assumptions were revised based on sales distribution data from manufacturers and information provided in DEIS comments.

[9] The numerical levels of vehicle standards have been revised for the FEIS based on changes made to test procedures (including prescribed payloads and aerodynamic test procedures) in response to DEIS comments and updated information concerning model inputs, but these changes impact both the No Action Alternative and action alternatives equally and therefore do not impact the stringencies of action alternatives relative to the No Action Alternative.

Below, we provide additional information on the structure of the standards the agencies are proposing and describe the specific level of the standards under each action alternative. 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). Fuel consumption standards, including engine standards, are based on specific drive cycles 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.

2.2.1.1 Engine Standards

EPA currently regulates heavy-duty engines, that is, engine manufacturers, rather than the vehicle as a whole, to control criteria emissions. Under all of the action alternatives, NHTSA would similarly set engine performance standards for Class 2b through Class 8 vocational vehicles and tractors and would specify an engine test cell procedure, as EPA currently does for criteria pollutants (HD pickups and vans are regulated as complete vehicles, as described below in Section 2.2.1.2). 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 2.2-1.

Table 2.2-1

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.

The fuel consumption standards for engines used in 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 vocational vehicles. Table 2.2-2 shows the proposed fuel consumption standards (in gal/100 bhp-hr) for engines used in vocational vehicles, based on the FTP engine cycle. These standards for engines used in vocational vehicles would apply under all of the action alternatives.

Table 2.2-2

Standards for Engines Used in Vocational Vehicles (gal/100 bhp-hr)

	LHDD	MHDD	HHDD	Gasoline
MY 2014 (Voluntary)	5.89	5.89	5.57	
Effective MY 2016				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 2.2-3 shows the proposed fuel consumption standards (in gal/100 bhp-hr) for engines used in combination tractors, based on the SET steady-state test cycle. As shown in Table 2.2-3, the same engine standards would apply under Alternatives 2 and 3, and a more stringent set of tractor engine standards apply under Alternatives 4 and 5.

Table 2.2-3

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

	MHDD	HHDD
Alternatives 2 and 3		
MY 2014 (Voluntary)	4.93	4.67
Effective MY 2017	4.78	4.52
Alternatives 4 and 5		
MY 2014 (Voluntary)	4.79	4.54
Effective MY 2017	4.64	4.39

2.2.1.2 Class 2b and 3 Pickups and Vans Standards

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.[10]) 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.

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.

[10] In the light-duty vehicle rule, EPA and NHTSA based tailpipe standards on use of the FTP and HFET. *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.”

Figures 2.2-1 and 2.2-2 illustrate the functional relationship between the work factor for HD pickups and vans and the corresponding fuel consumption targets under the Preferred Alternative for the HD pickup and van segment, specified in gal/100 miles (specific formulas for calculating work factors for HD pickups and vans under the action alternatives are presented in the Preamble of the NPRM). Figure 2.2-1 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 2.2-2 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.

Figure 2.2-1. Proposed NHTSA Fuel Consumption Target and EPA CO_2 Target Standards for Diesel HD Pickups and Vans

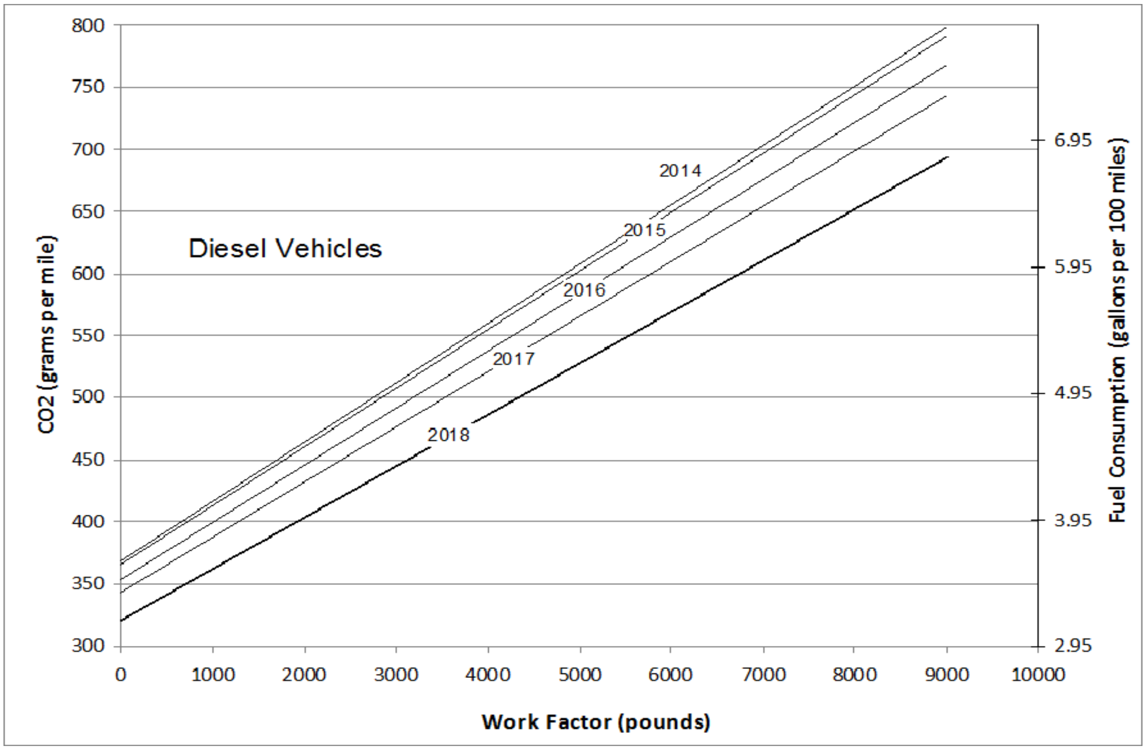
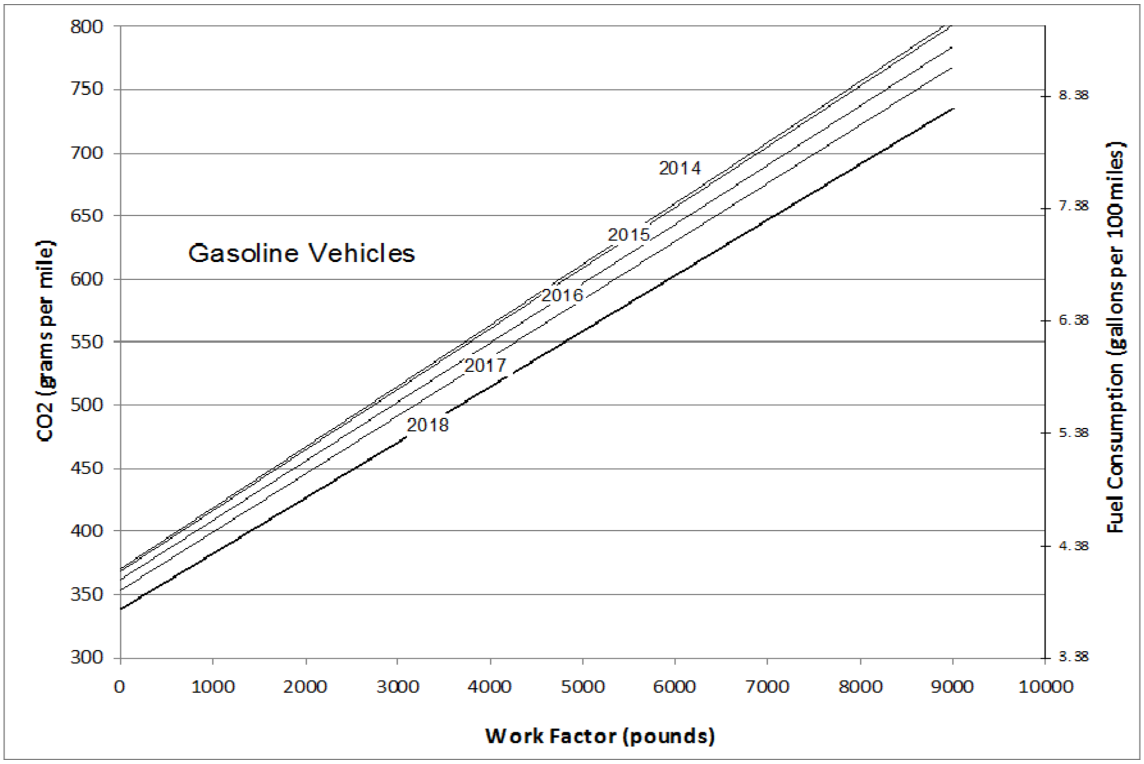


Figure 2.2-2. Proposed NHTSA Fuel Consumption Target and EPA CO_2 Target Standards for Gasoline HD Pickups and Vans



2.2.1.3 Class 2 through 8 Vocational Vehicle Standards

The fuel consumption standards for vocational vehicles vary by vehicle class (Classes 2b–5, Classes 6 and 7, and Class 8). Compliance with the vocational vehicle classes' overall vehicle performance standard would be determined by a computer model that would simulate overall vehicle fuel efficiency given a set of vehicle component inputs. Using this compliance approach, vocational vehicle manufacturers would supply certain vehicle characteristics that would serve as model inputs. The agency would supply a standard vocational vehicle engine's contribution to overall vehicle efficiency (consistent with the proposed HD engine standards), 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 vocational vehicle overall fuel consumption standards. Table 2.2-4 shows the proposed standards for vocational vehicles.

Table 2.2-4

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
Alt 2: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/	Engine Standards Only		
Alt. 2: MYs 2017–18			
Alt. 3: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/	38.4	23.2	22.4
Alt: 3: MYs 2017–18	36.9	22.4	22.0
Alt. 4: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/	38.4	23.2	22.4
Alt. 4: MYs 2017–18	36.2	21.9	21.6
Alt. 5: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/	38.1	23.1	22.3
Alt. 5: MYs 2017–18	31.0	18.8	18.5

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

2.2.1.4 Class 7 and 8 Tractor Standards

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. In addition to the engine standards described above, the action alternatives would require Class 7 and 8 tractor manufacturers 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 that NHTSA has proposed for a Class 7 or 8 combination tractor vary 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 than 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 2.2-5, 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).

[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 2.2-5

Tractor Drive Cycle Mode Weightings

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

The fuel consumption standards for Class 7 and 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 drag, which is a major component of determining tractor fuel efficiency.

Under NHTSA's proposed standards for Class 7 and 8 tractors, as for vocational vehicles, compliance with the overall vehicle standards 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 7 and 8 vehicle manufacturers would supply certain vehicle characteristics that would serve as model inputs (related to the categories of technologies noted in Chapter 2 of the draft RIA). The agency would supply a standard Class 7 and 8 vehicle engine's contribution to overall vehicle efficiency (consistent with the proposed HD engine standards), 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 7 and 8 tractor overall fuel consumption standards. Table 2.2-6 shows the proposed standards for Class 7 and 8 tractors (in gal/1,000 ton-miles).

Table 2.2-6

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

	Day Cab		Sleeper Cab
	Class 7	Class 8	Class 8
Alt. 2: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/			
Low Roof	10.5	8.0	6.6
Mid Roof	11.6	8.7	7.4
High Roof	12.2	9.1	7.3
Alt. 2: MYs 2017–2018			
Low Roof	10.3	7.8	6.5
Mid Roof	11.3	8.4	7.2
High Roof	11.8	8.8	7.1
Alt: 3: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/			
Low Roof	10.5	8.0	6.6
Mid Roof	11.6	8.7	7.4
High Roof	12.0	8.9	7.2
Alt 3: MYs 2017–2018			
Low Roof	10.3	7.8	6.5
Mid Roof	11.3	8.4	7.2
High Roof	11.6	8.6	7.0
Alt. 4: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/			
Low Roof	10.5	8.0	6.6
Mid Roof	11.6	8.7	7.4
High Roof	11.8	8.8	7.1
Alt. 4: MYs 2017–2018			
Low Roof	10.3	7.8	6.5
Mid Roof	11.3	8.4	7.2
High Roof	11.4	8.5	6.9

Table 2.2-6 (continued)

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

	Day Cab		Sleeper Cab
	Class 7	Class 8	Class 8
Alt. 5: MYs 2014–2016 (Voluntary in MYs 2014–2015, Mandatory in MY 2016) a/			
Low Roof	10.5	8.0	6.6
Mid Roof	11.6	8.7	7.4
High Roof	11.8	8.8	7.1
Alt. 5: MYs 2017–2018			
Low Roof	10.2	7.8	6.5
Mid Roof	11.2	8.4	7.2
High Roof	11.4	8.4	6.9

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

2.3 ALTERNATIVES

The 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 that no action would occur under the HD National Program. NHTSA also analyzed four action alternatives which specify increasingly stringent fuel consumption standards for HD engines and vehicles.

2.3.1 Alternative 1: No Action Alternative

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.[12] 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 in order to demonstrate the environmental effects of the action alternatives. 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 level of fuel efficiency and GHG performance NHTSA believes manufacturers would achieve without regulation.[13] The No Action Alternative would yield no additional environmental improvement other than might occur from natural market forces. The environmental impacts of other alternatives are calculated relative to the baseline of the No Action Alternative.

[12] *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. [*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).

[13] The No Action Alternative used to calculate the results in this chapter and referred to elsewhere in this EIS, unless otherwise indicated, is the market-based baseline described in Section 3.5. For additional information about the No Action Alternative, as well as an analysis using a MY 2010 baseline, *see* Chapter 3.

Table 2.3-1 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 2.3-1 reflect NHTSA's 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 the environmental effects of the action alternatives with the effects of the No Action Alternative.

Table 2.3-1

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

	MYs 2010-2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.5	6.3	6.2	6.1	5.9	5.8
Pickups & Vans (Classes 2b–3) – diesel	7.5	7.3	7.2	7.0	6.9	6.7
Vocational (Classes 2b–8) – gasoline	11.3	11.3	11.3	11.2	11.2	11.2
Vocational (Classes 2b–8) – diesel	10.3	10.2	10.2	10.2	10.2	10.2
Tractors (Classes 7–8)	20.4	20.2	20.1	20.0	19.8	19.6

2.3.2 Action Alternatives

NHTSA examined four action alternatives, each of which would separately regulate segments of the HD vehicle fleet. Under all of the action alternatives, NHTSA would set overall fuel consumption standards for HD vehicles and engines, as described above. Each of these action alternatives would include standards for engines used in Classes 2b–8 vehicles (except engines in HD pickups and vans, which are regulated as complete vehicles), fuel consumption standards for HD pickups and vans by work factor, overall vehicle fuel consumption standards for Classes 2b–8 vocational vehicles (in gal/1,000 ton-miles), and overall fuel consumption standards for Classes 7 and 8 tractors. Alternatives 2 through 4 would regulate the same vehicle categories, but at increasing levels of stringency, with Alternative 2 being the least stringent alternative and Alternative 4 being the most stringent.[14] Alternative 5 would build on these requirements by adding, in addition to the components regulated under the other action alternatives, a performance standard for the commercial trailers pulled by tractors and by specifying more stringent standards based on accelerated adoption of hybrid powertrains for HD vehicles.

For each of the standards described below, the estimated average fuel efficiency in gal/100 miles is shown to facilitate comparison with the estimated average fuel efficiency under the No Action Alternative shown in Table 2.3-1.[15] All of the action alternatives would specify standards in gal/100 bhp-

[14] Alternatives 2 and 4 were constructed by starting with the Preferred Alternative (Alternative 3) and either removing the least cost effective technology in each of the vehicle categories or adding the next most cost effective technology in each of the vehicle categories. For example, the combination tractor standard for Alternative 2 would be based on the removal of the Advanced SmartWay aerodynamic package and weight reduction technologies assumed under the Preferred Alternative. The vocational vehicle standard for Alternative 2 would be based on the removal of low rolling resistance tires and some diesel engine technologies assumed under the Preferred Alternative. The Alternative 4 standard for combination tractors would be based on the addition of Rankine waste heat recovery systems not assumed under the Preferred Alternative.

[15] In estimating average fuel efficiency under the action alternatives, NHTSA has made the same market-based assumptions as applied in Section 3.5. This method differs from that used in the draft RIA and the DEIS; when NHTSA estimates that average fuel efficiency under the No Action Alternative will exceed (i.e., gal/100 miles will be lower than) that predicted under an action alternative in any particular model year, the agency assumes that market forces will cause manufacturers to achieve that level of fuel efficiency instead.

hr for engines, gal/100 miles for pickups and vans, and gal/1,000 ton-miles for vocational vehicles and tractors.

2.3.2.1 Alternative 2: 12% below Preferred Alternative Stringency

Alternative 2 represents a stringency level which is 12 percent less than the preferred approach.[16] The agencies calculated this stringency by removing the least cost effective technology in each of the vehicle categories (as described in Chapter 6 of the draft RIA). Table 2.3-2 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA forecasts manufacturers would achieve under Alternative 2.

Table 2.3-2

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 2 (12% below Preferred Alternative Stringency)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.5	6.3	6.2	6.1	5.9	5.8
Pickups & Vans (Classes 2b–3) – diesel	7.5	7.3	7.2	7.0	6.9	6.5
Vocational (Classes 2b–8) – gasoline	11.3	11.3	11.3	10.7	10.7	10.7
Vocational (Classes 2b–8) – diesel	10.3	9.9	9.9	9.9	9.7	9.7
Tractors (Classes 7–8)	20.3	18.4	18.4	18.4	17.9	17.9

2.3.2.2 Alternative 3: Preferred Alternative

Alternative 3 is NHTSA's Preferred Alternative. Table 2.3-3 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA forecasts manufacturers would achieve under Alternative 3.

Table 2.3-3

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for the Preferred Alternative

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.5	6.3	6.2	6.1	5.9	5.8
Pickups & Vans (Classes 2b–3) – diesel	7.5	7.3	7.2	7.0	6.8	6.4
Vocational (Classes 2b–8) – gasoline	11.3	11.3	11.3	10.6	10.6	10.6
Vocational (Classes 2b–8) – diesel	10.3	9.7	9.7	9.7	9.3	9.3
Tractors (Classes 7–8)	20.3	18.3	18.3	18.3	17.7	17.7

[16] DEIS Alternative 6A was calculated to regulate the same engine and vehicle categories as the Preferred Alternative, but at a lower level of stringency, achieved by removal of the least cost effective technology (i.e., the technology that the agencies believe manufacturers would add last in order to meet the Preferred Alternative). The stringency of DEIS Alternative 6A was described as "15% below Preferred Alternative Stringency," but using our assumption about the type of technologies manufacturers would use to meet the standard, the stringency of Alternative 6A was actually 12% below the Preferred Alternative stringency. FEIS Alternative 2 is also approximately 12% less stringent than the Preferred Alternative and is described in this document as "12% below Preferred Alternative Stringency."

2.3.2.3 Alternative 4: 20% above Preferred Alternative Stringency

Alternative 4 represents a stringency level which is 20 percent more stringent than the preferred approach.[17] 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 2.3-4 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA forecasts manufacturers would achieve under Alternative 4.

Table 2.3-4

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 4 (20% above Preferred Alternative Stringency)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.5	6.3	6.2	6.1	5.9	5.5
Pickups & Vans (Classes 2b–3) – diesel	7.5	7.3	7.2	7.0	6.8	6.4
Vocational (Classes 2b–8) – gasoline	11.3	11.3	11.3	10.5	10.5	10.5
Vocational (Classes 2b–8) – diesel	10.3	9.5	9.5	9.5	9.0	9.0
Tractors (Classes 7–8)	20.3	17.7	17.7	17.7	17.2	17.2

2.3.2.4 Alternative 5: Trailers and Accelerated Hybrid

This alternative builds on the Preferred Alternative by adding a performance standard for the commercial trailers pulled by tractors and by specifying more stringent standards based on accelerated adoption of hybrid powertrains for HD vehicles. 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 2.2-6 for tractors alone.

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 (EPA 2010).[18]

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. This alternative is dependent on an aggressive deployment of manufacturing infrastructure to support a high rate of hybrid production in a short time span. 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

[17] DEIS Alternative 6B was calculated to regulate the same engine and vehicle categories as the Preferred Alternative, but at a higher level of stringency, achieved by adding the next most cost effective technology. The stringency of DEIS Alternative 6B was described as "20% above Preferred Alternative Stringency," but using our assumption about the type of technologies manufacturers would use to meet the standard, the stringency of Alternative 6B was actually 18% above the Preferred Alternative stringency. Because of revised technology assumptions, the corresponding FEIS Alternative 4 is 20% more stringent than the Preferred Alternative and is described in this document as "20% above Preferred Alternative Stringency."

[18] *See* http://www.epa.gov/smartway/documents/hybrid%20powertrain.pdf (Accessed: May 25, 2011).

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 2.2-1 and 2.2-2 for HD pickups and vans and the gallons-per-1,000-ton-mile standards for vocational vehicles in Table 2.2-4.

Table 2.3-5 shows the estimated fleet-wide fuel efficiency (gal/100 miles) that NHTSA forecasts manufacturers would achieve under Alternative 5, resulting from standards for HD vehicles, trailers, and engines, including standards that anticipate accelerated hybrid adoption for HD vehicles.

Table 2.3-5

Estimated Fleet-wide Fuel Efficiency (gal/100 miles) by Model Year for Alternative 5 (Trailers and Accelerated Hybrid)

	MYs 2010–2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018
Pickups & Vans (Classes 2b–3) – gasoline	6.5	6.3	6.2	6.1	5.4	5.0
Pickups & Vans (Classes 2b–3) – diesel	7.5	7.3	7.2	7.0	6.2	5.8
Vocational (Classes 2b–8) – gasoline	11.3	11.3	11.3	10.5	10.5	10.5
Vocational (Classes 2b–8) – diesel	10.3	9.5	9.5	9.5	7.8	7.8
Tractors (Classes 7–8)	20.3	17.4	17.4	17.4	16.8	16.8

2.3.3 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 2.3-6 and 2.3-7 show the EPA CO_2 emission standards for HD engines that correspond to the NHTSA fuel consumption standards in Tables 2.2-2 and 2.2-3, respectively.

Table 2.3-6

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

	LHDD	MHDD	HHDD	Gasoline
MY 2014	600	600	567	
Effective MY 2016				627
Effective MY 2017	576	576	555	

Table 2.3-7

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

	MMDD	HMDD
Alternatives 2 and 3		
MY 2014 (Voluntary)	502	487
Effective MY 2017	487	460
Alternatives 4 and 5		
MY 2014 (Voluntary)	488	473
Effective MY 2017	462	447

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 2.3-8 and 2.3-9

Table 2.3-8

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
Alt. 2: MY 2016	Engine Standards Only		
Alt. 2: MYs 2017–18			
Alt. 3: MY 2016	391	236	228
Alt. 3: MYs 2017–18	376	227	224
Alt. 4: MY 2016	391	236	228
Alt. 4: MYs 2017–18	369	223	220
Alt. 5: MY 2016	388	235	227
Alt. 5: MYs 2017–18	316	191	188

Table 2.3-9

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
Alt. 2: MYs 2014–2016			
Low Roof	107	81	68
Mid Roof	119	88	75
High Roof	124	92	74
Alt. 2: MYs 2017–2018			
Low Roof	104	79	66
Mid Roof	115	86	73
High Roof	120	90	72
Alt: 3: MYs 2014–2016			
Low Roof	107	81	68
Mid Roof	119	88	75
High Roof	122	90	73
Alt 3: MYs 2017–2018			
Low Roof	104	79	66
Mid Roof	115	86	73
High Roof	118	88	71
Alt. 4: MYs 2014–2016			
Low Roof	107	81	68
Mid Roof	119	88	75
High Roof	120	89	72
Alt. 4: MYs 2017–2018			
Low Roof	104	79	66
Mid Roof	115	86	73
High Roof	117	87	70
Alt. 5: MYs 2014–2016			
Low Roof	107	81	68
Mid Roof	119	88	75
High Roof	120	89	72

Table 2.3-9 (continued)

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

MYs 2014–2016	Day Cab Class 7	Day Cab Class 8	Sleeper Cab Class 8
Alt. 5: MYs 2017–2018 a/			
Low Roof	103	79	66
Mid Roof	114	86	73
High Roof	116	87	70

show the EPA CO_2 emission standards for vocational vehicles and tractors that correspond to the NHTSA standards in Tables 2.2-4 and 2.2-6.

2.4 COMPARISON OF ALTERNATIVES

The CEQ NEPA regulations direct Federal agencies to present in an EIS "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."[19] This section summarizes and compares the direct, indirect, and cumulative effects of the proposed action and alternatives on energy resources, air quality, and climate as presented in Chapters 3 and 4. No quantifiable, alternative-specific effects were identified for the other resource areas discussed in Sections 3.6 and 4.5 of this EIS, so they are not summarized here.

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).

2.4.1 Direct and Indirect Effects

This section compares the direct and indirect effects of the No Action Alternative and the four action alternatives on energy, air quality, and climate as presented in Chapter 3 (s*ee* Table 2.4-1). Under NEPA, direct effects "are caused by the action and occur at the same time and place." 40 CFR § 1508.8. Indirect effects are 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.

For detailed discussions of the assumptions and methodologies used to estimate the results presented in this Section, *see* Chapter 3. As explained in Section 3.1, the direct and indirect effects methodology assumes no further increases in HD vehicle fuel efficiency after MY 2018 under the action alternatives. The No Action Alternative assumes increases in HD fuel efficiency through 2050 consistent with projected market trends (s*ee* Section 3.5).

[19] *See* 40 CFR § 1502.14.

Table 2.4-1

Direct and Indirect Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Energy	**Total Combined Gas and Diesel Fuel Consumption by All U.S. HD Vehicles for 2014-2050**	2115.3 billion gallons	2068.6 billion gallons	2050.9 billion gallons	2012.7 billion gallons	1925.9 billion gallons
Energy	**Total Fuel Savings by All U.S. HD Vehicles Compared to No Action for 2014-2050**	--	46.7 billion gallons	64.4 billion gallons	102.5 billion gallons	189.4 billion gallons
Air Quality	**Criteria Air Pollutant Emissions Reductions from 2018 to 2050 Compared to No Action**	--	Emissions of most criteria pollutants (CO, NO_x, SO_2, and VOCs) will decrease compared to the No Action Alternative, while $PM_{2.5}$ emissions will increase.	Emissions of most criteria pollutants (CO, NO_x, SO_2, and VOCs) will decrease, while $PM_{2.5}$ will increase. The increase in $PM_{2.5}$ emissions will be less than the increase under Alt. 2, while the decrease in other emissions will be greater than the decrease under Alt. 2.	Emissions of most criteria pollutants (CO, NO_x, SO_2, and VOCs) will decrease. $PM_{2.5}$ will decrease in 2018 and increase in 2030 and 2050. The increases in $PM_{2.5}$ emissions will be less than the increases under Alt. 3, while the decreases in other emissions will be greater than the decreases under Alt. 3.	Emissions of most criteria pollutants (CO, NO_x, SO_2, and VOCs) will decrease. $PM_{2.5}$ emissions will decrease in 2018 and increase in 2030 and 2050. This will be the lowest increase in $PM_{2.5}$ and the greatest decrease in NO_x, SO_2, and VOC emissions.
Air Quality	**Toxic Air Pollutants Emissions Reductions from 2018 to 2050 Compared to No Action**	--	Emissions of most toxic pollutants (acetaldehyde, acrolein, benzene, and formaldehyde) will decrease compared to the No Action Alternative. 1,3-butadiene emissions will change only slightly in all years. DPM emissions will increase in all years.	Emissions of most toxic pollutants (acetaldehyde, acrolein, benzene, and formaldehyde) will decrease, compared to the No Action Alternative. 1,3-butadiene emissions will change only slightly in all years. DPM emissions decrease in 2018 and increase in 2030 and 2050. The increases in DPM emissions will be less than the increases under Alt. 2. The decreases in acetaldehyde, acrolein, benzene, and formaldehyde emissions will be similar to those under the other action alternatives.	Emissions of most toxic pollutants (acetaldehyde, acrolein, benzene, and formaldehyde) will decrease. 1,3-butadiene emissions will change only slightly in all years. DPM emissions decrease in 2018 and increase in 2030 and 2050. The increases in DPM emissions will be less than the increases under Alt. 3. The decreases in acetaldehyde, acrolein, benzene, and formaldehyde emissions will be similar to those under other action alternatives.	Emissions of most toxic pollutants (acetaldehyde, acrolein, benzene, and formaldehyde) will decrease. 1,3-butadiene emissions will change only slightly in all years. DPM emissions decrease in 2018 and increase in 2030 and 2050. The increases in DPM emissions will be less than the increases under the other action alternatives. The decreases in acetaldehyde, acrolein, benzene, and formaldehyde emissions will be similar to those under the other action alternatives.

Table 2.4-1 (continued)

Direct and Indirect Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Air Quality	**Reductions in Premature Mortality Cases and Work-loss Days in 2030** (values within ranges depend on assumptions used)	--	Premature mortality: reduced by 122 to 312 cases Work-loss days: reduced by 15,450 days	Premature mortality: reduced by 127 to 324 cases Work-loss days: reduced by 16,018 days	Premature mortality: reduced by 145 to 371 cases Work-loss days: reduced by 18,183 days	Premature mortality: reduced by 181 to 464 cases Work-loss days: reduced by 22,545 days
Air Quality	**Range of Monetized Health Benefits in 2030 Compared to No Action Under a 3% and 7% Discount Rate** (values within ranges depend on assumptions used)	--	3%: $1,125 million to $2,749 million 7%: $1,020 million to $2,483 million	3%: $1,169 million to $2,859 million 7%: $1,061 million to $2,583 million	3%: $1,336 million to $3,268 million 7%: $1,212 million to $2,952 million	3%: $1,673 million to $4,092 million 7%: $1,518 million to $3,696 million

Table 2.4-1 (continued)

Direct and Indirect Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Climate	**Total GHG Emissions by All U.S. HD Vehicles from 2014 to 2100**	66,000 $MMTCO_2$	65,000 $MMTCO_2$ (900 $MMTCO_2$ [1%] less than the No Action Alternative)	64,600 $MMTCO_2$ (1,400 $MMTCO_2$ [2%] less than the No Action Alternative)	63,700 $MMTCO_2$ (2,300 $MMTCO_2$ [3%] less than the No Action Alternative)	60,500 $MMTCO_2$ (5,500 $MMTCO_2$ [8%] less than the No Action Alternative)
	Atmospheric Carbon Dioxide Concentrations in 2100	784.9 ppm	784.8 ppm (0.1 ppm less than the No Action Alternative)	784.7 ppm in 2100 (0.1 ppm less than the No Action Alternative)	784.7 ppm (0.2 ppm less than the No Action Alternative)	784.4 ppm (0.5 ppm less than the No Action Alternative)
	Increase in Global Mean Surface Temperature by 2100	3.064 °C	3.064 °C (0.000 °C less than the No Action Alternative)	3.064 °C (0.001 °C less than the No Action Alternative)	3.063 °C (0.001 °C less than the No Action Alternative)	3.062 °C by 2100 (0.002 °C less than the No Action Alternative)
	Global Sea-Level Rise by 2100	37.40 cm	37.39 cm (0.01 cm less than the No Action Alternative)	37.39 cm (0.01 cm less than the No Action Alternative)	37.39 cm (0.01 cm less than the No Action Alternative)	37.38 cm (0.02 cm less than the No Action Alternative)
	Global mean Precipitation Increase by 2090	4.50%	4.50% (0.00% less than the No Action Alternative)	4.50% (0.00% less than the No Action Alternative)	4.50% (0.00% less than the No Action Alternative)	4.50% (0.00% less than the No Action Alternative)

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

2.4.2 Cumulative Effects

This section compares the cumulative effects of the No Action Alternative and the four action alternatives on energy, air quality, and climate as presented in Chapter 4 (s*ee* Table 2.4-2). CEQ regulations define cumulative effects 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.

For detailed discussions of the assumptions and methodologies used to estimate the results presented in this Section, *see* Chapter 4. As explained in Section 4.1, the cumulative effects methodology assumes continuing increases in HD vehicle fuel efficiency after 2018 under the No Action Alternative and each action alternative.

Table 2.4-2

Cumulative Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Energy	**Total Combined Gas and Diesel Fuel Consumption by All U.S. HD Vehicles for 2014-2050**	2115.3 billion gallons	1957.2 billion gallons	1934.2 billion gallons	1892.3 billion gallons	1811.2 billion gallons
Energy	**Total Fuel Savings by All U.S. HD Vehicles Compared to No Action for 2014-2050**	--	158.0 billion gallons	181.1 billion gallons	223.0 billion gallons	304.0 billion gallons
Air Quality	**Criteria Air Pollutant Emissions Reductions from 2018 to 2050 Compared to No Action**	--	Emissions of most criteria pollutant (CO, NO_x, SO_2, and VOCs) will decrease, while $PM_{2.5}$ will increase in 2018 and decrease in 2030 and 2050 compared to the No Action Alternative.	Emissions of all criteria pollutants ($PM_{2.5}$, CO, NO_x, SO_2, and VOCs) will decrease in all years compared to the No Action Alternative. The decreases in emissions will be greater than the decreases under Alt. 2.	Emissions of all criteria pollutants ($PM_{2.5}$, CO, NO_x, SO_2, and VOCs) will decrease in all years compared to the No Action Alternative. Except for CO, the decreases in emissions of all criteria pollutants will be greater than the decreases under Alt. 3.	Emissions of all criteria pollutants ($PM_{2.5}$, CO, NO_x, SO_2, and VOCs) will decreasefrom in all years compared to the No Action Alternative. Except for CO, the decreases in emissions of all criteria pollutants will be greater than the decreases under Alt. 4.
Air Quality	**Toxic Air Pollutants Emissions Reductions from 2018 to 2050 Compared to No Action**	--	Emissions of all toxic air pollutants (acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, and DPM) will decreasein all years compared to the No Action Alternative.	Emissions of all toxic air pollutants (acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, and DPM) will decrease in all years compared to the No Action Alternative. Decreases in emissions of benzene and DPM will be greater than under Alt. 2.	Emissions of all toxic air pollutants (acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, and DPM) will decrease in all years compared to the No Action Alternative. Decreases in emissions of benzene and DPM will be greater than under Alt. 2.	Emissions of all toxic air pollutants (acetaldehyde, acrolein, benzene, formaldehyde, 1,3-butadiene, and DPM) will decrease in all years compared to the No Action Alternative. The decreases in emissions will be greater than the decreases under Alt. 2 for acetyaldehyde, acrolein, , formaldehyde, and 1,3-butadiene in 2050, and for benzene and DPM in all years.

Table 2.4-2 (continued)

Cumulative Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Air Quality	**Reductions in Premature Mortality Cases and Work-loss Days in 2030** (values within range depend on assumptions used)	--	Premature mortality: reduced by 226 to 579 cases Work-loss days: reduced by 28,191 days	Premature mortality: reduced by 235 to 601 cases Work-loss days: reduced by 29,189 days	Premature mortality: reduced by 251 to 642 cases Work-loss days: reduced by 31,126 days	Premature mortality: reduced by 283 to 725 cases Work-loss days: reduced by 34,994 days
Air Quality	**Range of Monetized Health Benefits in 2030 Compared to No Action Under a 3% and 7% Discount Rate** (values within range depend on assumptions used)	--	3%: $2,087 million to $5,106 million 7%: $1,894 million to $4,612 million	3%: $2,165 million to $5,295 million 7%: $1,964 million to $4,784 million	3%: $2,314 million to $5,661 million 7%: $2,100 million to $5,114 million	3%: $2,613 million to $6,394 million 7%: $2,371 million to $5,776 million

Table 2.4-2 (continued)

Cumulative Impacts a/

		Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Climate	**Total GHG Emissions by All U.S. HD Vehicles from 2014 to 2100**	66,000 $MMTCO_2$	60,400 $MMTCO_2$ (5,600 $MMTCO_2$ [8%] less than the No Action Alternative)	59,600 $MMTCO_2$ (6,400 $MMTCO_2$ [10%] less than the No Action Alternative)	58,100 $MMTCO_2$ (7,900 $MMTCO_2$ [12%] less than the No Action Alternative)	55,100 $MMTCO_2$ (10,900 $MMTCO_2$ [17%] less than the No Action Alternative)
	Atmospheric Carbon Dioxide Concentrations in 2100	677.8 ppm	677.3 ppm (0.5 ppm less than the No Action Alternative)	677.2 ppm (0.6 ppm less than the No Action Alternative)	677.1 ppm (0.7 ppm less than the No Action Alternative)	676.8ppm (1.0 ppm less than the No Action Alternative)
	Increase in Global Mean Surface Temperature by 2100	2.564 °C	2.561 °C (0.002 °C less than the No Action Alternative)	2.561 °C (0.003 °C less than the No Action Alternative)	2.560 °C (0.003 °C less than the No Action Alternative)	2.559 °C (0.004 °C less than the No Action Alternative)
	Global Sea-Level Rise by 2100	33.42 cm	33.40 cm (0.02 cm less than the No Action Alternative)	33.40 cm (0.02 cm less than the No Action Alternative)	33.39 cm (0.03 cm less than the No Action Alternative)	33.38 cm (0.04 cm less than the No Action Alternative)
	Global mean Precipitation Increase by 2090	3.89%	3.89% (0.00% less than the No Action Alternative)	3.89% (0.00% less than the No Action Alternative)	3.88% (0.00% less than the No Action Alternative)	3.88% (0.01% less than the No Action Alternative)

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

Chapter 3 Affected Environment – Direct and Indirect Impacts

3.1 INTRODUCTION

In accordance with Council on Environmental Quality (CEQ) regulations for implementing NEPA, this chapter describes the affected environment and potential environmental consequences of the proposed action and alternatives.

In order to calculate the benefits of the Heavy Duty Fuel Efficiency Improvement Program, NHTSA compares the effects of the proposed standard and its alternatives to a baseline (No Action Alternative). In the DEIS, the agency compared the action alternatives to a baseline constructed on the assumption that future new vehicles would match levels of fuel efficiency equivalent to MY 2010 vehicles. NHTSA received comments to the DEIS indicating that, in analyzing the effects of the action alternatives, the agency should take into account projected increases in fuel efficiency due to market forces. The likelihood that increases in fuel efficiency in response to market demand would occur even in the absence of this Program raises the question of whether they should be reflected in the baseline.

NHTSA recognizes that there is substantial uncertainty in determining an appropriate baseline against which to compare the effects of the proposed action. The lack of prior regulation of HD fuel efficiency means that there is a lack of historic data regarding trends in this sector. Still, projections of fuel efficiency for this sector indicate that, as a result of market forces, fuel efficiency of HD vehicles will increase in the future even in the absence of the proposed rule.

For purposes of continuity with the DEIS and the NPRM, this chapter first analyzes the effects of the proposed action and alternatives compared to a baseline that reflects constant MY 2010 fuel efficiency levels. These effects are analyzed in sections under a heading for each affected resource – energy (Section 3.2), air quality (Section 3.3), and climate (Section 3.4). Next, in recognition of commenter concerns regarding the effects of market forces in the absence of NHTSA's action, this chapter includes an analysis of these affected resources that compares the action alternatives to a baseline that incorporates a market forecast of changes in fuel efficiency (Section 3.5).

The agency also analyzes various other potentially affected resource areas (Section 3.6) and the unavoidable impacts and irreversible and irretrievable commitments of resources (Section 3.7) associated with the implementation of the proposed rule.

3.1.1 Direct and Indirect Impacts

An EIS must "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. 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. The analysis that follows considers the direct and indirect effects of the proposed action and alternatives on energy, air, and climate, as well as other potentially affected resource areas (including biological resources, water resources, noise, safety, and other impacts on human health, hazardous materials and regulated wastes, and environmental justice). Where NHTSA is unable to conduct a quantitative analysis, either because sufficient data were not available in the literature or because effects are not localized, the agency has presented a qualitative analysis of the affected resource.

3.1.2 Areas Not Affected

NHTSA has determined that the proposed action would not have a direct or indirect effect on several areas outlined in the Department of Transportation (DOT) NEPA procedures, 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 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 EIS, 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.[2] 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).

[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).

[2] 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)).

3.1.4 Common Methodologies

To analyze impacts relevant to GHGs, energy, and air quality, the agencies 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.

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 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, 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.[3] The alternatives in the tables and figures in this chapter are arranged in ascending order of stringency and fuel savings to aid in the environmental analysis and the comparison of alternatives.

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, parked, or being refueled, and consist of tailpipe exhaust, evaporative emissions of volatile compounds from its fuel storage and delivery system, and particulates generated by brake and tire wear. These emissions are estimated using the most recent version of EPA's Motor Vehicle Emission Simulator (MOVES2010a) model (EPA 2010). Upstream emissions are those associated with crude petroleum extraction and transportation, as well as with 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.[4] EPA developed national emission estimates for all HD vehicles projected to be in use during various future years using the MOVES2010a model (EPA 2010). 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.

[3] 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 regulation of the fuel efficiency of HD vehicles does not cover recreational vehicles (*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 covered by NHTSA's regulation, that is, all HD vehicles covered by the National Program with the exception of recreational vehicles.

[4] Emissions that occur during vehicle storage and refueling are estimated separately and pro-rated over the number of vehicle-miles traveled between periods when the vehicle is stored or between times when it is refueled.

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). In modeling tailpipe emissions of particulate matter 2.5 microns or less in diameter ($PM_{2.5}$), EPA included emissions from 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.[5]

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 energy consumption rates under various operating conditions (modes), rather than on engine Federal Test Procedure cycle-based results (such as those used for passenger vehicles and light trucks), EPA applied the expected percent reductions in engine CO_2 emissions under each action alternative to the default energy consumption rates by each vehicle/engine class, for all operating modes for the running exhaust and start exhaust processes. In other words, the (percent) reductions in CO_2 emission rates under each action alternative were assumed to reflect the 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 corresponding reductions in vehicle movement energy demand (or road load) for use as inputs to MOVES.

In MOVES, emission rates for criteria air pollutants, such as nitrogen 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, because they are formed from sulfur contained in fuel itself, emissions of the criteria pollutant sulfur dioxide (SO_2) are directly proportional to fuel consumption, and are thus affected by changes in 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 estimate 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 the No Action Alternative, the agencies do not assume any increase after MY 2013 in the percent of trucks that use APUs during extended idling.[6] For alternatives under which combination long-

[5] 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."

[6] The agencies assumed that 30% of long-haul trucks use APUs in the baseline (No Action Alternative) for Sections 3.2, 3.3, and 3.4, but the market forecast baseline (No Action Alternative) in Section 3.5 reflects zero use of APUs because this assumption was embedded in the overall AEO 2011 estimates reflected in the market forecast baseline. This one outdated technology assumption does not materially affect overall market forecast baseline gains in fuel efficiency and related impacts on fuel consumption and GHG emissions. However, the market forecast baseline for

haul trucks are regulated (Alternatives 2 through 5), the agencies assumed that 100 percent[7] 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.

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 transportation, 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 2009 Renewable Fuel Standard 2 (RFS2) proposed rulemaking.[8] 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.[9]

The actual calculations of the impacts of decreased fuel production on total emissions of each pollutant use the volumes of petroleum-based fuels estimated to be produced and consumed under each action alternative, together with 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 2009). The emission factors derived from GREET (expressed as grams of pollutant per million British thermal units (BTU) of fuel energy content) for each phase of the fuel production and distribution process were multiplied by the volumes of different types of fuel produced and distributed under each action alternative to estimate the resulting changes in emissions during each phase of fuel production and distribution. These emissions were added together to get the total emissions from fuel production and distribution resulting from each action alternative. This process was repeated

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non-GHG emissions has been adjusted to reflect the use of APUs by 30% of long-haul trucks in order to provide a more accurate and meaningful comparison of non-GHG impacts for the action alternatives.

[7] 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).

[8] Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program (RFS2), Notice of Proposed Rulemaking, 74 *FR* 24904 (May 26, 2009). EPA has continued to amend the RFS2 program, most recently with the December 21, 2010 Final Rule (75 FR 79964).

[9] 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.

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.

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."[10] 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 NPRM 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.[11] 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

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

[11] *See* the Draft Regulatory Impact Analysis (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.

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 of criteria air pollutants or air toxics 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.

However, 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 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 under the proposed standards compared to the No Action Alternative. 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 geographic 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 increase in emissions from vehicle use and the decline in emissions resulting from reduced fuel production and distribution within that geographic region.

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 is calculated as the sum of all energy supplied to an economy divided by its GDP. The energy intensity of the U.S. economy has been improving at an average rate of 2.0 percent per year since 1992.[12] This improvement is primarily due to a structural shift in the economy towards less energy-intensive industries. However, increased energy efficiency throughout the U.S. economy has been offset by growth in population and economic activities – including motor vehicle use – so that total U.S. energy consumption has risen. In this EIS, NHTSA uses energy projections from the EIA, an agency in the Department of Energy, which collects and provides 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. The EIA forecasts that the energy intensity of the entire U.S. economy (measured in 2005 USD) will continue to improve at an average annual rate of 1.9 percent from 2009 to 2035. However, ongoing economic and population growth will result in continued increases in total energy use, including increased transportation fuel consumption.[13]

3.2.1 Affected Environment

Every year, EIA issues projections of energy consumption and supply for both the United States (*Annual Energy Outlook* [AEO]) and the world (*International Energy Outlook* [IEO]). EIA reports energy consumption and projections by energy mode, sector, and geographic region. The model used to formulate EIA's projections incorporates all Federal and State laws and regulations that are in force at the time of modeling. Potential legislation and regulations, as well as laws under debate in Congress are not included. In this EIS, unless otherwise noted, NHTSA uses projections of energy consumption and supply up to 2035 from the Annual Energy Outlook 2011 Early Release Reference Case.[14] All projections in Section 3.2.1 are from the Annual Energy Outlook 2011 Final Release.

Table 3.2.1-1 shows actual and projected U.S. and global energy consumption by sector. As shown in this table, energy consumption is projected to increase across all U.S. sectors through 2035. Since 1990, the transportation sector has been the second largest consumer of energy after the industrial sector in the U.S. By 2007, the transportation sector accounted for 28.5 percent of total U.S. energy consumption.

According to the EIA, on-road transportation modes (including light-duty vehicles, commercial light trucks weighing from 8,500 to 10,000 pounds, buses, and freight trucks weighing greater than 10,000 pounds) together account for approximately 80 percent of total U.S. transportation sector energy consumption. More than half of energy consumption from the U.S. transportation sector is attributable to

[12] EIA 2011. "U.S. energy demand;" EIA 2010. "Table 2.1a Energy Consumption by Sector, 1949-2009 (billion btu);" BEA 2011a. "Table 1.1.5 Gross Domestic Product, 1929 – 2010;" BEA 2011b. "Table 1.1.9 Implicit Price Deflators for Gross Domestic Product."

[13] EIA 2011. "Table A2. Energy Consumption by Sector and Source, AEO 2011 Reference Case (quadrillion Btu, unless otherwise noted)."

[14] The reference case refers to a scenario under which forecasts are made with the following assumptions: (i) all current laws and regulations, including sunset clauses, remain unchanged throughout the forecast period, (ii) an annual average real GDP growth rate of 2.7 percent, (iii) an annual average growth rate in nonfarm business and employment productivity of 2.0 percent, (iv) an annual average growth rate in nonfarm business and employment of 1.0 percent, and (v) an annual average growth rate in the price of crude delivered to refineries in the United States of 2.6 percent. This price of crude is expected to reach $113.70 per barrel in 2009 U.S. dollars in 2030. *See* EIA 2011, "Macroeconomic Growth Cases., the *Reference Case;*" EIA 2011, "Table A12. Petroleum Product Prices, AEO 2011 Reference Case (2009 dollars per gallon, unless otherwise noted)."

Table 3.2.1-1

Energy Consumption by Sector a/

Sector (Quadrillion BTU d/)	Actual b/ 1990	1995	2000	2007	Forecast c/ 2015	2020	2025	2030	2035
United States									
Residential	17.0	18.6	20.5	21.5	20.5	21.0	21.6	22.2	22.8
Commercial	13.3	14.7	17.2	18.3	18.9	20.2	21.4	22.7	24.0
Industrial	31.9	34.0	34.8	32.5	34.0	34.7	35.3	35.5	35.5
Transportation	22.4	23.8	26.6	29.0	28.6	29.0	29.7	30.7	32.0
Total	84.7	91.2	99.0	101.5	102.0	104.9	108.0	111.0	114.2
Transportation (%)	26.5	26.2	26.8	28.5	28.0	27.6	27.5	27.7	28.0
International									
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	- -	- -	- -	184.4	194.3	212.5	229.3	244.7	261.8
Transportation	- -	- -	- -	97.9	109.0	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	20.1	19.5	19.3	19.3	19.2
International (World less United States)									
Residential	- -	- -	- -	28.6	36.1	39.1	41.7	43.7	46.2
Commercial	- -	- -	- -	8.2	11.5	12.5	13.9	15.1	16.4
Industrial	- -	- -	- -	151.9	160.3	177.8	194.1	209.4	226.3
Transportation	- -	- -	- -	68.9	81.1	86.7	94.4	102.5	110.8
Total	262.8	273.9	299.2	393.9	442.2	486.3	531.6	576.2	625.1
Transportation (%)	- -	- -	- -	17.5	18.3	17.8	17.8	17.8	17.7

a/ EIA data were used to create this table. For historical, international energy consumption statistics, EIA does not disaggregate data by sector. However, EIA's most recent International Energy Outlook does provide this information, although only for recent historical periods (e.g. 2007).
b/ Actual United States data: EIA 2009b. Actual World data: EIA 2009a.
c/ Forecasted United States data: EIA 2011. "Energy Consumption by Sector and Source, United States, Reference Case (quadrillion Btu, unless otherwise noted)." Forecasted World data: EIA 2010. "Table F1. Total world delivered energy consumption by end-use sector and fuel, 2007-2035 (quadrillion Btu)."
d/ Btu = British thermal unit.

petroleum (gasoline and diesel) consumption from light vehicles.[15] In comparison, petroleum used by commercial light trucks and freight trucks account for roughly 18 percent of total transportation sector energy consumption.[16] Diesel consumption from heavy duty vehicles made up an estimated 16.4 percent of energy consumption in the U.S. transportation sector in 2008, and is projected to increase to 19.6 percent in 2035.[17]

[15] Excluding E85, a fuel that contains 85 percent ethanol and 15 percent conventional or reformulated gasoline used in flex-fuel vehicles.
[16] EIA 2011. "Transportation Sector Energy Use by Mode and Type, AEO2011 Reference Case (trillion Btu)."
[17] EIA 2011. "Transportation Sector Energy Use by Fuel Type Within a Mode, AEO 2011 Reference Case (trillion Btu)." 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. EIA data indicates that, during 2008 and 2009, ethanol accounted for approximately 4.9 and 5.6 percent of the energy content of fuel labeled at retail as gasoline, while biodiesel accounted for about 0.66 and 0.72

While total vehicle miles traveled (VMT) on U.S. roads has increased steadily over the last 30 years, the proportion of VMT by vehicles with more than two axles and four tires and combination trucks (*e.g.* tractor-semitrailer and tractor trailer) has remained relatively steady.[18]

In the future, the transportation sector is projected to continue to be the second largest consumer of total U.S. energy after the industrial sector. However, the gap between energy consumption in the two sectors is projected to narrow considerably in the out-years. These various sectors consume different types of fuels; gasoline is the primary source of fuel energy in the U.S. transportation sector, while natural gas is the primary energy source for the U.S. 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 for different types of fuels), is projected to fall from 10.2 quads in 1995 to 3.5 quads in 2035.[19] This decrease reflects not only the decline of the U.S. industrial sector but also improved efficiency in the U.S. transportation sector. As a percentage of total economy-wide energy consumption, energy use in the U.S. transportation sector is projected to remain fairly constant, growing at a gradual rate of 0.6 percent throughout the projection years from 2009 to 2035.[20]

The EIA projections of transportation sector energy consumption take into account all forms of energy, including renewable fuels and biofuels. Currently, U.S. transportation fuel remains largely petroleum based, though efforts exist to increase the use of non-fossil fuels in this sector, such as EPA's adoption of the Renewable Fuel Standard (RFS), which aims to increase non-fossil fuel use in transportation to 36 billion gallons by 2022 (RFA 2010). In 2008, 99.8 percent of fuel energy consumed by on-road motor vehicles, excluding that used by transit, intercity, and school buses, was petroleum based. This proportion is expected to decline to 94.5 percent by 2035. EIA projects that as a percentage of all transportation sector fuel consumed, the use of biofuels (*e.g.*, ethanol used in E85, ethanol used in gasoline blending, biodiesel used in distillate blending, liquids from biomass) will increase in the future. The biofuel component of the total U.S. transportation sector energy consumption was 0.87 quads in 2008 and 0.99 quads in 2009, representing about 3 and 4 percent of all energy consumed in the U.S. transportation sector.[21] According to EIA projections, this share will rise to 3.73 quads, or approximately 12 percent of all energy consumed in the U.S. transportation sector, by 2035.[22]

NHTSA's analysis in this EIS projects that fuel consumed by HD vehicles will remain predominantly petroleum based (both diesel and gasoline) for the foreseeable future. As a consequence, petroleum consumption by HD vehicles as a proportion of total on-road transportation sector energy

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percent of the energy content of fuel sold at retail as on- or off-road diesel. Computed from information reported in: EIA 2011, "Renewable Energy Consumption by Sector and Source, AEO2011 Reference Case (quadrillion Btu, unless otherwise noted)" and "Energy Consumption by Sector and Source, United States, AEO2011 Reference Case (quadrillion Btu, unless otherwise noted)." Percentage of ethanol in gasoline does not account for retail sales of E85.

[18] From 1970 to 2008, total VMT in the US increased from 1.1 to 3.0 trillion miles. VMT of heavy duty vehicles with more than two axles and four tires and combination trucks (*e.g.* tractor-semitrailer and tractor trailer) made up 2.6 and 4.4 percent of all VMT in the US in 1970 and 2008, respectively. ORNL 2010. "Table 3.6. Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2008" and "Table 5.1. Summary Statistics for Heavy Single-Unit Trucks, 1970-2008."

[19] EIA 2011. Table A2. "Energy Consumption by Sector and Source, United States, AEO 2011 Reference Case (quadrillion Btu, unless otherwise noted)." EIA 2010. "Table 2.1a Energy Consumption by Sector, 1949-2009."

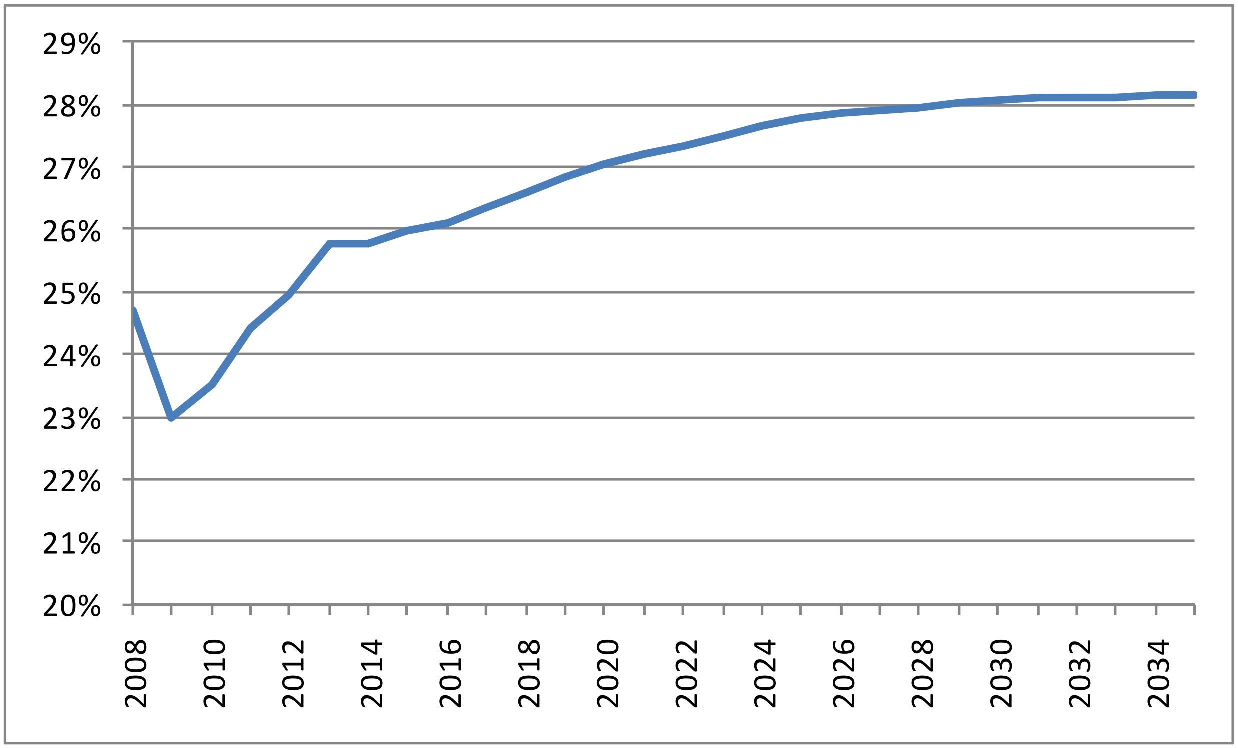
[20] EIA 2011. Table A2. "Energy Consumption by Sector and Source, United States, AEO 2011 Reference Case (quadrillion Btu, unless otherwise noted)."

[21] EIA 2011. "Table A-17. Renewable Energy Consumption by Sector and Source, AEO2011 Reference Case (quadrillion Btu)."

[22] EIA 2011. "Table A-17. Renewable Energy Consumption by Sector and Source, AEO2011 Reference Case (quadrillion Btu)."

consumption will continue to grow. In the reference case, EIA projects that from 2009 to 2012, total energy consumption in the transportation sector will decline by 2.6 percent from 2009-2010, and then grow at roughly 1 percent annually thereafter. Energy consumption by HD vehicles is projected to drop by 9.1 percent from 2008-2009, and then to grow by 3.2, 5.0, and 3.4 percent between 2009-2010, 2010-2011, and 2011-2012, respectively. The AEO 2011 Reference Case also projects that petroleum consumption by HD vehicles will reach approximately 28 percent of total petroleum consumed by highway modes of transportation by 2035. This translates to approximately 5 quads (40 billion gallons) per year from 2008 to 2013 and nearly 7 quads (51 billion gallons) annually by 2035. Total energy consumption by the transportation sector is projected to be approximately 30 quads (240 billion gallons) from 2008 to 2013, and to grow to nearly 32 quads (256 billion gallons) by 2035.[23] Figure 3.2.1-1 illustrates forecast petroleum consumption by HD vehicles as a proportion of total on-road vehicle consumption from 2008 until 2035.

Figure 3.2.1-1. Proportion of Petroleum Consumption by HD Vehicles from 2008–2035



EIA 2011. "Transportation Sector Energy Use by Fuel Type Within a Mode, AEO2011 Reference Case."

Historically, to meet demand, the U.S. transportation sector has been heavily dependent on imports of both refined petroleum products and crude oil for domestic refining. More recently, however, U.S. petroleum imports have declined. From 2006 to 2008, petroleum imports declined from 1.3 to 1.1 billion barrels, a decrease of approximately 4 percent from 2006-2007 and 9 percent from 2007-2008. In 2006, 5.14 percent of finished motor gasoline and 8.75 percent of distillate fuel oil (diesel) supplied to the U.S. economy – mostly to its transportation sector – were imported. By 2007 and 2008, these numbers had dropped to 4.44 and 3.36 percent of motor gasoline and to 7.25 and 5.40 percent of distillate fuel oil. Although imports had typically hovered around 66 percent of all petroleum products supplied to the U.S.

[23] EIA 2011. "Transportation Sector Energy Use by Fuel Type Within a Mode, AEO2011 Reference Case (trillion Btu)."

economy from 2005 to 2008, by 2009, this figure had declined to 63 percent.[24] Factors that could have contributed to the decrease in petroleum imports include the sharp decline in U.S. economic output, required improvements in fuel efficiency for passenger cars and light trucks, biofuels mandates on state- and nationwide levels, rising oil prices, and lifting of bans on drilling in various U.S. offshore areas from July 2008 to May 2010.

3.2.2 Methodology

NHTSA's 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 above in Section 3.1.4, calculates energy consumption and emissions based on user inputs describing characteristics of the vehicle fleet and vehicle operating patterns, including (1) a forecast of the future market for new HD vehicles; (2) estimates of the availability, applicability, and incremental effectiveness of fuel-saving technologies; (3) estimates of vehicle survival and mileage accumulation patterns; and (4) fuel characteristics and vehicular emission rates. Technologies to reduce fuel consumption considered by the MOVES model are described in Chapter 2 of the Draft Regulatory Impact Analysis (RIA) (*see* http://www.epa.gov/oms/climate/regulations/420d10901.pdf [Accessed: June 13, 2011]).

3.2.3 Environmental Consequences

Table 3.2.3-1 shows the impact of the action alternatives in reducing fuel consumption through 2050, when the entire HD vehicle fleet is likely to be composed of MY 2018 or later vehicles. This table reports total 2014-2050 consumption of both gasoline and diesel by HD pickups and vans (Classes 2b–3), vocational vehicles (Classes 2b–8), and tractors (Classes 7–8), under the No Action Alternative and each of the four action alternatives. The table also shows the fuel savings resulting from each action alternative as compared to the No Action Alternative in these same years.

Table 3.2.3-1

HD Vehicle Fuel Consumption and Fuel Savings by Alternative
(billion gallons total for calendar years 2014-2050)

	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Fuel Consumption					
HD Pickups and Vans	342.3	316.1	312.0	306.0	285.8
Vocational Vehicles	435.6	419.9	409.1	397.2	356.4
Tractor Trucks	1493.4	1347.5	1337.6	1309.7	1283.7
All HD Vehicles	2271.2	2083.5	2058.6	2013.0	1926.0
Fuel Savings Compared to No Action Alternative					
HD Pickups and Vans	--	26.2	30.3	36.2	56.4
Vocational Vehicles	--	15.7	26.6	38.4	79.2
Tractor Trucks	--	145.9	155.8	183.6	209.6
All HD Trucks	--	187.8	212.6	258.2	345.3

[24] 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)."

Total fuel consumption from 2014 through 2050 across all HD vehicle classes under the No Action Alternative is projected to amount to 2271.2 billion gallons. Fuel consumption from 2014-2050 decreases across the alternatives, from 2083.5 billion gallons under Alternative 2 to 1926.0 billion gallons under Alternative 5. Under the Preferred Alternative, fuel consumption from 2014-2050 is projected to total 2058.6 billion gallons.

Less fuel would be consumed under each of the action alternatives than under the No Action Alternative, with total 2014-2050 fuel savings ranging from 187.8 billion gallons under Alternative 2 to 345.3 billion gallons under Alternative 5. As compared to the No Action Alternative, total 2014-2050 fuel savings under the Preferred Alternative amounts to 212.6 billion gallons.

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).[25] 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 motor vehicles do not directly emit ozone, 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).[26]

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 2009a).

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 2009a). 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.[27] SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the

[25] 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.

[26] 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.

[27] 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 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

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 $\mu g/m^3$	Rolling 3-month average	Same as Primary	
Nitrogen dioxide	0.053 ppm (100 $\mu g/m^3$)	Annual (arithmetic mean)	Same as Primary	
	0.100 ppm (200 $\mu g/m^3$)	1 hour c/	None	
Particulate matter (PM_{10})	150 $\mu g/m^3$	24 hours d/	Same as Primary	
Particulate matter ($PM_{2.5}$)	15.0 $\mu g/m^3$	Annual (arithmetic mean) e/	Same as Primary	
	35 $\mu g/m^3$	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 $\mu g/m^3$)	1 hour k/	0.5 ppm (1,300 $\mu g/m^3$)	3 hours b/

a/ Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m3), and micrograms per cubic meter of air (µg/m3).

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 PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m3.

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/m3 (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 July 2011.

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.

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 welfare, the NAAQS specify different permissible levels for each pollutant. NAAQS for some pollutantsinclude 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. EPA is currently considering further changes to the $PM_{2.5}$ standards and to the ozone standard, and expects to issue the revised ozone standard at the end of July 2011.

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 the 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).[28] 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.

[28] 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/ [Accessed: June 16, 2011]).

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 (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.[29] 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.

[29] 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 to be 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 plus polycyclic organic matter (POM) and naphthalene were identified as national or regional risk drivers or contributors in the EPA 2005 National-scale Air Toxics Assessment (NATA) and have significant inventory contributions from mobile sources (EPA 2011). 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 (EPA 2003a).[30] 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).[31] 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).[32] 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).

[30] *See* pg. 10.
[31] *See* pg. 11.
[32] *See* pg. 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 (or black carbon) particles emitted from diesel engines (*see* Section 3.4.1.7). EPA has not provided special status, such as a 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.* 2003, 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 stronger 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.[33] 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.

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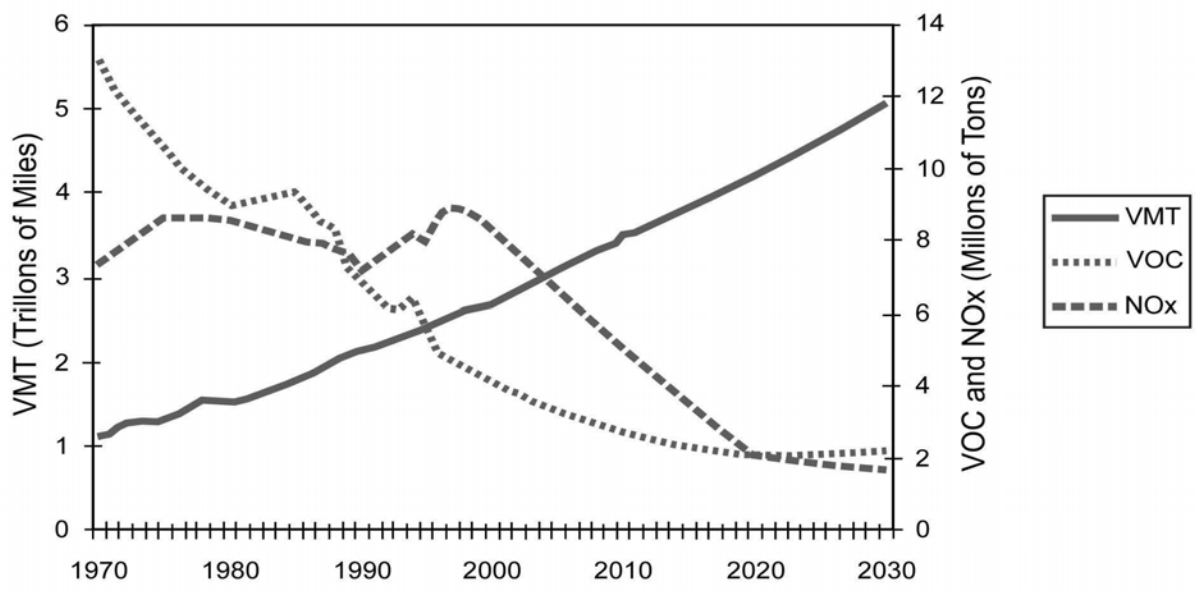
[33] Model year 1984 heavy-duty engines met standards of 10.7 grams per brake horsepower-hour (g/bhp-hr) NO_x and 0.6 g/bhp-hr PM; model year 2007 and later heavy-duty engines meet standards of 0.2 g/bhp-hr NO_x and 0.01 g/bhp-hr PM.

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 decreased substantially (with the exception of NO_x) even as VMT increased by approximately 149 percent from 1970 to 1999, and approximately 220 percent from 1970 to 2010, as shown in Figure 3.3.1-1. NO_x emissions, due mainly to light trucks and heavy-duty vehicles, increased 16 percent between 1970 and 1999 before declining thereafter, as shown in Figure 3.3.1-1. 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 action alternatives.

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 (s*ee* 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 proposed 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, it 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 (including 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, or 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 under each action alternative by comparing emissions under that alternative to those under 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.

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.[34] The distribution of emissions is not uniform nationwide, and either increases or decreases in emissions can occur within individual nonattainment or maintenance areas. *See* Sections 3.3.2.4 and 3.3.2.5 for details on the assumptions NHTSA used to allocate upstream and downstream emissions to individual nonattainment and maintenance areas. NHTSA focused on 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. 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

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

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 of the proposed rule and the other alternatives considered 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.[35] 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 manufacturers would continue to meet the fuel efficiency levels required by the MY 2018 standards following the period of the rule.

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 MY 2014–2018 fuel consumption standards.

[35] 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.

- 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 MY 2014–2018 standards.
- 2050 – By 2050, almost all HD vehicles in operation would meet the MY 2014–2018 standards, and the impact of these standards would be determined primarily by VMT growth rather than MY 2014-2018 vehicles replacing older, less fuel-efficient vehicles. The year-by-year impacts of NHTSA's fuel consumption standards and EPA's emission standards for MYs 2014–2018 will change little from model year turnover by 2050, and most changes in emissions from year to year due to these standards will come from added driving due to the rebound effect.

3.3.2.4 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 in specific factors affecting heavy duty vehicle use projected for individual counties in EIA (2006). VMT data used in the NEI were estimated 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 among counties or nonattainment areas in factors 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 for analysis years 2030 and 2050 compared to 2018.

The geographic definitions of ozone and $PM_{2.5}$ nonattainment areas came from the current EPA Green Book Nonattainment Areas for Criteria Pollutants (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 additional 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
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

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
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
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

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
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 National Park), 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
Kansas City, MO-KS	Ozone	Maintenance	N.A.
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
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

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
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
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

Table 3.3.2-1 (continued)

Nonattainment Areas for Ozone and $PM_{2.5}$

Nonattainment/Maintenance Area	Pollutant	Status a/	General Conformity Threshold b/
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. N.A. indicates conformity is not applicable.
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.[36] Emissions of pollutants at each stage are associated with expenditure of energy, as well as with leakage or spillage and evaporation of fuel products.

[36] Emissions that occur while vehicles are being refueled at retail stations are included in estimates of emissions from vehicle operation.

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 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 2010c) 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 2010c) 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. This assumption enables the analysis to account for all upstream acetaldehyde emissions in the absence of data on the proportion attributable to TS&D). 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.

3.3.2.7 Health Outcomes and Monetized Benefits

3.3.2.7.1 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.

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

The benefits estimates 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.[37]

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

[37] 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.

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. Throughout the discussion of mortality in this section, the mortality rate calculated from Pope *et al.* is presented side-by-side with the mortality rate calculated from Laden *et al.*

The benefits-per-ton estimates used in this analysis are based on a value of statistical life[38] (VSL) estimate that was vetted and endorsed by the EPA Science Advisory Board (SAB) in the Guidelines for Preparing Economic Analyses (EPA 2000).[39] 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, adjusted to 2009 dollars, and listed in Table 3.3.2-3.[40]

Table 3.3.2-3

Benefit-per-ton Values (2009$) Derived Using the ACS Cohort Study for PM-related Premature Mortality

	All Sources b/		Stationary (Non-EGU c/) Sources		Mobile Sources	
Year a/	SO_2	VOC	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
3-Percent Discount Rate						
Pope *et al.* (2002)						
2018	$30,083	$1,247	$4,973	$232,348	$5,184	$283,617
2030	$36,602	$1,539	$6,129	$280,712	$6,434	$350,960
2050	$42,074	$1,785	$7,104	$321,190	$7,489	$407,531
Laden *et al.* (2006)						
2018	$73,663	$3,053	$12,167	$569,346	$12,673	$693,925
2030	$89,650	$3,770	$14,998	$688,001	$15,733	$859,056
2050	$103,083	$4,375	$17,386	$787,384	$18,315	$997,849
7-Percent Discount Rate						
Pope *et al.* (2002)						
2018	$27,296	$1,132	$4,513	$210,810	$4,705	$257,398
2030	$33,202	$1,396	$5,561	$254,619	$5,838	$318,404
2050	$38,157	$1,619	$6,444	$291,275	$6,793	$369,639

[38] 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").
[39] 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.
[40] The VSL derived by EPA and used for this study is $6.3 million in year 2000 dollars. When adjusted to 2009 dollars the value of VSL is approximately $7.8 million. These values agree reasonably closely with the standard VSL adopted by the U.S. Department of Transportation for benefit-cost analyses, which is $6.0 million in year 2009 dollars (DOT 2009). The discrepancy between these estimates is not unexpected, as no single dollar value has been accepted in the academic community or across the Federal government.

Table 3.3.2-3 (continued)

Benefit-per-ton Values (2009$) Derived Using the ACS Cohort Study for PM-related Premature Mortality

Year a/	All Sources b/ SO$_2$	All Sources b/ VOC	Stationary (Non-EGU c/) Sources NO$_x$	Stationary (Non-EGU c/) Sources Direct PM$_{2.5}$	Mobile Sources NO$_x$	Mobile Sources Direct PM$_{2.5}$
7-Percent Discount Rate (cont'd)						
Laden *et al.* (2006)						
2018	$66,547	$2,758	$10,993	$514,329	$11,450	$626,943
2030	$80,980	$3,406	$13,549	$621,445	$14,212	$776,023
2050	$93,105	$3,952	$15,704	$711,155	$16,544	$901,312

a/ 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.
b/ 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.
c/ Non-EGU = Sources other than electric generating units (power plants).

3.3.2.7.3 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 (*see* 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) Except as Noted

Outcome and Year a/	All Sources b/ SO$_2$	All Sources b/ VOC	Stationary (Non-EGU c/) Sources NO$_x$	Stationary (Non-EGU c/) Sources Direct PM$_{2.5}$	Mobile Sources NO$_x$	Mobile Sources 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	0.000663928	0.030515150	0.000697373	0.038060658
2050	0.004493326	0.000190635	0.000756994	0.034314755	0.000798739	0.043482308
Premature Mortality – Laden *et al.* (2006)						
2018	0.008700361	0.000360338	0.001435232	0.067271964	0.001494947	0.081880941
2030	0.010175473	0.000427775	0.001700371	0.078112764	0.001784000	0.097439091
2050	0.011482872	0.000487481	0.001935411	0.087712831	0.002039711	0.111145055
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

Table 3.3.2-4 (continued)

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

Outcome and Year a/	All Sources b/ SO_2	All Sources b/ VOC	Stationary (Non-EGU c/) Sources NO_x	Stationary (Non-EGU c/) Sources Direct $PM_{2.5}$	Mobile Sources NO_x	Mobile Sources Direct $PM_{2.5}$
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/ 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.
c/ Non-EGU = Sources other than electric generating units (power plants).

3.3.2.7.4 Assumptions and Uncertainties

The benefit-per-ton estimates are subject to many assumptions and uncertainties, as follows:

- These estimates 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 precise 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 is necessary to control for local variability. Full-scale photochemical modeling provides the needed spatial and temporal detail to more completely and accurately estimate changes in ambient levels of these pollutants and their associated health and welfare impacts. To support and confirm the screening-level, benefit-per-ton estimates, NHTSA performed full-scale photochemical air quality modeling of a selection of alternatives as discussed below and in Appendix F. This modeling provides insight into the uncertainties associated with the use of benefit-per-ton estimates. EPA is also conducting full-scale photochemical modeling for the Final Rule on HD vehicle GHG standards.

- 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 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. EPA projects that these emissions 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.

The analysis in this section shows that the action alternatives result in different levels of emissions from HD vehicles when measured against projected trends in the absence of the proposed fuel consumption standards. These reductions or increases in emissions vary by pollutant, calendar year, and action alternative. The more stringent 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 through 3.3.3-6 present the results of the air quality analysis. Following the comparative overview in this section, Sections 3.3.3.2 through 3.3.3.9 describe the results of the analysis of emissions for Alternatives 1 through 5 in greater detail.

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 5) left to right in order of increasing fuel efficiency requirements. Figure 3.3.3-1 illustrates this information.

Figure 3.3.3-2 summarizes the changes over time in total national emissions of criteria pollutants from HD vehicles for the Preferred Alternative (Alternative 3). Figure 3.3.3-2 indicates a consistent trend among the criteria pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production, but increase from 2030 to 2050 due to continuing growth in VMT.

Total emissions are made up of eight components, consisting of two sources of emissions (tailpipe and upstream) for each of the four vehicle classes covered by the proposed rule: Classes 2b–3 HD pickups and vans, Classes 3–8 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 3.3.3-1

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

Pollutant and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	2,688,126	2,660,455	2,660,265	2,659,701	2,658,888
2030	2,558,497	2,503,155	2,502,825	2,502,153	2,500,056
2050	3,250,451	3,173,779	3,173,466	3,172,463	3,169,442
Nitrogen oxides (NO_x)					
2018	1,808,032	1,695,466	1,694,299	1,690,995	1,687,139
2030	1,149,301	906,122	903,830	897,332	888,453
2050	1,417,153	1,079,288	1,075,945	1,066,372	1,053,524
Particulate matter ($PM_{2.5}$)					
2018	73,483	73,423	73,322	73,108	72,807
2030	33,967	34,488	34,337	34,081	33,473
2050	40,904	41,593	41,369	41,004	40,070
Sulfur dioxide (SO_2)					
2018	99,692	95,636	95,139	94,031	92,689
2030	67,160	61,099	60,309	58,861	56,091
2050	88,750	80,134	78,956	76,862	72,604
Volatile organic compounds (VOC)					
2018	252,803	238,391	238,117	237,430	236,567
2030	179,747	150,736	149,959	148,094	144,912
2050	217,465	177,356	176,213	173,452	168,630

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

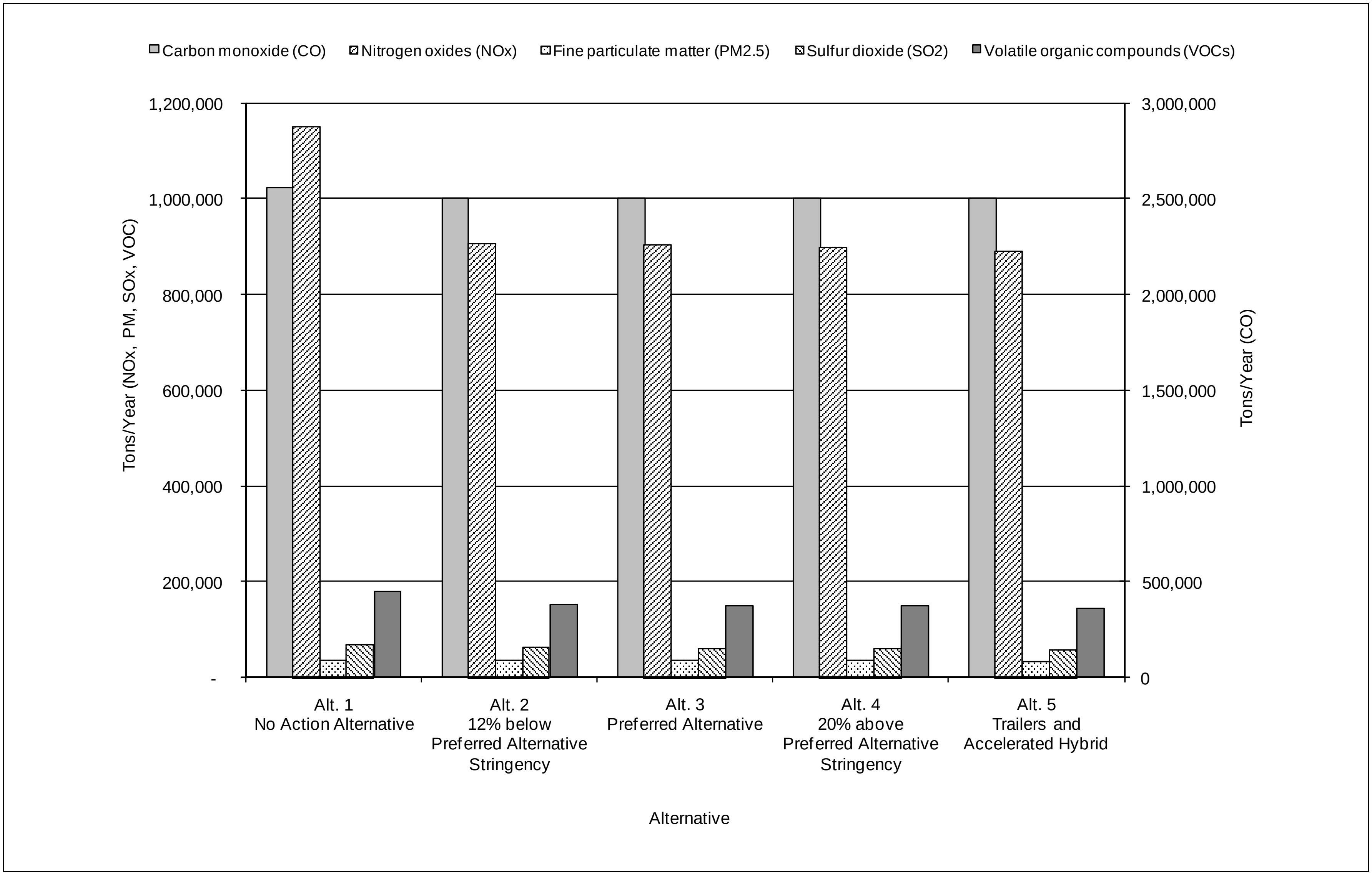


Figure 3.3.3-2. Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative

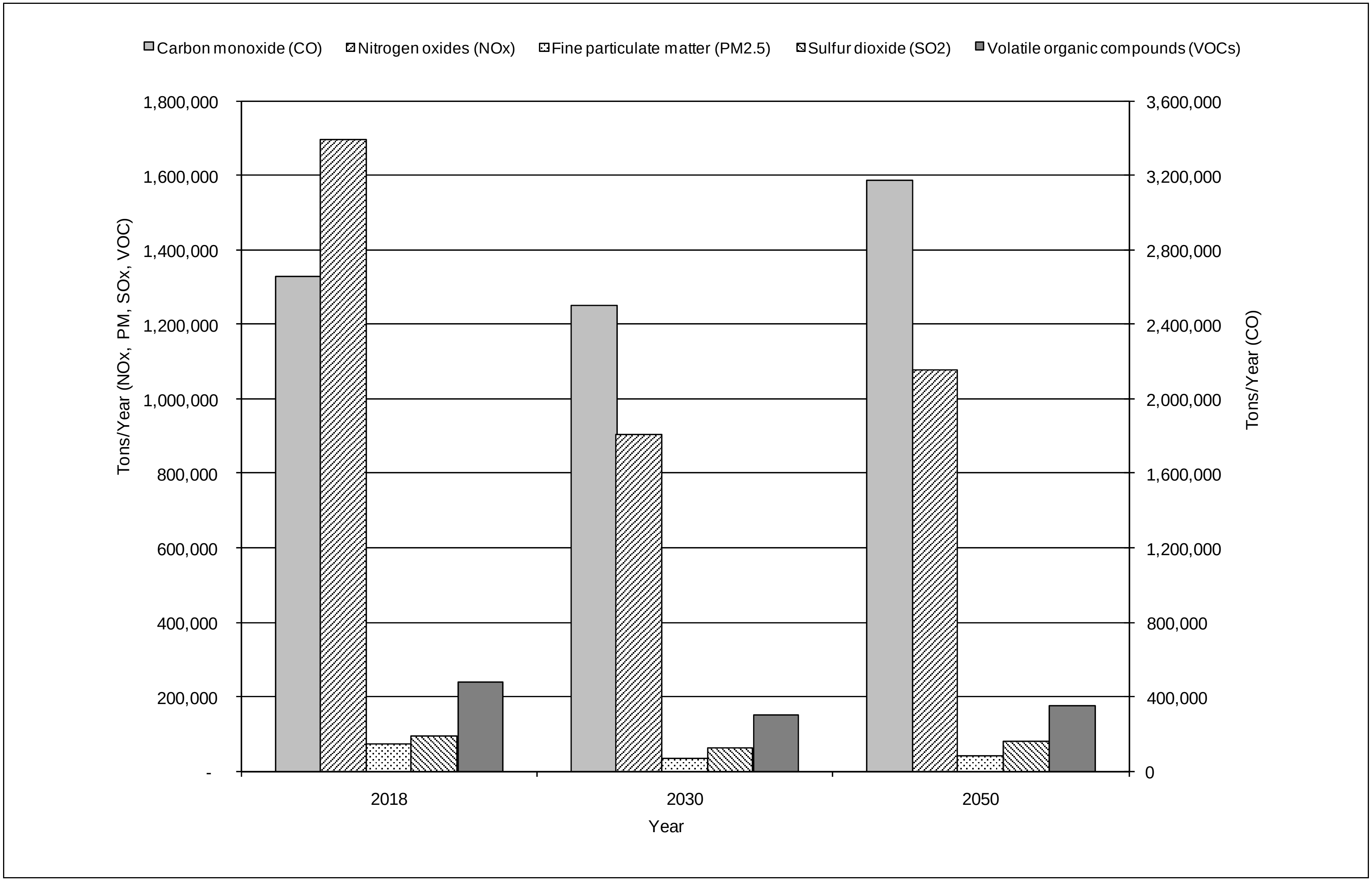


Table 3.3.3-2

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
Class 2b-3 Work Trucks Tailpipe	1,900,311	1,907,133	1,907,499	1,907,864	1,907,437
Class 2b-3 Work Trucks Upstream	4,713	4,309	4,247	4,164	3,857
Class 3-8 Vocational Vehicles Tailpipe	395,464	396,798	396,455	396,022	395,629
Class 3-8 Vocational Vehicles Upstream	6,064	5,827	5,664	5,488	4,870
Class 7-8 Day Cab Combination Unit Tailpipe	41,099	41,140	41,152	41,183	41,168
Class 7-8 Day Cab Combination Unit Upstream	8,389	7,715	7,642	7,633	7,533
Class 7-8 Sleeper Cab Combination Unit Tailpipe	189,125	128,552	128,569	128,630	128,706
Class 7-8 Sleeper Cab Combination Unit Upstream	13,331	11,680	11,596	11,169	10,855
Total	2,558,497	2,503,155	2,502,825	2,502,153	2,500,056
Nitrogen oxides (NO_x)					
Class 2b-3 Work Trucks Tailpipe	277,068	279,271	279,389	279,507	279,369
Class 2b-3 Work Trucks Upstream	14,252	13,033	12,846	12,591	11,661
Class 3-8 Vocational Vehicles Tailpipe	144,709	145,862	145,416	143,023	142,944
Class 3-8 Vocational Vehicles Upstream	18,163	17,454	16,966	16,439	14,591
Class 7-8 Day Cab Combination Unit Tailpipe	131,586	128,854	128,819	128,951	127,969
Class 7-8 Day Cab Combination Unit Upstream	25,085	23,071	22,852	22,823	22,526
Class 7-8 Sleeper Cab Combination Unit Tailpipe	498,577	263,652	262,869	260,601	256,934
Class 7-8 Sleeper Cab Combination Unit Upstream	39,862	34,926	34,673	33,396	32,457
Total	1,149,301	906,122	903,830	897,332	888,453
Particulate matter ($PM_{2.5}$)					
Class 2b-3 Work Trucks Tailpipe	3,233	3,252	3,253	3,254	3,250
Class 2b-3 Work Trucks Upstream	1,973	1,804	1,778	1,743	1,614
Class 3-8 Vocational Vehicles Tailpipe	4,645	4,681	4,701	4,751	4,726
Class 3-8 Vocational Vehicles Upstream	2,511	2,413	2,346	2,273	2,018
Class 7-8 Day Cab Combination Unit Tailpipe	4,121	4,101	4,098	4,102	4,103
Class 7-8 Day Cab Combination Unit Upstream	3,468	3,189	3,159	3,155	3,114
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,505	10,219	10,208	10,185	10,160
Class 7-8 Sleeper Cab Combination Unit Upstream	5,511	4,828	4,793	4,617	4,487
Total	33,967	34,488	34,337	34,081	33,473
Sulfur dioxide (SO_2)					
Class 2b-3 Work Trucks Tailpipe	908	837	825	802	743
Class 2b-3 Work Trucks Upstream	9,045	8,269	8,151	7,991	7,401
Class 3-8 Vocational Vehicles Tailpipe	879	844	822	792	708
Class 3-8 Vocational Vehicles Upstream	11,641	11,186	10,873	10,535	9,348
Class 7-8 Day Cab Combination Unit Tailpipe	1,146	1,054	1,044	1,043	1,029
Class 7-8 Day Cab Combination Unit Upstream	16,104	14,811	14,671	14,653	14,462

Table 3.3.3-2 (continued)

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Class 7-8 Sleeper Cab Combination Unit Tailpipe	1,845	1,675	1,663	1,605	1,562
Class 7-8 Sleeper Cab Combination Unit Upstream	25,591	22,422	22,260	21,440	20,838
Total	67,160	61,099	60,309	58,861	56,091
Volatile organic compounds (VOC)					
Class 2b-3 Work Trucks Tailpipe	48,103	48,231	48,222	48,192	48,050
Class 2b-3 Work Trucks Upstream	26,546	24,831	24,484	23,455	21,727
Class 3-8 Vocational Vehicles Tailpipe	18,275	18,198	18,118	17,994	17,670
Class 3-8 Vocational Vehicles Upstream	8,804	8,473	8,338	8,218	7,744
Class 7-8 Day Cab Combination Unit Tailpipe	9,328	8,946	8,903	8,901	8,849
Class 7-8 Day Cab Combination Unit Upstream	6,116	5,625	5,571	5,564	5,492
Class 7-8 Sleeper Cab Combination Unit Tailpipe	52,856	27,917	27,870	27,627	27,467
Class 7-8 Sleeper Cab Combination Unit Upstream	9,718	8,515	8,453	8,142	7,913
Total	179,747	150,736	149,959	148,094	144,912

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 compared to the No Action Alternative. Figure 3.3.3-3 shows these changes in percentage terms for 2030. As a general trend, emissions of each pollutant decrease from Alternatives 2 through 5, as each successive Alternative becomes more stringent. However, the magnitudes of the declines are not consistent across all pollutants, reflecting the complex interactions between tailpipe emission rates of the various vehicle types, the technologies assumed to be incorporated by manufacturers in response to the proposed standards, upstream emission rates, the relative proportions of gasoline and diesel in total fuel consumption reductions, and increases in VMT. The greatest relative reductions in emissions among the criteria pollutants occur for NO_x, SO_2, and VOC, for which emissions decrease by less than 10 percent in 2018 and greater than 10 percent in 2030 and 2050 compared to the No Action Alternative. Emissions of $PM_{2.5}$ are a partial exception to this declining trend, showing slight increases under Alternatives 2, 3, and 4 due to the assumed usage of APUs by sleeper cab combination units.

Many of the differences between one action alternative and another in national emissions of criteria air pollutants are slight, in the range of 1 percent or less. Consequently, such differences are not expected to lead to measurable changes in ambient concentrations of criteria pollutants. For such small changes the impacts of those action alternatives would be essentially equivalent.

Table 3.3.3-3

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

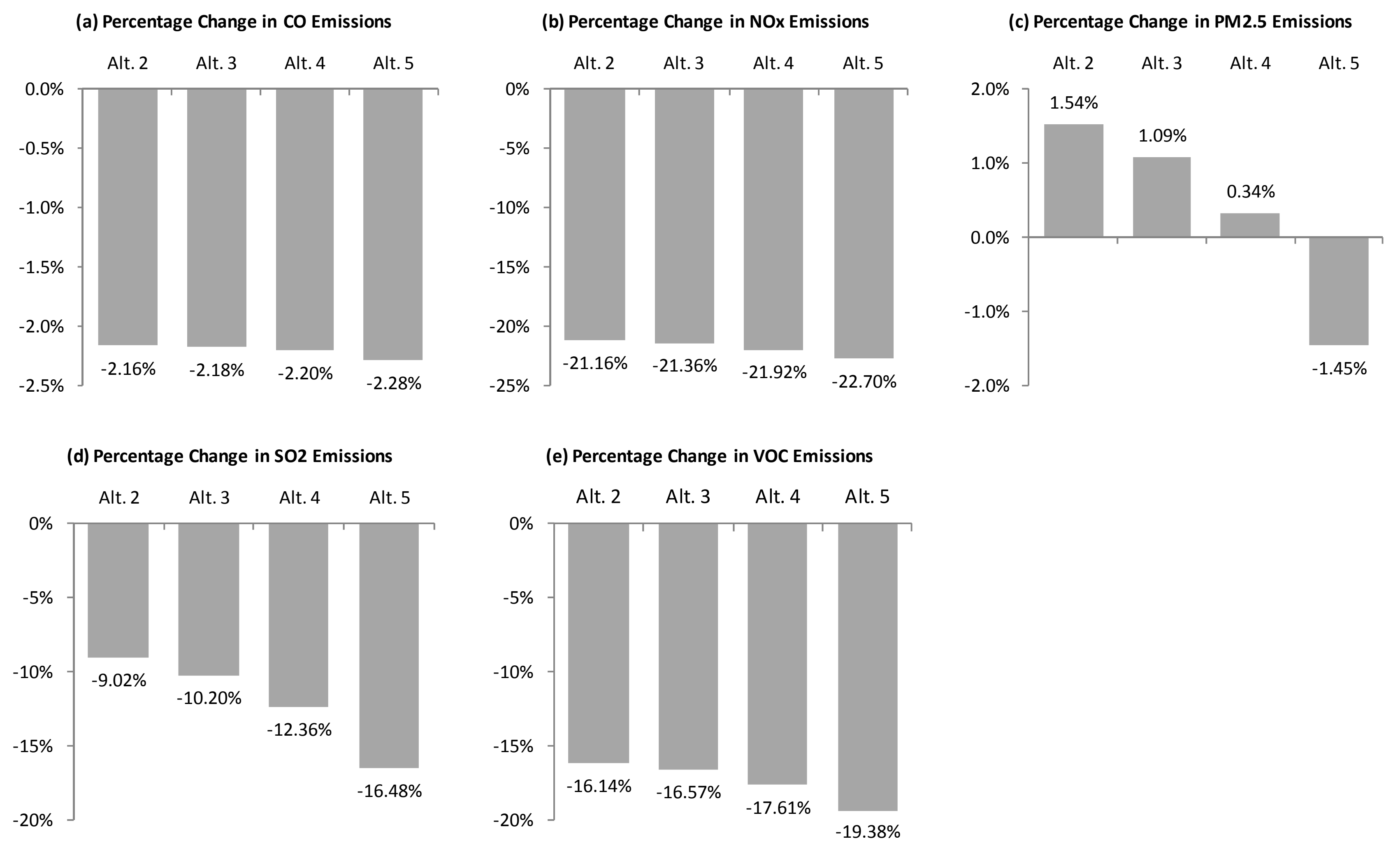
Poll. and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	0	-27,671	-27,861	-28,425	-29,237
2030	0	-55,343	-55,673	-56,344	-58,441
2050	0	-76,671	-76,984	-77,988	-81,009
Nitrogen oxides (NO_x)					
2018	0	-112,566	-113,733	-117,037	-120,893
2030	0	-243,179	-245,471	-251,968	-260,848
2050	0	-337,865	-341,208	-350,781	-363,629
Particulate matter ($PM_{2.5}$)					
2018	0	-60	-161	-375	-676
2030	0	522	371	114	-494
2050	0	689	465	100	-834
Sulfur dioxide (SO_2)					
2018	0	-4,057	-4,553	-5,661	-7,003
2030	0	-6,061	-6,851	-8,299	-11,069
2050	0	-8,615	-9,793	-11,887	-16,146
Volatile organic compounds (VOC)					
2018	0	-14,412	-14,685	-15,373	-16,236
2030	0	-29,011	-29,788	-31,653	-34,835
2050	0	-40,109	-41,252	-44,013	-48,835

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Figure 3.3.3-3. Nationwide Percentage Changes in Criteria Pollutant Emissions from HD Vehicles by Alternative in 2030, Compared to the No Action Alternative



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid
Note: percentage scales differ for each pollutant.

Table 3.3.3-4 summarizes the criteria air pollutant analysis results by nonattainment area. Tables in Appendix D list the emissions changes for each nonattainment area. For CO, NO_x, SO_2 and VOC, all nonattainment areas experience decreases in emissions across all alternatives and years, while for $PM_{2.5}$, most nonattainment areas experience increases in emissions across all alternatives and years.

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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-9,154	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-41,578	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Particulate matter ($PM_{2.5}$)	Maximum Increase	216	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-274	2050	Alt. 5	Houston-Galveston-Brazoria, TX (Ozone)
Sulfur dioxide (SO_2)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,240	2050	Alt. 5	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	-4,555	2050	Alt. 5	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 toxic air pollutants and analysis years. 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, benzene, and formaldehyde decrease from Alternative 1 to Alternative 2, then remain relatively stable under each successive alternative from Alternative 2 to Alternative 5. Emissions of 1,3-butadiene are approximately equivalent for each alternative and year. For DPM, emissions are slightly lower in 2018 for Alternatives 2 through 5 compared to the No Action Alternative. DPM emissions are higher for Alternatives 2 and 3, slightly lower for Alternative 4, and lower for Alternative 5 in 2030 and 2050. These trends are accounted for by the extent of technologies assumed to be deployed under the different alternatives to meet the different levels of fuel efficiency requirements.

Figure 3.3.3-4 shows changes in toxic air pollutant emissions for each alternative for 2030, the mid-term forecast year.

Table 3.3.3-5

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

Pollutant and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	6,213	5,340	5,340	5,340	5,340
2030	4,700	2,787	2,788	2,788	2,788
2050	5,946	3,289	3,290	3,291	3,290
Acrolein					
2018	952	832	832	832	832
2030	650	387	387	387	387
2050	812	446	446	446	446
Benzene					
2018	3,401	3,232	3,231	3,228	3,224
2030	2,314	1,956	1,954	1,949	1,940
2050	2,750	2,254	2,251	2,244	2,229
1,3-Butadiene					
2018	600	599	599	599	599
2030	300	299	299	299	299
2050	327	326	326	326	325
Diesel particulate patter (DPM)					
2018	67,936	67,847	67,734	67,472	67,158
2030	26,065	26,539	26,360	26,007	25,380
2050	30,247	30,863	30,596	30,080	29,122
Formaldehyde					
2018	15,509	12,644	12,644	12,642	12,640
2030	13,509	7,226	7,227	7,224	7,216
2050	17,537	8,810	8,812	8,808	8,795

Figure 3.3.3-4. Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative

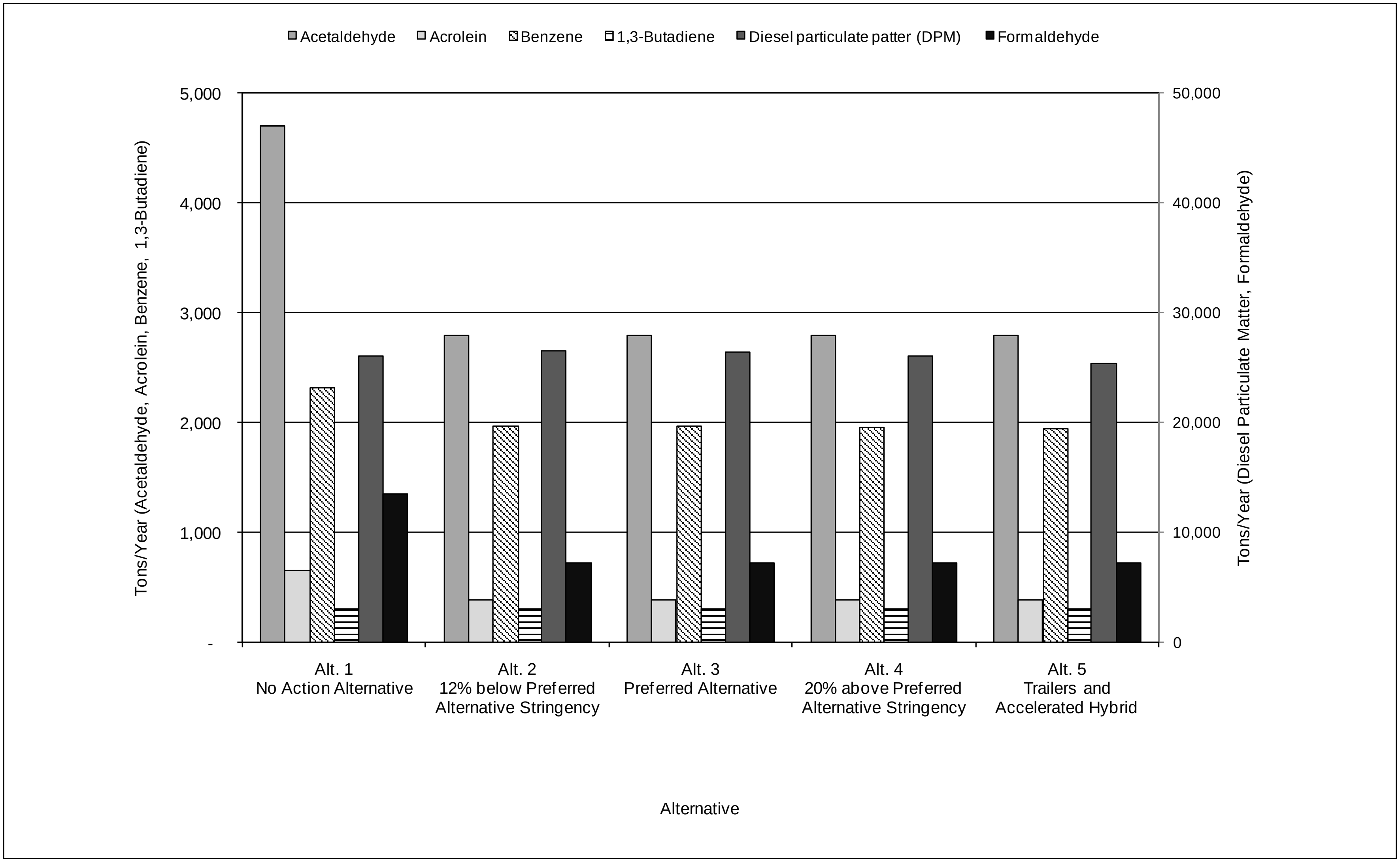


Figure 3.3.3-5 summarizes the changes over time in total national emissions of toxic air pollutants from HD vehicles for the Preferred Alternative. Figure 3.3.3-5 indicates a consistent trend among the toxic air pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production, but increase from 2030 to 2050 due to continuing growth in VMT.

As described above in Section 3.3.3.1.1, total emissions are made up of eight components: two types of emissions (tailpipe and upstream) for each of the four classes of vehicles covered by the proposal. To show the relationship among these eight emissions 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 compared to the No Action Alternative. Figure 3.3.3-6 shows these changes in percentage terms for 2030. Table 3.3.3-7 and Figure 3.3.3-6 show that the magnitude of nationwide emission changes tends to increase from 2018 to 2030 to 2050, and that emissions under the action alternatives are very similar for most pollutants (except DPM).

Many of the differences between one action alternative and another in national emissions of toxic air pollutants are slight, in the range of 1 percent or less. Consequently, such differences are not expected to lead to measurable changes in ambient concentrations of toxic air pollutants. For such small changes, the impacts of those action alternatives would be essentially equivalent.

Table 3.3.3-8 summarizes the air toxics analysis results by nonattainment area.[38] Tables in Appendix D list the estimated emission reductions for each nonattainment area. For acetaldehyde, acrolein, benzene, and formaldehyde, all nonattainment areas experience decreases in emissions across all alternatives and years. For 1,3-butadiene, emissions decrease in all nonattainment areas in 2018, but increase in most or all nonattainment areas in 2030 and 2050 across all alternatives. For DPM, emissions increase in most nonattainment areas in all years and alternatives.

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). Table 3.3.3-10 lists the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative. The reductions in adverse health effects and the monetized health benefits are greater under the more stringent alternatives.

For all health outcomes and years, the health benefits uniformly increase from Alternative 2 (least stringent) to Alternative 5 (most stringent). The benefits also increase steadily from the near future (2018) to later years (2050). These trends are consistent across all health outcomes: in 2018, there is a benefit of between 2 percent and 3 percent in every outcome. In 2050, this benefit increases to 8 percent to 12 percent. PM mortality is measured in two ways using the Pope and Laden coefficients. While the number of PM mortalities varies between the two methods, the percent change in mortality across alternatives and years is equal.

[38] EPA has not established NAAQS for airborne toxics. Thus, none of these areas is nonattainment because of emissions of airborne toxics.

Figure 3.3.3-5. Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative

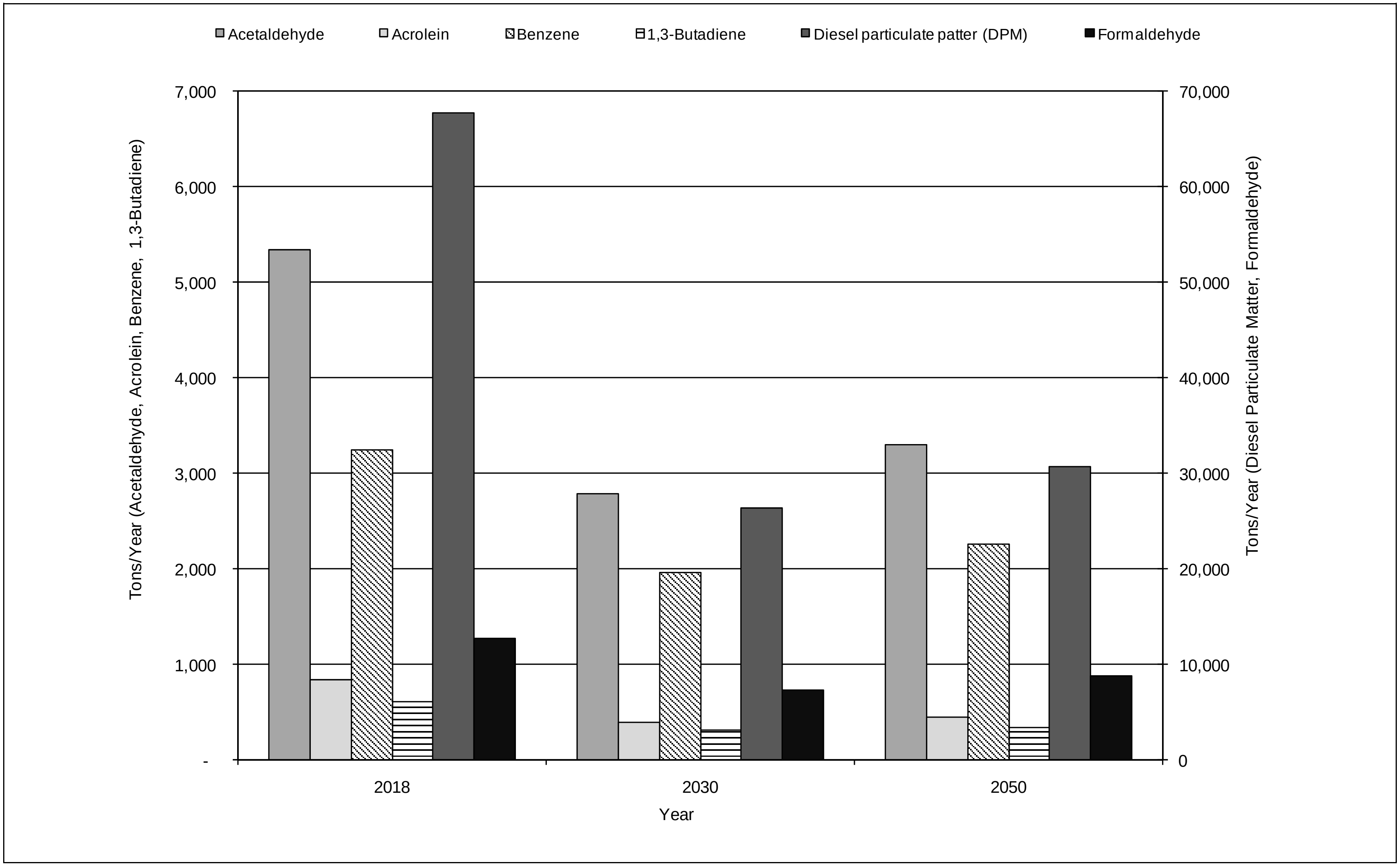


Table 3.3.3-6

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
Class 2b-3 Work Trucks Tailpipe	456	457	457	457	457
Class 2b-3 Work Trucks Upstream	5	4	4	4	4
Class 3-8 Vocational Vehicles Tailpipe	1058	1064	1065	1065	1063
Class 3-8 Vocational Vehicles Upstream	6	6	6	6	5
Class 7-8 Day Cab Combination Unit Tailpipe	279	280	280	280	281
Class 7-8 Day Cab Combination Unit Upstream	9	8	8	8	8
Class 7-8 Sleeper Cab Combination Unit Tailpipe	2875	956	956	957	958
Class 7-8 Sleeper Cab Combination Unit Upstream	14	12	12	11	11
Total	4,700	2,787	2,788	2,788	2,788
Acrolein					
Class 2b-3 Work Trucks Tailpipe	69	70	70	70	70
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	113	114	114	114	113
Class 3-8 Vocational Vehicles Upstream	1	1	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	41	41	41	41	41
Class 7-8 Day Cab Combination Unit Upstream	1	1	1	1	1
Class 7-8 Sleeper Cab Combination Unit Tailpipe	422	158	158	159	159
Class 7-8 Sleeper Cab Combination Unit Upstream	2	2	2	2	2
Total	650	387	387	387	387
Benzene					
Class 2b-3 Work Trucks Tailpipe	88	89	89	89	89
Class 2b-3 Work Trucks Upstream	61	57	56	54	50
Class 3-8 Vocational Vehicles Tailpipe	1,425	1,433	1,434	1,434	1,432
Class 3-8 Vocational Vehicles Upstream	37	35	34	34	31
Class 7-8 Day Cab Combination Unit Tailpipe	53	53	53	53	53
Class 7-8 Day Cab Combination Unit Upstream	41	37	37	37	36
Class 7-8 Sleeper Cab Combination Unit Tailpipe	545	195	195	195	196
Class 7-8 Sleeper Cab Combination Unit Upstream	64	56	56	54	52
Total	2,314	1,956	1,954	1,949	1,940

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
1,3-butadiene					
Class 2b-3 Work Trucks Tailpipe	12	12	12	12	12
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	228	230	230	230	230
Class 3-8 Vocational Vehicles Upstream	2	2	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	5	5	5	5	5
Class 7-8 Day Cab Combination Unit Upstream	2	2	2	2	2
Class 7-8 Sleeper Cab Combination Unit Tailpipe	47	46	46	46	46
Class 7-8 Sleeper Cab Combination Unit Upstream	3	3	3	3	3
Total	300	299	299	299	299
Diesel particulate matter (DPM)					
Class 2b-3 Work Trucks Tailpipe	1,491	1,495	1,495	1,495	1,493
Class 2b-3 Work Trucks Upstream	1,954	1,787	1,761	1,726	1,599
Class 3-8 Vocational Vehicles Tailpipe	2,332	2,345	2,339	2,306	2,298
Class 3-8 Vocational Vehicles Upstream	2,494	2,397	2,330	2,257	2,004
Class 7-8 Day Cab Combination Unit Tailpipe	2,652	2,609	2,606	2,609	2,595
Class 7-8 Day Cab Combination Unit Upstream	3,446	3,169	3,139	3,135	3,094
Class 7-8 Sleeper Cab Combination Unit Tailpipe	6,221	7,940	7,927	7,891	7,839
Class 7-8 Sleeper Cab Combination Unit Upstream	5,475	4,797	4,763	4,587	4,458
Total	26,065	26,539	26,360	26,007	25,380
Formaldehyde					
Class 2b-3 Work Trucks Tailpipe	1,341	1,346	1,347	1,347	1,347
Class 2b-3 Work Trucks Upstream	37	34	33	33	30
Class 3-8 Vocational Vehicles Tailpipe	2,244	2,258	2,261	2,260	2,256
Class 3-8 Vocational Vehicles Upstream	47	46	44	43	38
Class 7-8 Day Cab Combination Unit Tailpipe	852	856	857	857	859
Class 7-8 Day Cab Combination Unit Upstream	66	60	60	60	59
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,817	2,534	2,535	2,538	2,542
Class 7-8 Sleeper Cab Combination Unit Upstream	104	91	91	87	85
Total	13,509	7,226	7,227	7,224	7,216

Table 3.3.3-7

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

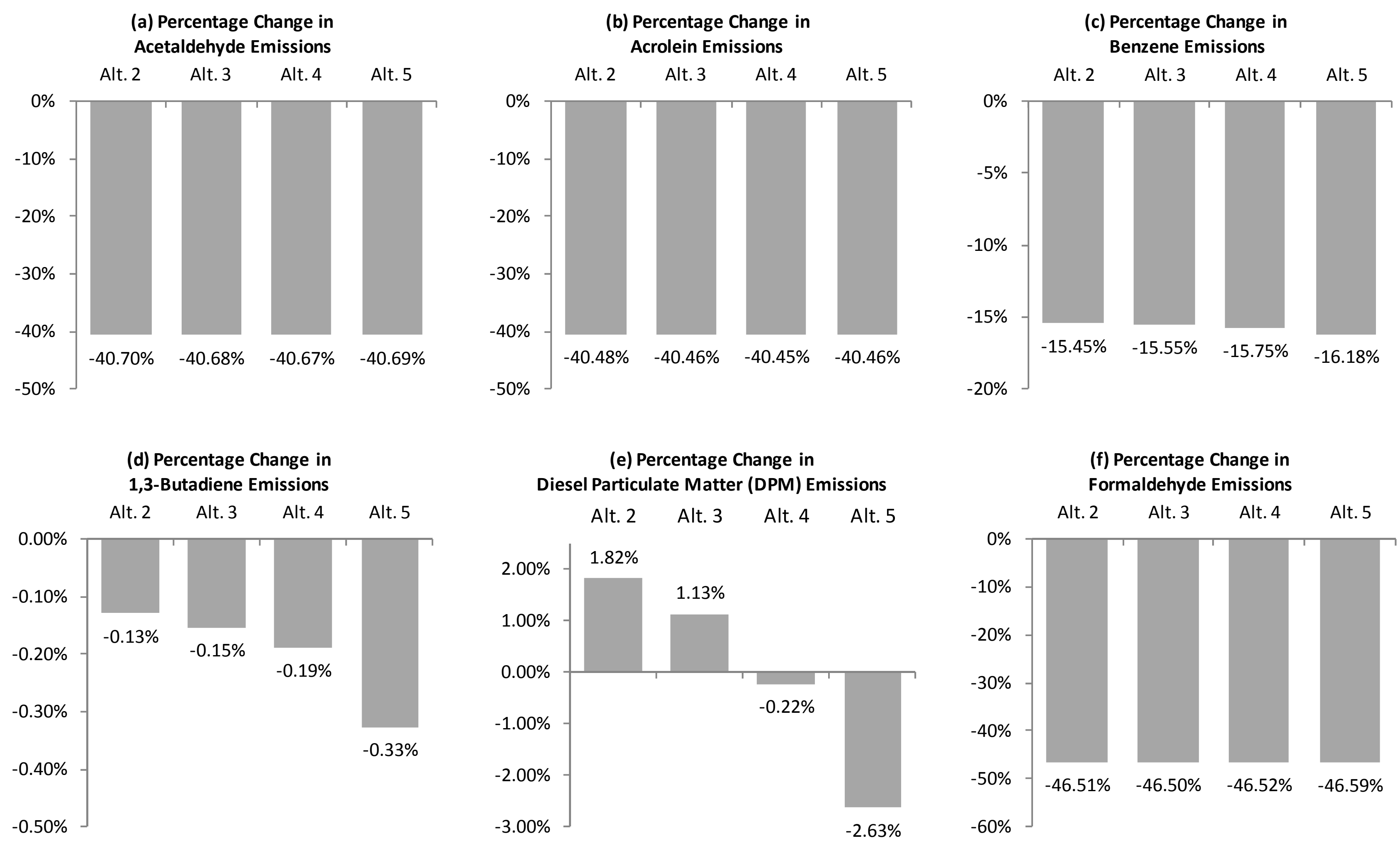
Pollutant and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	0	-873	-873	-873	-873
2030	0	-1,913	-1,912	-1,911	-1,912
2050	0	-2,657	-2,655	-2,655	-2,656
Acrolein					
2018	0	-120	-120	-120	-120
2030	0	-263	-263	-263	-263
2050	0	-366	-365	-365	-365
Benzene					
2018	0	-168	-170	-173	-176
2030	0	-358	-360	-364	-374
2050	0	-496	-499	-506	-521
1,3-Butadiene					
2018	0	-1	-1	-1	-1
2030	0	0	0	-1	-1
2050	0	0	0	-1	-1
Diesel particulate matter (DPM)					
2018	0	-89	-202	-464	-778
2030	0	**474**	**294**	-58	-685
2050	0	**616**	**349**	-167	-1,126
Formaldehyde					
2018	0	-2,865	-2,865	-2,867	-2,869
2030	0	-6,282	-6,282	-6,284	-6,293
2050	0	-8,726	-8,725	-8,729	-8,742

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Figure 3.3.3-6. Nationwide Percentage Changes in Toxic Air Pollutant Emissions from HD Vehicles by Alternative in 2030, Compared to the No Action Alternative



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid
Note: percentage scales differ for each pollutant.

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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-320	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Acrolein	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-44	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Benzene	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-57	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	0.1	2050	Alt. 4	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-0.5	2050	Alt. 5	Houston-Galveston-Brazoria, TX (Ozone)
Diesel particulate matter (DPM)	Maximum Increase	206	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-278	2050	Alt. 5	Houston-Galveston-Brazoria, TX (Ozone)
Formaldehyde	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,049	2050	Alt. 2	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.

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Mortality (ages 30 and older), Pope *et al.* (2002)					
2018	0	-78	-83	-95	-109
2030	0	-169	-179	-197	-233
2050	0	-270	-285	-315	-378
Mortality (ages 30 and older), Laden *et al.* (2006)					
2018	0	-201	-214	-242	-281
2030	0	-433	-457	-503	-597
2050	0	-689	-729	-804	-965
Chronic bronchitis					
2018	0	-56	-59	-67	-77
2030	0	-116	-122	-135	-159
2050	0	-179	-189	-208	-248
Emergency Room Visits for Asthma					
2018	0	-67	-71	-82	-96
2030	0	-131	-140	-156	-188
2050	0	-200	-213	-238	-291
Work-Loss Days					
2018	0	-10,748	-11,402	-12,879	-14,837
2030	0	-21,051	-22,168	-24,332	-28,695
2050	0	-30,952	-32,683	-35,952	-42,904

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Table 3.3.3-10

Nationwide Monetized Health Benefits (2009 U.S. million dollars per year) from Criteria Pollutant Emissions from HD Vehicles by Alternative a/

Pollutant and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
3-Percent Discount Rate					
Pope *et al.* (2002)					
2018	0	-695	-739	-839	-971
2030	0	-1,559	-1,646	-1,812	-2,149
2050	0	-2,528	-2,675	-2,951	-3,539
Laden *et al.* (2006)					
2018	0	-1,701	-1,809	-2,054	-2,377
2030	0	-3,814	-4,026	-4,434	-5,258
2050	0	-6,185	-6,544	-7,221	-8,663
7-Percent Discount Rate					
Pope *et al.* (2002)					
2018	0	-631	-671	-762	-881
2030	0	-1,415	-1,493	-1,644	-1,949
2050	0	-2,293	-2,426	-2,677	-3,210
Laden *et al.* (2006)					
2018	0	-1,537	-1,635	-1,855	-2,147
2030	0	-3,445	-3,637	-4,006	-4,750
2050	0	-5,586	-5,911	-6,522	-7,824

a/ Negative changes indicate monetized health benefits; positive emissions 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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

The monetized health benefits of these health trends follow similar trends to the changes in health outcomes. The monetized health benefits of each alternative increase (in percentage terms) from Alternative 2 (least stringent) to Alternative 5 (most stringent) and from the near future (2018) to later years (2050). Monetized health benefits are measured in several ways: first, benefits under the Pope methodology versus the Laden methodology (*see* Section 3.3.2.7.2), and second, benefits under a 3 percent discount rate versus a 7 percent discount rate. Because the 7 percent discount rate places less present value on future year benefits than the 3 percent discount rate, the present year benefit of reductions in 2050 is approximately 10 percent smaller under the 7 percent discount rate than the 3 percent discount rate. In total, the monetized health benefits range between $630 million and $8.7 billion depending on the scenario, alternative, and year.

Sections 3.3.3.2 through 3.3.3.9 describe the results of the analysis of emissions for Alternatives 1 through 5 in greater detail. The magnitude of emission change from one alternative to the next generally increases between Alternative 2 and Alternative 5 consistent with the required greater overall fuel efficiency. Health and monetized health benefits increase with each alternative from Alternative 2 through Alternative 5.

3.3.3.2 Alternative 1: No Action Alternative

3.3.3.2.1 Criteria Pollutants

Under the No Action Alternative used for the analysis in this section, future new vehicles would match levels of fuel efficiency equivalent to MY 2010 vehicles (s*ee* Section 3.1). Current trends in the levels of criteria pollutant emissions from vehicles would continue, with emissions continuing to decline due to tightening EPA emission standards (*see* Section 3.3.1), despite a growth in total VMT from 2018 to 2030, but increasing from 2030 to 2050 due to continuing growth in total VMT during that period (*see* Table 3.3.3-1). 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 (*see* Table 3.3.3-3) beyond changes projected to result from future trends in emissions and VMT.

3.3.3.2.2 Toxic Air Pollutants

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 under the No Action Alternative, with emissions continuing to decline due to the EPA emission standards (s*ee* Section 3.3.1), 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 (*see* Table 3.3.3-5 and Figure 3.3.3-4). 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 (*see* Table 3.3.3-7) beyond current trends shown in Table 3.3.3-5.

The difference in emissions from the No Action Alternative to each of the action alternatives is generally greater than 10 percent in 2018 and 40 percent in 2030 and 2050, though the differences between the action alternatives are generally slight. The exceptions are 1,3-butadiene, for which emissions reductions between the No Action Alternative and all action alternatives are slight for all years, and DPM, for which the change in emissions is less than 10 percent for all action alternatives and years.

3.3.3.2.3 Health Outcomes and Monetized Benefits

Under the No Action Alternative, current trends in the levels of criteria pollutant and toxic air pollutant emissions from vehicles would continue, with emissions continuing to decline due to the increasingly stringent EPA emission standards (*see* Section 3.3.1), despite a growth in total VMT. The human health-related impacts expected under current trends would continue (*see* Tables 3.3.3-9 and 3.3.3-10). 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: 12 percent below Preferred Alternative Stringency

3.3.3.3.1 Criteria Pollutants

Table 3.3.3-3 and Figure 3.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 2, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would be reduced. Alternative 2 is the least stringent of all the action alternatives and the reductions under Alternative 2 are smaller than those under the other action alternatives. Because Alternative 2 assumes that sleeper cab combination units would use APUs during extended idling, and because APUs have higher PM emission rates than do the truck main engines, this alternative would have higher $PM_{2.5}$ emissions than would the No Action Alternative in 2030 and 2050.

Under Alternative 2, 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 and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

3.3.3.3.2 Toxic Air Pollutants

Table 3.3.3-7 and Figure 3.3.3-4 show the changes in nationwide emissions of toxic air pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 2 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years. DPM emissions would increase slightly under some alternatives and years but decrease in others (*see* Table 3.3.3-7 and Figure 3.3.3-6). Emissions reductions under Alternative 2 would be approximately equivalent to those under the other action alternatives for all studied toxic air pollutants, except that DPM emissions would increase slightly.

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 rebound effect. However, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 2, 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 all nonattainment years in all years, and 1,3-butadiene, which would increase in all nonattainment areas in 2030 and most nonattainment areas in 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.

3.3.3.3.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced compared to the No Action Alternative (*see* Table 3.3.3-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.3.3-10, the monetized health benefits of Alternative 2 range from approximately $630 million to $6.2 billion. These monetized health benefits are the smallest of all the action alternatives.

3.3.3.4 Alternative 3: Preferred Alternative

3.3.3.4.1 Criteria Pollutants

Table 3.3.3-3 and Figure 3.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-3 shows these changes in percentage terms for 2030. Under this alternative, emissions of all pollutants except $PM_{2.5}$ are reduced compared to the No Action Alternative. Because Alternative 3 assumes that sleeper cab combination units would use APUs during extended idling, and the APUs have higher PM emission rates than do the truck main engines, this alternative would have higher $PM_{2.5}$ emissions than would the No Action Alternative in 2030 and 2050. This Alternative reduces emissions by a greater amount than Alternative 2, but less than the more stringent Alternatives 4 and 5.

Under Alternative 3, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (s*ee* Appendix D). 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 and APU usage.

3.3.3.4.2 Toxic Air Pollutants

Table 3.3.3-7 and Figure 3.3.3-4 show the changes in nationwide emissions of toxic pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 3 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and slightly reduced emissions of 1,3-butadiene, for all years. DPM emissions would decrease slightly in 2018 and increase in 2030 and 2050. Emissions reductions under Alternative 3 are approximately equivalent to those under Alternatives 4 and 5 for all studied toxic air pollutants except DPM. Emissions of DPM increase slightly under Alternative 3 and thus are slightly greater than under Alternatives 4 and 5 (*see* Figure 3.3.3-6, panel (e)).

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 rebound effect. As with less stringent alternatives, 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 all 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 all nonattainment areas in 2030 and most nonattainment areas in 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.

3.3.3.4.3 Health Outcomes and Monetized Benefits

Reductions in adverse health effects would occur nationwide under Alternative 3 compared to the No Action Alternative (*see* Table 3.3.3-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.3.3-10, the monetized health benefits of Alternative 3 range from approximately $670 million to $6.5 billion. These benefits are greater than those of Alternative 2 for all health outcomes and years, but less than those of Alternatives 4 and 5.

3.3.3.5 Alternative 4: 20 percent above Preferred Alternative Stringency

3.3.3.5.1 Criteria Pollutants

Table 3.3.3-3 and Figure 3.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 4, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would decrease in all years. Because Alternative 4 assumes that sleeper cab combination units would use APUs during extended idling, and the APUs have higher PM emission rates than do the truck main engines, this alternative would have higher slightly $PM_{2.5}$ emissions than would the No Action Alternative in 2030 and 2050.

This Alternative reduces CO, NO_x, SO_2, and VOC emissions by a greater amount than Alternatives 2 and 3, but less than the more stringent Alternative 5. $PM_{2.5}$ emissions under Alternative 4 are slightly less than under Alternatives 2 and 3, but slightly greater than under Alternative 5.

Under Alternative 4, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (s*ee* Appendix D). 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.

3.3.3.5.2 Toxic Air Pollutants

Tables 3.3.3-5, 3.3.3-6, and 3.3.3-7 and Figure 3.3.3-4 show the changes in nationwide emissions of criteria pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-6 shows these changes in percentage terms for 2030. 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; and slightly reduced emissions of DPM in all analysis years. Emissions reductions under Alternative 4 are approximately equivalent to those under Alternative 5 for all studied toxic air pollutants except DPM for which emissions are higher in 2030 and 2050. Compared to the No Action Alternative, Alternative 3 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and slightly reduced emissions of 1,3-butadiene and DPM, for all years.

At the national level, as for less stringent alternatives, emissions of toxic air pollutants could decrease for the reasons described above (*see* Section 3.3.3.4.2). Under Alternative 4, all nonattainment areas would experience net decreases in emissions of all 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.

3.3.3.5.3 Health Outcomes and Monetized Benefits

Adverse health effects would be reduced nationwide under Alternative 4 compared to the No Action Alternative (*see* Table 3.3.3-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.3.3-10, monetized health benefits of Alternative 4 range from approximately $760 million to $7.2 billion as compared to the No Action Alternative. The health and monetized health benefits are greater than under Alternatives 2 and 3 but less than under Alternative 5.

3.3.3.6 Alternative 5: Trailers and Accelerated Hybrid

3.3.3.6.1 Criteria Pollutants

Table 3.3.3-3 and Figure 3.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 5 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 5, nationwide emissions of all criteria pollutants compared to the No Action Alternative would be reduced. These reductions would be greater than under any other alternative.

Under Alternative 5, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (s*ee* Appendix D). 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 and APU usage.

3.3.3.6.2 Toxic Air Pollutants

Tables 3.3.3-5, 3.3.3-6, and 3.3.3-7 and Figure 3.3.3-4 show the changes in nationwide emissions of criteria pollutants under Alternative 5 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-6 shows these changes in percentage terms for 2030. Alternative 5 would result in reduced emissions of all studied toxic air pollutants in all analysis years compared to the No Action Alternative. Emissions of air toxics under Alternative 5 would be lower than, or essentially equivalent to, those under any other alternative. The differences in emissions among Alternatives 2 through 5 are slight, though the reductions in PM2.5 emissions under Alternative 5 are somewhat greater than under the other action alternatives.

At the national level, as for less stringent alternatives, emissions of toxic air pollutants could decrease for the reasons described above (*see* Section 3.3.3.4.2). Under Alternative 5, all nonattainment areas would experience net decreases in emissions of all 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

Reductions in adverse health effects nationwide would occur under Alternative 5 compared to the No Action Alternative (*see* Table 3.3.3-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.3.3-10, the monetized health benefits of Alternative 5 range from approximately $880 million to $8.7 billion. The health and monetized health benefits of Alternative 5 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. Although CEQ released Draft NEPA Guidance on Consideration of the Effects of Climate Change and GHG Emissions in February 2010, regarding the treatment of GHG emissions under NEPA, there is currently no formal guidance or regulation for addressing climate change within the structure of an EIS. Thus 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.[39]

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 supplement—but do not supersede—the findings of the panel-reviewed reports. In virtually every case, it corroborates the findings of these reports.

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[39] The climate modeling in Chapter 4 applies different assumptions about the effect of broader global GHG policies on emissions outside the U.S. HD vehicle fleet. 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 focus on particular issues responds to public comments received on the DEIS and scoping document, the EIS for the MY 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 MY 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.[40]

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:

[40] 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); in the Atlantic Ocean, the maximum rate of change over the last 50 years has been over 2 millimeters (0.08 inch) per year observed in a band running east-northeast from the U.S. east coast (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 almost entirely anthropogenic in origin. These gases are created mainly 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)

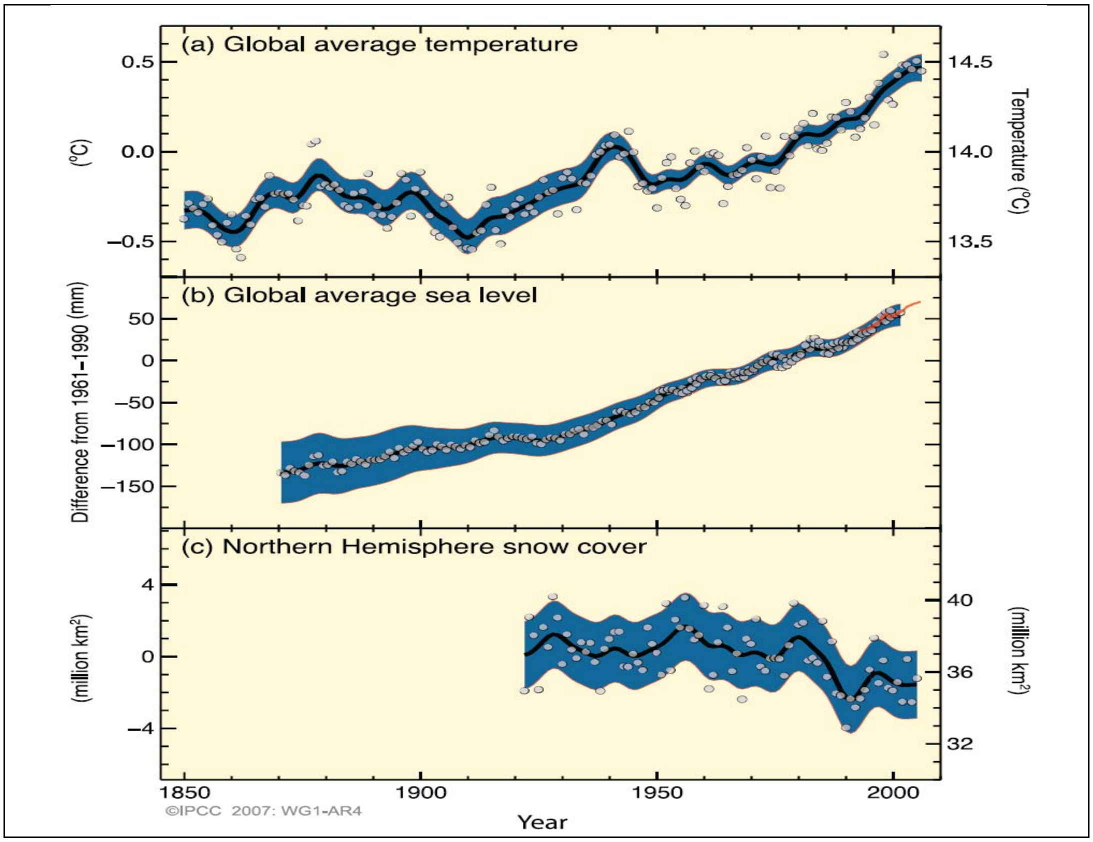
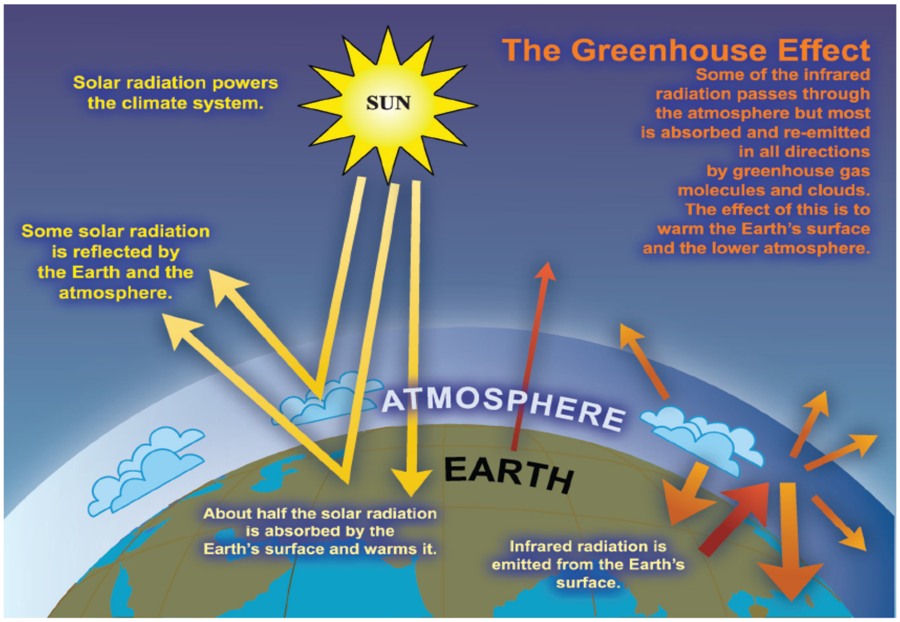


Figure 3.4.1-2. The Greenhouse Effect (Source: Le Treut *et al.* 2007)



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 2011)[41] – had, by 2007, 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 had increased from about 280 ppm to 386 ppm by 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.

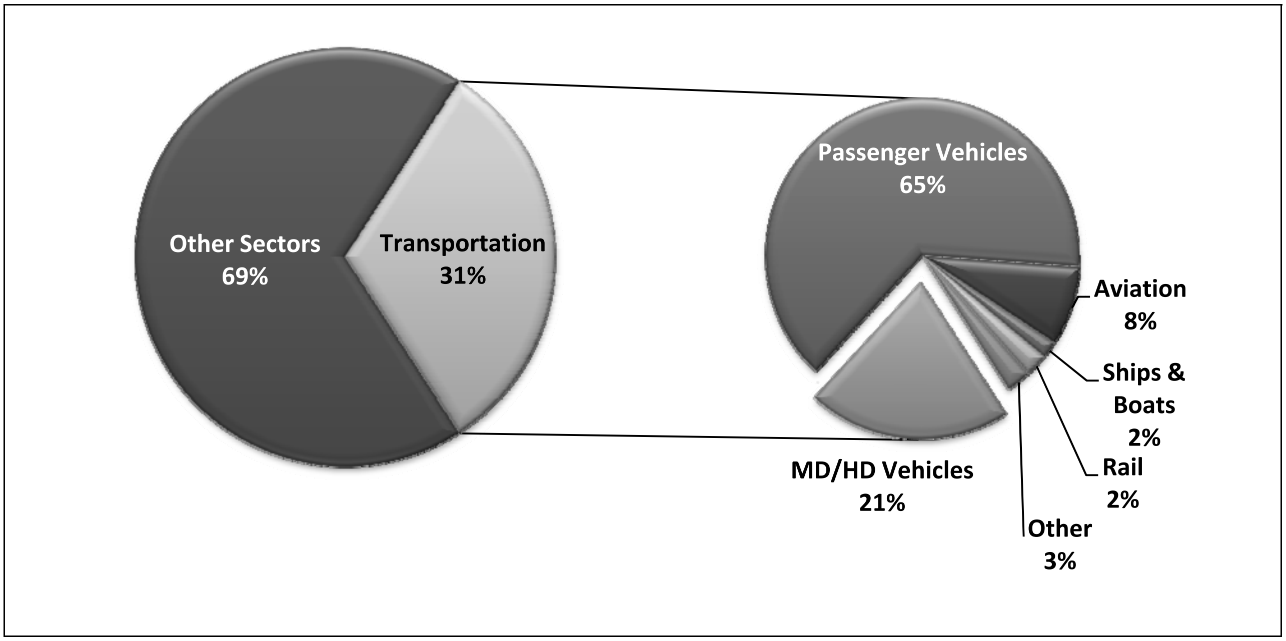
Contributions to the buildup of GHGs in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity, population, standard of living, character of a country's buildings and transportation system, available energy options, and climate. Emissions from the United States account for about 17.4 percent of total global CO_2 emissions (WRI 2011). The U.S. transportation sector contributed 31.2 percent of total U.S. CO_2 emissions in 2009, with HD vehicles accounting for 21.2 percent of total U.S. CO_2 emissions from transportation (EPA 2011). Thus, approximately 6.6 percent of total U.S. CO_2 emissions are from HD vehicles, and HD vehicles in the United States account for roughly 1.1 percent of total global CO_2 emissions, as compared to 4.1 percent for U.S. light-duty vehicles (based on comprehensive global CO_2 emissions data available for 2005).[42] 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). Nine of the ten warmest years on record have occurred since 2001 (NCDC 2011). 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.

[41] 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).
[42] 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 1990–2009, EPA 2011)



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). According to a number of studies, the effects of CO_2 in the atmosphere will persist beyond 2100. Under a business as usual scenario, CO_2 will remain in the atmosphere for the next few centuries with the potential of temperature anomalies continuing much longer (Archer *et al.* 2009; Archer and Brovkin 2008, Eby *et al.* 2009, Montenegro 2007).

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. Elevated global average temperatures could persist even if atmospheric CO_2 concentrations decline. Because of the heat capacity of the oceans, centuries are required in order to realize all the warming from a given level of CO_2 concentrations. Therefore, while reductions in CO_2 concentrations will slow the rate of temperature rise, temperatures will not drop from these reductions until the ocean has reached an equilibrium with the atmosphere (Matthews and Caldeira, 2008). In a multi-millennial simulation of the long-term temperature increase associated with cumulative anthropogenic CO_2 emissions similar to what would be released from burning known fossil fuel reserves, Eby *et al.* (2009) found that up to two-thirds of the maximum increase in global average temperature may persist for centuries. 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. Delaying reductions in anthropogenic GHG emissions will increase the concentration at which CO_2 stabilizes in the Earth's atmosphere, increasing the risk of catastrophic climate change (Allen *et al.* 2009, Lowe *et al.* 2009, Mignone *et al.* 2008 Vaughan *et al.* 2009).

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,[43] 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 for this EIS (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).[44] 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).[45] There is uncertainty concerning these emission

[43] 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.

[44] 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.

[45] 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.

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).

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[46] 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 redirects energy that would have warmed the surface to warming the atmosphere depends on the albedo of 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 and instead warms the atmosphere, thereby causing a surface 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) that would normally reflect sunlight at a high rate, the particles have little effect on cooling at the surface. Both scenarios cause an atmospheric warming effect. Additionally, the surface "dimming" scenario potentially affects the hydrologic cycle as a reduction of surface warming may reduce global mean evaporation and rainfall (Ramanathan and Carmichael 2008).

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;

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.)

[46] 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.

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).

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 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.

Recent studies have suggested the global warming potential (GWP) of black carbon is 480 to 680 over a 100-year time horizon (Reddy and Boucher 2007, Bond and Sun 2005). Estimates at the regional scale vary from a GWP of 374 to 677, accounting for the differences in the lifetime of black carbon in the atmosphere and the impact of black carbon on snow and ice albedo (Reddy and Boucher 2007). However, there is a large degree of uncertainty in current estimates (Reddy and Boucher 2007).

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. Because GHG emissions and climate impacts occur at not only the national scale (*i.e.*, the scale of the alternatives under consideration) but also at the global scale, both discussions begin with a description of conditions in the United States, followed by a description of global conditions. 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 2009[48] were estimated at 6,633.2 million metric tons of CO_2 equivalent ($MMTCO_2$ Eq.) (EPA 2011), comprising about 15 percent of total global emissions[49] (WRI 2011). Annual U.S. emissions, which have increased 7 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 2011).

CO_2 is by far the primary GHG emitted in the United States, representing almost 83.0 percent of all U.S. GHG emissions in 2009 (EPA 2011). 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 10.3 percent of total GHGs on a GWP-weighted basis, followed by N_2O (4.5 percent) and the high-GWP gases (2.2 percent) (EPA 2011).

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 almost 79 percent of total U.S. emissions (EPA 2011). These CO_2 emissions are due to fuels consumed in the electric power (41 percent of fossil-fuel emissions), transportation (31 percent), industry (13 percent), residential (6 percent), and commercial (4 percent) sectors (EPA 2011). When U.S. CO_2 emissions are apportioned by end use, however, 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 2011).[50]

CO_2 emissions from HD vehicles have increased by 53 percent since 1990 (EPA 2011). 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

[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 2011).
[49] Based on 2005 global data and excluding carbon sinks from forestry and agriculture.
[50] Apportioning by end use allocates emissions associated with electricity generation to the sectors (residential, commercial, industrial, transportation) where it is used.

attempt to minimize the 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 2011).

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 44,126.7 $MMTCO_2$ equivalent, a 20.3-percent increase since 1990[51] (WRI 2011). 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 76 percent of global emissions on a GWP-weighted basis, followed by CH_4 (15 percent) and N_2O (8 percent). Collectively, fluorinated gases represented 1 percent of global emissions covered by national inventories (WRI 2011).

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 64 percent of global emissions in 2005. Within this sector, the generation of electricity and heat accounts for 28 percent of total global emissions. The next highest contributors to emissions are agriculture (14 percent) and land-use change and forestry (12 percent) (WRI 2011).

Transportation CO_2 emissions comprise 12 percent of the global total, and are included in the 64 percent cited above for the energy sector (WRI 2011). 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 2011).[52]

[51] 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.
[52] Values in this paragraph exclude land-use change and forestry.

3.4.2.2 Climate Change Effects (Historic and Current)

3.4.2.2.1 U.S. Climate Change Effects

This section describes observed historical and current climate change effects 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 2010a). 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 since 1900, while the first fall frost has occurred about three days later (EPA 2010a 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 2010a). 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 2010a). 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 2010a).

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[53] 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). Using satellite radar to observe changes in monthly ice sheet properties and twin satellites to record minute differences in the Earth's gravity over the past 18 years, a recent study has estimated that the Greenland and Antarctic ice sheets have been melting at a rate that is three times faster than that for mountain glaciers and ice caps (Rignot et al. 2011). 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 Cazanave and Llovel 2010). For the period of 1993 to 2007, Cazanave 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

[53] 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.

Greenland net mass loss; the other half occurred because melting has exceeded snowfall accumulation (IPCC 2007b).

Global average sea level rose at an average rate of 1.8 +/− 0.5 millimeters (0.07 +/− 0.019 inch) per year from 1961 to 2003 with the rate increasing to about 3.1 +/− 0.7 millimeters (0.12 inch +/− 0.027) per year from 1993 to 2003 (EPA 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.[54] 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).[55]

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

[54] 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.

[55] 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.

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).

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 2009); 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 2009).

Acidification of Oceans

Oceans have absorbed some of the increase in atmospheric CO_2, which lowers the pH of the water. When CO_2 dissolves in seawater, 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. As discussed more fully in Section 4.7, 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:

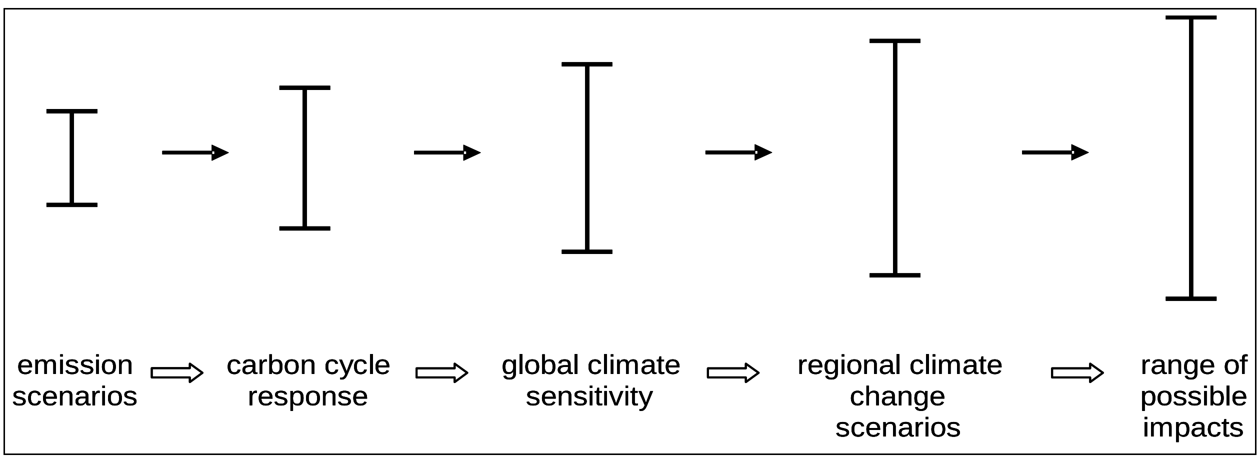
1. Analyzing the effects of the proposed action and alternatives on GHG emissions;
2. Estimating the monetized damages associated with CO_2 emissions and reductions attributable to each regulatory alternative; and
3. Analyzing how GHG emissions and reductions under each action alternative affect the 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 5) 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)



The scientific understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decision making, 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.[56]

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.[57]

Emissions under each action alternative were compared against those under the No Action Alternative to determine the impact of the action alternative on emissions. GHG emissions from MY 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 percentage change in U.S. transportation fuel consumption.[58] For years 2051−2100, the GCAMReference 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 MY 2012−2016 CAFE standards for passenger cars and light trucks (NHTSA 2010).

The emission estimates include global CO_2, CH_4, and N_2O emissions resulting from direct fuel combustion and from the production and distribution of fuel (upstream emissions). The MOVES model also accounts for and estimates the following non-GHGs: SO_2, NO_x, CO, and VOCs.

Fuel savings from stricter HD standards would result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[59] There is a direct relationship

[56] GCAM is used as the basis for the Representative Concentration Pathway (RCP) 4.5 scenario (Thomson *et al.* 2011).
[57] Note that unlike the GHG emission estimates in the Regulatory Impact Analysis accompanying EPA's and NHTSA's joint proposed HD standards, the estimates presented here do not include emission reductions from recreational vehicles, as described in Section 2.2.4.
[58] The last year for which the MOVES model provides estimates of fleet CO_2 emissions is 2050.
[59] 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. 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 0.3 percent of the tailpipe GHG emissions from HD vehicles, and CO_2 emissions account for the remaining 99.7 percent. Of the total (including non-tailpipe) GHG emissions from HD vehicles, tailpipe CO_2 represents about 96.6

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; 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.

For the analysis in this EIS, 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.[60] 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.[61] 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* http://www.epa.gov/oms/climate/regulations/420d10901.pdf (Accessed: June 13, 2011)).

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.

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percent, tailpipe CH_4 and N_2O represent about 0.3 percent, and HFCs represent about 3.2 percent. (Values are calculated from EPA 2011.)

[60] 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).

[61] 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.

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 Standards.[62] The SCC Technical Support Document (TSD) provides a complete discussion of the methods used to develop these SCC estimates.[63]

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.[64] 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

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[62] 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).
[63] (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 Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also *available at* http://epa.gov/otaq/climate/regulations.htm.
[64] 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).

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 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	$5.82	$24.30	$39.21	$74.33
2020	$6.94	$26.85	$42.58	$82.39
2025	$8.37	$30.22	$46.86	$92.30
2030	$9.90	$33.49	$51.05	$102.10
2035	$11.44	$36.76	$55.34	$112.00
2040	$12.97	$40.02	$59.63	$121.81
2045	$14.50	$42.98	$62.28	$130.48
2050	$16.03	$45.84	$66.37	$139.06

3.4.3.3 Methodology for Estimating Climate Effects

This EIS estimates and reports four effects of climate change driven by alternative scenarios of projected changes in 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 GHG emissions is a direct effect of the improvements in fuel efficiency associated with the alternatives; the four effects on climate change may be considered to be indirect effects.

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. NHTSA used MAGICC 5.3.v2 to incorporate 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 reductions in upstream emissions estimated using GREET. NHTSA also conducted a sensitivity analysis in order to examine variation in the direct and indirect climate impacts of the action alternatives under different assumptions about the sensitivity of climate to GHG concentrations in Earth's atmosphere. The results of the sensitivity analysis can be used to infer how the variation in GHG emissions associated with the action alternatives affects the anticipated magnitudes 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).[65]
- 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 will accompany the forthcoming joint NHTSA and EPA Final Rule.

[65] 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 MY 2012–2016 CAFE standards for passenger cars and light trucks released in February 2010 (NHTSA 2010).

For the purpose of the analysis of direct and indirect impacts presented in this chapter, NHTSA assumed that global emissions under the No Action Alternative follow the trajectory provided by the Global Change Assessment Model (GCAM, formerly MiniCAM) reference emission scenario used as the basis for the RCP4.5 scenario (Thomson *et al*. 2011). 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 GCAMReference 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 GCAMReference emissions scenario (Thomson *et al.,* 2011)[66] to model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise that could result under each alternative. The GCAMReference scenario is discussed in detail below in section 3.4.3.4.

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 GCAMReference 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 GCAMReference 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 GCAMReference 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 GCAMReference scenario.

Section 3.4.4 presents the results of the model runs for the alternatives.

[66] 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[67] 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.* 2007). 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. 2007).

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 and the Preferred Alternative – 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 GCAMReference scenario to represent emissions from the No Action Alternative.
2. Starting with the GCAMReference scenario, 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).[68]
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 RCP4.5 scenario (Thomson *et al.*, 2011). This scenario is used because it contains a comprehensive suite of greenhouse and pollutant gas emissions including carbonaceous aerosols. The GCAMReference scenario provides a global context for emissions of a full suite of GHGs and ozone precursors.

[67] In this EIS, the term "climate sensitivity" refers to "equilibrium climate sensitivity."
[68] *See* Box 10.2, Figure 2 in IPCC (2007a).

The GCAMReference 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).[69]

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 GCAMReference 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. To model the results presented in this chapter, NHTSA chose the GCAMReference scenario based on the following factors:

- The GCAMReference 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 GCAMReference 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.[70]
- In terms of global emissions of CO_2 from fossil fuels and industrial sources, the GCAMReference 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 GCAMReference scenario is a "middle ground" scenario.

[69] 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.

[70] As described in Thomson *et al.* (2011), "The GCAM reference scenario depicts a world in which global population reaches a maximum of more than 9 billion in 2065 and then declines to 8.7 billion in 2100 while global GDP grows by an order of magnitude and global energy triples. The reference scenario includes no explicit policies to limit carbon emissions, and therefore fossil fuels continue to dominate global energy consumption, despite substantial growth in nuclear and renewable energy."

- CCSP SAP 2.1 is more than a decade newer than the IPCC SRES, and therefore has updated economic and technology data and assumptions and uses improved integrated assessment models that account for advances in economics and science over the past 10 years.
- EPA also used the GCAMReference scenario for the HD National Program Draft RIA, which accompanied the joint NHTSA and EPA NPRM.

The GCAMReference 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.

As noted above, 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 GCAMReference 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 the No Action Alternative are 625 $MMTCO_2$; the emissions in 2020 under the Preferred Alternative are 587 $MMTCO_2$ (*see* Table 3.4.4-2). The difference of 38 $MMTCO_2$ represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global emissions for the GCAMReference 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 38 $MMTCO_2$ less than this reference level, or 37,979 $MMTCO_2$ 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 2011 Early Release (EIA 2011) and IEO 2010 (EIA 2010), which forecast energy supply and demand in the United States and globally to 2035.[71] Appendix C to this EIS 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.

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 could occur so quickly and unexpectedly that human systems would have difficulty adapting to them (EPA 2009 citing NRC 2002).

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[71] MOVES incorporates data from the AEO 2011 Early Release since the final AEO 2011 was only recently released.
[72] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

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.* 2007) 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

Using the methodology discussed in Section 3.4.3.1, emission reductions resulting from the proposed action and alternatives for MY 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 U.S. HD vehicles in use between their estimated future levels under the No Action Alternative and each action alternative (Alternatives 2 through 5). 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 U.S. HD CO_2 emissions and emission reductions resulting from applying the five alternative standards to new HD vehicles from 2014 to 2100. U.S. HD emissions for this period range from a low of 60,500 $MMTCO_2$ under Alternative 5 to 72,900 $MMTCO_2$ under the No Action Alternative. Compared to the No Action Alternative, projections of emission reductions from 2014 to 2100 due to the action alternatives range from 6,700 to 12,500 $MMTCO_2$.

[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"); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1997b), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (Accessed: June 17, 2011) (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.

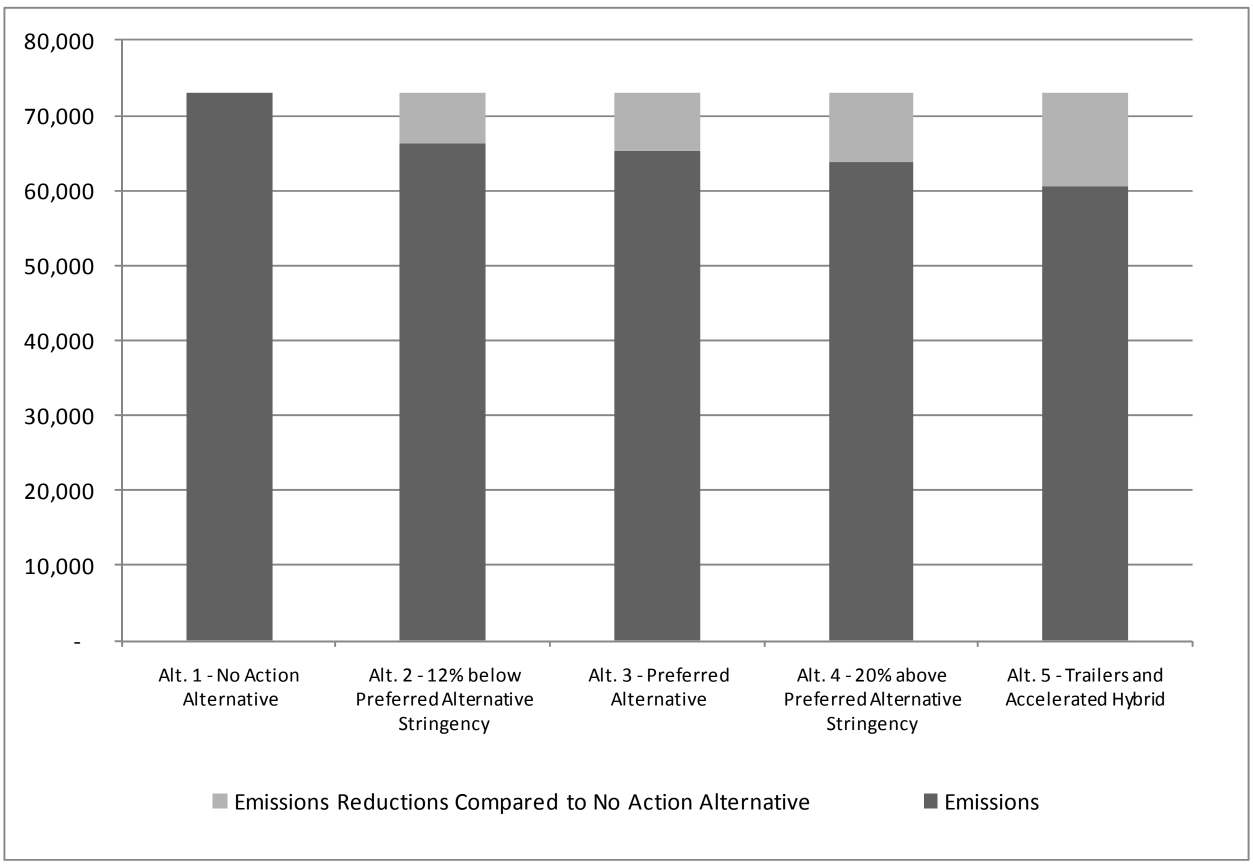
Table 3.4.4-1

CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles 2014 to 2100 by Alternative a/

Alternative	Total Emissions	Emission Reductions Compared to No Action Alternative	Percent Emission Reductions Compared to No Action Emissions
Alt.1 - No Action Alternative	72,900	0	
Alt. 2 - 12% below Preferred Alternative Stringency	66,200	6,700	9%
Alt. 3 - Preferred Alternative	65,300	7,600	10%
Alt. 4 - 20% above Preferred Alternative Stringency	63,700	9,200	13%
Alt. 5 - Trailers and Accelerated Hybrid	60,500	12,500	17%

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.

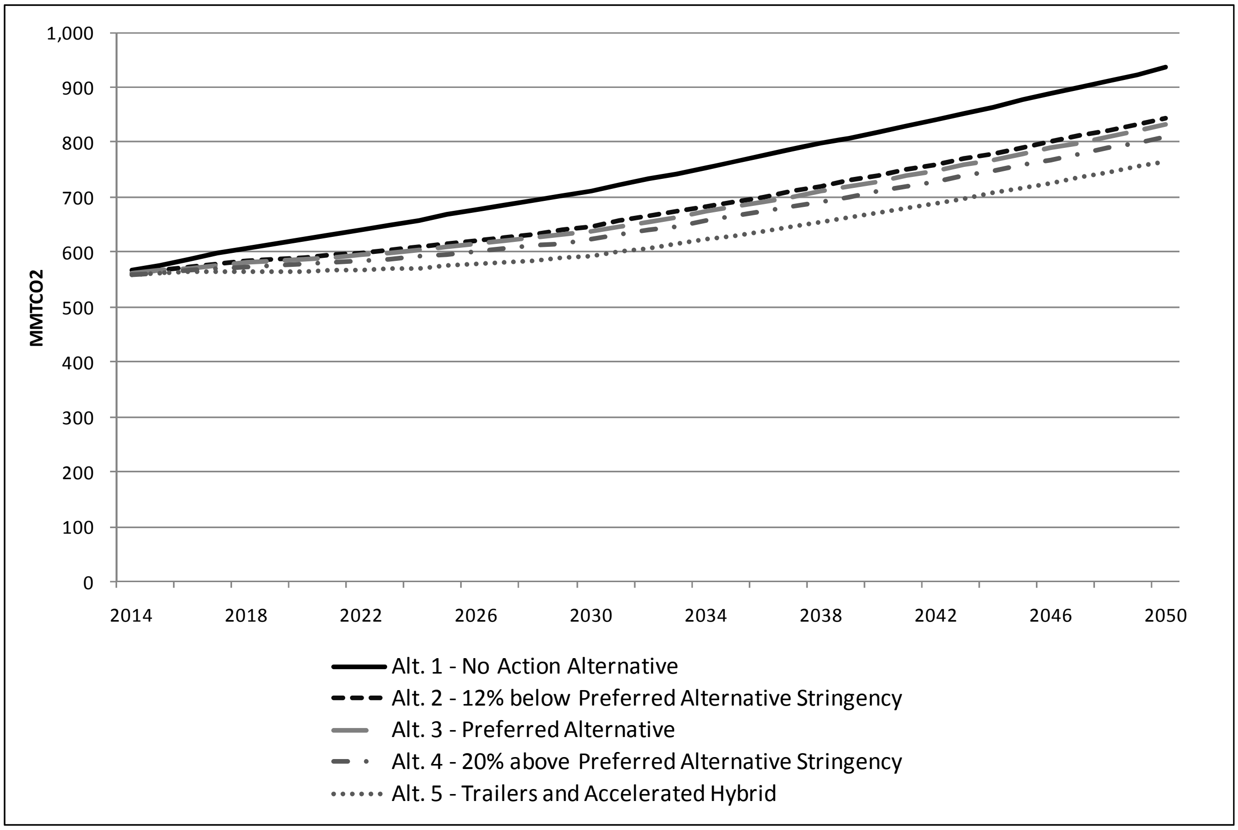
Figure 3.4.4-1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles 2014 to 2100 by Alternative



Compared to cumulative global emissions of 5,204,115 $MMTCO_2$ over this period (projected by the GCAMReference 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. 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 9−17 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 GCAMReference scenario (Thomson *et al.* 2011), the action alternatives would reduce total U.S. CO_2 emissions from all sources by 1.2–2.2 percent in 2100. Figure 3.4.4-2 shows projected annual emissions from U.S. HD vehicles under the alternatives.

Figure 3.4.4-2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. HD Vehicles by Alternative



As Table 3.4.4-2 shows, under the No Action Alternative, 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 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. 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.

Table 3.4.4-2

Emissions of Greenhouse Gases ($MMTCO_2e$ per year) a/ from U.S. HD Vehicles by Alternative

GHG and Year	Alt. 1 No Action Alternative	Alt. 2 12% Below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% Above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon dioxide (CO_2)					
2020	625	591	587	578	565
2030	711	647	638	623	594
2050	936	844	832	810	765
2080	924	834	821	800	756
2100	860	775	764	744	703
Methane (CH_4)					
2020	20.41	19.01	18.90	18.65	18.31
2030	19.88	17.41	17.19	16.80	16.04
2050	24.53	21.23	20.93	20.40	19.32
2080	24.23	20.97	20.68	20.15	19.08
2100	22.54	19.51	19.23	18.75	17.75
Nitrous oxide (N_2O)					
2020	1.57	1.55	1.55	1.54	1.53
2030	1.25	1.20	1.20	1.18	1.16
2050	1.48	1.41	1.40	1.39	1.35
2080	1.46	1.40	1.39	1.37	1.34
2100	1.36	1.30	1.29	1.27	1.24

a/ $MMTCO_2e$ is million metric tons CO_2 equivalent

The table also shows that each action alternative would reduce HD vehicle emissions of CO_2 from its projected levels under the No Action Alternative. Similarly, under each of the action alternatives, CH_4 and N_2O emissions in future years are projected to decline 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 5, because these action alternatives require progressively larger increases in fuel efficiency levels.

As another way to provide context for these GHG results, in 2010 President Obama 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.[75] Although the action alternatives would reduce projected CO_2 emissions in 2020 compared to what they would otherwise be without action, total CO_2 emissions from the HD vehicle sector in 2020 would increase in the range of 9.2−14.1 percent above 2005 levels.[76] This increase occurs

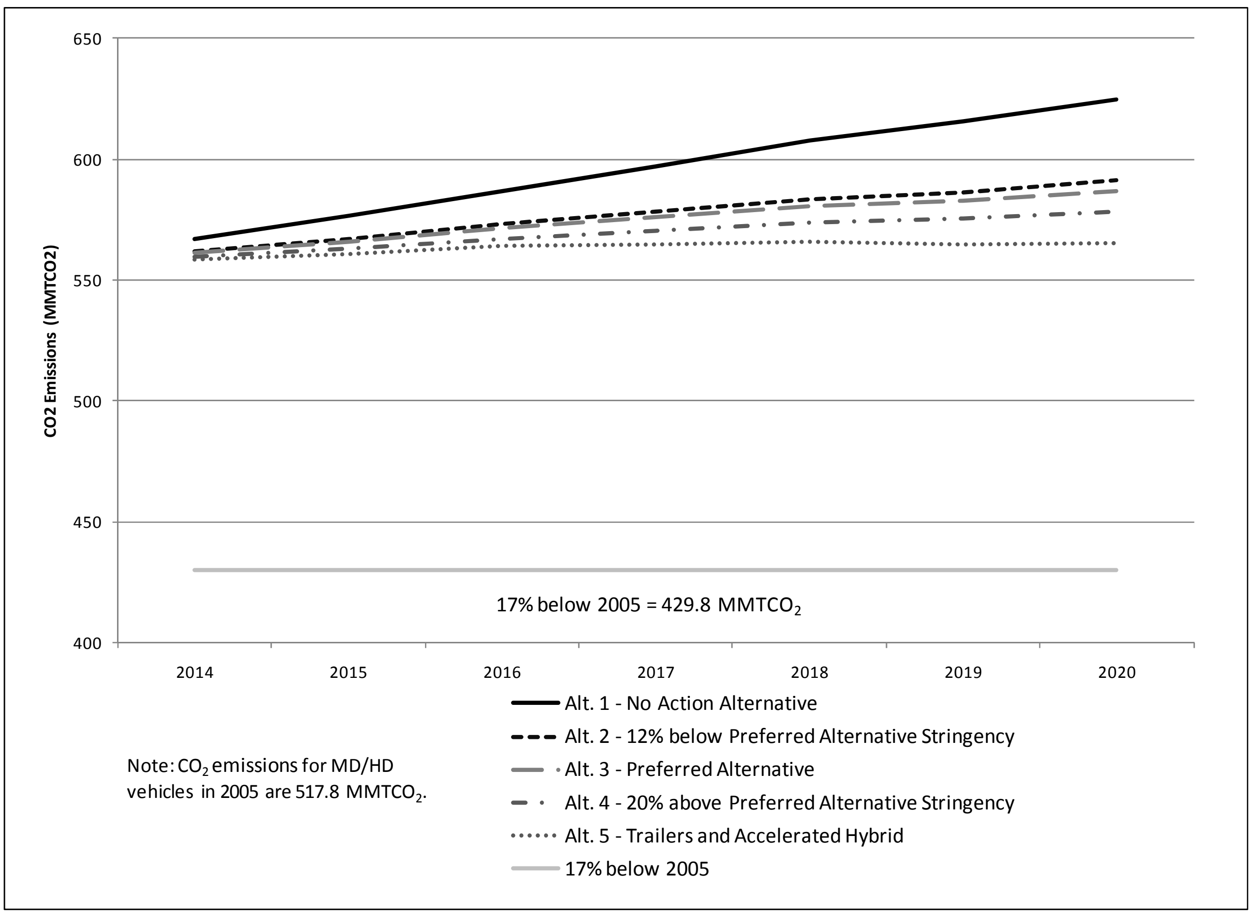
[75] On January 28, 2010, the United States submitted this target to the United Nations Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the [U.N.] in light of enacted legislation" (U. S. Department of State 2010).
[76] A 17-percent reduction would mean a reduction of 106.9 $MMTCO_2$ from 2005 levels, or a reduction of 194.9 $MMTCO_2$ from the No Action baseline.

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.

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 does not allow NHTSA to regulate other factors affecting emissions, including driving habits – NHTSA cannot, therefore, control VMT. 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 (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

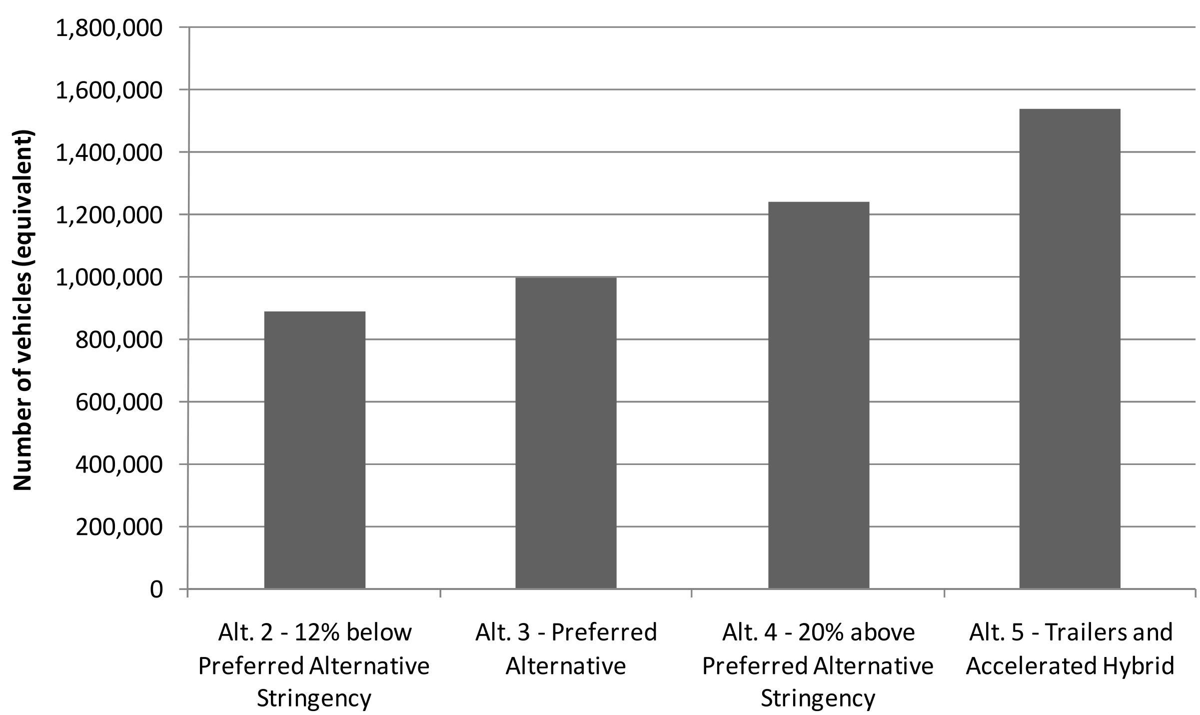
Figure 3.4.4-3. Projected Annual CO_2 Emissions from U.S. HD Vehicles by Alternative, Compared to 2005 Levels



occur in the absence of the HD Fuel Efficiency Improvement Program. However, these reductions in emissions are not sufficient by themselves to reduce total HD vehicle emissions below their 2005 levels by 2020.

Figure 3.4.4-4 expresses the CO_2 reductions from each Action Alternative in 2018 as the equivalent 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 0.89 million HD vehicles (Alternative 2) and 1.54 million HD vehicles (Alternative 5) in 2018, as compared to the annual emissions that would occur under the No Action Alternative. Emission reductions in 2018 from the Preferred Alternative are equivalent to the annual emissions of 1 million HD vehicles. These annual CO_2 reductions, their equivalent in vehicles, and differences among alternatives grow larger in future years as older vehicles continue to be replaced by newer ones meeting the increasingly stringent fuel efficiency standards required by each alternative.[77]

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 and

[77] 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 27.32 metric tons of CO_2 in the year 2018 based on MOVES and GREET model analysis.

stated a goal of reducing 350 $MMTCO_2e$ over the period 2009 to 2020 (WCI 2007).[78] As of early 2011, seven U.S. states and four Canadian provinces have partnered under the WCI to collaboratively reduce their GHG emissions. In 2010, WCI released its "Design for the Regional WCI Program," in which WCI explains its commitment to, and strategy for, reducing GHG emissions within the WCI region by 15 percent below 2005 levels by 2020 (WCI 2010). By comparison, the proposed HD Fuel Efficiency Improvement Program is expected to reduce CO_2 emissions by 135 to 232 $MMTCO_2$ between 2014 and 2020 (depending on the alternative), with emissions levels in 2020 representing a 6- to 10-percent reduction from the future baseline emissions for U.S. HD vehicles in the year 2020. Ten northeastern and mid-Atlantic States have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce CO_2 emissions from power plants in the Northeast by 10 percent by 2018 (RGGI 2011). Projected emission reductions from 2006 to 2024 under the initiative were estimated at 268 $MMTCO_2$ when this program began in 2006 (RGGI 2006).[79] This estimate represents a 23-percent reduction relative to the future baseline (as estimated in 2006) and a 10-percent reduction in 2024 emissions from their levels at the beginning of the action (RGGI 2006). By comparison, NHTSA forecasts that the proposed HD Fuel Efficiency Improvement Program would reduce CO_2 emissions by 309 to 542 $MMTCO_2$ between 2014 and 2024 (depending on the alternative), with emissions levels in 2024 representing a 8- to 15-percent reduction relative to the future baseline emissions for U.S. 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 total emissions from the vehicles covered under the proposed rule are projected to *increase* under each alternative, 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 in this EIS 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. NHTSA derived the net present value of the benefits reported in Table 3.4.4-3 by (1) utilizing the estimates of the SCC reported previously in Section 3.4.3.2, (2) applying each future year's SCC estimate (cost per ton) to the projected reduction in CO_2 emissions during that year under each Action Alternative, presented in Section 3.4.4.1, (3) discounting the resulting figure to its present value, and (4) summing those estimates for each year from 2014 to 2050. 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

[78] Since this goal was initially stated, Montana, Quebec, Ontario, British Columbia, Manitoba and Utah have joined the WCI. Thus, the total emissions reduction would likely be much greater than 350 $MMTCO_2$.
[79] 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.

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)
Alt. 2 - 12% below Preferred Alternative Stringency	$7,296	$39,050	$66,642	$118,964
Alt. 3 - Preferred Alternative	$8,251	$44,178	$75,400	$134,586
Alt. 4 - 20% above Preferred Alternative Stringency	$10,013	$53,588	$91,452	$163,255
Alt. 5 - Trailers and Accelerated Hybrid	$13,311	$71,381	$121,864	$217,444

future benefits. Consistent with Table 3.4.4-3, these estimates show increasing benefits with decreasing discount rates and with higher CO_2 damage estimates. The estimated net present value for a given action 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.

3.4.4.3 Direct and Indirect Effects on Climate Change Indicators

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.[80] As the table indicates, the

Table 3.4.4-4

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

Scenario	CO_2 Concentration (ppm)		Global Mean Increase in Surface Temperature (°C)		Sea-Level Rise (cm)	
	IPCC WGI (2100)	MAGICC (2100)	IPCC WGI (2080-2099)	MAGICC (2090)	IPCC WGI (2090-2099) a/	MAGICC (2095)
B1 (low)	550	538.3	1.79	1.81	28	26
A1B (medium)	715	717.2	2.65	2.76	35	35
A2 (high)	836	866.8	3.13	3.31	37	38

a/ The IPCC values represent the average of the 5- to 95-percent range of the rise of sea level between 1980–1989 and 2090−2099.

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

results of the model runs developed for this analysis agree relatively well with IPCC estimates for both CO_2 concentrations and surface temperature.

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 GCAMReference 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 four 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 783.7 ppm under Alternative 5 to 784.9 ppm under the No Action Alternative. For 2030 and 2050, the corresponding range is even tighter. 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.

Table 3.4.4-5

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

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C) b/			Sea-Level Rise (cm) b/		
Totals by Alternative	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
Alt. 1 - No Action Alternative	443.6	519.0	784.9	0.880	1.516	3.064	8.06	14.81	37.40
Alt. 2 - 12% below Preferred Alternative Stringency	443.6	518.8	784.2	0.880	1.515	3.061	8.06	14.81	37.37
Alt. 3 - Preferred Alternative	443.5	518.7	784.1	0.880	1.515	3.061	8.06	14.81	37.37
Alt. 4 - 20% above Preferred Alternative Stringency	443.5	518.7	784.0	0.880	1.515	3.061	8.06	14.81	37.37
Alt. 5 - Trailers and Accelerated Hybrid	443.5	518.6	783.7	0.880	1.514	3.059	8.06	14.80	37.35
Reductions Under Alternative HD Standards									
Alt. 2 - 12% below Preferred Alternative Stringency	0.0	0.2	0.7	0.000	0.001	0.003	0.00	0.00	0.03
Alt. 3 - Preferred Alternative	0.1	0.3	0.8	0.000	0.001	0.003	0.00	0.00	0.03
Alt. 4 - 20% above Preferred Alternative Stringency	0.1	0.3	0.9	0.000	0.002	0.003	0.00	0.00	0.03
Alt. 5 - Trailers and Accelerated Hybrid	0.1	0.4	1.2	0.001	0.002	0.005	0.00	0.01	0.05

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/ The values for global mean surface temperature and sea-level rise are relative to the year 1990.

Figure 3.4.4-5. CO_2 Concentrations (ppm)

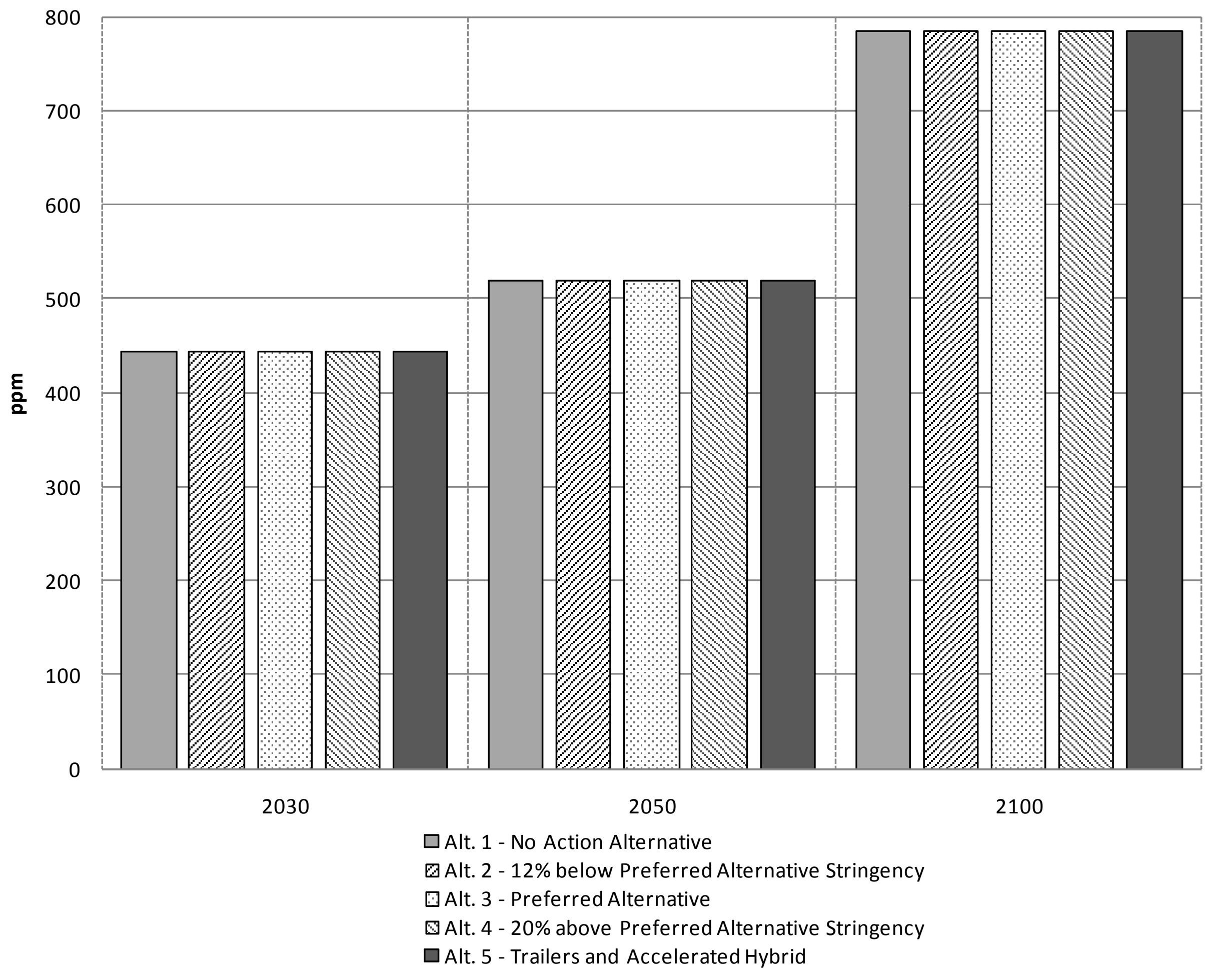


Figure 3.4.4-6. Change in Global Mean Surface Temperature Increase (°C)

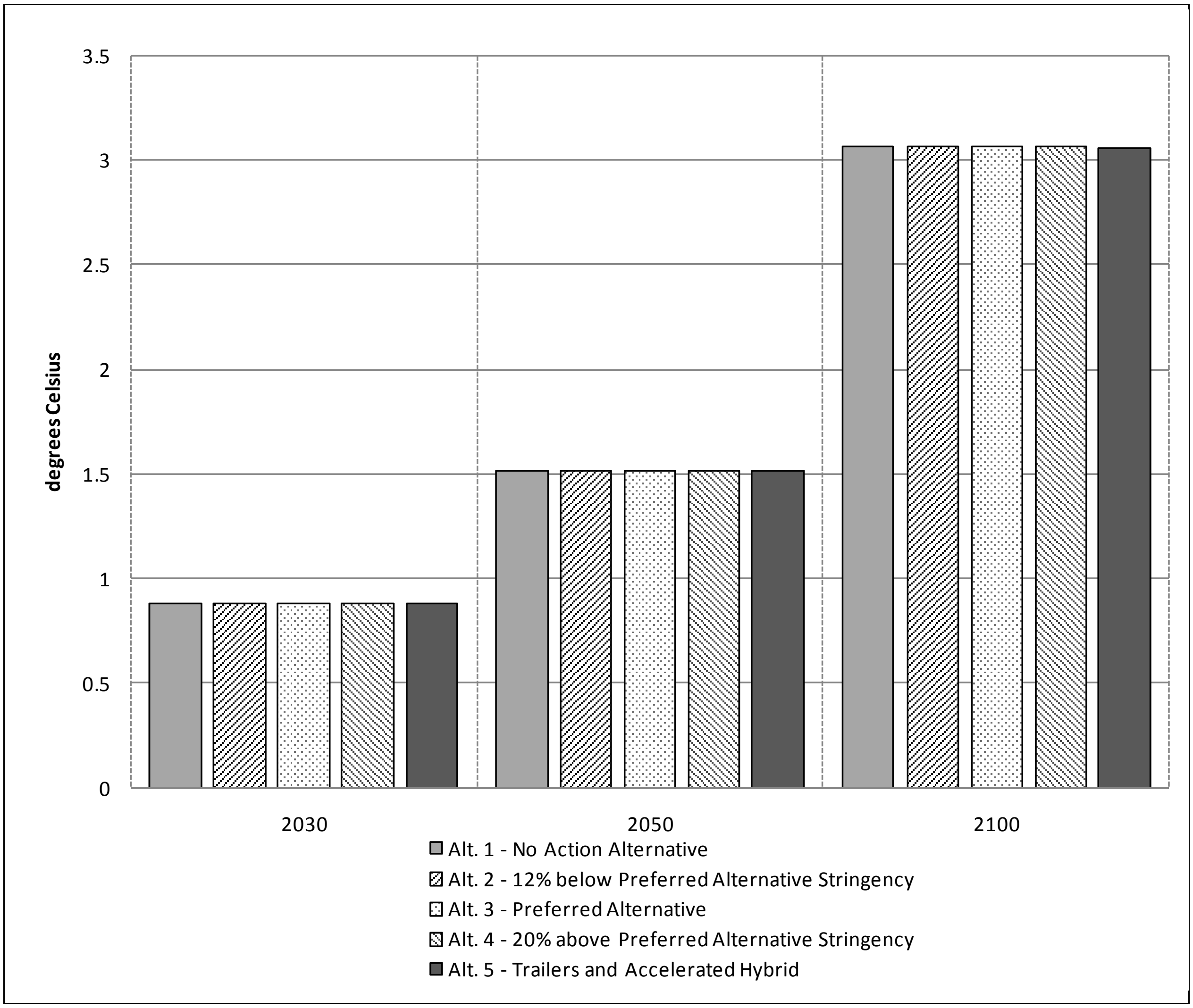


Figure 3.4.4-7. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative

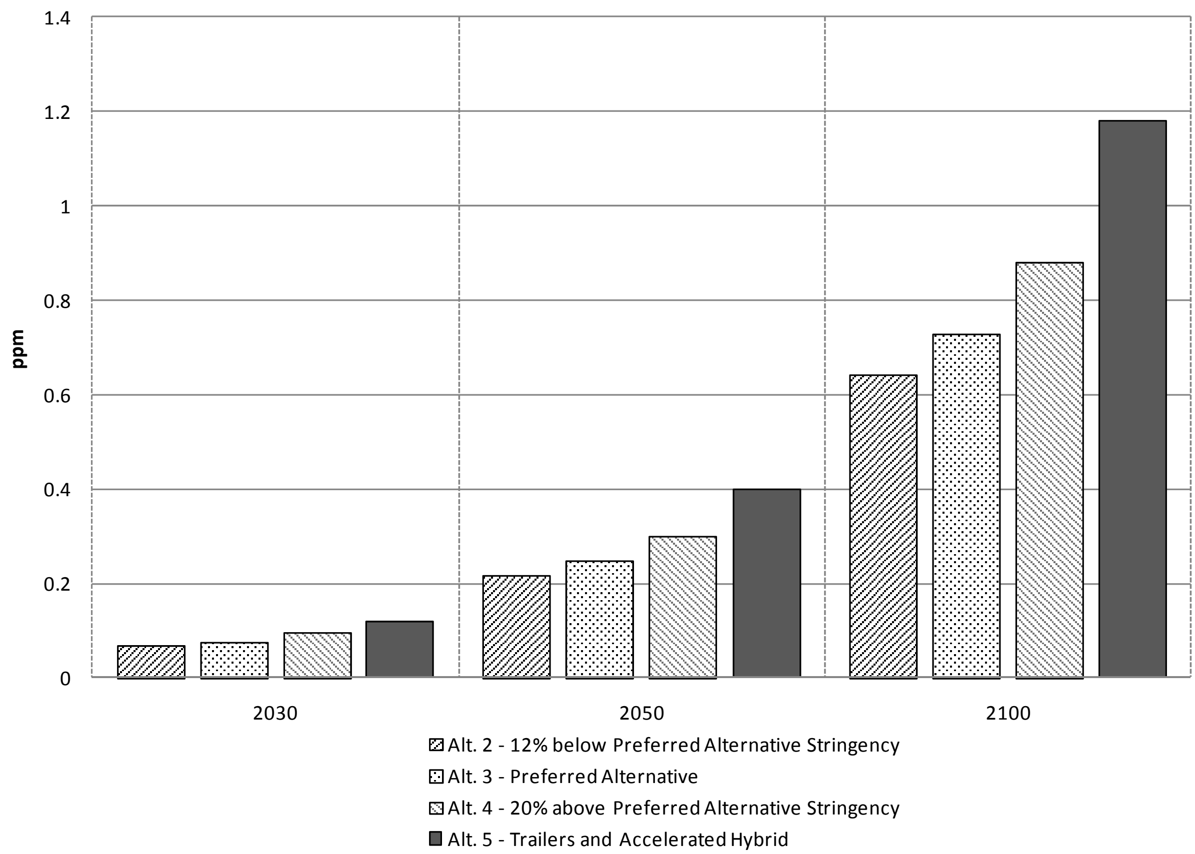
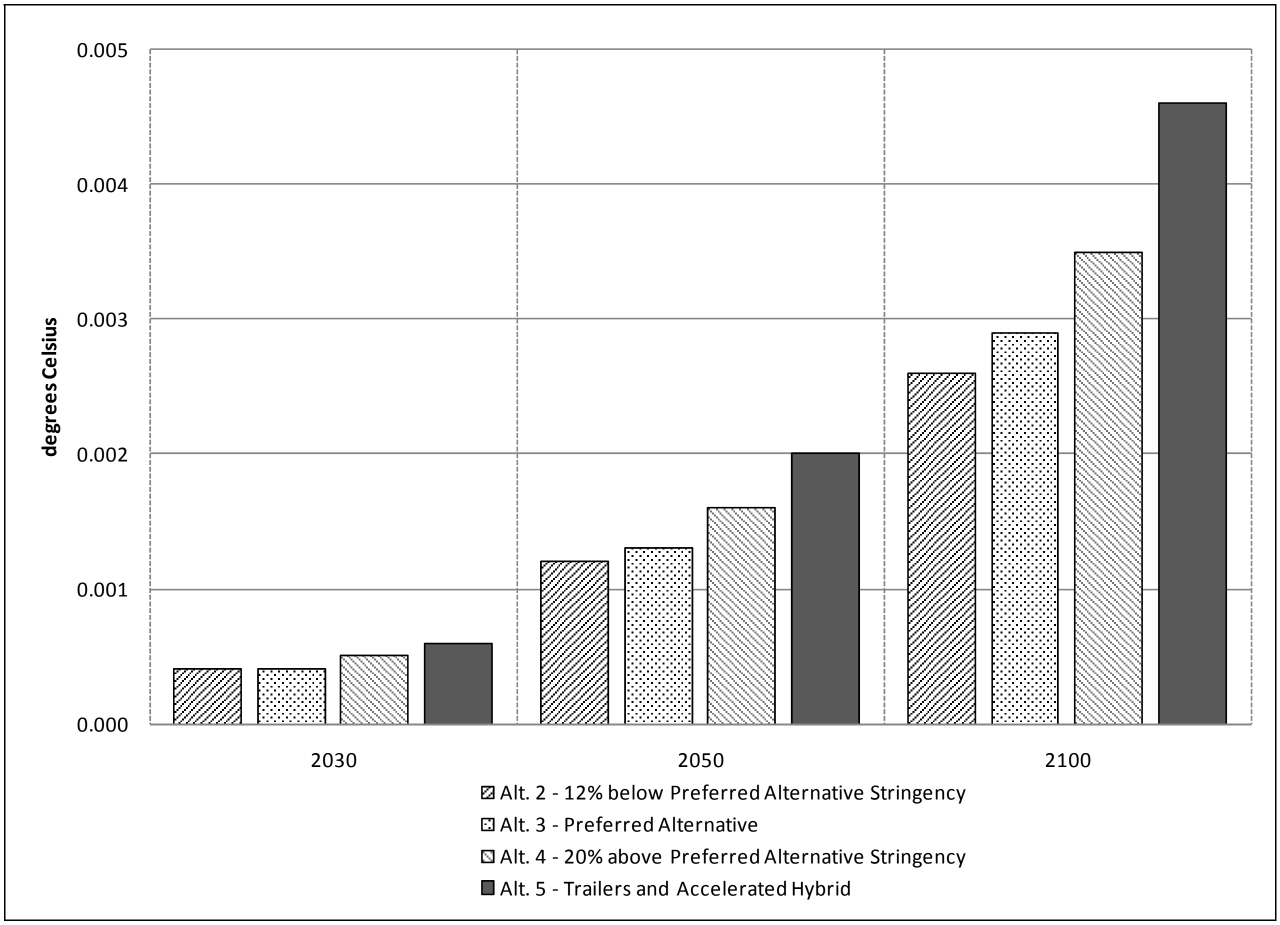


Figure 3.4.4-8. Reduction in Change in Global Mean Temperature Compared to the No Action Alternative



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 5 is almost 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.[81] The differences among the reductions in baseline temperature increases projected to result from the various action alternatives are small in comparison to total projected changes. In 2100, for example, the

[81] 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.

reduction in temperature increase as compared to the No Action Alternative ranges from 0.003 °C (0.005 °F) under Alternative 2 to 0.005 °C (0.009 °F) under Alternative 5.

Figure 3.4.4-8 also illustrates that reductions in the growth of projected global mean surface temperature from each action alternative as compared to the No Action Alternative are anticipated to be small in comparison to total projected changes. 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 5. As shown in Figure 3.4.4-8, the reduction in the projected growth in global temperature under Alternative 5 is almost twice as large as 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.* 2007), 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).

As noted in Section 3.4.3, MAGICC does not directly simulate changes in precipitation, and NHTSA has not undertaken precipitation modeling with a full Atmospheric-Ocean General Circulation Model. However, the IPCC (Meehl *et al.* 2007) 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.* 2007) 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 GCAMReference scenario in this analysis because MAGICC does not directly estimate changes in global mean precipitation.[82]

Table 3.4.4-7

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

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 are projected to reduce temperature increases as well as predicted increases in precipitation slightly in relation to the No Action Alternative, as shown in Table 3.4.4-8 (based on the A1B [medium] scenario).

Table 3.4.4-8

Global Mean Precipitation (Percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario and Alternative HD Standards b/			
Alt. 1 - No Action Alternative	0.600	1.675	2.760
Alt. 2 - 12% below Preferred Alternative Stringency	0.599	1.674	2.758
Alt. 3 - Preferred Alternative	0.599	1.674	2.758
Alt. 4 - 20% above Preferred Alternative Stringency	0.599	1.673	2.757
Alt. 5 - Trailers and Accelerated Hybrid	0.599	1.673	2.756
Reduction in Global Temperature (°C) for Alternative HD Standards, Mid-level Results (Compared to No Action Alternative) c/			
Alt. 2 - 12% below Preferred Alternative Stringency	0.000	0.001	0.002
Alt. 3 - Preferred Alternative	0.000	0.002	0.003
Alt. 4 - 20% above Preferred Alternative Stringency	0.000	0.002	0.003
Alt. 5 - Trailers and Accelerated Hybrid	0.000	0.002	0.004

[82] 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 (continued)

Global Mean Precipitation (Percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Increase (%)			
Alt. 1 - No Action Alternative	0.87%	2.53%	4.50%
Alt. 2 - 12% below Preferred Alternative Stringency	0.87%	2.53%	4.50%
Alt. 3 - Preferred Alternative	0.87%	2.53%	4.50%
Alt. 4 - 20% above Preferred Alternative Stringency	0.87%	2.53%	4.49%
Alt. 5 - Trailers and Accelerated Hybrid	0.87%	2.53%	4.49%
Reduction in Global Mean Precipitation Increase by Alternative HD Standards (% Compared to No Action Alternative)			
Alt. 2 - 12% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 3 - Preferred Alternative	0.00%	0.00%	0.00%
Alt. 4 - 20% above Preferred Alternative Stringency	0.00%	0.00%	0.01%
Alt. 5 - Trailers and Accelerated Hybrid	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 1980–1999.
c/ Precipitation changes reported as 0.000 are greater than zero but smaller than 0.001.

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation.[83]

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.

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.

[83] As described in Meehl *et al.* 2007, the "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" (Meehl *et al.* 2007).

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	
	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	

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
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 2007 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 of the Action Alternatives on sea-level rise under the GCAMReference scenario. It shows sea-level rise in 2100 ranging from 37.40 centimeters (14.72 inches) under the No Action Alternative to 37.35 centimeters (14.70 inches) under Alternative 5. This represents a maximum reduction of 0.05 centimeters (0.02 inches) by 2100 under Alternative 5 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 GCAMReference scenario.[84] 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

Using the methodology discussed in Section 3.4.3.3.3, NHTSA examined the sensitivity of projected climate effects to key technical or scientific assumptions used in the analysis. This examination

[84] 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.

included modeling the impact of various climate sensitivities on the climate effects under the No Action Alternative and the Preferred Alternative using 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)			Global Mean Surface Temperature Increase (°C) b/			Sea-level Rise (cm) b/
		2030	2050	2100	2030	2050	2100	2100
Alternative 1 (No Action)								
	1.5	441.253	512.770	757.689	0.538	0.912	1.761	22.80
	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	55.59
Alternative 3 (Preferred Alternative)								
	1.5	441.177	512.528	756.999	0.538	0.911	1.759	22.78
	2.0	442.076	514.847	766.754	0.669	1.139	2.238	28.25
	2.5	442.857	516.900	775.783	0.781	1.339	2.670	33.08
	3.0	443.542	518.726	784.141	0.880	1.515	3.061	37.37
	4.5	445.161	523.148	805.710	1.110	1.934	4.033	47.78
	6.0	446.326	526.426	822.975	1.274	2.238	4.776	55.55
Reduction Under Preferred Alternative Compared to No Action Alternative								
	1.5	0.076	0.242	0.690	0.000	0.001	0.002	0.02
	2.0	0.076	0.244	0.703	0.000	0.001	0.002	0.02
	2.5	0.076	0.245	0.717	0.000	0.001	0.002	0.02
	3.0	0.076	0.246	0.728	0.000	0.001	0.003	0.03
	4.5	0.076	0.249	0.758	0.000	0.002	0.004	0.03
	6.0	0.077	0.252	0.783	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/ The values for global mean surface temperature and sea-level rise are relative to levels in the year 1990.

As the table illustrates, varying 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. This complex set of interactions occurs because sea level is influenced by temperature, while atmospheric CO_2 concentrations are affected by temperature-dependent effects of ocean carbon storage (specifically, higher temperatures result in lower aqueous solubility of CO_2). Thus as Table 3.4.4-10 illustrates, projected future atmospheric CO_2 concentrations differ with varying climate sensitivities even under the same alternative, despite the fact that CO_2 emissions are fixed under each alternative.

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 response of simulated global mean surface temperatures to variation in the climate sensitivity parameter varies among the years 2030, 2050, and 2100, as shown in Table 3.4.4-10. In 2030, the impact of assumed variation in climate sensitivity 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 of variation in climate sensitivity is magnified by 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.

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 projected 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 assumed climate sensitivity.

3.5 MARKET FORECAST ANALYSIS

NHTSA received several comments to the DEIS that compared the action alternatives to the HD vehicle annual energy consumption forecast produced by the U.S. Energy Information Administration (EIA) and described that forecast, known as the Annual Energy Outlook (AEO), as "business as usual." The AEO takes into account predicted changes to the HD fleet based on the uptake of technologies in response to market forces. While the AEO forecasts do reflect current law and regulations, they do not incorporate proposed laws or regulations, including the proposed HD Fuel Efficiency Improvement Program.

Selecting an appropriate baseline against which to compare this proposal and the alternatives is challenging. NHTSA understands that market forces may independently result in changes to the future HD fleet even in the absence of the proposed rule, and that, to the extent they can be estimated, those changes should be incorporated into the baseline. Nonetheless, the broad range and many types of HD vehicles in the fleet, the lack of prior regulation of fuel efficiency for this sector, and economic uncertainty make estimating fuel efficiency of future HD vehicles particularly difficult.

Market-based forecasts of fuel economy rely on inherently uncertain measures, such as future oil prices, and therefore cannot perfectly predict future fuel economy. With these cautions in mind, NHTSA nevertheless believes that a market forecast of changes in fuel efficiency is the appropriate baseline for the evaluation of the environmental impacts of the proposed action and alternatives. NHTSA further believes that AEO represents the best available market-based forecast of future fuel efficiency and fuel consumption by HD vehicles that would occur in the absence of this rule. The EIA is the primary source of data used by government agencies and private organizations to analyze and model energy systems.

To address comments to the DEIS, this section of the FEIS compares the environmental impacts of the action alternatives to those of a baseline derived from the AEO 2011 Early Release Reference Case, the AEO forecast available at the time the modeling for this section was performed. For the purpose of this section, therefore, the No Action Alternative takes into account market forces and technology advances that would result in fuel efficiency gains even in the absence of regulatory action.[85] As a result, overall estimated fuel savings and emission reductions are lower in this section's analysis than those reported in in Sections 3.2 through 3.4.

NHTSA treats the action alternatives in this section the same as in Sections 3.2 through 3.4 above, with one modification based on the agency's assumption of how market forces predicted by AEO would interact with the regulated fleet. As in the above sections, NHTSA assumes no further increase in new vehicle fuel efficiency for the action alternatives after MY 2018. However, in this section, when market forces are predicted to result in levels of fuel efficiency exceeding those required by the standards, NHTSA has assumed that those market forces would dictate future fuel efficiency. This is expected to occur beginning at the point when the AEO 2011 Early Release Reference Case (No Action Alternative) forecasts that new vehicle fuel efficiency will be greater than the latest standard in effect for those vehicles. After that time, the fuel efficiency of new vehicles would be expected to match its market-determined level reflected in the No Action Alternative. Because the resulting levels of future fuel economy achieved by new vehicles would exceed those required by the standards for MY 2018 vehicles, the results in this section should show lower fuel consumption and emissions in absolute terms than the analysis reported previously in Sections 3.2 through 3.4.

[85] The AEO forecast extends only to 2035. NHTSA extended these efficiency gains in the baseline through 2050, by which time virtually all of the HD vehicle fleet is expected to be comprised of MY 2018 and later vehicles. This extended forecast assumes compound annual percentage gains in overall HD vehicle fleet fuel efficiency from 2035 to 2050 that are equal to the average annual percentage increase forecasted by AEO in 2030 through 2035.

We note, however, that modeling limitations prevented the agency from applying this assumption specifically to projected fuel economy for new vehicles; instead, NHTSA adjusted fuel consumption and VMT in future years under each action alternative to match that under the No Action Alternative for three broad segments of the HD vehicle fleet: pickups and vans, vocational vehicles, and tractors. This limitation means that the benefits of the action alternatives shown in this section are likely to be understated. If the agency had been able to make the same adjustment to the fuel economy of new HD vehicles, then until the point where new vehicle fuel efficiency under the No Action Alternative exceeded that required by the MY 2018 standards, manufacturers would be expected to produce more fuel efficient vehicles than what would have been produced in the absence of this action. So long as the more fuel efficient vehicles phased in under the proposed action remained in use, the entire fleet would consume less fuel and emit less CO_2 than under the No Action Alternative.

Instead, however, because of the modeling limitations, in any year where the fuel efficiency of the HD fleet under the No Action Alternative exceeds the fuel efficiency of the fleet under an action alternative, fuel consumption and VMT for the action alternative fleet is adjusted to match the No Action Alternative. This creates the appearance that the action alternative fleet is consuming the same amount of fuel and emitting the same amount of CO_2 as would otherwise have occurred under the No Action Alternative. Thus, the analysis in this section shows no benefits after the approximate year when market forces are predicted to overtake the effect of the proposed action. In actuality, however, those benefits are likely to persist for quite some time.

Despite these methodological limitations, NHTSA believes this analysis provides important information to the decisionmaker by taking into account market forces that are predicted to have a considerable impact on this vehicle sector. For this reason, in all references to the No Action Alternative (and analyses stemming from its use) elsewhere in this FEIS, with the exception of Sections 3.2 through 3.4 above, NHTSA refers to the market forecast baseline set forth in this section.

This analysis is meant to be read in tandem with Sections 3.2 through 3.4 above. For each Table below, the agency has identified the corresponding Table from Sections 3.2 through 3.4. This information is provided to assist the reader in locating descriptive information about each of the tables as well as to facilitate an understanding of the overall environmental impacts of the proposed action, in light of the uncertainty in the baseline. Furthermore, much of the analytical context surrounding this information has been omitted below as it would be duplicative of the information presented in those sections. Please refer to Sections 3.2 through 3.4 for more information regarding the context and environmental effects identified below.

3.5.1 Energy Use and its Environmental Consequences

Table 3.5.1-1 shows the impact of the action alternatives in reducing fuel consumption through 2050, when the entire HD vehicle fleet is likely to be composed of MY 2018 or later vehicles. The table reports total 2014-2050 fuel consumption, both gasoline and diesel, for HD pickups and vans, vocational vehicles, and tractors, under the No Action Alternative and under each of the four action alternatives described in Section 2.3. It also shows the fuel savings for HD vehicles under each action alternative as compared to the No Action Alternative.

Total 2014-2050 fuel consumption under the No Action Alternative is 2115.3 billion gallons. Fuel consumption decreases across the alternatives, from 2068.6 billion gallons under Alternative 2 to 1925.9 billion gallons under Alternative 5. Total 2014-2050 fuel consumption is 2050.9 billion gallons under the Preferred Alternative.

Table 3.5.1-1
(Corresponds to Table 3.2.3-1)

Total 2014-2050 HD Vehicle Fuel Consumption and Fuel Savings by Alternative
(billion gallons for calendar years 2014-2050)

	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Fuel Consumption					
HD Pickups and Vans	307.6	307.6	307.6	305.8	285.7
Vocational Vehicles	435.4	419.9	409.1	397.2	356.4
Tractor Trucks	1372.4	1341.1	1334.3	1309.7	1283.7
All HD Vehicles	2115.3	2068.6	2050.9	2012.7	1925.9
Fuel Savings Compared to No Action					
HD Pickups and Vans	--	0.0	0.0	1.8	21.8
Vocational Vehicles	--	15.4	26.3	38.1	78.9
Tractor Trucks	--	31.3	38.1	62.6	88.6
All HD Vehicles	--	46.7	64.4	102.5	189.4

Less fuel would be consumed under any action alternative than under the No Action Alternative, with total 2014-2050 fuel savings ranging from 46.7 billion gallons under Alternative 2 to 189.4 billion gallons under Alternative 5. As compared to the No Action Alternative, total 2014-2050 fuel savings under the Preferred Alternative amounts to 64.4 billion gallons.

3.5.2 Air Quality Environmental Consequences

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. EPA projects that these emissions will continue to decline. As future trends show, however, vehicle travel is having a decreasing impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with continued 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 result in different levels of emissions from HD vehicles when measured against projected trends in the absence of the proposed fuel consumption standards. These reductions or increases in emissions vary by pollutant, calendar year, and action alternative, with the more stringent action alternatives generally resulting in greater emission reductions compared to the No Action Alternative.

3.5.2.1 Criteria Pollutants Overview

Table 3.5.2-1 summarizes the total national emissions from HD vehicles by alternative for each of the criteria pollutants and analysis years. The table presents the alternatives left to right in order of increasing fuel efficiency requirements. Figure 3.5.2-1 illustrates this information.

Figure 3.5.2-2 summarizes the changes over time in total national emissions of criteria pollutants from HD vehicles for the Preferred Alternative. Figure 3.5.2-2 indicates a consistent trend among the

Table 3.5.2-1
(Corresponds to Table 3.3.3-1)

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

Pollutant and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	2,687,441	2,658,867	2,658,610	2,659,701	2,658,888
2030	2,556,297	2,496,242	2,502,825	2,502,153	2,500,056
2050	3,245,528	3,162,525	3,161,881	3,172,463	3,169,442
Nitrogen oxides (NO_x)					
2018	1,806,256	1,694,684	1,693,529	1,690,995	1,687,139
2030	1,139,852	903,641	903,830	897,332	888,453
2050	1,397,350	1,071,436	1,068,649	1,066,372	1,053,524
Particulate matter ($PM_{2.5}$)					
2018	73,288	73,396	73,302	73,108	72,807
2030	33,053	34,431	34,337	34,081	33,473
2050	38,821	41,106	40,981	41,004	40,070
Sulfur dioxide (SO_2)					
2018	98,863	95,541	95,076	94,031	92,689
2030	63,038	60,926	60,309	58,861	56,091
2050	79,347	78,241	77,515	76,862	72,604
Volatile organic compounds (VOC)					
2018	251,985	238,048	237,837	237,430	236,567
2030	175,283	149,540	149,959	148,094	144,912
2050	208,921	174,188	173,745	173,452	168,630

Figure 3.5.2-1. Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative (Corresponds to Figure 3.3.3-1)

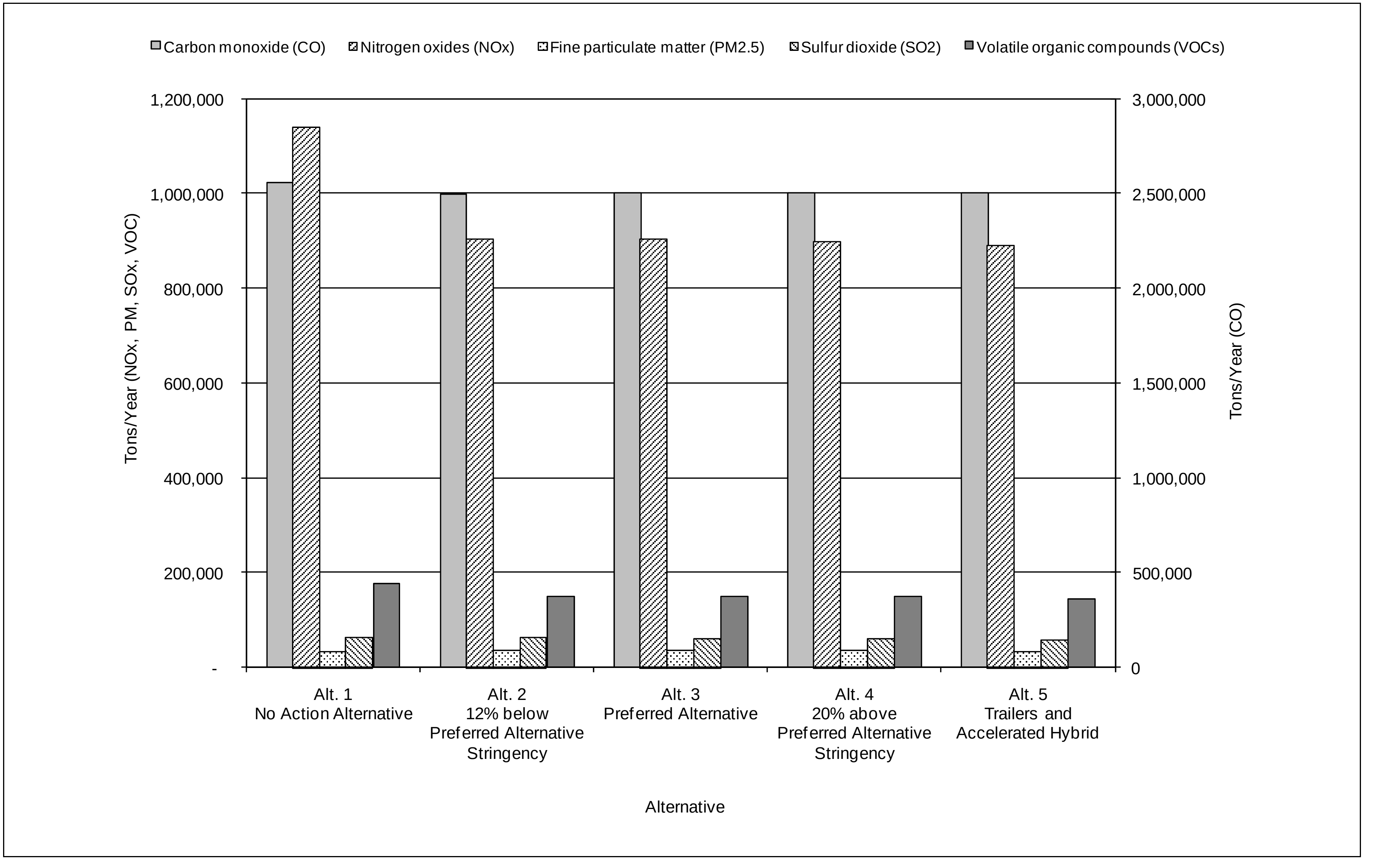
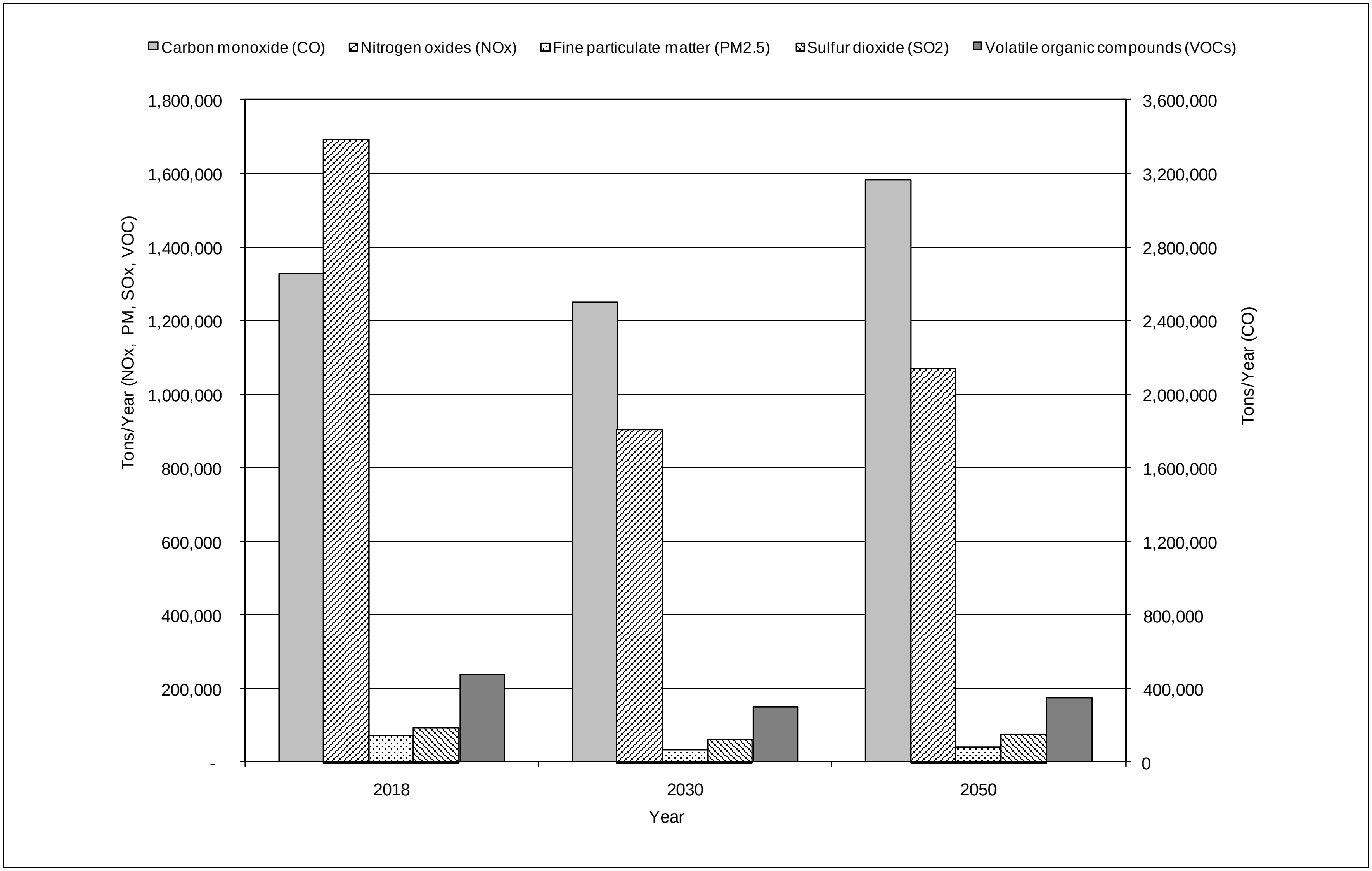


Figure 3.5.2-2. Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative (Corresponds to Figure 3.3.3-2)



criteria pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production, but increase from 2030 to 2050 due to continuing growth in VMT.

Total emissions are made up of eight components, consisting of two sources of emissions (tailpipe and upstream) for each of the four vehicle classes covered by the proposed rule: Classes 2b–3 HD pickups and vans, Classes 3–8 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 3.5.2-2 breaks down the total emissions of criteria pollutants by component for calendar year 2030.

Table 3.5.2-2
(Corresponds to Table 3.3.3-2)

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
Class 2b-3 Work Trucks Tailpipe	1,900,311	1,900,311	1,907,499	1,907,864	1,907,437
Class 2b-3 Work Trucks Upstream	4,219	4,219	4,247	4,164	3,857
Class 3-8 Vocational Vehicles Tailpipe	395,464	396,798	396,455	396,022	395,629
Class 3-8 Vocational Vehicles Upstream	6,059	5,827	5,664	5,488	4,870
Class 7-8 Day Cab Combination Unit Tailpipe	40,995	41,140	41,152	41,183	41,168
Class 7-8 Day Cab Combination Unit Upstream	7,695	7,715	7,642	7,633	7,533
Class 7-8 Sleeper Cab Combination Unit Tailpipe	189,125	128,552	128,569	128,630	128,706
Class 7-8 Sleeper Cab Combination Unit Upstream	12,428	11,680	11,596	11,169	10,855
Total	2,556,297	2,496,242	2,502,825	2,502,153	2,500,056
Nitrogen oxides (NO_x)					
Class 2b-3 Work Trucks Tailpipe	277,068	277,068	279,389	279,507	279,369
Class 2b-3 Work Trucks Upstream	12,756	12,756	12,846	12,591	11,661
Class 3-8 Vocational Vehicles Tailpipe	144,709	145,862	145,416	143,023	142,944
Class 3-8 Vocational Vehicles Upstream	18,148	17,454	16,966	16,439	14,591
Class 7-8 Day Cab Combination Unit Tailpipe	128,423	128,854	128,819	128,951	127,969
Class 7-8 Day Cab Combination Unit Upstream	23,010	23,071	22,852	22,823	22,526
Class 7-8 Sleeper Cab Combination Unit Tailpipe	498,577	263,652	262,869	260,601	256,934
Class 7-8 Sleeper Cab Combination Unit Upstream	37,162	34,926	34,673	33,396	32,457
Total	1,139,852	903,641	903,830	897,332	888,453
Particulate matter ($PM_{2.5}$)					
Class 2b-3 Work Trucks Tailpipe	3,233	3,233	3,253	3,254	3,250
Class 2b-3 Work Trucks Upstream	1,766	1,766	1,778	1,743	1,614
Class 3-8 Vocational Vehicles Tailpipe	4,645	4,681	4,701	4,751	4,726
Class 3-8 Vocational Vehicles Upstream	2,509	2,413	2,346	2,273	2,018
Class 7-8 Day Cab Combination Unit Tailpipe	4,077	4,101	4,098	4,102	4,103
Class 7-8 Day Cab Combination Unit Upstream	3,181	3,189	3,159	3,155	3,114
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,505	10,219	10,208	10,185	10,160
Class 7-8 Sleeper Cab Combination Unit Upstream	5,137	4,828	4,793	4,617	4,487
Total	33,053	34,431	34,337	34,081	33,473

Table 3.5.2-2 (continued)

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Sulfur dioxide (SO_2)					
Class 2b-3 Work Trucks Tailpipe	908	837	825	802	743
Class 2b-3 Work Trucks Upstream	8,096	8,096	8,151	7,991	7,401
Class 3-8 Vocational Vehicles Tailpipe	879	844	822	792	708
Class 3-8 Vocational Vehicles Upstream	11,631	11,186	10,873	10,535	9,348
Class 7-8 Day Cab Combination Unit Tailpipe	1,048	1,054	1,044	1,043	1,029
Class 7-8 Day Cab Combination Unit Upstream	14,773	14,811	14,671	14,653	14,462
Class 7-8 Sleeper Cab Combination Unit Tailpipe	1,845	1,675	1,663	1,605	1,562
Class 7-8 Sleeper Cab Combination Unit Upstream	23,858	22,422	22,260	21,440	20,838
Total	63,038	60,926	60,309	58,861	56,091
Volatile organic compounds (VOC)					
Class 2b-3 Work Trucks Tailpipe	48,103	48,103	48,222	48,192	48,050
Class 2b-3 Work Trucks Upstream	23,764	23,764	24,484	23,455	21,727
Class 3-8 Vocational Vehicles Tailpipe	18,275	18,198	18,118	17,994	17,670
Class 3-8 Vocational Vehicles Upstream	8,713	8,473	8,338	8,218	7,744
Class 7-8 Day Cab Combination Unit Tailpipe	8,903	8,946	8,903	8,901	8,849
Class 7-8 Day Cab Combination Unit Upstream	5,610	5,625	5,571	5,564	5,492
Class 7-8 Sleeper Cab Combination Unit Tailpipe	52,856	27,917	27,870	27,627	27,467
Class 7-8 Sleeper Cab Combination Unit Upstream	9,060	8,515	8,453	8,142	7,913
Total	175,283	149,540	149,959	148,094	144,912

Table 3.5.2-3 lists the net change in nationwide criteria pollutant emissions from HD vehicles for each of the criteria pollutants and analysis years, compared to the No Action Alternative. Figure 3.5.2-3 shows these changes in percentage terms for 2030. As a general trend, emissions of each pollutant decrease from Alternatives 2 through 5, as each successive alternative becomes more stringent. For some pollutants the changes are small: CO decreases by less than 3 percent under all Alternatives and in all years. Emissions of other pollutants show greater decreases: VOC decreases by up to 17 percent and NO_x decreases by up to 22 percent. $PM_{2.5}$ is the only pollutant to show emissions increases, growing by up to 4 percent depending on the alternative and year. The magnitudes of the declines are not consistent across all pollutants, 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.

Many of the differences between one action alternative and another in national emissions of criteria air pollutants are slight, in the range of 1 percent or less. Such small differences are not expected to lead to measurable changes in ambient concentrations of criteria pollutants. Consequently, for such small changes the impacts of those action alternatives would be essentially equivalent.

Table 3.5.2-3
(Corresponds to Table 3.3.3-3)

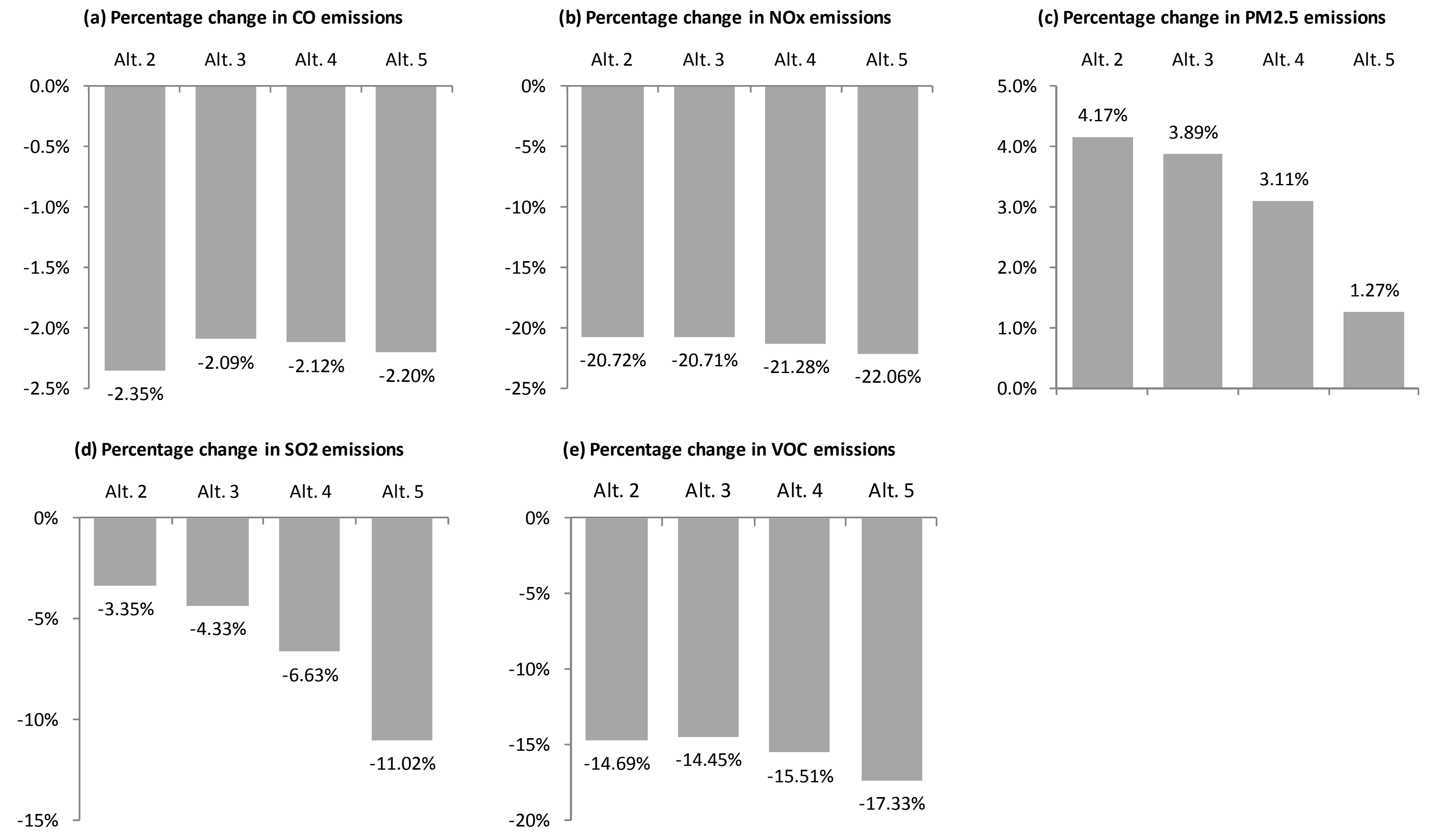
Nationwide Changes in Criteria Pollutant Emissions (tons/year) from HD Vehicles by Alternative a/ b/

Pollutant and Year	Alt. 1 c/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	0 c/	-28,574	-28,831	-27,741	-28,553
2030	0	-60,055	-53,473	-54,144	-56,242
2050	0	-83,003	-83,647	-73,065	-76,086
Nitrogen oxides (NO_x)					
2018	0	-111,572	-112,727	-115,261	-119,118
2030	0	-236,211	-236,023	-242,520	-251,400
2050	0	-325,914	-328,700	-330,977	-343,826
Particulate matter ($PM_{2.5}$)					
2018	0	107	14	-180	-481
2030	0	1,378	1,284	1,028	420
2050	0	2,285	2,159	2,182	1,249
Sulfur dioxide (SO_2)					
2018	0	-3,322	-3,788	-4,832	-6,174
2030	0	-2,113	-2,729	-4,177	-6,947
2050	0	-1,107	-1,832	-2,485	-6,743
Volatile organic compounds (VOC)					
2018	0	-13,937	-14,148	-14,556	-15,419
2030	0	-25,743	-25,324	-27,189	-30,371
2050	0	-34,734	-35,177	-35,469	-40,291

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Figure 3.5.2-3. Nationwide Percentage Changes in Criteria Pollutant Emissions from HD Vehicles by Alternative in 2030, Compared to the No Action Alternative (Corresponds to Figure 3.3.3-3)



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid
Note: percentage scales differ for each pollutant.

Table 3.5.2-4 summarizes the criteria air pollutant analysis results by nonattainment area. Tables in Appendix D list the emissions changes for each nonattainment area. For CO, NO_x, SO_2 and VOC, all nonattainment areas experience decreases in emissions across all alternatives and years. For $PM_{2.5}$, most nonattainment areas experience increases in emissions across all alternatives and years.

Table 3.5.2-4
(Corresponds to 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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-10,038	2050	Alt. 3	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-40,600	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Particulate matter ($PM_{2.5}$)	Maximum Increase	294	2050	Alt. 4	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-108	2018	Alt. 5	Houston-Galveston-Brazoria, TX (Ozone)
Sulfur dioxide (SO_2)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-529	2030	Alt. 5	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	-4,379	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)

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

3.5.2.2 Toxic Air Pollutants Overview

Table 3.5.2-5 summarizes the total national emissions of toxic air pollutants from HD vehicles by alternative for each of the toxic air pollutants and analysis years. Figure 3.5.2-4 illustrates this information for 2030, the mid-term forecast year.

The trends for toxic air pollutant emissions across the alternatives are mixed, for the same reasons as for criteria pollutants (*see* Section 3.5.2.1). Table 3.5.2-5 shows that emissions of acetaldehyde, acrolein, benzene, and formaldehyde decrease from Alternative 1 to Alternative 2, then remain relatively stable under each successive alternative from Alternative 2 to Alternative 5. Emissions of 1,3-butadiene are approximately equivalent for each alternative and year. For DPM, emissions in 2030 and 2050 are generally higher for Alternatives 2 through 5 compared to the No Action Alternative, and are approximately equivalent in 2018. Emissions of DPM under Alternative 5 are less than those under any other action alternative. These trends are accounted for by the extent of technologies assumed to be deployed under the different alternatives to meet the different levels of fuel efficiency requirements.

Figure 3.5.2-5 summarizes the changes over time in total national emissions of toxic air pollutants from HD vehicles for the Preferred Alternative. Figure 3.5.2-5 indicates a consistent trend among the toxic air pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA

Table 3.5.2-5
(Corresponds to 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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	6,212	5,339	5,339	5,340	5,340
2030	4,698	2,786	2,788	2,788	2,788
2050	5,941	3,284	3,285	3,291	3,290
Acrolein					
2018	952	832	832	832	832
2030	650	387	387	387	387
2050	811	445	446	446	446
Benzene					
2018	3,398	3,232	3,230	3,228	3,224
2030	2,300	1,954	1,954	1,949	1,940
2050	2,719	2,245	2,244	2,244	2,229
1,3-Butadiene					
2018	600	599	599	599	599
2030	299	299	299	299	299
2050	325	326	326	326	325
Diesel particulate patter (DPM)					
2018	67,978	68,057	67,948	67,700	67,382
2030	25,284	26,635	26,497	26,141	25,507
2050	28,333	30,589	30,419	30,256	29,287
Formaldehyde					
2018	15,506	12,642	12,642	12,642	12,640
2030	13,493	7,221	7,227	7,224	7,216
2050	17,502	8,790	8,793	8,808	8,795

Figure 3.5.2-4. Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative (Corresponds to Figure 3.3.3-4)

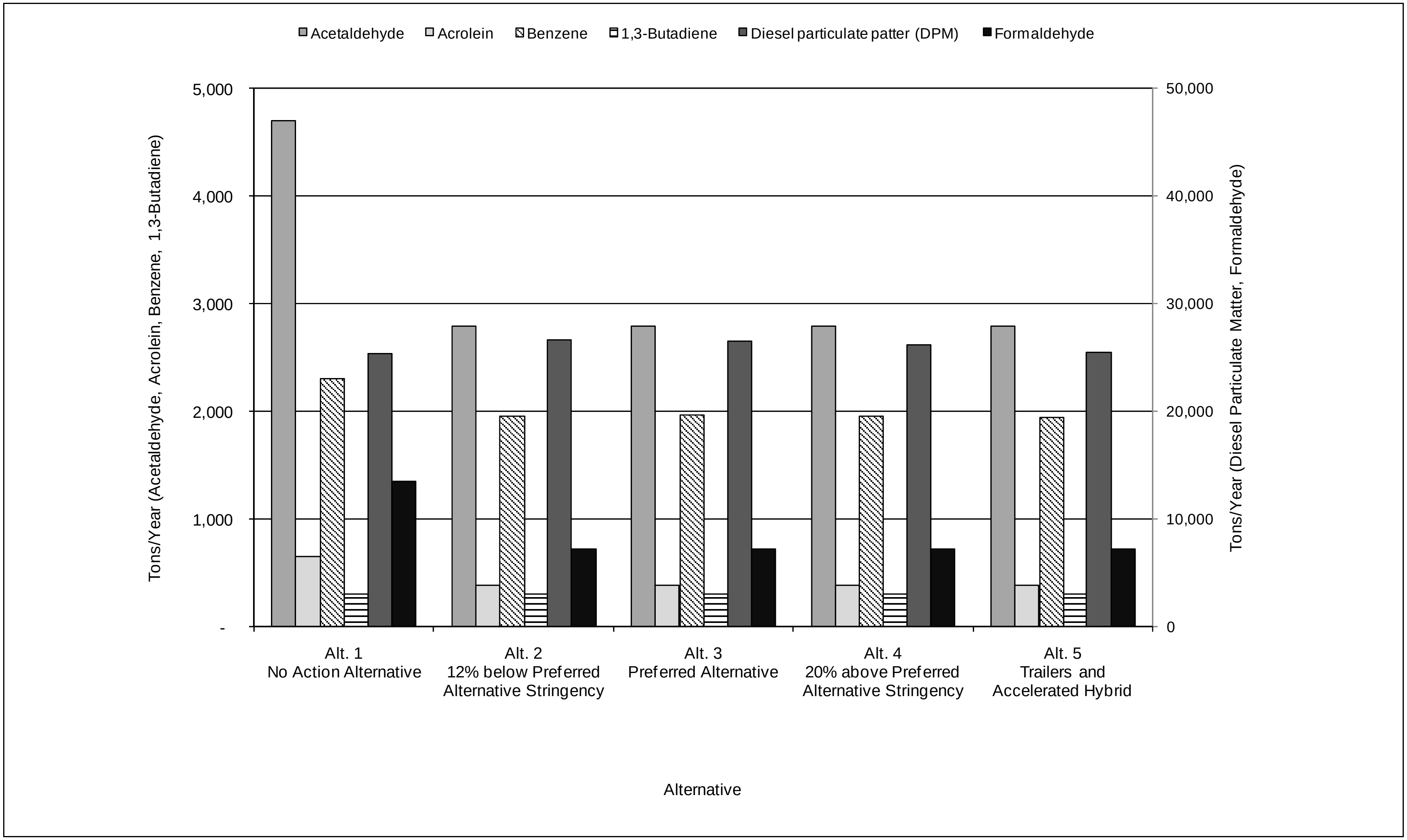
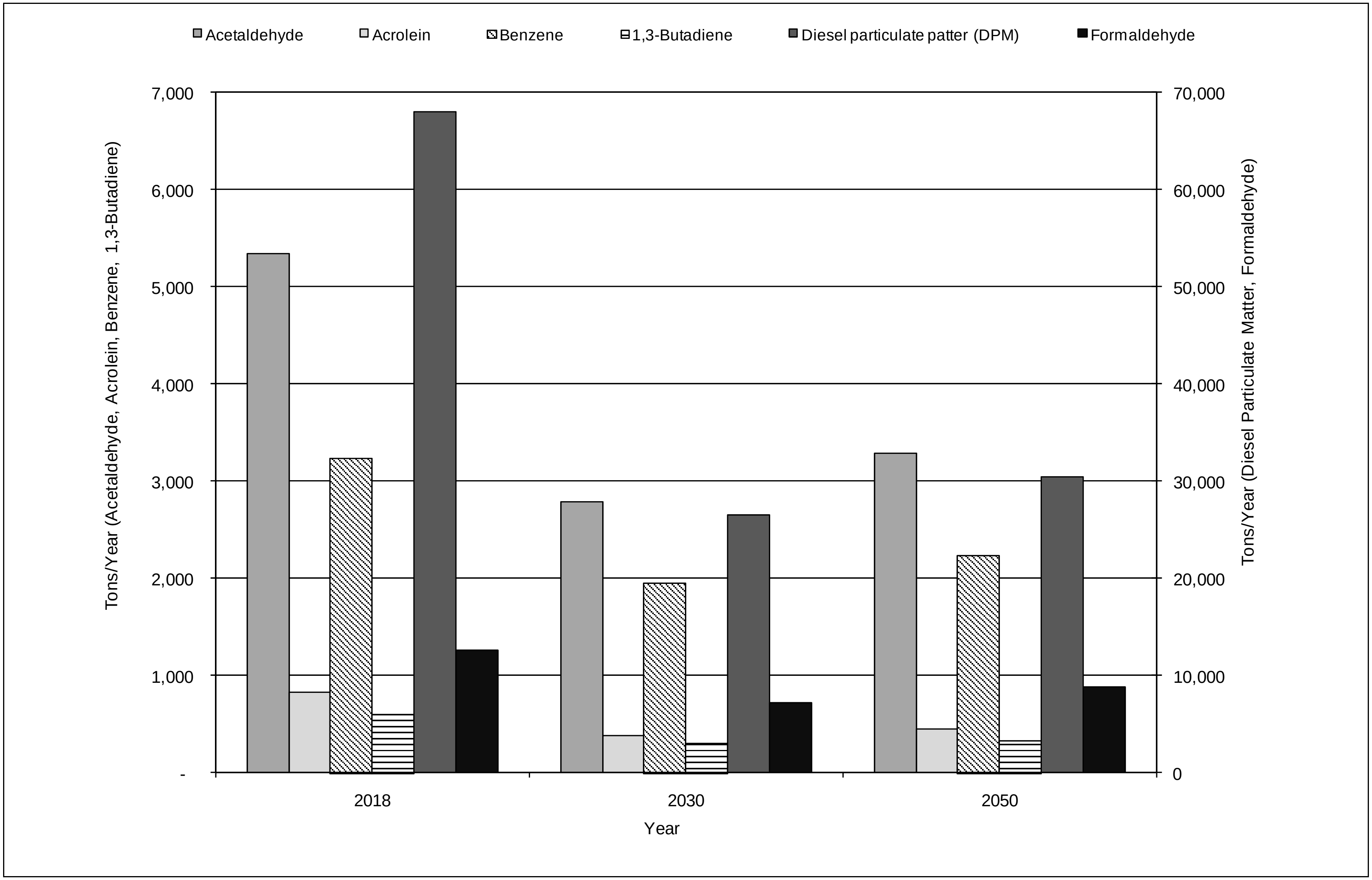


Figure 3.5.2-5. Nationwide Toxic Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative (Corresponds to Figure 3.3.3-5)



regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production, but increase from 2030 to 2050 due to continuing growth in VMT.

To show the relationship among the eight emissions components described in Section 3.5.2.1, Table 3.5.2-6 breaks down the total emissions of air toxic pollutants by component for calendar year 2030.

Table 3.5.2-6
(Corresponds to 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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
Class 2b-3 Work Trucks Tailpipe	456	456	457	457	457
Class 2b-3 Work Trucks Upstream	4	4	4	4	4
Class 3-8 Vocational Vehicles Tailpipe	1,058	1,064	1,065	1,065	1,063
Class 3-8 Vocational Vehicles Upstream	6	6	6	6	5
Class 7-8 Day Cab Combination Unit Tailpipe	279	280	280	280	281
Class 7-8 Day Cab Combination Unit Upstream	8	8	8	8	8
Class 7-8 Sleeper Cab Combination Unit Tailpipe	2,875	956	956	957	958
Class 7-8 Sleeper Cab Combination Unit Upstream	13	12	12	11	11
Total	4,698	2,786	2,788	2,788	2,788
Acrolein					
Class 2b-3 Work Trucks Tailpipe	69	69	70	70	70
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	113	114	114	114	113
Class 3-8 Vocational Vehicles Upstream	1	1	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	41	41	41	41	41
Class 7-8 Day Cab Combination Unit Upstream	1	1	1	1	1
Class 7-8 Sleeper Cab Combination Unit Tailpipe	422	158	158	159	159
Class 7-8 Sleeper Cab Combination Unit Upstream	2	2	2	2	2
Total	650	387	387	387	387

Table 3.5.2-6 (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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Benzene					
Class 2b-3 Work Trucks Tailpipe	88	88	89	89	89
Class 2b-3 Work Trucks Upstream	55	55	56	54	50
Class 3-8 Vocational Vehicles Tailpipe	1,425	1,433	1,434	1,434	1,432
Class 3-8 Vocational Vehicles Upstream	36	35	34	34	31
Class 7-8 Day Cab Combination Unit Tailpipe	53	53	53	53	53
Class 7-8 Day Cab Combination Unit Upstream	37	37	37	37	36
Class 7-8 Sleeper Cab Combination Unit Tailpipe	545	195	195	195	196
Class 7-8 Sleeper Cab Combination Unit Upstream	60	56	56	54	52
Total	2,300	1,954	1,954	1,949	1,940
1,3-butadiene					
Class 2b-3 Work Trucks Tailpipe	12	12	12	12	12
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Vehicles Tailpipe	228	230	230	230	230
Class 3-8 Vocational Vehicles Upstream	2	2	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	5	5	5	5	5
Class 7-8 Day Cab Combination Unit Upstream	2	2	2	2	2
Class 7-8 Sleeper Cab Combination Unit Tailpipe	47	46	46	46	46
Class 7-8 Sleeper Cab Combination Unit Upstream	3	3	3	3	3
Total	299	299	299	299	299
Diesel particulate matter (DPM)					
Class 2b-3 Work Trucks Tailpipe	1,491	1,491	1,495	1,495	1,493
Class 2b-3 Work Trucks Upstream	1,769	1,769	1,781	1,746	1,617
Class 3-8 Vocational Vehicles Tailpipe	2,332	2,345	2,339	2,306	2,298
Class 3-8 Vocational Vehicles Upstream	2,521	2,424	2,356	2,283	2,026
Class 7-8 Day Cab Combination Unit Tailpipe	2,591	2,609	2,606	2,609	2,595
Class 7-8 Day Cab Combination Unit Upstream	3,197	3,205	3,175	3,171	3,130
Class 7-8 Sleeper Cab Combination Unit Tailpipe	6,221	7,940	7,927	7,891	7,839
Class 7-8 Sleeper Cab Combination Unit Upstream	5,163	4,852	4,817	4,640	4,509
Total	25,284	26,635	26,497	26,141	25,507

Table 3.5.2-6 (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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Formaldehyde					
Class 2b-3 Work Trucks Tailpipe	1,341	1,341	1,347	1,347	1,347
Class 2b-3 Work Trucks Upstream	33	33	33	33	30
Class 3-8 Vocational Vehicles Tailpipe	2,244	2,258	2,261	2,260	2,256
Class 3-8 Vocational Vehicles Upstream	47	46	44	43	38
Class 7-8 Day Cab Combination Unit Tailpipe	853	856	857	857	859
Class 7-8 Day Cab Combination Unit Upstream	60	60	60	60	59
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,817	2,534	2,535	2,538	2,542
Class 7-8 Sleeper Cab Combination Unit Upstream	97	91	91	87	85
Total	13,493	7,221	7,227	7,224	7,216

Table 3.5.2-7 lists the net changes in nationwide emissions from HD vehicles for each of the toxic air pollutants and analysis years compared to the No Action Alternative. Figure 3.5.2-6 shows these changes in percentage terms for 2030. Table 3.5.2-7 shows that the magnitude of nationwide emission changes tends to increase from 2018 to 2030 to 2050, and that emissions of toxic air pollutants are very similar under the action alternatives, except for DPM.

Table 3.5.2-7
(Corresponds to 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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	0	-873	-873	-872	-872
2030	0	-1,912	-1,910	-1,909	-1,910
2050	0	-2,657	-2,656	-2,650	-2,651
Acrolein					
2018	0	-120	-120	-120	-120
2030	0	-263	-263	-263	-263
2050	0	-366	-365	-365	-365

Table 3.5.2-7 (continued)
(Corresponds to Table 3.3.3-7)

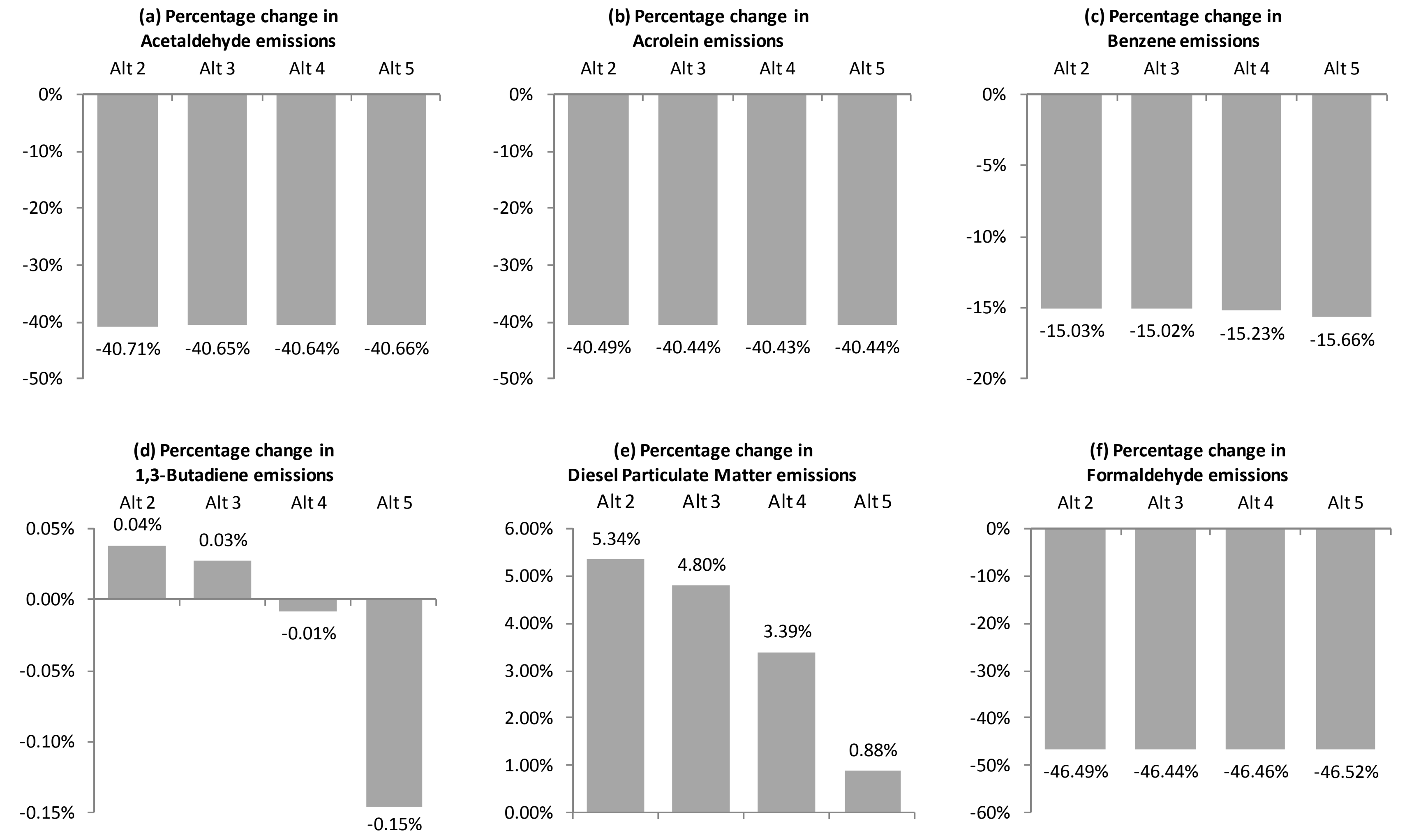
Nationwide Changes in Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Poll. and Year	Alt. 1 c/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Benzene					
2018	0	-166	-167	-169	-173
2030	0	-346	-345	-350	-360
2050	0	-474	-476	-476	-491
1,3-Butadiene					
2018	0	-1	-1	-1	-1
2030	0	0	0	0	0
2050	0	1	1	1	0
Diesel particulate matter (DPM)					
2018	0	79	-30	-278	-596
2030	0	**1,351**	**1,213**	**857**	223
2050	0	**2,256**	**2,086**	**1,923**	**954**
Formaldehyde					
2018	0	-2,865	-2,864	-2,864	-2,866
2030	0	-6,272	-6,266	-6,268	-6,277
2050	0	-8,711	-8,709	-8,693	-8,707

a/ Emissions changes have been rounded to the nearest whole number.
b/ Negative emissions changes indicate reductions; positive emissions changes are increases.
c/ Emissions changes are shown as zero because the No Action Alternative is the baseline to which emissions from the action alternatives are compared.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Figure 3.5.2-6. Nationwide Percentage Changes in Toxic Air Pollutant Emissions from HD Vehicles by Alternative in 2030 Compared to the No Action Alternative (Corresponds to Figure 3.3.3-6)



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid
Note: percentage scales differ for each pollutant.

Many of the differences between one action alternative and another in national emissions of toxic air pollutants are slight, in the range of 1 percent or less. Such small differences are not expected to lead to measurable changes in ambient concentrations of toxic air pollutants. Consequently, for such small changes the impacts of those action alternatives would be essentially equivalent.

Table 3.5.2-8 summarizes the air toxics analysis results by nonattainment area. Tables in Appendix D list the emission reductions for each nonattainment area. For acetaldehyde, acrolein, benzene, and formaldehyde, all nonattainment areas experience decreases in emissions across all alternatives and years. For 1,3-butadiene, emissions change very little compared to the No Action Alternative across all action alternatives and years. For DPM, emissions increase in most nonattainment areas in all years and alternatives.

Table 3.5.2-8
(Corresponds to 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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-321	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Acrolein	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-44	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Benzene	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-57	2050	Alt. 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	0.1	2050	Alt. 4	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-0.3	2018	Alt. 4	Houston-Galveston-Brazoria, TX (Ozone)
Diesel particulate matter (DPM)	Maximum Increase	284	2050	Alt. 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-113	2018	Alt. 5	Houston-Galveston-Brazoria, TX (Ozone)
Formaldehyde	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,051	2050	Alt. 2	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.

3.5.2.3 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 3.5.2-9). Table 3.5.2-10 lists the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative. The reductions in adverse health effects and the monetized health benefits become greater under the more stringent alternatives.

Table 3.5.2-9
(Corresponds to Table 3.3.3-9)

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

Out. and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Mortality (ages 30 and older), Pope *et al.* (2002)					
2018	0	-71	-75	-85	-100
2030	0	-122	-127	-145	-181
2050	0	-171	-181	-184	-246
Mortality (ages 30 and older), Laden *et al.* (2006)					
2018	0	-181	-193	-219	-257
2030	0	-312	-324	-371	-464
2050	0	-437	-462	-469	-629
Chronic bronchitis					
2018	0	-51	-54	-61	-71
2030	0	-85	-88	-100	-125
2050	0	-116	-122	-124	-164
Emergency Room Visits for Asthma					
2018	0	-59	-64	-73	-87
2030	0	-89	-93	-110	-142
2050	0	-113	-122	-125	-178
Work-Loss Days					
2018	0	-9,760	-10,377	-11,682	-13,640
2030	0	-15,450	-16,018	-18,183	-22,545
2050	0	-20,105	-21,179	-21,470	-28,422

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Table 3.5.2-10
(Corresponds to Table 3.3.3-10)

Nationwide Monetized Health Benefits (2009 U.S. million dollars per year) from Criteria Pollutant Emissions from HD Vehicles by Alternative a/

Poll. and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
3-Percent Discount Rate					
Pope *et al.* (2002)					
2018	0	-628	-670	-758	-890
2030	0	-1,125	-1,169	-1,336	-1,673
2050	0	-1,605	-1,696	-1,721	-2,310
Laden *et al.* (2006)					
2018	0	-1,537	-1,639	-1,855	-2,178
2030	0	-2,749	-2,859	-3,268	-4,092
2050	0	-3,922	-4,145	-4,207	-5,649
7-Percent Discount Rate					
Pope *et al.* (2002)					
2018	0	-570	-608	-688	-808
2030	0	-1,020	-1,061	-1,212	-1,518
2050	0	-1,456	-1,538	-1,561	-2,095
Laden *et al.* (2006)					
2018	0	-1,388	-1,481	-1,676	-1,968
2030	0	-2,483	-2,583	-2,952	-3,696
2050	0	-3,543	-3,744	-3,800	-5,103

a/ Negative changes indicate monetized health benefits; positive emissions 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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

For all health outcomes the health benefits would uniformly increase from Alternative 2 (least stringent) to Alternative 5 (most stringent). The benefits would also increase steadily from the near future (2018) to later years (2050). These trends are consistent across all health outcomes: in 2018, the incidences of all outcomes decrease between 1 percent and 2 percent. In 2050, this benefit increases to 5 percent to 8 percent. The results in Table 3.5.2-9 present mortality as measured using the Pope *et al.* and the Laden *et al.* coefficients (*see* Section 3.3.2.7.2). While the magnitude of mortality varies between the two methods, the percent change in mortality remains constant across the two approaches.

The monetized health benefits of these health trends follow similar trends to the changes in health outcomes. The monetized health benefits of each alternative increase (in percentage terms) from

Alternative 2 (least stringent) to Alternative 5 (most stringent) and from the near future (2018) to later years (2050). Monetized health benefits are measured under the Pope *et al.* methodology and the Laden *et al.* methodology. Further, benefits are calculated using a 3 percent discount rate and a 7 percent discount rate. Because the 7 percent monetized health benefits places less present value on future year benefits than the 3 percent monetized health benefits, the present year benefit of emissions reductions in 2050 is approximately 10 percent smaller under the 7 percent discount rate than under the 3 percent discount rate. In total, the monetized health benefits range between approximately $570 million and $5.6 billion depending on the scenario, alternative, and year.

Sections 3.5.2.4 through 3.5.2.8 describe the results of the analysis of emissions for Alternatives 1 through 5 in greater detail. The magnitude of emission change from one alternative to the next generally increases between Alternative 2 and Alternative 5 consistent with the required greater overall fuel efficiency. Health and monetized health benefits increase with each alternative from Alternative 2 through Alternative 5.

3.5.2.4 Alternative 1: No Action Alternative

3.5.2.4.1 Criteria Pollutants

Under the No Action Alternative, the average fuel efficiency for HD vehicles would increase in future years according to AEO projections. Current trends in the levels of criteria pollutant emissions from vehicles would continue, with emissions continuing to decline due to tightening EPA emission standards (*see* Section 3.3.1), despite a growth in total VMT from 2018 to 2030. From 2030 to 2050, however, emissions would increase overall due to continuing growth in total VMT, which during this period, would outweigh the decline in emissions due to emission standards (*see* Table 3.5.2-1). 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 (*see* Table 3.5.2-3), beyond changes projected to result from future trends in emissions and VMT.

3.5.2.4.2 Toxic Air Pollutants

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 under the No Action Alternative, with emissions continuing to decline due to the EPA emission standards from 2018 to 2030 (*see* Section 3.3.1), despite a growth in total VMT. From 2030 to 2050, however, emissions would increase due to growth in total VMT during that period (*see* Table 3.5.2-5). 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 (*see* Table 3.5.2-7), beyond current trends shown in Table 3.5.2-5.

3.5.2.4.3 Health Outcomes and Monetized Benefits

Under the No Action Alternative, current trends in the levels of criteria pollutant and toxic air pollutant emissions from vehicles would continue, with emissions continuing to decline due to the increasingly stringent EPA emission standards (*see* Section 3.3-1), despite a growth in total VMT. The human health-related impacts expected under current trends would continue (*see* Tables 3.5.2-9 and 3.5.2-10). The No Action Alternative would not result in any other increase or decrease in human health impacts throughout the United States.

3.5.2.5 Alternative 2: 12 percent below Preferred Alternative Stringency

3.5.2.5.1 Criteria Pollutants

Table 3.5.2-3 and Figure 3.5.2-1 show the changes in nationwide emissions of criteria pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-3 shows these changes in percentage terms for 2030. Under Alternative 2, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative. Alternative 2 is the least stringent of all the action alternatives and most reductions under Alternative 2 are smaller than or equivalent to those under the other action alternatives. Because Alternative 2 assumes that sleeper cab combination units would use APUs during extended idling, and because APUs have higher PM emission rates than do the truck main engines at idle, this alternative would have higher $PM_{2.5}$ emissions than would the No Action Alternative.

Under Alternative 2, 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 and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

3.5.2.5.2 Toxic Air Pollutants

Table 3.5.2-7 and Figure 3.5.2-5 show the changes in nationwide emissions of toxic air pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 2 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde, and approximately equivalent emissions of 1,3-butadiene, for all analysis years. DPM emissions would change slightly under all alternatives in 2018 and increase by less than 10 percent under all alternatives in 2030 and 2050 (*see* Table 3.5.2-7). Emissions reductions under Alternative 2 would be approximately equivalent to those under the other action alternatives for all studied toxic air pollutants, except that DPM emissions would increase. Emissions of DPM are higher under Alternative 2 than those under Alternatives 3 through 5 (*see* Figure 3.5.2-6, panel (e)).

At the national level, emissions of toxic air pollutants could decrease overall because both 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 together tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. However, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas.

Under Alternative 2, 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 all 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.

3.5.2.5.3 Health Outcomes and Monetized Benefits

Under Alternative 2, adverse health effects nationwide would be reduced compared to the No Action Alternative (*see* Table 3.5.2-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.5.2-10, the monetized health benefits of Alternative 2 range from approximately $570 million to $3.9 billion. The health and monetized health benefits of Alternative 2 are the smallest of all the action alternatives.

3.5.2.6 Alternative 3: Preferred Alternative

3.5.2.6.1 Criteria Pollutants

Table 3.5.2-3 and Figure 3.5.2-1 show the changes in nationwide emissions of criteria pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-3 shows these changes in percentage terms for 2030. Under this alternative, emissions of all pollutants except $PM_{2.5}$ would be reduced compared to the No Action Alternative. Because Alternative 3 assumes that sleeper cab combination units would use APUs during extended idling, this alternative would have higher $PM_{2.5}$ emissions than would the No Action Alternative. This Alternative reduces emissions of the other criteria pollutants by amounts approximately equivalent to those under Alternative 2, but less than the more stringent Alternatives 4 and 5.

Under Alternative 3, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (*see* Appendix D). 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 and APU usage.

3.5.2.6.2 Toxic Air Pollutants

Table 3.5.2-7 and Figure 3.5.2-5 show the changes in nationwide emissions of toxic air pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 3 would result in reduced emissions of acetaldehyde, acrolein, benzene, and formaldehyde for all years. Emissions of 1,3-butadiene would remain approximately unchanged in all years. DPM emissions would remain approximately unchanged in 2018 and would increase in 2030 and 2050 (*see* Table 3.5.2-7). Emissions reductions under Alternative 3 are approximately equivalent (within 1 percent) to those under Alternatives 4 and 5 for all studied toxic air pollutants except DPM. Emissions of DPM are higher under Alternative 3 than under Alternatives 4 or 5 (*see* Figure 3.5.2-6, panel (e)).

At the national level, as for less stringent alternatives, emissions of toxic air pollutants could decrease for the reasons described above (*see* Section 3.5.2.5.2). As with less stringent alternatives, 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 all 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 all 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.

3.5.2.6.3 Health Outcomes and Monetized Benefits

Reductions in adverse health effects would occur nationwide under Alternative 3 compared to the No Action Alternative (*see* Table 3.5.2-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.5.2-10, the monetized health benefits of Alternative 3 range from approximately $610 million to $4.1 billion. These benefits are greater than those of Alternative 2 for all health outcomes and years, but less than those of Alternatives 4 and 5.

3.5.2.7 Alternative 4: 20 percent above Preferred Alternative Stringency

3.5.2.7.1 Criteria Pollutants

Table 3.5.2-3 and Figure 3.5.2-1 show the changes in nationwide emissions of criteria pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-3 shows these changes in percentage terms for 2030. Under Alternative 4, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would decrease in all years. Because Alternative 4 assumes that sleeper cab combination units would use APUs during extended idling, this alternative would have slightly higher $PM_{2.5}$ emissions than would the No Action Alternative in 2030 and 2050. For the other criteria pollutants Alternative 4 produces slightly greater emission reductions than Alternatives 2 and 3 but less than Alternative 5.

Under Alternative 4, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (s*ee* Appendix D). 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.

3.5.2.7.2 Toxic Air Pollutants

Table 3.5.2-7 and Figure 3.5.2-5 show the changes in nationwide emissions of toxic pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 4 would result in approximately equivalent emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde for all analysis years and slightly reduced emissions of DPM in 2018 but increased emissions in 2030 and 2050 (*see* Table 3.5.2-7). Emissions reductions under Alternative 4 would be approximately equivalent to those under Alternative 5 for all studied toxic air pollutants except DPM for which emissions would be slightly higher than under Alternative 5.

At the national level, as with less stringent alternatives, emissions of toxic air pollutants could decrease for the reasons described above (*see* Section 3.5.2.5.2). 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 all 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 slightly in most or all 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.

3.5.2.7.3 Health Outcomes and Monetized Benefits

Adverse health effects would be reduced nationwide under Alternative 4 compared to the No Action Alternative (*see* Table 3.5.2-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.5.2-10, the monetized health benefits of Alternative 4 range from approximately $690 million to $4.2 billion as compared to the No Action Alternative. The health and monetized health benefits are greater than under Alternatives 2 and 3 but less than under Alternative 5.

3.5.2.8 Alternative 5: Trailers and Accelerated Hybrid

3.5.2.8.1 Criteria Pollutants

Table 3.5.2-3 and Figure 3.5.2-1 show the changes in nationwide emissions of criteria pollutants under Alternative 5 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-3 shows these changes in percentage terms for 2030. Under Alternative 5, nationwide emissions of CO, NO_x, SO_2, and VOCs compared to the No Action Alternative would decrease in all years. Alternative 5 produces greater emission reductions of NO_x, SO_2, and VOCs than any other alternative. Emissions of CO are reduced to the greatest extent under Alternatives 2 and 3, though these differences are generally slight. Because Alternative 5 assumes that sleeper cab combination units would use APUs during extended idling, this alternative would have higher slightly $PM_{2.5}$ emissions than would the No Action Alternative in 2030 and 2050.

Under Alternative 5, all nonattainment areas would experience reductions in emissions of CO, NO_x, SO_2, and VOCs (*see* Appendix D). 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 and APU usage.

3.5.2.8.2 Toxic Air Pollutants

Table 3.5.2-7 and Figure 3.5.2-5 show the changes in nationwide emissions of toxic air pollutants under Alternative 5 compared to the No Action Alternative and the other action alternatives. Figure 3.5.2-6 shows these changes in percentage terms for 2030. Alternative 5 would result in reduced or approximately equivalent emissions of all studied toxic air pollutants in all analysis years compared to the No Action Alternative (*see* Table 3.5.2-7). Emissions of air toxics under Alternative 5 would be lower than, or essentially equivalent to, those under any other action alternative. The differences in emissions among Alternatives 2 through 5 are generally slight, though DPM emissions under Alternative 5 would be less than under the other action alternatives.

At the national level, as for less stringent alternatives, emissions of toxic air pollutants could decrease for the reasons described above (*see* Section 3.5.2.5.2). 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 all 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 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.

3.5.2.8.3 Health Outcomes and Monetized Benefits

Reductions in adverse health effects nationwide would occur under Alternative 5 compared to the No Action Alternative (*see* Table 3.5.2-9). These health benefits increase greatly from 2018 to 2050. As shown in Table 3.5.2-10, the monetized health benefits of Alternative 2 range from approximately $810 million to $5.6 billion. The health and monetized health benefits of Alternative 5 are greater than those of all other alternatives.

3.5.3 Climate Environmental Consequences

3.5.3.1 Greenhouse Gas Emissions

NHTSA estimated emission reductions resulting from the proposed action and alternatives for MY 2014–2018 HD vehicles. In the following discussion, emission reductions are the differences in the estimated future annual emissions of HD vehicles in use under the No Action Alternative and each action alternative. For further discussion of this methodology, please *see* Section 3.4.

Table 3.5.3-1 and Figure 3.5.3-1 show total U.S. HD CO_2 emissions and emission reductions that would result from the four action alternative standards in the years 2014 to 2100. U.S. HD vehicle emissions for this period range from a low of 60,500 $MMTCO_2$ under Alternative 5 to 66,000 $MMTCO_2$ under the No Action Alternative.

Compared to the No Action Alternative, projections of emission reductions from 2014 to 2100 due to the action alternatives range from 900 to 5,500 $MMTCO_2$. Compared to cumulative global emissions of 5,204,115 $MMTCO_2$ over this period (projected by the GCAMReference scenario), the proposed alternatives are expected to reduce global CO_2 emissions by between 0.02 percent (Alternative 2) and 0.11 percent (Alternative 5) from their projected levels under the No Action Alternative.

The action alternatives reduce CO_2 emissions in the United States by 1–8 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 GCAMReference scenario (Thomson *et al.*, 2011), the action alternatives would reduce total U.S. CO_2 emissions from all sources by 0.1–0.8 percent in 2100. Figure 3.5.3-2 shows projected annual emissions from HD vehicles under the alternatives.

Table 3.5.3-1
(Corresponds to Table 3.4.4-1)

CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles 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 Alternative	66,000	0	
2 12% below Preferred Alternative Stringency	65,000	900	1%
3 Preferred Alternative	64,600	1,400	2%
4 20% above Preferred Alternative Stringency	63,700	2,300	3%
5 Trailers and Accelerated Hybrid	60,500	5,500	8%

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.

Figure 3.5.3-1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles from 2014 to 2100 by Alternative (Corresponds to Figure 3.4.4-1)

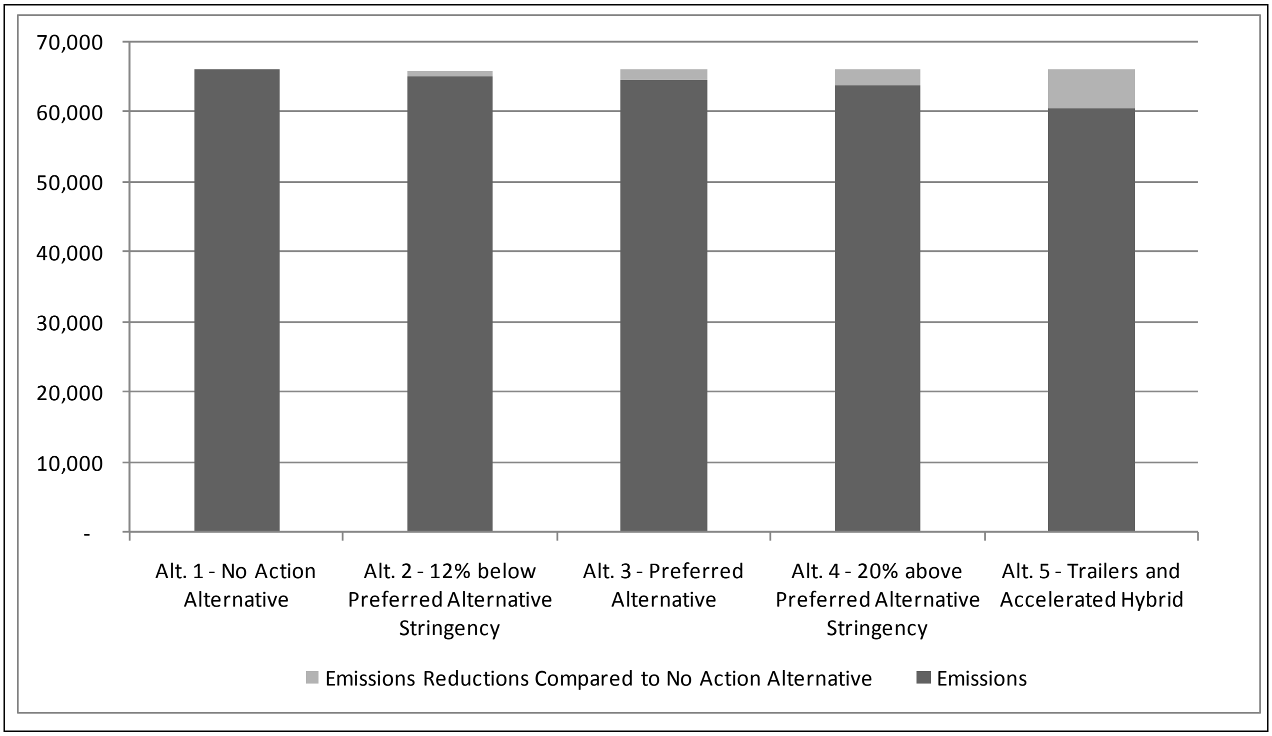


Figure 3.5.3-2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. HD Vehicles by Alternative
(Corresponds to Figure 3.4.4-2)

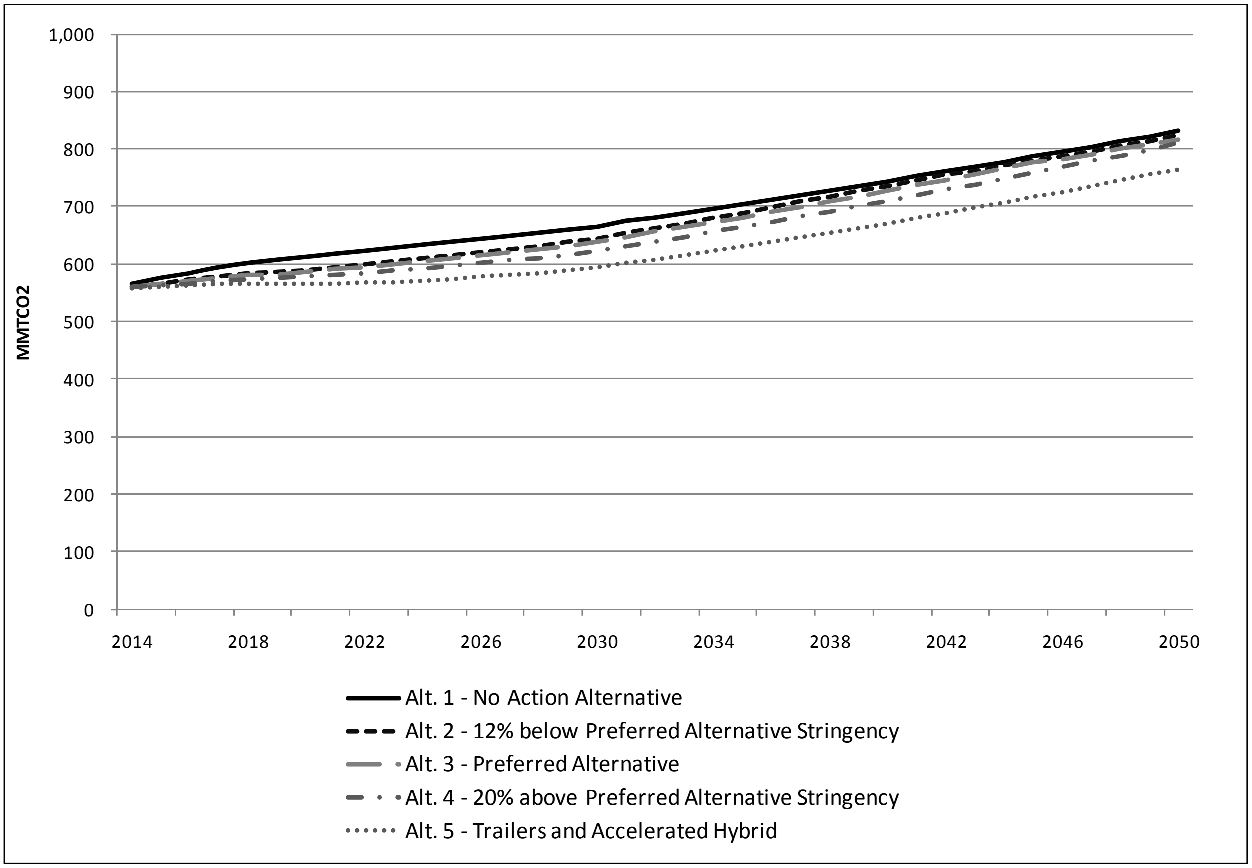


Table 3.5.3-2 shows total CO_2, CH_4, and N_2O emissions from HD vehicles in the United States for the No Action Alternative and each action alternative after 2020. The table also shows that each action alternative would reduce HD vehicle CO_2. CH_4, and N_2O emissions in future years significantly from 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 as stringency increases.

Table 3.5.3-2
(Corresponds to Table 3.4.4-2)

Emissions of Greenhouse Gases ($MMTCO_2e$ per year) a/ from U.S. HD Vehicles by Alternative

GHG and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon dioxide (CO_2)					
2020	614	590	586	578	565
2030	666	645	638	623	594
2050	831	823	817	810	765
2080	821	813	807	800	756
2100	764	756	751	744	703
Methane (CH_4)					
2020	20.32	19.01	18.90	18.65	18.31
2030	19.04	17.41	17.19	16.80	16.04
2050	22.47	22.29	22.15	20.40	19.32
2080	22.20	22.01	21.88	20.15	19.08
2100	20.65	20.48	20.35	18.75	17.75
Nitrous oxide (N_2O)					
2020	1.56	1.55	1.54	1.54	1.53
2030	1.22	1.20	1.20	1.18	1.16
2050	1.40	1.39	1.39	1.39	1.35
2080	1.38	1.38	1.37	1.37	1.34
2100	1.29	1.28	1.28	1.27	1.24

a/ $MMTCO_2e$ is million metric tons CO_2 equivalent

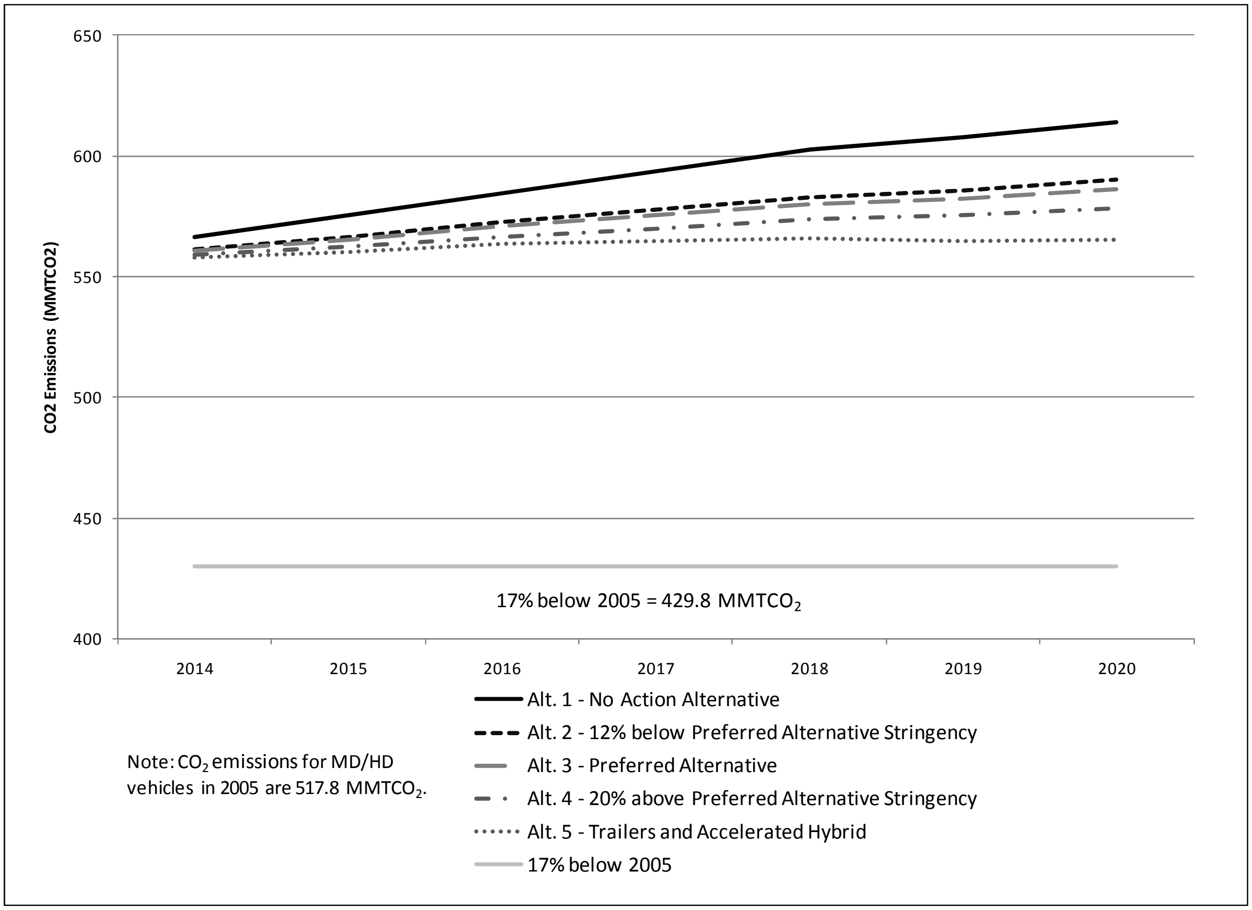
Under each alternative analyzed, growth in the number of HD vehicles in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth of HD vehicle travel. This growth in travel more than offsets the effect of improvements in fuel efficiency 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 3.5.3-1. 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.

In regard to the reduction target for the United States in the range of 17 percent below 2005 levels by 2020 in association with the Copenhagen Accord, total CO_2 emissions from the HD vehicle sector in

2020 would increase in the range of 9.2−14.0 percent above 2005 levels.[86] 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. For more information regarding this reduction target, *see* Section 3.4.4.1.

As Figure 3.5.3-3 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.

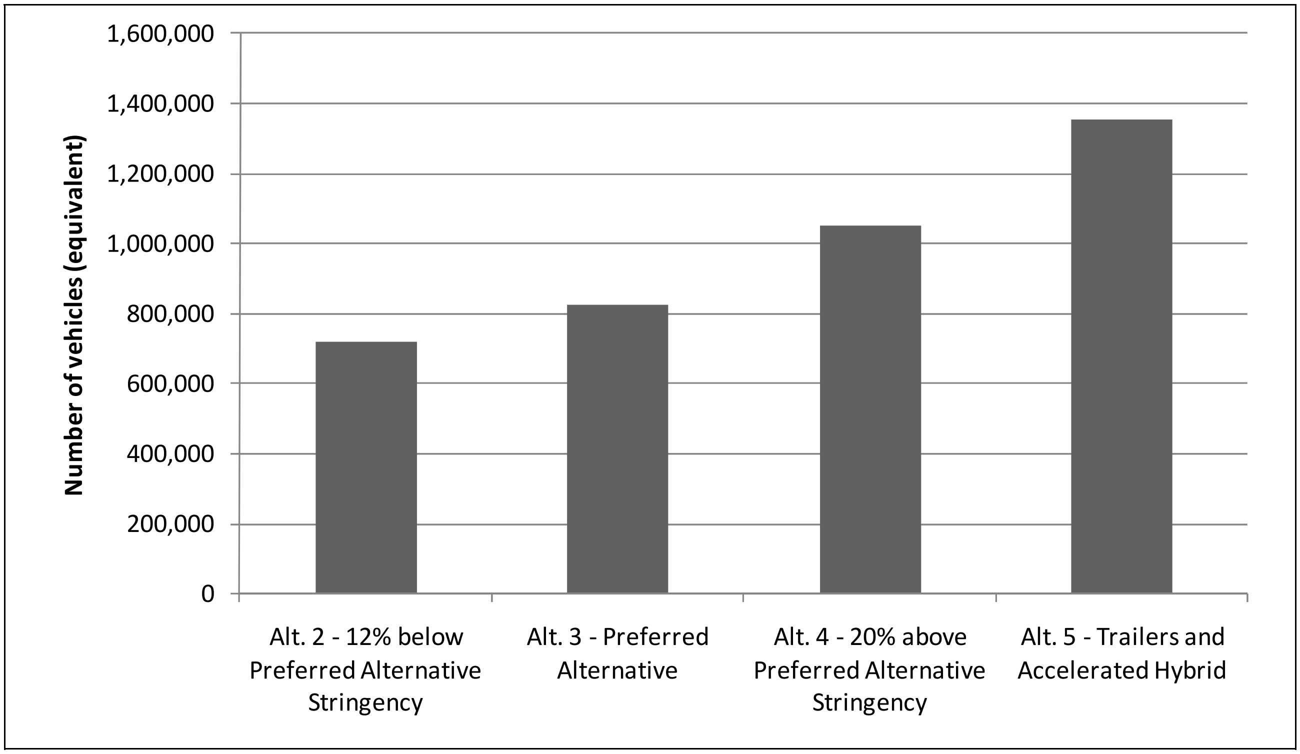
Figure 3.5.3-3. Projected Annual CO_2 Emissions from U.S. HD Vehicles by Alternative, Compared to 2005 Levels (Corresponds to Figure 3.4.4-3)



[86] A 17-percent reduction would mean a reduction of 106.9 $MMTCO_2$ from 2005 levels or a reduction of 194.9 $MMTCO_2$ from the No Action Alternative baseline.

Figure 3.5.3-4 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 0.72 million HD vehicles (Alternative 2) and 1.35 million HD vehicles (Alternative 5) in 2018, as compared to the annual emissions that would occur under the No Action Alternative. Emission reductions in 2018 from the Preferred Alternative are equivalent to the annual emissions of 0.83 million HD vehicles, as compared to the No Action Alternative. 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 increasingly stringent fuel efficiency standards required by each alternative.[87]

Figure 3.5.3-4. Number of HD Vehicles Equivalent to CO_2 Reductions in 2018, Compared to the No Action Alternative (Corresponds to Figure 3.4.4-4)



These emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. In comparison to the Western Climate Initiative goal (outlined above in Section 3.4.4.1), the proposed HD Fuel Efficiency Improvement Program is expected to reduce CO_2 emissions by 107 to 201 $MMTCO_2$ between 2014 and 2020 (depending on the alternative), with emissions levels in 2020 representing a 4- to 9-percent reduction from the future baseline emissions for HD vehicles in the United States. In comparison to the Regional Greenhouse Gas Initiative (RGGI) goal outlined in Section 3.4.4.1, this Program would reduce CO_2 emissions by 206 to 433 $MMTCO_2$ 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 U.S. HD vehicles.

[87] 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 27.07 metric tons of CO_2 in the year 2018 based on MOVES and GREET model analysis.

3.5.3.2 Social Cost of Carbon

Table 3.5.3-3 provides the benefits of the HD vehicle rule in terms of reduced monetized damages. This Table uses the same methodology as applied in Section 3.4.4.2.

Table 3.5.3-3
(Corresponds to 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	$2,079	$10,372	$17,439	$31,670
3	$2,788	$14,103	$23,786	$43,043
4	$4,378	$22,476	$38,024	$68,562
5	$7,674	$40,257	$68,419	$122,718

3.5.3.3 Direct and Indirect Effects on Climate Change Indicators

Sections 3.5.3.3.1 through 3.5.3.3.4 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. Where insufficient information exists to quantitatively analyze the effects of the alternatives or to analyze each alternative separately, NHTSA refers readers to the corresponding qualitative analysis in Section 3.4.

3.5.3.3.1 Atmospheric CO_2 Concentrations

As discussed in Section 3.4.3, NHTSA used the MAGICC 5.3v2 simple climate model and the GCAMReference scenario to represent the No Action Alternative in the MAGICC modeling runs. Table 3.5.3-4 and Figures 3.5.3-5 through 3.5.3-8 present the results of MAGICC simulations for the No Action Alternative and the four action alternatives in terms of CO_2 concentrations and increases in global mean surface temperature in 2030, 2050, and 2100.

As shown in Table 3.5.3-4 and Figures 3.5.3-5 through 3.5.3-8, estimated CO_2 concentrations for 2100 range from 784.4 ppm under Alternative 5 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 differences in these effects. Even though these effects are small in comparison to total projected changes, they occur on a global scale and are long-lived.

Table 3.5.3-4
(Corresponds to Table 3.4.4-5)

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

	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C) b/			Sea-Level Rise (cm) b/		
Totals by Alternative	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**
1 No Action Alternative	443.6	519.0	784.9	0.880	1.516	3.064	8.06	14.81	37.40
2 12% below Preferred Alternative Stringency	443.6	518.9	784.8	0.880	1.516	3.064	8.06	14.81	37.39
3 Preferred Alternative	443.6	518.9	784.7	0.880	1.516	3.064	8.06	14.81	37.39
4 20% above Preferred Alternative Stringency	443.6	518.9	784.7	0.880	1.516	3.063	8.06	14.81	37.39
5 Trailers and Accelerated Hybrid	443.5	518.8	784.4	0.880	1.515	3.062	8.06	14.81	37.38
Reductions Under Alternative HD Standards									
2 12% below Preferred Alternative Stringency	0.0	0.1	0.1	0.000	0.000	0.000	0.00	0.00	0.01
3 Preferred Alternative	0.0	0.1	0.1	0.000	0.000	0.001	0.00	0.00	0.01
4 20% above Preferred Alternative Stringency	0.1	0.1	0.2	0.000	0.001	0.001	0.00	0.00	0.01
5 Trailers and Accelerated Hybrid	0.1	0.2	0.5	0.000	0.001	0.002	0.00	0.00	0.02

a/ The numbers in this table have been rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b/ The values for global mean surface temperature and sea-level rise are relative to levels in the year 1990.

Figure 3.5.3-5. CO_2 Concentrations (ppm)
(Corresponds to Figure 3.4.4-5)

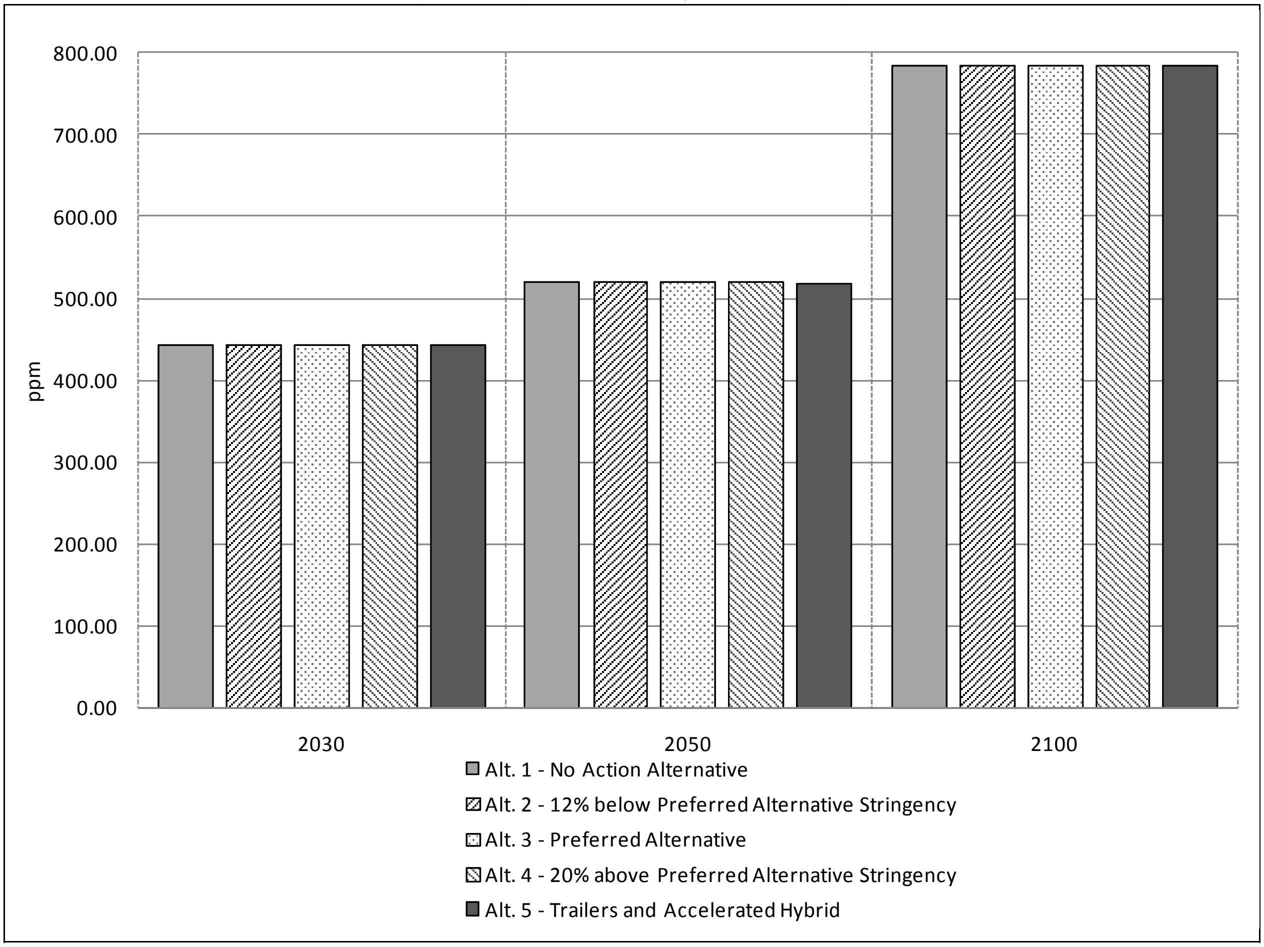


Figure 3.5.3-6. Change in Global Mean Surface Temperature Increase (°C) (Corresponds to Figure 3.4.4-6)

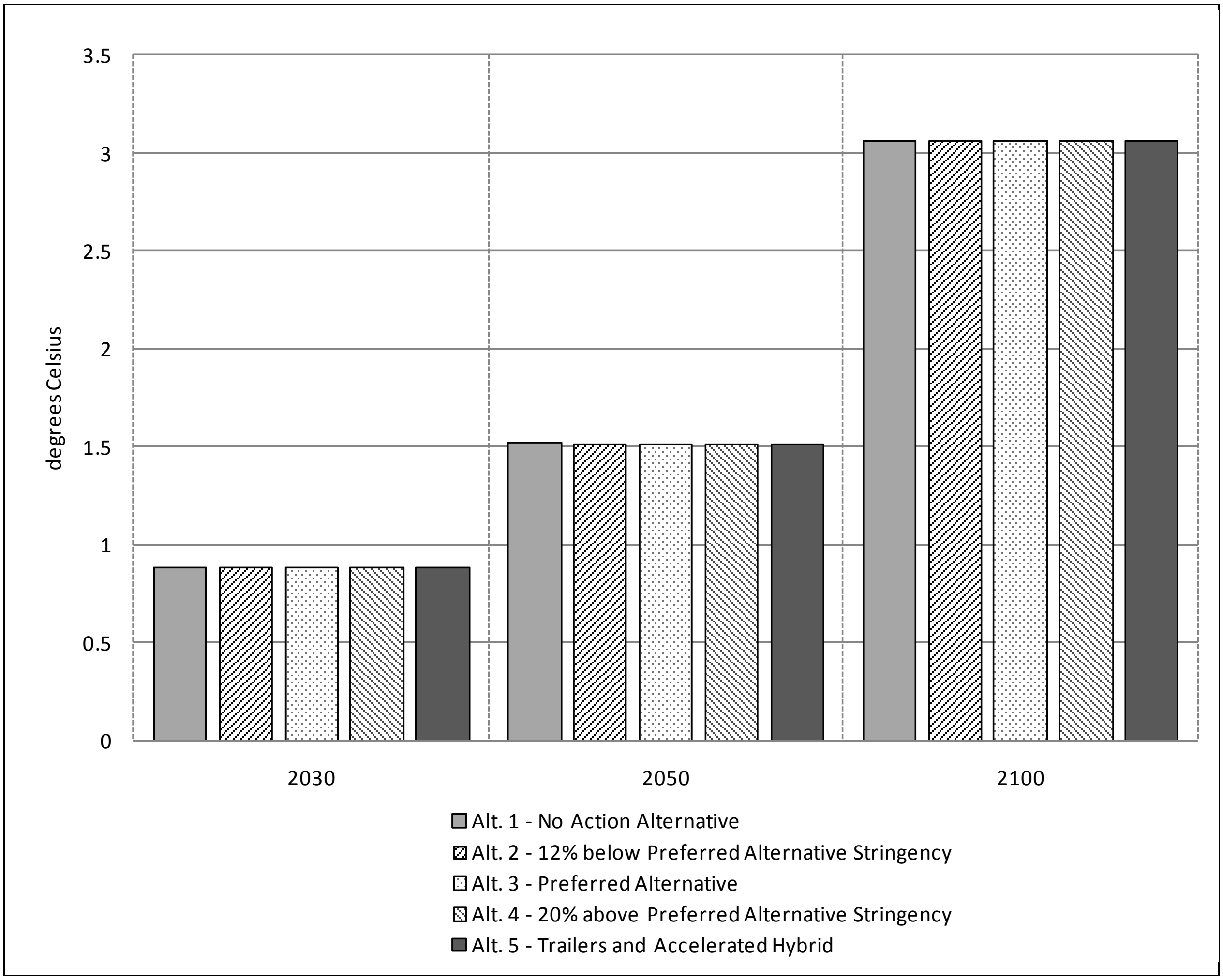


Figure 3.5.3-7. Reduction in CO_2 Concentrations (ppm) Compared to the No Action Alternative
(Corresponds to Figure 3.4.4-7)

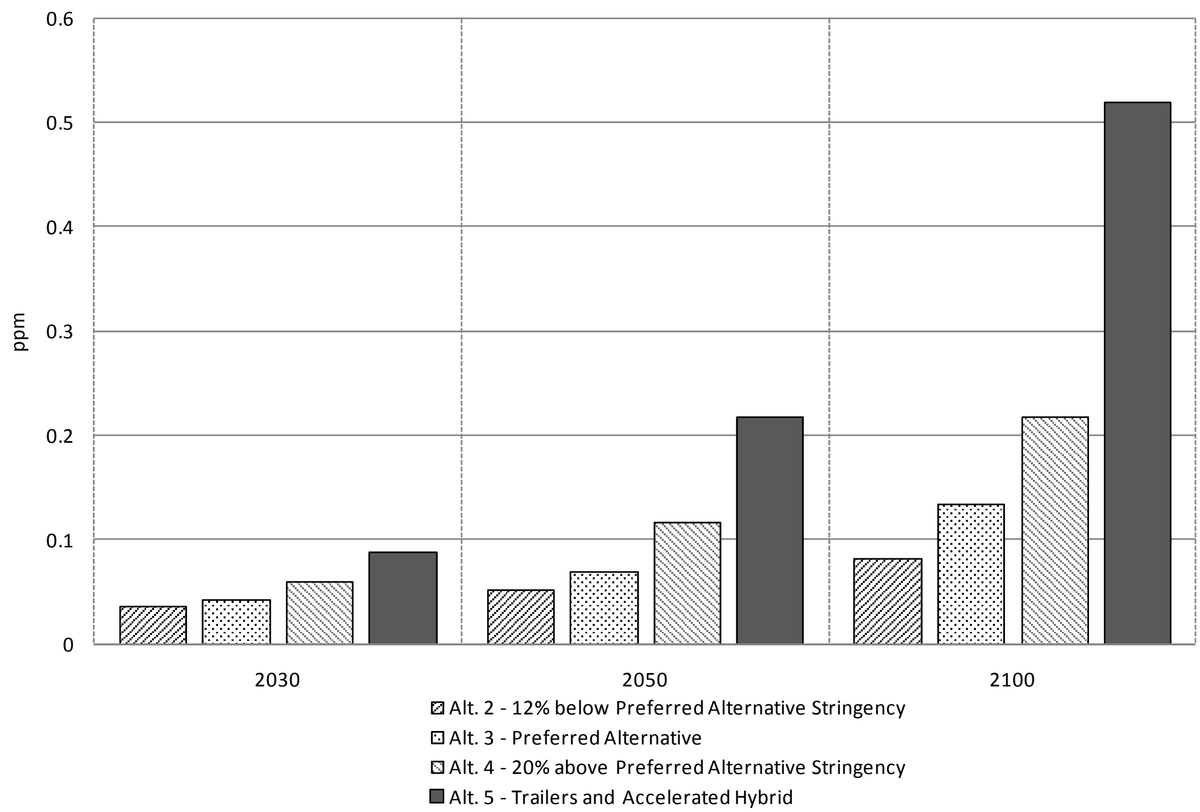
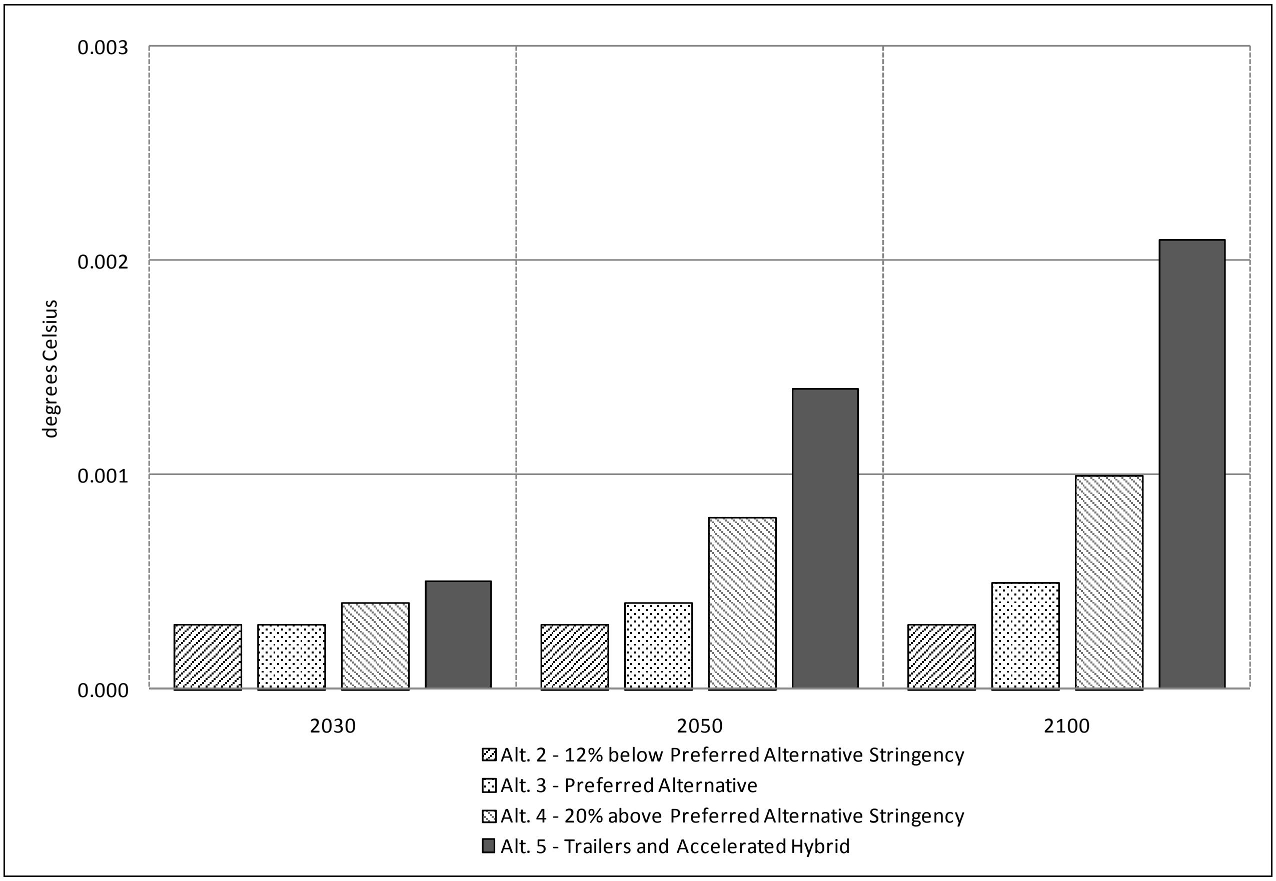


Figure 3.5.3-8. Reduction in Change in Global Mean Temperature Compared to the No Action Alternative
(Corresponds to Figure 3.4.4-8)



As Figure 3.5.3-7 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 3.5.3-7, the reduction in increase of CO_2 concentrations by 2100 under Alternative 5 is much larger as compared to Alternative 2.

3.5.3.3.2 Temperature

Table 3.5.3-4 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.[88] The differences among alternatives are small in comparison to total projected changes. For 2100, the reduction in temperature increase as compared to the No Action Alternative ranges from 0.0003 °C (0.0005 °F) under Alternative 2 to 0.0021 °C (0.0037 °F) under Alternative 5.

[88] 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 3.5.3-8 shows, reductions in the growth of projected global mean surface temperature from each action alternative as compared to the No Action Alternative are small in comparison to total projected changes. 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 5. As shown in Figure 3.5.3-8, the reduction in the projected growth in global temperature under Alternative 5 is more than twice that under Alternative 2.

Table 3.4.4-6 in Section 3.4.4.3.2 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 regional impacts in proportion to reduction in global mean surface temperature.

3.5.3.3.3 Precipitation

NHTSA refers readers to Section 3.4.4.3.3 above for a qualitative discussion of global precipitation effects, as well as the methodology used for this section. 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 3.5.3-5 (based on the A1B [medium] scenario). In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation.[89]

Table 3.5.3-5
(Corresponds to Table 3.4.4-8)

Global Mean Precipitation (Percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario and Alternative HD Standards b/			
Alt. 1 - No Action Alternative	0.600	1.675	2.760
Alt. 2 - 12% below Preferred Alternative Stringency	0.599	1.675	2.760
Alt. 3 - Preferred Alternative	0.599	1.675	2.760
Alt. 4 - 20% above Preferred Alternative Stringency	0.599	1.674	2.759
Alt. 5 - Trailers and Accelerated Hybrid	0.599	1.674	2.758
Reduction in Global Temperature (°C) for Alternative HD Standards, Mid-level Results (Compared to No Action Alternative) c/			
Alt. 2 - 12% below Preferred Alternative Stringency	0.000	0.000	0.000
Alt. 3 - Preferred Alternative	0.000	0.000	0.001
Alt. 4 - 20% above Preferred Alternative Stringency	0.000	0.001	0.001
Alt. 5 - Trailers and Accelerated Hybrid	0.000	0.001	0.002

[89] As described in Meehl *et al.* (2007a), the "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" (Meehl *et al.* 2007a).

Table 3.5.3-5 (continued)
(Corresponds to Table 3.4.4-8)

Global Mean Precipitation (Percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC by Alternative a/

Scenario	2020	2055	2090
Global Mean Precipitation Increase (%)			
Alt. 1 - No Action	0.87%	2.53%	4.50%
Alt. 2 - 12% below Preferred Alternative Stringency	0.87%	2.53%	4.50%
Alt. 3 - Preferred Alternative	0.87%	2.53%	4.50%
Alt. 4 - 20% above Preferred Alternative Stringency	0.87%	2.53%	4.50%
Alt. 5 - Trailers and Accelerated Hybrid	0.87%	2.53%	4.50%
Reduction in Global Mean Precipitation Increase by Alternative HD Standards (% Compared to No Action Alternative)			
Alt. 2 - 12% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 3 - Preferred Alternative	0.00%	0.00%	0.00%
Alt. 4 - 20% above Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 5 - Trailers and Accelerated Hybrid	0.00%	0.00%	0.00%

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 3.5.3-4 because the increases in temperature in Table 3.5.3-4 are relative to the global mean surface temperature in 1990 and those in this table represent increases relative to average temperature in the interval 1980–1999.
c/ Precipitation change in year 2020 is greater than zero but smaller than 0.001.

As discussed in Section 3.4.4, 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. 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.

3.5.3.3.4 Sea-level Rise

To analyze projected changes in sea-level rise, NHTSA has used the same methodology as outlined in Section 3.4.4.3.4. That section also contains a qualitative discussion of some potential global sea-level effects. Table 3.5.3-4 above lists the impacts on sea-level rise under the GCAMReference scenario and shows sea-level rise in 2100, ranging from 37.40 centimeters (14.724 inches) under the No Action Alternative to 37.38 centimeters (14.717 inches) under Alternative 5, for a maximum reduction of 0.02 centimeters (0.008 inches) by 2100 under Alternative 5 as compared to the No Action Alternative.

3.5.3.3.5 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 and the Preferred Alternative with the GCAMReference scenario. Table 3.5.3-6 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 3.5.3-6
(Corresponds to 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)			Global Mean Surface Temperature Increase (°C) b/			Sea-level Rise (cm) b/
		2030	2050	2100	2030	2050	2100	2100
Alternative 1 (No Action Alternative)								
	1.5	441.253	512.770	757.689	0.538	0.912	1.761	22.80
	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	55.59
Alternative 3 (Preferred Alternative)								
	1.5	441.211	512.703	757.563	0.538	0.911	1.760	22.80
	2.0	442.109	515.023	767.328	0.669	1.140	2.240	28.27
	2.5	442.891	517.077	776.368	0.782	1.340	2.672	33.10
	3.0	443.576	518.903	784.735	0.880	1.516	3.064	37.39
	4.5	445.194	523.327	806.327	1.110	1.935	4.036	47.81
	6.0	446.360	526.606	823.611	1.274	2.240	4.779	55.58
Reduction Under Preferred Alternative Compared to No Action Alternative								
	1.5	0.042	0.067	0.126	0.000	0.000	0.000	0.00
	2.0	0.042	0.068	0.129	0.000	0.000	0.000	0.00
	2.5	0.042	0.068	0.132	0.000	0.000	0.000	0.00
	3.0	0.042	0.069	0.134	0.000	0.000	0.001	0.01
	4.5	0.043	0.070	0.141	0.000	0.000	0.001	0.01
	6.0	0.043	0.072	0.147	0.000	0.001	0.001	0.01

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/ The values for global mean surface temperature and sea-level rise are relative to the year 1990.

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 3.5.3-6, 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 3.5.3-6. 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 0.000 °C (0.000 °F) for the 1.5 °C (2.7 °F) climate sensitivity to 0.001 °C (0.002 °F) for the 6.0 °C (10.8 °F) climate sensitivity, as listed in Table 3.5.3-6. 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 3.5.3-6. 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 0.00–0.01 centimeter (0.000–0.004 inch), depending on the climate sensitivity.

3.6 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 3.6.1), biological resources (Section 3.6.2), safety and other impacts to human health (Section 3.6.3), hazardous materials and regulated wastes (Section 3.6.4), noise (Section 3.6.5), and environmental justice (Section 3.6.6). 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.

3.6.1 Water Resources

3.6.1.1 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 3.6.1.2 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 3.5.2 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 can 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 3.6.2.1.1). 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 3.6.4.1.1 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 type of 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.

3.6.1.2 Environmental Consequences

Each of the four 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 be reduced as compared to the No Action Alternative. This might result in less water pollution due to oil and other chemical spills.

As discussed in Section 3.3, each action alternative is generally expected to decrease the amount of SO_2, NO_x, and other air pollutants in relation to the No Action Alternative levels. 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.

3.6.2 Biological Resources

3.6.2.1 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.

3.6.2.1.1 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[96] 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).

3.6.2.2 Environmental Consequences

Reductions in the rate of fuel consumption under all of the action alternatives 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.

3.6.3 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. NHTSA and EPA have been considering the effect of vehicle weight on vehicle safety for the past several years in the context of the agencies' joint rulemaking for light-duty vehicle CAFE and GHG standards, consistent with NHTSA's long-standing consideration of safety effects in setting CAFE standards. The latest analysis by NHTSA for the MY 2012–2016 Final Rule found that reducing the weight of heavier light

[96] 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. For more information, *see* the U.S. Geological SurveyToxic Substances Hydrology Program's definition of eutrophication available at: http://toxics.usgs.gov/definitions/eutrophication.html (Accessed: June 13, 2011).

trucks had a positive overall effect on safety, thereby reducing fatalities.[97] 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. However, 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, 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 HD vehicles.

3.6.4 Hazardous Materials and Regulated Wastes

3.6.4.1 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.

3.6.4.1.1 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 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

[97] 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).

from improperly treated produced water released into the waters surrounding the oil platform (EPA 2000).

3.6.4.1.2 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.

3.6.4.1.3 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.[98] 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

[98] 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.

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, 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 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,[99] 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[100] under the DOE Vehicle Technologies Program;
- The U.S. Advanced Battery Consortium,[101] a component of the United States Council for Automotive Research (USCAR) industry partnership;
- The USCAR Vehicle Recycling Partnership[102] developing "green" materials and separator technology advances to enable vehicle End-of-Life recycling; and
- The DOE FreedomCAR and Fuel Partnership[103] within the DOE Advanced Vehicles Technologies and Fuels programs includes major research thrusts on battery and powertrain for energy management optimization in HD vehicles.

3.6.4.2 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 and advanced technologies 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 in terms of increased waste during the refining process. Because uncertainty is still substantial regarding how manufacturers would choose to implement the standards, including whether they would use lighter weight materials, the EIS does not quantify the effects on waste produced during the refining process due to downweighting.

3.6.5 Noise

3.6.5.1 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,

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[99] DOE (2008).
[100] *See* details related to HD goals, including advanced batteries, in DOE (2007).
[101] USABC (2011).
[102] VRP (2011).
[103] Partnership activities include batteries and other electrochemical energy storage technology development, and demonstration (DOE 2011).

and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property.

3.6.5.2 Environmental Consequences

Under all of the alternatives, NHTSA predicts that vehicle use will increase due to projected trends in VMT growth, resulting 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. Because uncertainty is substantial regarding how manufacturers would choose to implement the standards, including whether they would use hybrid technologies, the EIS does not quantify the effects on noise due to hybridization.

3.6.6 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.

3.6.6.1 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.

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).

Research studies also indicate that minority and low-income populations also often disproportionately reside near mobile sources of air pollutants, as in the case of populations living near highways (Morello-Frosch 2002, Jerrett *et al.* 2001, O'Neill *et al.* 2003). Air pollutant emissions are of particular concern for environmental justice populations because of their disproportionate proximity to truck stops, highways, and nonattainment areas. 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). In a 2009 report to EPA examining air pollutant 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). The exact nature of the relationship between 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).

3.6.6.2 Environmental Consequences

As discussed in Section 3.3, the decreases in emissions predicted to occur as a result of the proposed action (as compared to the No Action Alternative) are not evenly distributed due to the increase in VMT from the rebound effect and regional changes in upstream emissions. As a result, emissions of $PM_{2.5}$, DPM, and 1-3 butadiene are predicted to increase in some air quality nonattainment areas where HD vehicle traffic is more prevalent. Because nonattainment areas tend to be more urbanized than attainment areas and accordingly are more likely to have large populations living and working near major roadways with high volumes of HD vehicles, these emissions increases may disproportionately impact environmental justice populations due to their disproportionately close proximity to truck stops and highways. Tables 3.5.2-4 and 3.5.2-8 and Appendix D to this document present information about emissions changes for nonattainment areas. Section 4.6.2 also discusses potential cumulative impacts to air quality.

3.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

3.7.1 Unavoidable Adverse Impacts

NHTSA's 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 the No Action Alternative, neither NHTSA nor EPA would issue a rule regarding fuel-efficiency improvement or GHG emissions for MYs 2014–2018. Each of the four action alternatives (Alternatives 2 through 5) 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 2011).

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 3.5.3.1, 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 criteria and toxic air pollutants would generally decrease for all action alternatives and analysis years as compared to their levels under the No Action Alternative. As stated in Section 3.5.2, the only exceptions to this decline are emissions of $PM_{2.5}$, which is projected to increase in year 2018 under Alternatives 2 and 3, and in years 2030 and 2050 under Alternatives 2 through 5; DPM, which is projected to increase in year 2018 under Alternative 2, and in years 2030 and 2050 under Alternatives 2 through 5; and 1,3-butadiene, which is projected to increase slightly in 2050 under Alternatives 2 through 4. Adverse health outcomes would be reduced and monetized health benefits would increase under all of the action alternatives for all years. Thus the emissions under the four action alternatives would have few unavoidable adverse impacts. However, because $PM_{2.5}$, DPM, and 1,3-butadiene emissions could increase from the levels that are projected under the No Action Alternative under certain alternatives and in certain years, the potential for unavoidable impacts depends on the alternative selected by the decisionmaker. As shown in Section 3.5.2, the maximum projected increases in nationwide HD emissions compared to the No Action Alternative are for $PM_{2.5}$ under Alternative 2 in 2050 (5.9 percent increase), for DPM under Alternative 2 in 2050 (8.0 percent increase) and for 1,3-butadiene under Alternative 4 in 2050 (0.2 percent increase). Under the Preferred Alternative, increases in nationwide emissions in 2030 compared to the No Action Alternative would be 1,284 tons (3.9 percent) for $PM_{2.5}$ and 1,213 tons (4.8 percent) for DPM.

Increases in $PM_{2.5}$, DPM, and 1,3-butadiene emissions could also 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.

3.7.2 Short-term Uses and Long-term Productivity

The four action alternatives (Alternatives 2 through 5) 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 the No Action Alternative. Manufacturers would need to apply various technologies 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 four action alternatives; NHTSA estimates that existing technologies and existing vehicle production facilities, however, could be utilized to meet the proposed fuel consumption standards. 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.

3.7.3 Irreversible and Irretrievable Commitments of Resources

Energy consumption in the United States would decrease under all the action alternatives compared to the No Action Alternative. Table 3.5.1-1 (*see* Section 3.5.1 of this EIS) summarizes fuel consumption under each alternative. For the Preferred Alternative, the total fuel savings over the No Action Alternative from 2014 to 2050 would be 64.4 billion gallons for the HD vehicle fleet.

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 four 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.

Chapter 4 Cumulative Impacts

4.1 INTRODUCTION

The Council on Environmental Quality (CEQ) regulations implementing the National Environmental Policy Act (NEPA) require agencies to consider the long-term cumulative impacts of major federal actions. CEQ regulations 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.

While this chapter follows the same format as Chapter 3 – detailing the potential impacts of the proposed standards on the affected environment – this chapter describes the cumulative impacts, rather than the direct and indirect impacts, of the proposed standards. In Chapter 3, NHTSA modeled the projected direct and indirect impacts of the proposed standards and alternatives by isolating the impacts of the proposal. There, NHTSA assumed that the fuel efficiency of new HD vehicles under each action alternative would remain constant at the required MY 2018 level during all subsequent model years, except where market forces are anticipated to result in a level of fuel efficiency that is higher than the MY 2018 standard. In contrast, in this chapter, NHTSA 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 cumulative impacts analysis. These reasonably foreseeable actions include further gains in the fuel efficiency of HD vehicles projected to result from market forces affecting the demand and supply of fuel efficiency in the immediate aftermath of the proposed action.

In addition, to provide further context for the impacts of the proposed action, NHTSA has included a new analysis in Section 4.2.4 that demonstrates the projected impacts of NHTSA's present action in conjunction with the agency's past and reasonably foreseeable future actions under the Joint National Program.

4.1.1 Temporal and Geographic Boundaries

When evaluating cumulative effects, the analysis must consider both expanding the geographic study area beyond that of the proposed action and expanding the temporal (time) scope of its analysis to encompass past, present, and reasonably foreseeable future actions that might affect the environmental resources of concern. NHTSA has determined that a reasonable timeframe for this cumulative impacts analysis is the same as that used in Chapter 3 - extending through 2050 for the energy and air quality analysis, and through 2100 for climate change. These timeframes are based on the reasonable ability of the agency to model fuel consumption and emissions of the heavy-duty vehicle sector. As noted in Chapter 3, the inherently long-term nature of the effects of increasing greenhouse gas (GHG) accumulations on global climate requires that fuel consumption and GHG emissions for the proposed alternatives be estimated over a longer time span than other environmental impacts.

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 Environmental Impacts of the Alternatives

As described in Chapter 3, throughout this FEIS NHTSA reports environmental impacts of the proposed standards by comparing the projected environmental consequences under the baseline, or No Action Alternative, to those anticipated to occur under each of the action alternatives.

As in Section 3.5, to derive the baseline used in this Chapter, NHTSA used the Energy Information Administration's (EIA) Annual Energy Outlook 2011 Early Release Reference Case forecast (EIA 2011) 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 in future calendar years. The Annual Energy Outlook (AEO) 2011 forecasts of fuel efficiency reflect the influence of changes in the availability, cost, and effectiveness of technologies to increase truck fuel efficiency, as well as projected fuel prices and patterns of vehicle use. The forecasts incorporate the effects of previously adopted emissions standards for medium- and heavy-duty 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 medium- and heavy-duty vehicles, because NHTSA had not yet taken action with respect to that provision at the time of publication of the AEO 2011 forecast.[1]

Although AEO 2011 projections only extend through 2035, NHTSA extended these efficiency gains in the baseline through 2050, by which time virtually all of the HD vehicle fleet is expected to be comprised of MY 2018 and later vehicles. This extended forecast assumes compound annual percentage gains in overall HD vehicle fleet fuel efficiency from 2035 to 2050 that are equal to the average annual percentage increase forecasted by AEO in 2030 through 2035.

NHTSA used separate AEO forecasts for the three categories of HD vehicles that are roughly comparable to the following three broad vehicle categories in the EIS (described in more detail in Section 2.3):

- **2b-3 Pickups and Vans**: The AEO "commercial" truck category includes all Class 2b pickups, but also includes some vocational trucks under 10,000 pounds, and excludes Class 3 pickups included in the EIS 2b-3 category.
- **Vocational**: The AEO "medium freight" category includes mostly vocational vehicles.
- **Tractors**: The AEO "heavy freight" truck category encompasses the tractor truck segment in the EIS, but also includes some heavy vocational trucks.

For this EIS, EPA used the MOVES model to calculate fuel consumption and emissions for each truck segment for the baseline, reflecting fuel efficiency gains consistent with the AEO 2011 forecasts for 2014 through 2035 by truck segment, extended to 2050 as described above.

[1] In its AEO forecast of gasoline light truck fuel economy for model years 2017 through 2020, EIA factors in the requirement in EISA that combined automobile and light truck fuel economy of 35 mpg be achieved by MY 2020. The AEO forecast assumes that the fuel economy of Class 2b trucks will increase at the same rate as that of smaller gasoline light trucks as s consequence of their utilization of similar technologies. Thus EIA's forecast of fuel economy for Class 2b trucks indirectly reflects the EISA provision applicable to light-duty vehicle fuel economy. (*See* http://www.eia.gov/oiaf/aeo/assumption/transportation.html. Accessed: May 24, 2011.) However, NHTSA believes that this assumption of a future regulatory action has little impact on the present analysis because, under the agency's previous CAFE action, combined automobile and light truck fuel economy was *already* required to achieve 34.1 mpg by MY 2016. The additional increase in fuel economy mandated by EISA and contemplated by EIA is therefore relatively small and distributed over a long period of time.

Unlike in Chapter 3, the action alternative impacts reported in this Chapter also anticipate ongoing gains in new vehicle fuel efficiency through 2050 based on a market (AEO 2011 Early Release) forecast. NHTSA used the same procedure for extending the AEO forecast described above to project ongoing gains in fuel efficiency under the action alternatives after the years covered by the rule because NHTSA believes the AEO forecast represents a reasonable proxy for reasonably foreseeable future actions that are together likely to result in continuing fuel efficiency increases in the HD sector in the absence of further regulation. Specifically, to arrive at the projected HD fuel efficiency for each action alternative in each year after 2018, NHTSA assumed continued cumulative percentage gains in the fuel efficiency of the three vehicle categories included under the proposed standards matching the extended AEO forecasts for the corresponding year. Thus to derive the impacts reported in this chapter, NHTSA took the following analytical steps with the AEO forecast:

- For each of the three vehicle categories covered under the proposal (HD pickups and vans, vocational vehicles, and tractors) NHTSA separately calculated the average mpg for the entire stock of vehicles in use in that category under each action alternative for every year after 2018 by dividing the total vehicle-miles traveled (VMT) of that vehicle category by its total fuel consumption.
- NHTSA then divided the average mpg for each year after 2018 by the average mpg forecast for 2018 to calculate the percentage increase in fuel efficiency for that year. These results are reflected in Table 4.1.2-1.
- NHTSA then estimated the corresponding average mpg for the entire stock of vehicles in use in that category for each action alternative under the assumption that HD vehicle fuel efficiency continues to increase after model year 2018, 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 2050 is multiplied by 1.1251 (reflecting the 12.51% increase for HD pickups and vans in 2050 shown in the table) to calculate the average mpg for use in this cumulative analysis for the corresponding year and alternative.

Table 4.1.2-1 shows the resulting projected percentage gains in vehicle fleet fuel efficiency after 2018 for each action alternative, reflected in the cumulative impacts analysis reported in this chapter. For example, based on the AEO forecast for "light commercial truck" fuel efficiency gains, Table 4.1.2-1 shows that the overall fuel efficiency of all HD pickups and vans in use is forecasted to be 0.65 percent higher in 2019 than in 2018, while by 2050 the overall fuel efficiency of HD pickups and vans in use is forecasted to be 12.51 percent higher than in 2018.

Table 4.1.2-1

Cumulative Percent Increase in HD Vehicle Stock Average Fuel Efficiency vs. 2018

Calendar Year	HD Pickups and Vans (Class 2b-3)	Vocational Vehicles (Class 2b-8)	Tractors (Class 7-8)
2019	0.65%	0.01%	0.46%
2020	1.38%	0.02%	0.97%
2021	2.17%	0.02%	1.57%
2022	2.94%	0.02%	2.24%
2023	3.68%	0.02%	2.95%
2024	4.38%	0.02%	3.66%
2025	5.05%	0.02%	4.38%
2026	5.68%	0.02%	5.09%
2027	6.23%	0.02%	5.73%

Table 4.1.2-1 (continued)

Cumulative Percent Increase in HD Vehicle Stock Average Fuel Efficiency vs. 2018

Calendar Year	HD Pickups and Vans (Class 2b-3)	Vocational Vehicles (Class 2b-8)	Tractors (Class 7-8)
2028	6.77%	0.02%	6.30%
2029	7.27%	0.02%	6.82%
2030	7.74%	0.02%	7.30%
2031	8.15%	0.10%	7.76%
2032	8.57%	0.17%	8.22%
2033	8.95%	0.22%	8.68%
2034	9.29%	0.27%	9.16%
2035	9.60%	0.31%	9.64%
2036	9.89%	0.34%	10.10%
2037	10.16%	0.37%	10.54%
2038	10.40%	0.39%	10.96%
2039	10.62%	0.41%	11.37%
2040	10.82%	0.42%	11.77%
2041	11.01%	0.42%	12.16%
2042	11.19%	0.43%	12.54%
2043	11.36%	0.43%	12.91%
2044	11.54%	0.43%	13.28%
2045	11.71%	0.42%	13.65%
2046	11.88%	0.42%	14.01%
2047	12.04%	0.41%	14.37%
2048	12.20%	0.40%	14.72%
2049	12.35%	0.39%	15.08%
2050	12.51%	0.38%	15.43%

The methodology NHTSA used in the agency's most recent CAFE analysis[2] differs from that used in this analysis of cumulative impacts because of differences in modeling methodologies. In the cumulative impacts analysis for the CAFE EIS, AEO projections of new light vehicle fuel efficiency were input into 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. 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 mpg accounted for an increasing proportion of the overall vehicle stock over time.

In contrast, projected cumulative gains in fleet average mpg after 2018 derived from the AEO forecast, 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 that achieve higher mpg levels. This methodology was developed to reflect overall percentage gains in HD fuel efficiency after 2018 consistent with the AEO forecast, without requiring NHTSA to specify the exact combination of technologies needed to achieve this fuel efficiency gain, as would have

[2] *See* NHTSA 2010. A complete version of NHTSA's EIS for the MY 2012–2016 CAFE standards is available online at http://www.nhtsa.gov/fuel-economy.

been required if the agency had elected to apply the MOVES model to forecasts of *new* vehicle fuel efficiency under each action alternative.

NHTSA notes that the changes in fuel consumption reported in this chapter are 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 varies among different vehicle categories in the HD vehicle fleet. 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 vehicle categories are partially 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;
- 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
- 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 were also reflected in the estimates of reductions in fuel consumption and other impacts reported for the action alternatives in Chapter 3. The analysis of cumulative impacts reported in this chapter also incorporates the rebound effects associated with the projected gains in fuel efficiency after 2018 shown above in Table 4.1.2-1. Thus the cumulative impacts reported in this chapter reflect the fuel efficiency gains through 2050 shown in Table 4.1.2-1, as well as the changes in VMT and the resulting net changes in fuel consumption 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

An EIS must describe the environment of the areas affected or created by the alternatives under consideration[3] as well as the environmental consequences of the alternatives.[4] This section describes cumulative impacts to energy (fuel consumption) projected to occur under the proposed standards.

4.2.1 Affected Environment

The affected environment for energy is discussed in Section 3.2.1. That section describes current and future trends in fuel consumption from U.S. HD vehicles.

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 reduction in fuel consumption under each action alternative when compared to the No Action Alternative. The methodology used to estimate total fuel consumption under each alternative for use in this cumulative impacts analysis is described in Section 4.1. The methodology for calculating the expected reductions in fuel consumption as a result of each alternative is the same as that described in Section 3.2.2.

4.2.3 Environmental Consequences

Table 4.2.3-1 shows the cumulative impacts of the proposed alternatives on fuel consumption through 2050, when virtually the entire HD vehicle fleet is likely to be comprised of MY 2018 or later vehicles. This table reports total 2014-2050 consumption of both gasoline and diesel by HD pickups and vans (Classes 2b–3), vocational vehicles (Classes 2b–8), and tractors (Classes 7–8), under the No Action Alternative as well as under each of the four action alternatives. The table also shows the fuel savings resulting from each action alternative as compared to the No Action Alternative in these same years.

Table 4.2.3-1

Cumulative HD Vehicle Fuel Consumption and Fuel Savings by Alternative (billion gallons total for calendar years 2014-2050)

	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Fuel Consumption					
HD Pickups and Vans	307.6	294.5	291.0	285.8	267.9
Vocational Vehicles	435.4	419.4	408.7	397.1	357.2
Tractor Trucks	1372.4	1243.3	1234.5	1209.4	1186.1
All HD Vehicles	2115.3	1957.2	1934.2	1892.3	1811.2
Fuel Savings Compared to No Action Alternative					
HD Pickups and Vans	--	13.1	16.6	21.8	39.6
Vocational Vehicles	--	15.9	26.6	38.2	78.2
Tractor Trucks	--	129.1	137.9	163.0	186.2
All HD Trucks	--	158.0	181.1	223.0	304.0

[3] 40 CFR § 1502.15.
[4] 40 CFR § 1502.16.

For the cumulative impacts analysis, total fuel consumption from 2014 through 2050 across all HD vehicle classes under the No Action Alternative is projected to be 2115.3 billion gallons. Fuel consumption from 2014-2050 decreases across the alternatives, to 1957.2 billion gallons under Alternative 2 and further to 1811.2 billion gallons under Alternative 5. Under the Preferred Alternative, total fuel consumption from 2014-2050 is projected to be 1934.2 billion gallons.

Table 4.2.3-1 also shows that less fuel would be consumed under each of the action alternatives than under the No Action Alternative, with total 2014-2050 fuel savings ranging from 158.0 billion gallons under Alternative 2 to 304.0 billion gallons under Alternative 5. As compared to the No Action Alternative, total 2014-2050 fuel savings under the Preferred Alternative would be 181.1 billion gallons.

4.2.4 Overall Benefits of Joint National Program

This proposed action, in combination with NHTSA's past and reasonably foreseeable future fuel economy actions, is expected to lead to substantial fuel savings. On April 1, 2010, NHTSA and EPA finalized the first-ever National Program for passenger cars and light trucks, which set GHG and fuel economy standards for MYs 2012-2016. (*See* Section 1.2.1.2). On May 10, 2011, NHTSA issued a Notice of Intent to prepare an EIS for fuel economy and GHG standards for MY 2017-2025 light duty vehicles, which the agency plans to propose together with EPA.[5] Using procedures adapted from the analysis of fuel savings conducted for the MY 2012-2016 light duty CAFE standards,[6] NHTSA has estimated total fuel savings through 2050 projected to result from the MY 2012-2016 standards, together with a range of potential savings anticipated from the forthcoming light duty standards for MY 2017-2025. To be consistent with the analysis shown in Section 3.5 for the HD rule, NHTSA estimated these fuel savings relative to a baseline that incorporates a market forecast of fuel economy (with fuel efficiency rising at the rates that were forecast by AEO to occur without the adoption of these rules).[7]

Table 4.2.4-1 shows the fuel savings through 2050 expected to result from the past, present, and reasonably foreseeable future National Program actions for light vehicles and HD vehicles. Under the analysis presented here, the fuel economy increases for light vehicles required by the MY 2012-2016 standards are projected to result in fuel savings of 253 billion gallons through 2050. Based on a preliminary analysis done for this EIS, further increases in light vehicle fuel economy due to reasonably foreseeable future standards for model years 2017-2025 could save an additional 569 billion gallons through 2050 (with a 2% annual increase in both passenger car and light truck CAFE standards) and could save up to 1,621 billion gallons through 2050 (with a 7% annual increase in both passenger car and light truck CAFE standards). Together with the 64 billion gallons in fuel savings expected to result from the Preferred Alternative for HD vehicle fuel efficiency, these past and foreseeable future CAFE standards could result in cumulative fuel savings for the National Program through 2050 ranging from 886 to 1,938 billion gallons.

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[5] *See* 76 *FR* 26996 (May 10, 2011).
[6] These procedures are described in detail in the Final Environmental Impact Statement prepared by NHTSA for the MY 2012-16 car and light truck CAFE standards; *see* NHTSA 2010. A complete version of NHTSA's EIS for the MY 2012–2016 CAFE standards is available online at http://www.nhtsa.gov/fuel-economy.
[7] This analysis used the forecasts of fuel economy for new passenger cars and light trucks reported in AEO 2007 as the baseline for estimating the fuel savings expected to result from the MY 2012-2016 and MY 2017-2025 CAFE standards. These forecasts were used to develop the baseline because they reflect the effects of changes in buyers' demands for fuel efficiency in response to future changes in fuel prices and other factors as well as the anticipated response by vehicle manufacturers, but do *not* incorporate the effects of CAFE standards for MY 2012 and later years.

Table 4.2.4-1

Cumulative National Program Fuel Savings through 2050 (billion gallons)

	Cars	Light Trucks	HD Trucks	Total
CAFE MYs 2012-2016	158	95		253
HD MY 2014-2018 (Preferred)			64	64
CAFE MYs 2017-2025 (low) (*estimated*)	328	241		569
CAFE MYs 2017-2025 (high) (*estimated*)	926	695		1621
Cumulative Total (low)	486	336	64	886
Cumulative Total (high)	1084	790	64	1938

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 4.1.2. 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 there.

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 decreasing 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 the proposed HD Fuel Efficiency Improvement Program standards.

The cumulative analysis in this section shows that the action alternatives 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 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 3.5.2. Sections 4.3.3.1.1 through 4.3.3.1.3 below provide an overview of the results. Sections 4.3.3.2 through 4.3.3.6 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 from HD vehicles by alternative for each of the criteria pollutants and analysis years. The table presents the action alternatives (Alternatives 2 through 5) left to right in order of increasing fuel efficiency requirements. Figure 4.3.3-1 illustrates this information for each analyzed criteria pollutant in 2030. The mid-term forecast year of 2030 was selected because, by that year, a large proportion of HD vehicle VMT would be accounted for by vehicles that meet the MY 2014–2018 standards.

Figure 4.3.3-2 summarizes the total national emissions of criteria pollutants over time from HD vehicles for the Preferred Alternative. Figure 4.3.3-2 indicates a consistent trend among the criteria pollutants. As with the direct and indirect air quality results shown in Chapter 3, emissions shown in this

Table 4.3.3-1

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

Pollutant and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	2,687,441	2,642,622	2,646,961	2,653,412	2,658,888
2030	2,556,297	2,377,309	2,378,153	2,379,227	2,383,725
2050	3,245,528	2,889,712	2,889,388	2,888,416	2,885,602
Nitrogen oxides (NO_x)					
2018	1,806,256	1,692,000	1,691,716	1,689,776	1,687,139
2030	1,139,852	859,619	857,697	851,874	844,825
2050	1,397,350	968,980	965,912	957,056	945,554
Particulate matter ($PM_{2.5}$)					
2018	73,288	73,319	73,245	73,072	72,807
2030	33,053	32,719	32,584	32,357	31,810
2050	38,821	37,132	36,929	36,610	35,740
Sulfur dioxide (SO_2)					
2018	98,863	95,516	95,052	93,992	92,689
2030	63,038	57,820	57,077	55,727	53,123
2050	79,347	71,227	70,139	68,257	64,288
Volatile organic compounds (VOC)					
2018	251,985	237,401	237,382	237,086	236,567
2030	175,283	142,910	142,227	140,555	137,817
2050	208,921	159,507	158,467	155,998	151,600

Figure 4.3.3-1. Cumulative Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative

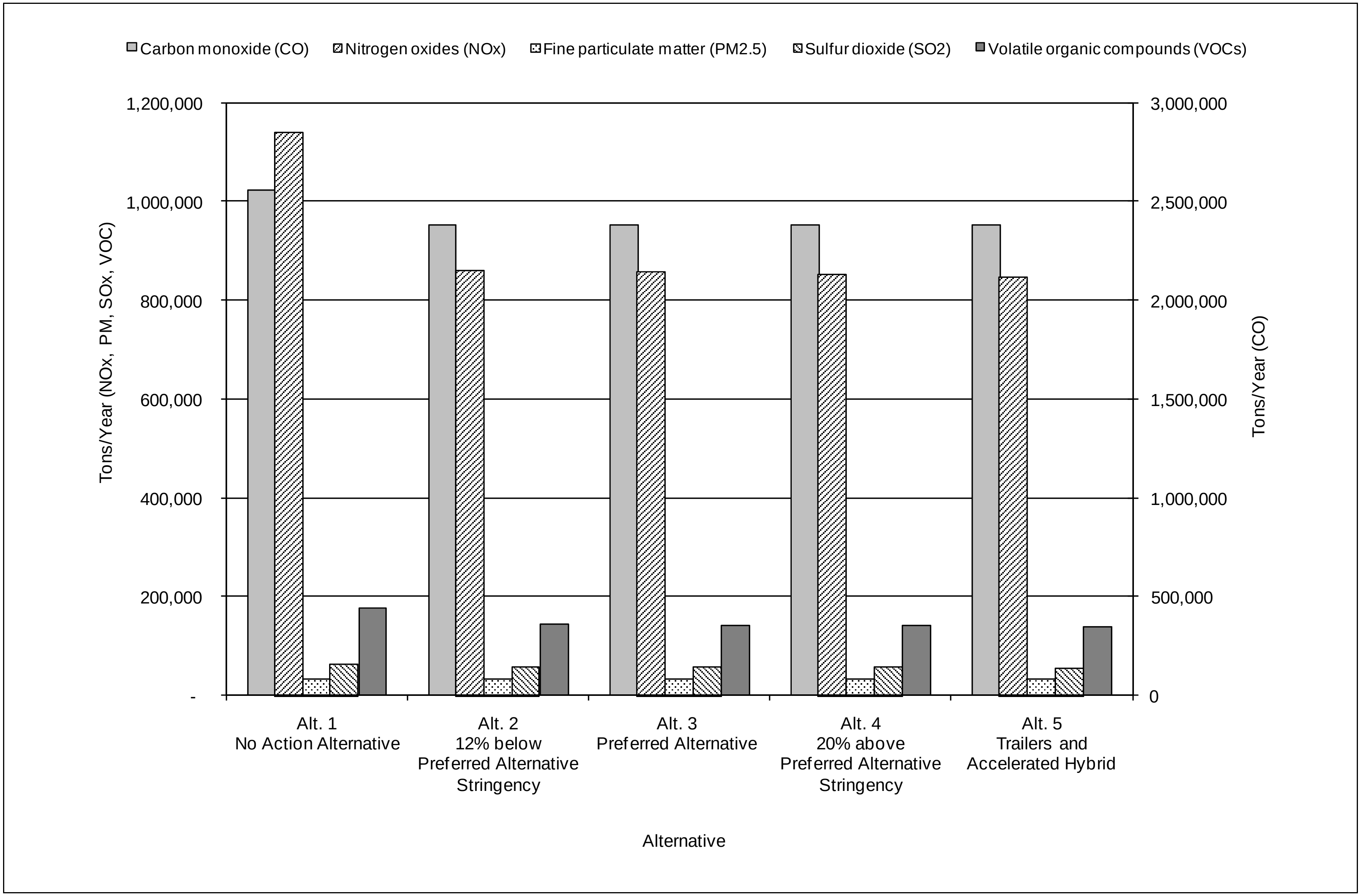
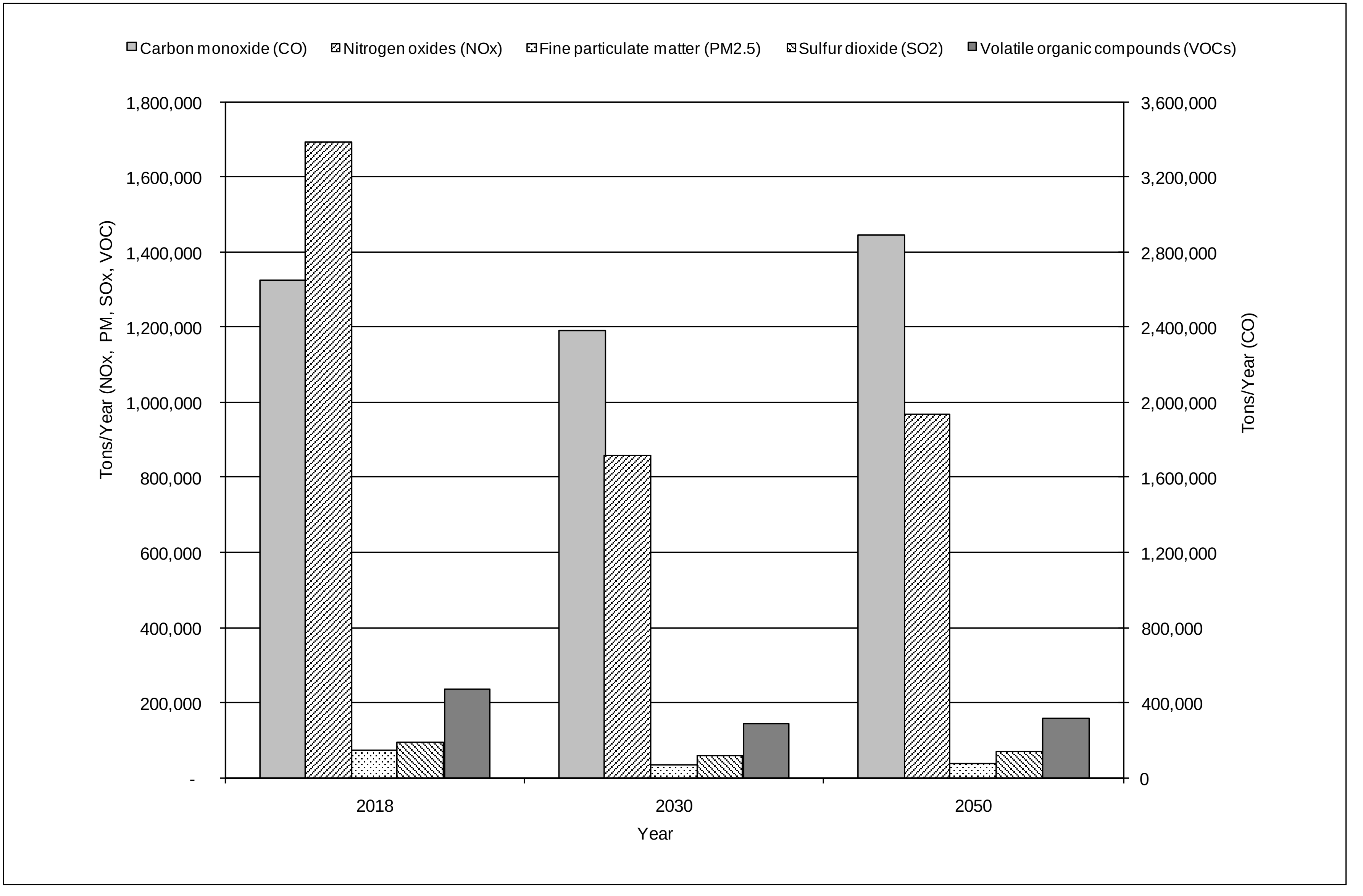


Figure 4.3.3-2. Cumulative Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative



Section decline from 2018 to 2030 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production. However, these emissions increase from 2030 to 2050 due to continuing growth in VMT.

Because the cumulative impact analysis assumes reasonably foreseeable increases in fuel efficiency after the regulatory period (*i.e.*, after MY 2018), the emissions estimated in the cumulative impacts analysis are less than in the direct and indirect impacts analysis (*see* Section 3.5.2) in later years. By year 2050, emissions in the cumulative impact analysis would be up to 12 percent less than in the direct and indirect impacts analysis depending on pollutant and alternative. The emissions reductions estimated in the cumulative impacts analysis are greater than in the direct and indirect impacts analysis in later years. These trends are consistent across all alternatives and pollutants.

As in 3.5.2 above, total emissions reported in this Section are made up of eight components, consisting of two types of emissions (tailpipe and upstream) 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 change in nationwide criteria pollutant emissions from HD vehicles for each of the criteria pollutants and analysis years, compared to the No Action Alternative. Figure 4.3.3-3 shows these changes in percentage terms for 2030.

Criteria pollutant emissions under Alternatives 2 through 5 are lower than under the No Action Alternative. For NO_X, SO_2, and VOC, total emissions of each pollutant decrease from Alternatives 2 through 5 as the stringency of the alternatives increase. For CO, emissions under all the action alternatives are lower than under the No Action Alternative, though the trend across Alternatives 2 through 5 varies by year. Emissions of $PM_{2.5}$ are a partial exception to the declining trend, showing an increase under Alternative 2 in 2018, but decreases in all other years and alternatives. The greatest relative reductions in emissions among the criteria pollutants occur for NO_x, SO_2, and VOC, for which emissions decrease by less than 10 percent in 2018, up to 26 percent in 2030, and up to 32 percent in 2050 compared to the No Action Alternative.

Many of the differences between one action alternative and another in national emissions of CO and NO_x are slight, in the range of 1 percent or less. Consequently, such differences are not expected to lead to measurable changes in ambient concentrations of criteria pollutants. For such small changes the impacts of those action alternatives would be essentially equivalent.

Table 4.3.3-4 summarizes the cumulative criteria air pollutant results by 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 would experience greater reductions in upstream emissions than an area without any refining facilities. 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 $PM_{2.5}$ emissions, most nonattainment areas would experience increases while others would experience decreases. For CO, NO_X, SO_2 and VOC emissions, all nonattainment areas would experience decreases. Tables in Appendix D present the emission changes for each nonattainment area.

Table 4.3.3-2

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
Class 2b-3 Work Trucks Tailpipe	1,900,311	1,793,564	1,794,899	1,796,727	1,801,822
Class 2b-3 Work Trucks Upstream	4,219	4,023	3,968	3,894	3,618
Class 3-8 Vocational Trucks Tailpipe	395,464	396,997	396,816	396,572	397,114
Class 3-8 Vocational Trucks Upstream	6,059	5,831	5,671	5,497	4,892
Class 7-8 Day Cab Combination Unit Tailpipe	40,995	38,501	38,518	38,559	38,561
Class 7-8 Day Cab Combination Unit Upstream	7,695	7,195	7,128	7,121	7,032
Class 7-8 Sleeper Cab Combination Unit Tailpipe	189,125	120,305	120,339	120,435	120,555
Class 7-8 Sleeper Cab Combination Unit Upstream	12,428	10,892	10,815	10,420	10,132
Total	2,556,297	2,377,309	2,378,153	2,379,227	2,383,725
Nitrogen oxides (NO_x)					
Class 2b-3 Work Trucks Tailpipe	277,068	262,641	262,897	263,225	263,901
Class 2b-3 Work Trucks Upstream	12,756	12,167	12,000	11,772	10,941
Class 3-8 Vocational Trucks Tailpipe	144,709	145,935	145,548	143,222	143,480
Class 3-8 Vocational Trucks Upstream	18,148	17,465	16,985	16,466	14,658
Class 7-8 Day Cab Combination Unit Tailpipe	128,423	120,588	120,572	120,736	119,864
Class 7-8 Day Cab Combination Unit Upstream	23,010	21,514	21,313	21,294	21,026
Class 7-8 Sleeper Cab Combination Unit Tailpipe	498,577	246,740	246,041	243,999	240,661
Class 7-8 Sleeper Cab Combination Unit Upstream	37,162	32,570	32,339	31,159	30,295
Total	1,139,852	859,619	857,697	851,874	844,825
Particulate matter ($PM_{2.5}$)					
Class 2b-3 Work Trucks Tailpipe	3,233	3,058	3,061	3,064	3,070
Class 2b-3 Work Trucks Upstream	1,766	1,684	1,661	1,630	1,515
Class 3-8 Vocational Trucks Tailpipe	4,645	4,683	4,706	4,758	4,744
Class 3-8 Vocational Trucks Upstream	2,509	2,415	2,349	2,277	2,027
Class 7-8 Day Cab Combination Unit Tailpipe	4,077	3,838	3,836	3,841	3,843
Class 7-8 Day Cab Combination Unit Upstream	3,181	2,974	2,946	2,944	2,907
Class 7-8 Sleeper Cab Combination Unit Tailpipe	8,505	9,564	9,555	9,537	9,517
Class 7-8 Sleeper Cab Combination Unit Upstream	5,137	4,503	4,471	4,308	4,188
Total	33,053	32,719	32,584	32,357	31,810

Table 4.3.3-2 (continued)

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

Pollutant and Vehicle Class	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Sulfur dioxide (SO_2)					
Class 2b-3 Work Trucks Tailpipe	908	787	776	755	702
Class 2b-3 Work Trucks Upstream	8,096	7,720	7,614	7,472	6,944
Class 3-8 Vocational Trucks Tailpipe	879	845	823	793	710
Class 3-8 Vocational Trucks Upstream	11,631	11,193	10,885	10,552	9,391
Class 7-8 Day Cab Combination Unit Tailpipe	1,048	987	977	976	964
Class 7-8 Day Cab Combination Unit Upstream	14,773	13,812	13,683	13,671	13,499
Class 7-8 Sleeper Cab Combination Unit Tailpipe	1,845	1,567	1,557	1,503	1,463
Class 7-8 Sleeper Cab Combination Unit Upstream	23,858	20,910	20,762	20,004	19,450
Total	63,038	57,820	57,077	55,727	53,123
Volatile organic compounds (VOC)					
Class 2b-3 Work Trucks Tailpipe	48,103	45,359	45,375	45,385	45,389
Class 2b-3 Work Trucks Upstream	23,764	23,181	22,871	21,931	20,384
Class 3-8 Vocational Trucks Tailpipe	18,275	18,207	18,134	18,019	17,736
Class 3-8 Vocational Trucks Upstream	8,713	8,478	8,347	8,232	7,779
Class 7-8 Day Cab Combination Unit Tailpipe	8,903	8,372	8,333	8,334	8,288
Class 7-8 Day Cab Combination Unit Upstream	5,610	5,245	5,196	5,192	5,126
Class 7-8 Sleeper Cab Combination Unit Tailpipe	52,856	26,127	26,086	25,867	25,727
Class 7-8 Sleeper Cab Combination Unit Upstream	9,060	7,941	7,884	7,597	7,386
Total	175,283	142,910	142,227	140,555	137,817

Table 4.3.3-3

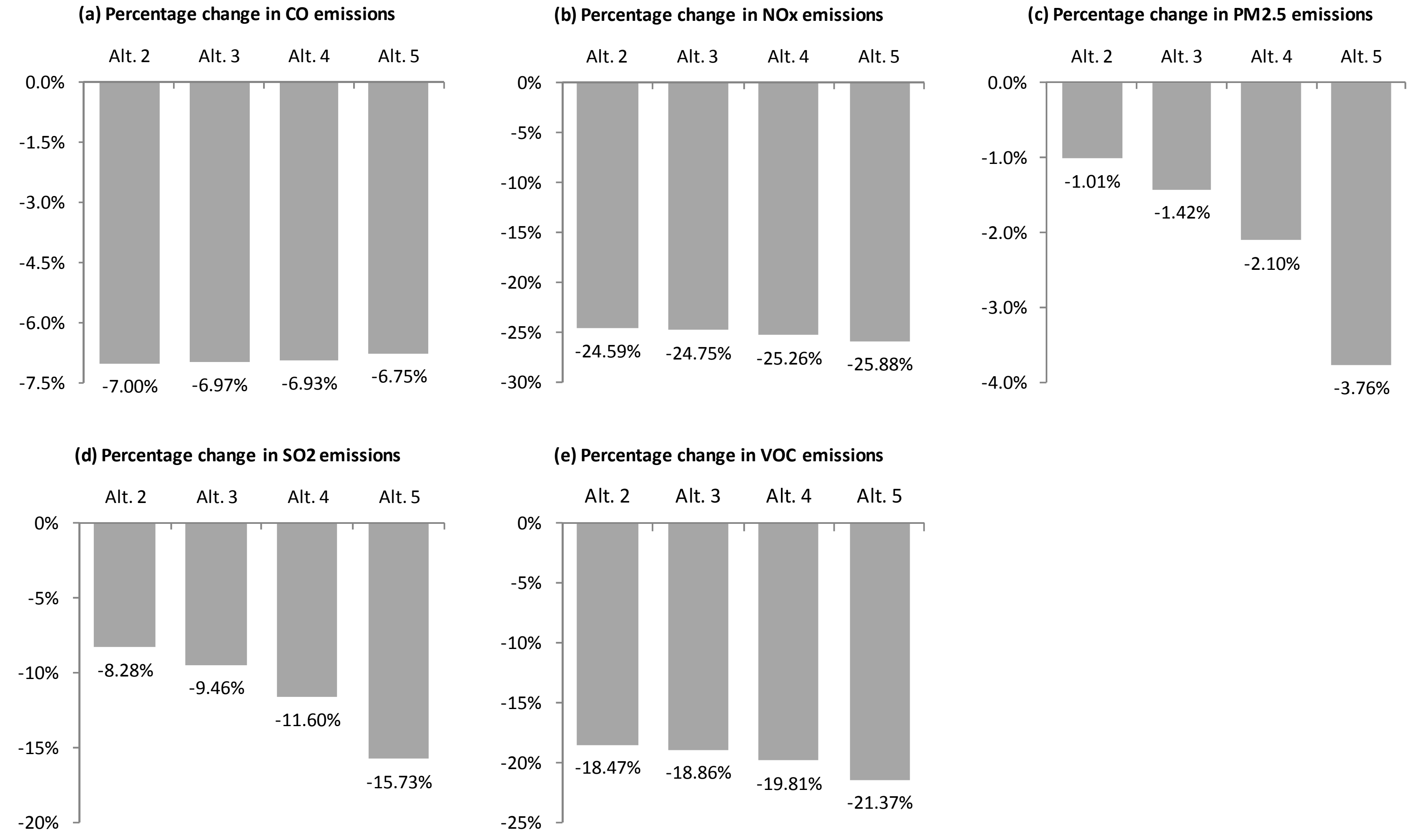
Cumulative Nationwide Changes in Criteria Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Pollutant and Year	Alt. 1 No Action Alternative c/	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	0	-44,820	-40,481	-34,030	-28,553
2030	0	-178,989	-178,145	-177,071	-172,573
2050	0	-355,816	-356,140	-357,112	-359,927
Nitrogen oxides (NO_x)					
2018	0	-114,256	-114,541	-116,480	-119,118
2030	0	-280,233	-282,156	-287,979	-295,027
2050	0	-428,370	-431,437	-440,294	-451,796
Particulate matter ($PM_{2.5}$)					
2018	0	31	-43	-216	-481
2030	0	-334	-469	-696	-1,243
2050	0	-1,689	-1,892	-2,211	-3,081
Sulfur dioxide (SO_2)					
2018	0	-3,347	-3,811	-4,871	-6,174
2030	0	-5,218	-5,961	-7,311	-9,916
2050	0	-8,120	-9,208	-11,090	-15,060
Volatile organic compounds (VOC)					
2018	0	-14,584	-14,603	-14,899	-15,419
2030	0	-32,373	-33,056	-34,728	-37,466
2050	0	-49,414	-50,455	-52,924	-57,322

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Figure 4.3.3-3. Cumulative Nationwide Percentage Changes in Criteria Pollutant Emissions from HD Vehicles by Alternative in 2030, Compared to the No Action Alternative



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid
Note: percentage scales differ for each pollutant.

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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-42,874	2050	Alt 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-52,445	2050	Alt 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Particulate matter ($PM_{2.5}$)	Maximum Increase	140	2018	Alt 4	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-277	2050	Alt 5	Houston-Galveston-Brazoria, TX (Ozone)
Sulfur dioxide (SO_2)	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,150	2050	Alt 5	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	-5,832	2050	Alt 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)

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

4.3.3.1.2 Toxic Air Pollutants Overview

Table 4.3.3-5 summarizes the total national emissions of toxic air pollutants from HD vehicles by alternative for each of the toxic air pollutants and analysis years. Figure 4.3.3-4 illustrates this information by alternative for 2030.

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	6,212	5,331	5,334	5,337	5,340
2030	4,698	2,680	2,681	2,683	2,686
2050	5,941	3,036	3,037	3,037	3,036
Acrolein					
2018	952	831	831	832	832
2030	650	370	370	370	371
2050	811	407	407	407	407

Table 4.3.3-5 (continued)

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

Pollutant and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Benzene					
2018	3,398	3,230	3,229	3,227	3,224
2030	2,300	1,926	1,924	1,921	1,915
2050	2,719	2,175	2,172	2,166	2,152
1,3-Butadiene					
2018	600	599	599	599	599
2030	299	295	295	295	295
2050	325	316	316	316	316
Diesel particulate matter (DPM)					
2018	67,978	67,758	67,667	67,441	67,158
2030	25,284	25,120	24,954	24,628	24,052
2050	28,333	27,356	27,110	26,644	25,756
Formaldehyde					
2018	15,506	12,623	12,628	12,635	12,640
2030	13,493	6,917	6,920	6,921	6,923
2050	17,502	8,071	8,073	8,069	8,056

Figure 4.3.3-4. Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for 2030 by Alternative

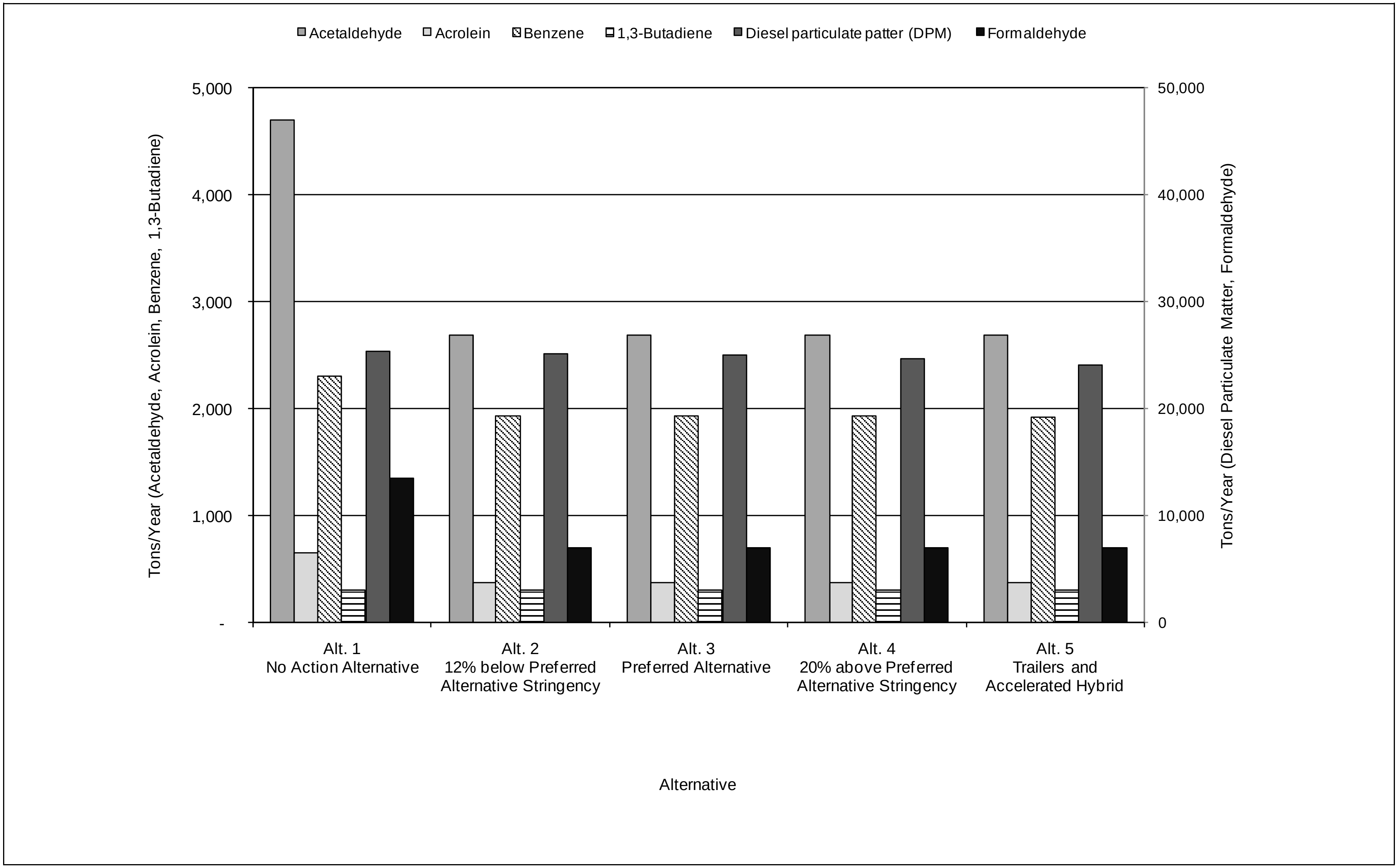


Figure 4.3.3-4 shows changes in toxic air pollutant emissions for each alternative for 2030, the mid-term forecast year. The trends for toxic air pollutant emissions across the alternatives are similar to those for criteria pollutants, for the same reasons listed above (*see* Section 4.3.3.1.1). Table 4.3.3-5 shows that emissions of acetaldehyde, acrolein, benzene, and formaldehyde decrease from Alternative 1 to Alternative 2, then remain relatively stable under each successive alternative from Alternative 2 to Alternative 5. Emissions of 1,3-butadiene are approximately equivalent for each alternative and year. For DPM, compared to the No Action Alternative, emissions decrease under each successive alternative from Alternative 2 to Alternative 5. These trends are accounted for by the extent of technologies assumed to be deployed under the different alternatives to meet the different levels of fuel efficiency requirements.

Figure 4.3.3-5 summarizes the total national emissions of toxic air pollutants over time from HD vehicles for the Preferred Alternative. Figure 4.3.3-5 indicates a consistent trend over time among the toxic air pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles as well as from reductions in upstream emissions from fuel production, but increase from 2030 to 2050 due to continuing growth in VMT.

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.

Table 4.3.3-7 lists the net change in nationwide toxic air pollutant emissions from HD vehicles for each toxic air pollutant and analysis year compared to the No Action Alternative. Figure 4.3.3-6 shows these changes in percentage terms for 2030. Table 4.3.3-7 shows that the magnitudes of the changes in nationwide emissions tend to increase from 2018 to 2030 to 2050, and that emissions under the action alternatives are very similar for most pollutants (except DPM).

Many of the differences between one action alternative and another in national emissions of toxic air pollutants are slight, in the range of 1 percent or less. Consequently, such differences are not expected to lead to measurable changes in ambient concentrations of toxic air pollutants. For such small changes the impacts of those action alternatives would be essentially equivalent.

Table 4.3.3-8 summarizes the air toxics analysis results by nonattainment area. Tables in Appendix D list the emission reductions for each nonattainment area. For acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, all nonattainment areas experience decreases in emissions across all alternatives and years. For DPM, emissions increase in most nonattainment areas in all years and alternatives.

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.

4.3.3.1.3 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 4.3.3-9). The reductions in adverse health effects become greater with increasing stringency of the alternatives. Table 4.3.3-10 lists the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative. The monetized health benefits are greater with increasing stringency of the alternatives.

Figure 4.3.3-5. Cumulative Nationwide Toxic Air Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative

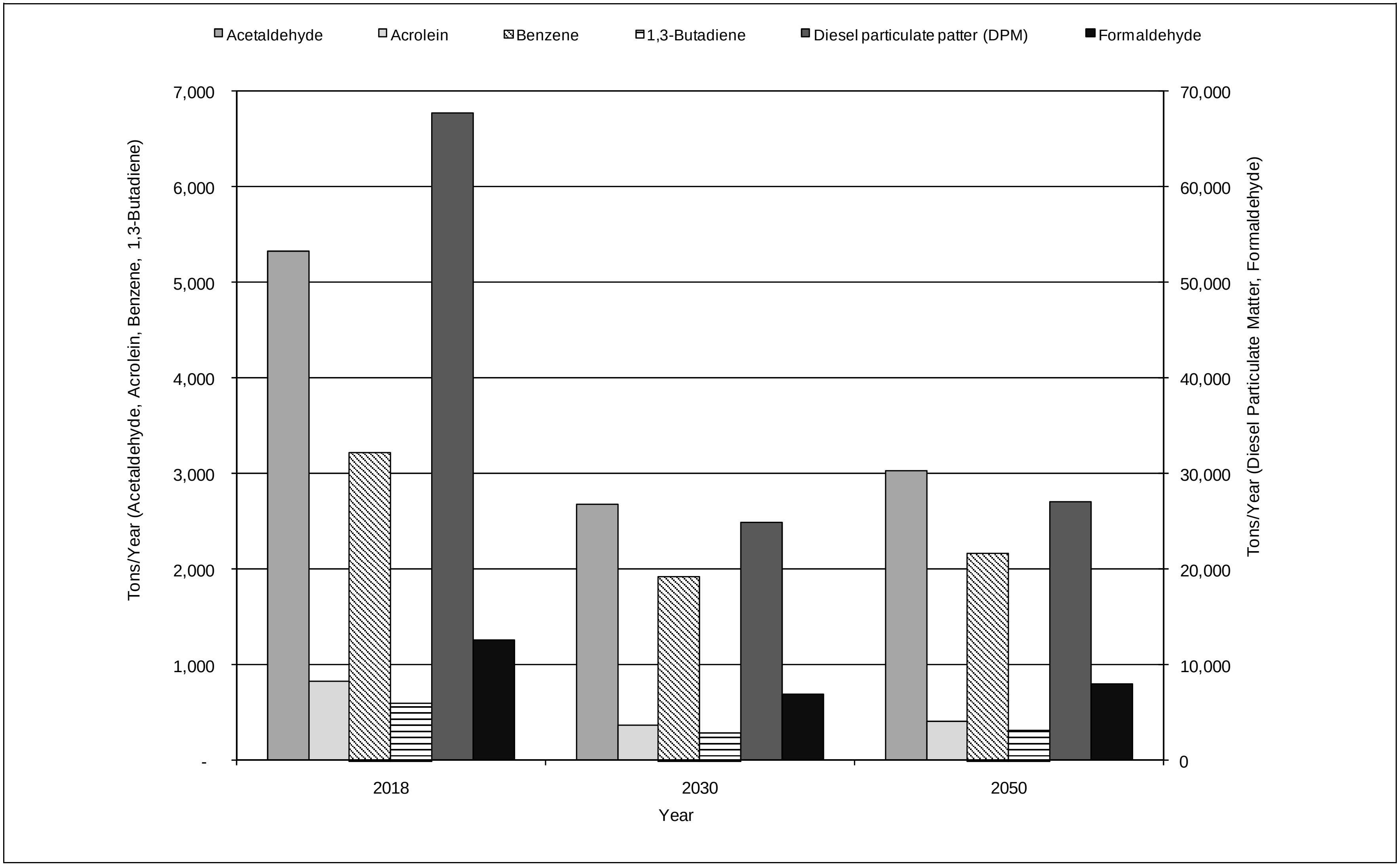


Table 4.3.3-6

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
Class 2b-3 Work Trucks Tailpipe	456	430	430	431	432
Class 2b-3 Work Trucks Upstream	4	4	4	4	4
Class 3-8 Vocational Trucks Tailpipe	1,058	1,065	1,066	1,066	1,067
Class 3-8 Vocational Trucks Upstream	6	6	6	6	5
Class 7-8 Day Cab Combination Unit Tailpipe	279	262	262	262	263
Class 7-8 Day Cab Combination Unit Upstream	8	7	7	7	7
Class 7-8 Sleeper Cab Combination Unit Tailpipe	2,875	894	895	896	898
Class 7-8 Sleeper Cab Combination Unit Upstream	13	11	11	11	10
Total	4,698	2,680	2,681	2,683	2,686
Acrolein					
Class 2b-3 Work Trucks Tailpipe	69	66	66	66	66
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Trucks Tailpipe	113	114	114	114	114
Class 3-8 Vocational Trucks Upstream	1	1	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	41	39	39	39	39
Class 7-8 Day Cab Combination Unit Upstream	1	1	1	1	1
Class 7-8 Sleeper Cab Combination Unit Tailpipe	422	148	148	148	149
Class 7-8 Sleeper Cab Combination Unit Upstream	2	2	2	1	1
Total	650	370	370	370	371
Benzene					
Class 2b-3 Work Trucks Tailpipe	88	83	83	84	84
Class 2b-3 Work Trucks Upstream	55	53	52	51	47
Class 3-8 Vocational Trucks Tailpipe	1,425	1,434	1,435	1,436	1,438
Class 3-8 Vocational Trucks Upstream	36	35	34	34	31
Class 7-8 Day Cab Combination Unit Tailpipe	53	50	50	50	50
Class 7-8 Day Cab Combination Unit Upstream	37	35	34	34	34
Class 7-8 Sleeper Cab Combination Unit Tailpipe	545	183	183	183	183
Class 7-8 Sleeper Cab Combination Unit Upstream	60	53	52	50	49
Total	2,300	1,926	1,924	1,921	1,915
1,3-Butadiene					
Class 2b-3 Work Trucks Tailpipe	12	11	11	11	11
Class 2b-3 Work Trucks Upstream	1	1	1	1	1
Class 3-8 Vocational Trucks Tailpipe	228	230	230	230	231
Class 3-8 Vocational Trucks Upstream	2	2	1	1	1
Class 7-8 Day Cab Combination Unit Tailpipe	5	4	4	4	4
Class 7-8 Day Cab Combination Unit Upstream	2	2	2	2	2
Class 7-8 Sleeper Cab Combination Unit Tailpipe	47	43	43	43	43
Class 7-8 Sleeper Cab Combination Unit Upstream	3	3	3	3	3
Total	299	295	295	295	295

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Diesel particulate matter (DPM)					
Class 2b-3 Work Trucks Tailpipe	1,491	1,406	1,407	1,408	1,410
Class 2b-3 Work Trucks Upstream	1,769	1,668	1,645	1,614	1,500
Class 3-8 Vocational Trucks Tailpipe	2,332	2,346	2,341	2,309	2,307
Class 3-8 Vocational Trucks Upstream	2,521	2,398	2,332	2,261	2,013
Class 7-8 Day Cab Combination Unit Tailpipe	2,591	2,442	2,439	2,443	2,431
Class 7-8 Day Cab Combination Unit Upstream	3,197	2,955	2,928	2,925	2,888
Class 7-8 Sleeper Cab Combination Unit Tailpipe	6,221	7,431	7,420	7,388	7,343
Class 7-8 Sleeper Cab Combination Unit Upstream	5,163	4,474	4,442	4,280	4,161
Total	25,284	25,120	24,954	24,628	24,052
Formaldehyde					
Class 2b-3 Work Trucks Tailpipe	1,341	1,266	1,267	1,268	1,272
Class 2b-3 Work Trucks Upstream	33	32	31	31	28
Class 3-8 Vocational Trucks Tailpipe	2,244	2,259	2,263	2,263	2,264
Class 3-8 Vocational Trucks Upstream	47	46	44	43	38
Class 7-8 Day Cab Combination Unit Tailpipe	853	801	802	803	804
Class 7-8 Day Cab Combination Unit Upstream	60	56	56	56	55
Class 7-8 Sleeper Cab Combination Unit Tailpipe	10,663	2,571	2,572	2,376	2,381
Class 7-8 Sleeper Cab Combination Unit Upstream	97	85	84	81	79
Total	13,493	6,917	6,920	6,921	6,923

Table 4.3.3-7

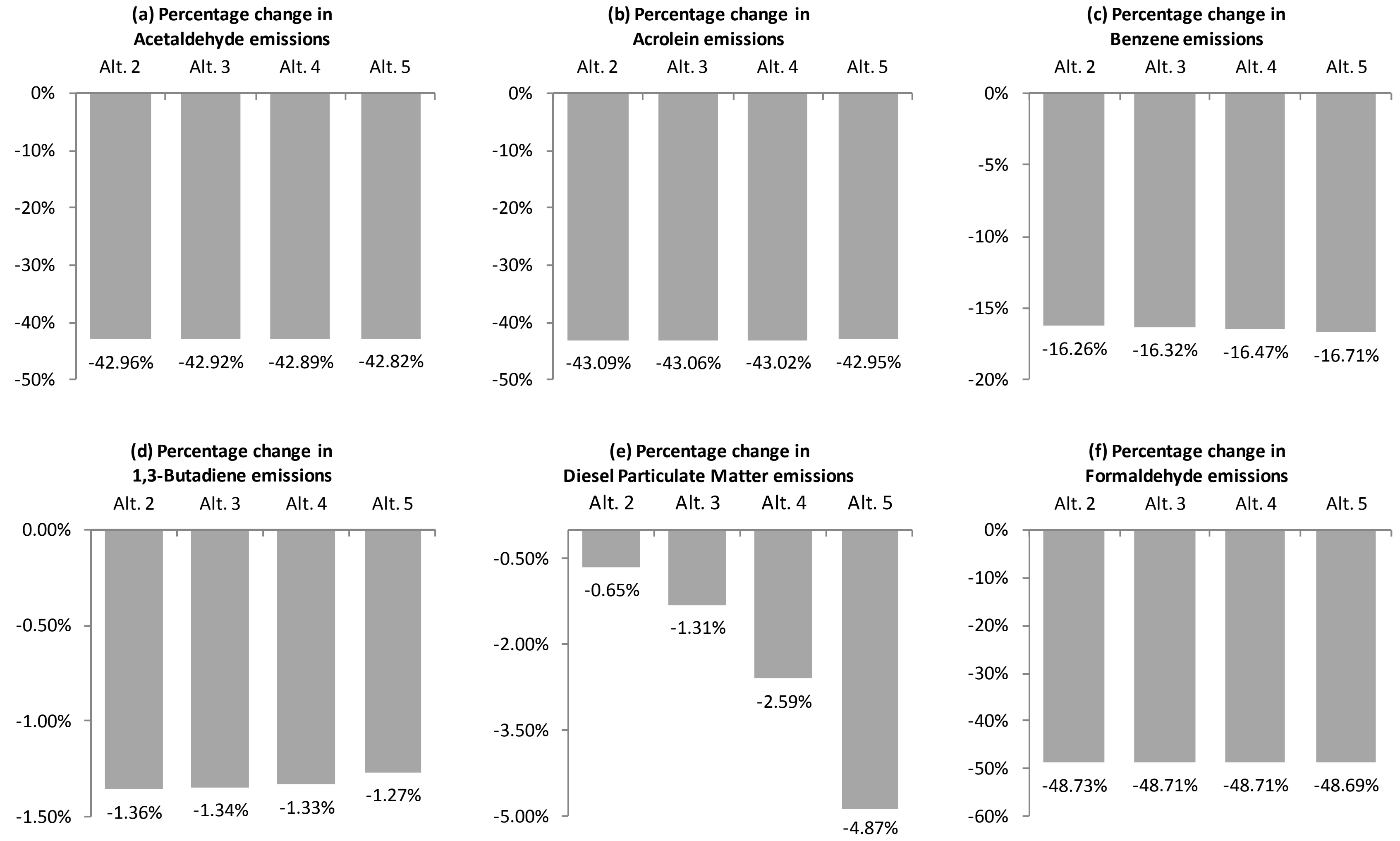
Cumulative Nationwide Changes in Toxic Air Pollutant Emissions (tons per year) from HD Vehicles by Alternative a/ b/

Pollutant and Year	Alt. 1 No Action Alternative c/	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	0	-881	-879	-875	-872
2030	0	-2,018	-2,017	-2,015	-2,011
2050	0	-2,905	-2,904	-2,904	-2,905
Acrolein					
2018	0	-121	-121	-120	-120
2030	0	-280	-280	-280	-279
2050	0	-404	-404	-404	-404
Benzene					
2018	0	-168	-168	-170	-173
2030	0	-374	-375	-379	-384
2050	0	-545	-547	-554	-568
1,3-Butadiene					
2018	0	-1	-1	-1	-1
2030	0	-4	-4	-4	-4
2050	0	-9	-9	-9	-10
Diesel particulate matter (DPM)					
2018	0	-221	-311	-538	-820
2030	0	-164	-330	-656	-1,232
2050	0	-977	-1,223	-1,690	-2,577
Formaldehyde					
2018	0	-2,884	-2,878	-2,871	-2,866
2030	0	-6,575	-6,573	-6,572	-6,570
2050	0	-9,430	-9,429	-9,432	-9,445

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10 %	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

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.

Figure 4.3.3-6. Cumulative Nationwide Percentage Changes in Toxic Air Pollutant Emissions from HD Vehicles by Alternative in 2030, Compared to the No Action Alternative



Alternative 2: 12% below Preferred Alternative Stringency
Alternative 3: Preferred Alternative
Note: percentage scales differ for each pollutant.
Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid

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	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-350	2050	Alt 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Acrolein	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-49	2050	Alt 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Benzene	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-64	2050	Alt 5	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1.0	2050	Alt 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	124	2018	Alt 2	Los Angeles South Coast Air Basin, CA (Ozone, $PM_{2.5}$)
	Maximum Decrease	-285	2050	Alt 5	Houston-Galveston-Brazoria, TX (Ozone)
Formaldehyde	Maximum Increase	*No increases are predicted for any alternatives.*			
	Maximum Decrease	-1,135	2050	Alt 2	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.

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 Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Mortality (ages 30 and older), Pope *et al.* (2002)					
2018	0	-75	-78	-87	-100
2030	0	-226	-235	-251	-283
2050	0	-447	-461	-488	-546
Mortality (ages 30 and older), Laden *et al.* (2006)					
2018	0	-192	-201	-224	-257
2030	0	-579	-601	-642	-725
2050	0	-1,141	-1,178	-1,245	-1,394
Chronic bronchitis					
2018	0	-54	-56	-62	-71
2030	0	-156	-161	-172	-194
2050	0	-296	-305	-322	-359
Emergency room visits for asthma					
2018	0	-63	-66	-75	-87
2030	0	-172	-180	-194	-223
2050	0	-323	-336	-358	-408
Work-loss days					
2018	0	-10,335	-10,787	-11,955	-13,640
2030	0	-28,191	-29,189	-31,126	-34,994
2050	0	-51,187	-52,766	-55,683	-62,115

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/ Negative changes indicate fewer health impacts; positive changes indicate additional health impacts.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

Table 4.3.3-10

Cumulative Nationwide Monetized Health Benefits (2009 U.S. million dollars per year) from Criteria Pollutant Emissions from HD Vehicles by Alternative a/

Rate and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
3-Percent Discount Rate					
Pope *et al.*(2002)					
2018	0	-665	-696	-776	-890
2030	0	-2,087	-2,165	-2,314	-2,613
2050	0	-4,189	-4,323	-4,569	-5,114
Laden *et al.* (2006)					
2018	0	-1,627	-1,704	-1,899	-2,178
2030	0	-5,106	-5,295	-5,661	-6,394
2050	0	-10,249	-10,577	-11,181	-12,515
7-Percent Discount Rate					
Pope *et al.* (2002)					
2018	0	-604	-632	-704	-808
2030	0	-1,894	-1,964	-2,100	-2,371
2050	0	-3,799	-3,921	-4,144	-4,638
Laden *et al.* (2006)					
2018	0	-1,470	-1,539	-1,716	-1,968
2030	0	-4,612	-4,784	-5,114	-5,776
2050	0	-9,257	-9,554	-10,099	-11,304

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.

≥ 1% increase	1% or greater increase compared to No Action Alternative
< 1% (+/-)	Less than 1% increase or decrease compared to No Action Alternative
-1% to -10%	1% - 10% decrease compared to No Action Alternative
> 10% decrease	Greater than 10% decrease compared to No Action Alternative

For all health outcomes and years, the health benefits uniformly increase from Alternative 2 to Alternative 5. The benefits also increase steadily from the near future (2018) to later years (2050). These trends are consistent across all health outcomes: in 2018, the reduction of each outcome is less than or equal to 3 percent. In 2050, this benefit increases to between 8 percent and 12 percent. The results in Table 4.3.3-9 present PM mortality as measured using the Pope *et al.* and the Laden *et al.* coefficients. (*See* Section 3.3.2.7 for description of the health effects methodology and how the Pope and Laden study data were used.) While the magnitude of PM mortality varies between the two methods, the percent change in mortality remains constant between the two approaches.

The monetized health benefits follow a pattern similar to the trends in the health outcomes. The monetized health benefits of each alternative also increase from Alternative 2 to Alternative 5 and from the near future to later years. Monetized health benefits are measured under the Pope *et al.* methodology and the Laden *et al.* methodology. Benefits are calculated using a 3 percent discount rate and a 7 percent discount rate. (*See* Section 3.3.2.7.) Because the 7 percent discount rate places less present value on future year benefits than the 3 percent discount rate, the present year benefit of reductions in 2050 is approximately 10 percent smaller under the 7 percent discount rate than under the 3 percent discount rate. In total, the monetized health benefits range between \$600 million and \$12.5 billion depending on the coefficients (Pope *et al.* 2002 or Laden *et al.* 2006), discount rate, alternative, and year.

Under all alternatives, the health and monetized health benefits estimated by the cumulative effects analysis would be greater than those estimated by the direct and indirect effects analysis.

The following sections describe the results of the analysis of emissions for Alternatives 1 through 5 in greater detail. The magnitude of emission change from one alternative to the next generally increases between Alternative 2 and Alternative 5 consistent with the required greater overall fuel efficiency. Health and monetized health benefits increase with each alternative from Alternative 2 through Alternative 5.

4.3.3.2 Alternative 1: No Action Alternative

4.3.3.2.1 Criteria Pollutants

Under the No Action Alternative, the average fuel efficiency for HD vehicles would increase in future years, as projected by the AEO 2011 Early Release (EIA 2011). Average fuel efficiency of HD vehicles is assumed to increase from 2014 through 2050 due to a projected rise in demand for fuel efficiency (*see* Section 4.1.2). Current trends in the levels of criteria pollutant emissions from vehicles would continue, with emissions continuing to decline due to more stringent EPA emission standards (*see* Section 3.3.1), despite a growth in total VMT from 2018 to 2030. From 2030 to 2050, however, emissions would increase overall due to continuing growth in total VMT, which during this period would outweigh the decline in emissions due to emission standards (*see* Table 3.5.2-1). The No Action Alternative would not result in any change in criteria pollutant emissions nationally or in nonattainment areas (*see* Table 3.5.2-3) beyond those changes already projected to result from future trends in emissions and VMT in accordance with trends derived from AEO Early Release 2011 projections.

4.3.3.2.2 Toxic Air Pollutants

As with the criteria pollutants, under the No Action Alternative current trends in the levels of toxic air pollutant emissions from vehicles would continue, with emissions continuing to decline due to EPA emission standards, despite a growth in total VMT from 2018 to 2030. From 2030 to 2050, however, emissions would increase due to growth in total VMT during that period. The No Action Alternative would not result in any change in toxic air pollutant emissions nationally or in nonattainment and maintenance areas (*see* Table 3.5.2-7) 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

Under the No Action Alternative, current trends in the levels of criteria pollutant and toxic air pollutant emissions from vehicles would continue, with emissions continuing to decline due to the increasingly stringent EPA emission standards (*see* Section 3.3.1.1), despite a growth in total VMT. The human health-related impacts expected under current trends would continue (*see* Tables 4.3.3-9 and 4.3.3-10).

4.3.3.3 Alternative 2: 12 percent below Preferred Alternative Stringency

4.3.3.3.1 Criteria Pollutants

Table 4.3.3-3 and Figure 4.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 2, nationwide emissions of CO, NO_x, SO_2, and VOCs would be reduced compared to the No Action Alternative in all years. Alternative 2 is the least stringent of all the action alternatives, and the reductions under Alternative 2 would be smaller than or equivalent to those under the other action alternatives. Because Alternative 2 assumes that sleeper cab combination units would use APUs during extended idling, and the APUs have higher PM emission rates than do tractors' main engines, this alternative would have higher $PM_{2.5}$ emissions than would the No Action Alternative in 2018. Under Alternative 2, cumulative emissions would be the same as or less than direct and indirect emissions for all pollutants. Emission changes (compared to the No Action Alternative) under the Alternative 2 cumulative analysis would be the same as or less than the corresponding emission changes under the Alternative 2 direct and indirect analysis for all pollutants.

At the national level, emissions of criteria air pollutants could decrease overall because the reduction in upstream emissions of criteria air pollutants due to improved fuel efficiency and the resulting decline in the volume of fuel refined and distributed together tend to offset the increase in vehicle emissions due to the increase in VMT attributable to the rebound effect. However, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Most nonattainment areas would experience increases of $PM_{2.5}$ emissions compared to the No Action Alternative, which are the result of increased tailpipe emissions due to the rebound effect and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

4.3.3.3.2 Toxic Air Pollutants

Table 4.3.3-7 and Figure 4.3.3-4 show the changes in nationwide emissions of toxic air pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 2 would result in reduced emissions of all studied toxic air pollutants, for all analysis years (*see* Table 4.3.3-7). Emissions reductions under Alternative 2 would be approximately equivalent to those under the other action alternatives for all studied toxic air pollutants except DPM, for which emissions would be higher. Cumulative emissions of toxic air pollutants would be lower than direct and indirect emissions for the same combinations of pollutant and year.

At the national level, emissions of toxic air pollutants could decrease overall as explained in Section 4.3.3.3.1. However, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 2, 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.

4.3.3.3.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 2 compared to the No Action Alternative (*see* Table 4.3.3-9).

Table 4.3.3-10 lists the corresponding monetized health benefits under Alternative 2 and the other action alternatives compared to the No Action Alternative. The monetized health benefits of Alternative 2 range from approximately $600 million to $10.2 billion. The health and monetized health benefits of Alternative 2 are the smallest of all the action alternatives.

Under Alternative 2, the cumulative health and monetized health benefits would be greater than the benefits due to direct and indirect emissions.

4.3.3.4 Alternative 3: Preferred Alternative

4.3.3.4.1 Criteria Pollutants

Table 4.3.3-3 and Figure 4.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 3, nationwide emissions of all pollutants would be reduced in all years. Alternative 3 is less stringent than Alternatives 4 and 5, and for all pollutants the reductions would be smaller than or equivalent to those under Alternatives 4 and 5.

Cumulative emissions would be the same as or less than direct and indirect emissions for all pollutants. Emission changes (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be greater than the corresponding emission changes under the Alternative 3 direct and indirect analysis for all pollutants.

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, which are the result of increased tailpipe emissions due to the rebound effect and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

4.3.3.4.2 Toxic Air Pollutants

Table 4.3.3-7 and Figure 4.3.3-4 show the changes in nationwide emissions of toxic air pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 3.3.3-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 3 would result in reduced emissions of all studied toxic air polluutants, for all years. Emissions reductions under Alternative 3 would be approximately equivalent to those under Alternatives 4 and 5 for all studied toxic air pollutants except DPM. Emissions of DPM would be greater than under Alternatives 4 and 5 (*see* Figure 4.3.3-6, panel (e)). Under Alternative 3, cumulative emissions of toxic air pollutants would be lower than direct and indirect emissions for the same combinations of pollutant and year.

At the national level, emissions of toxic air pollutants could decrease overall as explained in Section 4.3.3.4.1. As with less stringent alternatives, 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 all 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.

4.3.3.4.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 3 compared to the No Action Alternative (*see* Table 4.3.3-9).

Table 4.3.3-10 lists the corresponding monetized health benefits under Alternative 3 and the other action alternatives compared to the No Action Alternative. The monetized health benefits of Alternative 3 range from approximately $630 million to $10.6 billion. The health and monetized health benefits of Alternative 3 would be greater than that of Alternative 2 but less than those of Alternatives 4 and 5.

Health and monetized health benefits (compared to the No Action Alternative) under the Alternative 3 cumulative analysis would be greater than the corresponding benefits under the Alternative 3 direct and indirect analysis.

4.3.3.5 Alternative 4: 20 percent above Preferred Alternative Stringency

4.3.3.5.1 Criteria Pollutants

Table 4.3.3-3 and Figure 4.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 4, nationwide emissions of all pollutants would be reduced in all years. Alternative 4 is less stringent than Alternative 5, and for all pollutants the reductions under this alternative would be smaller than or equivalent to those under Alternative 5.

As compared to the No Action Alternative, emission changes under the Alternative 4 cumulative analysis would be greater than the corresponding emission changes under the Alternative 4 direct and indirect analysis for all pollutants.

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, which are the result of increased tailpipe emissions due to the rebound effect and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

4.3.3.5.2 Toxic Air Pollutants

Table 4.3.3-7 and Figure 4.3.3-4 show the changes in nationwide emissions of toxic air pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-6 shows these changes in percentage terms for 2030. Compared to the No Action Alternative, Alternative 4 would result in reduced emissions of all studied toxic air pollutants, for all analysis years. Emissions reductions under Alternative 4 would be approximately equivalent to those under Alternative 5 for all studied toxic air pollutants except DPM for which emissions would be higher under Alternative 4. Under Alternative 4, cumulative emissions would be less than direct and indirect emissions for all toxic air pollutants for the same combinations of pollutant and year.

At the national level, emissions of toxic air pollutants could decrease overall as explained in Section 4.3.3.3.1. As with 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 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.

4.3.3.5.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 4 compared to the No Action Alternative (*see* Table 4.3.3-9).

Table 4.3.3-10 lists the corresponding monetized health benefits under Alternative 4 and the other action alternatives compared to the No Action Alternative. The monetized health benefits of Alternative 4 range from approximately $700 million to $11.2 billion. The health and monetized health benefits of Alternative 4 would be greater than those of Alternatives 2 and 3 but less than that of Alternative 5.

As compared to the No Action Alternative, health and monetized health benefits under the Alternative 4 cumulative analysis would be greater than the corresponding benefits under the Alternative 4 direct and indirect analysis.

4.3.3.6 Alternative 5: Accelerated Hybrid Adoption

4.3.3.6.1 Criteria Pollutants

Table 4.3.3-3 and Figure 4.3.3-1 show the changes in nationwide emissions of criteria pollutants under Alternative 3 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-3 shows these changes in percentage terms for 2030. Under Alternative 5, nationwide emissions of all pollutants would be reduced in all years. Alternative 5 is the most stringent alternative, and for all pollutants the reductions under this alternative would be equivalent to or greater than those of any other alternative.

Under Alternative 5, cumulative emissions would be the same as or less than direct and indirect emissions for all pollutants. As compared to the No Action Alternative, emission changes under the Alternative 5 cumulative analysis would be the same as or greater than the corresponding emission changes under the Alternative 5 direct and indirect analysis for all pollutants.

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, which are the result of increased tailpipe emissions due to the rebound effect and APU usage. Tables in Appendix D list the emission changes for each nonattainment area.

4.3.3.6.2 Toxic Air Pollutants

Table 4.3.3-7 and Figure 4.3.3-4 show the changes in nationwide emissions of toxic air pollutants under Alternative 5 compared to the No Action Alternative and the other action alternatives. Figure 4.3.3-6 shows these changes in percentage terms for 2030. Alternative 5 would result in reduced emissions of all studied toxic air pollutants in all analysis years compared to the No Action Alternative.

Emissions of air toxics under Alternative 5 would be essentially equivalent to those under any other action alternative except for DPM, for which emissions would be lower under Alternative 5. Under Alternative 5, cumulative emissions would be less than or equal to direct and indirect emissions for all toxic air pollutants, for the same combinations of pollutant and year.

At the national level, emissions of toxic air pollutants could decrease overall as explained in Section 4.3.3.4.1. As 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 all studied 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.

4.3.3.6.3 Health Outcomes and Monetized Benefits

Adverse health effects nationwide would be reduced under Alternative 5 compared to the No Action Alternative (*see* Table 4.3.3-9).

Table 4.3.3-10 lists the corresponding monetized health benefits under Alternative 5 and the other action alternatives compared to the No Action Alternative. The monetized health benefits of Alternative 5 range from approximately $800 million to $12.5 billion. The health and monetized health benefits of Alternative 5 are the largest of all the action alternatives.

As compared to the No Action Alternative, health and monetized health benefits under the Alternative 5 cumulative analysis would be the same as or greater than the corresponding benefits under the Alternative 5 direct and indirect analysis.

4.4 CLIMATE

This section focuses on the cumulative impacts on climate of the proposed action and alternatives and covers many of the same topics as in Section 3.4 and Section 3.5.3. To minimize the repetition of background information on climate science or modeling methodologies, this section refers the reader to Section 3.4 where appropriate.

The climate analysis in Chapter 4 is broader than the corresponding analysis in Chapter 3 because Chapter 4 addresses the effects of the HD Fuel Efficiency Improvement Program proposed standards together with those of past, present, and reasonably foreseeable future actions. The HD vehicle fleet's emission trajectory through 2050 is described in Section 4.1.2. That section describes how NHTSA models reasonably foreseeable increases in fuel efficiency of the HD vehicle fleet for each alternative from 2018 to 2050 based on AEO projections. As described below, 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).

4.4.1 Introduction – Greenhouse Gases and Climate Change

Section 3.4.1 provides a discussion of the science of climate change, including 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. 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, readers are referred to Section 3.4.2 for a discussion of this topic.

4.4.3 Methodology

The methodology used to characterize the effects of the proposed action and alternatives on climate has three key elements:

- *First*, NHTSA estimates GHG emissions under each alternative (including the No Action Alternative). The methodology for estimating GHG emissions is described in Section 4.4.3.1.
- *Second*, NHTSA estimates the monetized damages associated with carbon dioxide (CO_2) emissions (the social cost of carbon) and the reductions in those damages that would be attributable to each regulatory alternative. The methodology for estimating the social cost of carbon is described in Section 3.4.3.2.
- *Third*, NHTSA analyzes how the estimated GHG emissions might affect the climate system (climate effects). The methodologies for analyzing how GHG emissions affect global climate parameters are described in Section 4.4.3.3.

4.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

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. To estimate the emissions resulting from the proposed action, NHTSA used the MOVES and GREET models (*see* Section 3.1.4 for descriptions of the models) and scaled the estimates to take into account projected annual gains in fuel efficiency derived from the AEO Early Release 2011 forecast.[8] These CO_2 emission estimates also include upstream emissions, which occur from the use of fossil carbon-based energy during crude oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHGs emitted during fuel production and use (more than 95 percent, even after accounting for the higher global warming potentials of other GHGs), NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel efficiency.[9]

The methodology for modeling GHG emissions is described in Section 3.4.3.1. As described there, the MOVES model provides estimates of fleet CO_2 emissions until only 2050. In order to present longer-term projections of the cumulative impacts of this action, NHTSA used a scaling methodology to project the impact of MY 2051-2100 HD vehicles using Global Change Assessment Model (GCAM) assumptions regarding the growth of U.S. transportation fuel consumption.

To estimate the impact of the proposed action on global CO_2 emissions, NHTSA calculated the difference between the No Action Alternative described in Section 4.1 and the total fleet CO_2 emissions under each action alternative. NHTSA then subtracted this GHG emissions reduction from the GCAM6.0 scenario (described below) to generate modified global-scale emissions scenarios, which show the effect of the various alternatives on the global emissions path.

4.4.3.2 Social Cost of Carbon

Please *see* Section 3.4.3.2 for a description of 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.

4.4.3.3 Methodology for Estimating Climate Effects

This EIS estimates and reports four effects of climate change driven by alternative scenarios of projected changes in 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 GHG emissions is a direct effect of the improvements in fuel efficiency associated with the alternatives; the four effects on climate change may be considered to be indirect effects.

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 climate effects. MAGICC 5.3.v2 uses the

[8] In Chapter 3, NHTSA modeled the projected direct and indirect impacts of the proposed standards by isolating the impacts of the proposal. There, NHTSA assumed that the fuel efficiency of new HD vehicles under each action alternative would remain constant at the required 2018 level during all subsequent model years unless market forces would have pushed fuel efficiency higher. In contrast, in this chapter, NHTSA addresses the effects of the HD Fuel Efficiency Improvement Program together with those of reasonably foreseeable future actions. Thus, as discussed in Section 4.1.2, NHTSA assumes that further gains in fuel efficiency growth beyond 2018 implied by the AEO forecast will be achieved in the aftermath of the proposed action.

[9] Although this section includes only a discussion of CO_2 emissions, the climate modeling discussion in Section 4.4.4 assesses the cumulative impacts associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.

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.

4.4.3.3.1 MAGICC Version 5.3v2

For a description of MAGICC, *see* Section 3.4.3.3.1.

4.4.3.3.2 Reference Case Modeling Runs

In the cumulative impacts analysis presented in this chapter, NHTSA assumed that global emissions under the No Action Alternative would follow the trajectory provided by the GCAM6.0 scenario, rather than the GCAMReference scenario used in Chapter 3. Whereas the GCAMReference Scenario assumed no explicit policies to limit carbon emissions in the future, the GCAM6.0 scenario represents a Reference Case which takes into account significant future global actions to address climate change. The approach for the Reference Case modeling runs for the cumulative effects analysis was based on the same approach described in 3.4.3.3.2, with the only difference being the choice of global emission scenarios. Section 4.4.4 presents the results of the Reference Case modeling runs.

4.4.3.3.3 Sensitivity 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. The approach for the sensitivity analysis in this chapter was based on the same approach described in Section 3.4.3.3.3. Unlike the Chapter 3 analysis, which did not assess the sensitivity around different global emissions scenarios, for the results presented in this chapter, NHTSA assumed multiple global emissions scenarios including GCAM6.0 (678 ppm in 2100); RCP4.5 (522 ppm in 2100); and GCAMReference scenario (785 ppm in 2100). Section 4.4.4.3.5 presents the results of the sensitivity analysis for these different global emission scenarios.

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, such as, population growth, economic development, and policy change. 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 3.4.3.4 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.[10] This Reference Case global emissions scenario serves as a baseline against which the

[10] The RCP4.5 scenario is another, more aggressive, stabilization scenario that provides an illustration of the climate system response to stabilizing the anthropogenic components of radiative forcing at 4.5 W/m^2 in the year 2100. The RCP4.5 scenario "assumes that climate policies, in this instance the introduction of a set of global greenhouse gas emissions prices, are invoked to achieve the goal of limiting emissions, concentrations and radiative forcing" (Thomson *et al.* 2011). This scenario is a "stabilization scenario" – i.e., one that stabilizes the atmospheric concentration of CO_2 – with a pathway that minimizes cost. In other words, the RCP4.5 scenario "assumes that all nations of the world undertake emissions mitigation simultaneously and effectively, and share a common global price that all emissions to the atmosphere must pay with emissions of different gases priced according to their

climate benefits of the various HD Fuel Efficiency Improvement Program alternatives can be measured. NHTSA chose the GCAM6.0 scenario to represent reasonably foreseeable actions.

The GCAM6.0 scenario is the GCAM representation of the radiative forcing target (6.0 watts per square meter 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 assumes a moderate level of global GHG reductions. It is based on a set of assumptions about drivers such as population, technology, socioeconomic changes, and global climate policies that correspond to stabilization, by 2100, of total radiative forcing[11] and associated CO_2 concentrations at roughly 678 parts per million by volume (ppmv).[12] More specifically, GCAM6.0 is a scenario that incorporates declines in overall energy use, including fossil fuel use, as compared to the reference case. In addition, GCAM6.0 includes increases in renewable energy and nuclear energy, with the proportion of electricity-supplied total final energy increasing due to fuel switching in the end-use sectors. Carbon dioxide capture and storage (CCS) also plays an important role that allows for continued use of fossil fuels for electricity generation and cement manufacture while limiting CO_2 emissions. Although GCAM6.0 does not explicitly include specific climate change mitigation policies within the scenario, it does represent a plausible future pathway of global emissions in response to significant global action to mitigate climate change. GCAM scenarios were developed more than ten years after 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.

NHTSA used the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects but used the RCP4.5 scenario and the GCAMReference emissions scenario (an updated version of the MiniCAM model scenario) to evaluate the sensitivity of the results to alternative emissions scenarios.

Separately, each action 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 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 614 million metric tons of CO_2 ($MMTCO_2$); emissions in 2020 under the Preferred Alternative are 587 $MMTCO_2$ (*see* Table 4.4.4-2). The difference of 27 $MMTCO_2$ (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 27 $MMTCO_2$ less than this reference level, or 37,495 $MMTCO_2$ 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 2011 Early Release (EIA 2011) and International Energy Outlook (IEO) 2010 (EIA 2010), 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 GCAMReference scenario.

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hundred-year global warming potentials" (Thomson *et al.* 2011). Although RCP4.5 does not explicitly include specific climate change mitigation policies, it represents a plausible future pathway of global emissions in response to more significant global action to mitigate climate change than the GCAM6.0 scenario.

[11] *See* Section 3.4.1.7.3 for an explanation of the term "radiative forcing."

[12] Based on 3.0 °C climate sensitivity.

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.

4.4.3.4.1 Past, Present, and Reasonably Foreseeable Future Actions Related to the Cumulative Impacts Analysis

NHTSA chose the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects for this chapter because regional, national, and international initiatives and programs now in the planning stages and underway indicate that some reduction in the rate of global GHG emissions is reasonably foreseeable in the future. The initiatives and programs discussed below are those NHTSA has tentatively concluded are past, present, or reasonably foreseeable 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, a scenario that takes into account moderate reductions in the rate of global GHG emissions, such as the GCAM6.0 scenario, can be considered reasonably foreseeable under NEPA.

United States: Regional Actions[13]

- **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 2009). 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 2009). 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 2009; RGGI 2011). 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 Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec), along with 16 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

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

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 2010a). The second phase begins in 2015, when the program expands to include transportation fuels and residential, commercial, and industrial fuels not otherwise covered (WCI 2010a). When fully implemented in 2015, the program will cover nearly 90 percent of GHG emissions in the 11 WCI partner States and provinces.

United States: Federal Actions

- **NHTSA and EPA Joint Rule on Fuel Efficiency and GHG Emissions Standards for Light-Duty Vehicles.** In April 2010, NHTSA and EPA issued a joint Final Rule establishing a new National Program to regulate MY 2012–2016 passenger cars and light trucks to improve fuel efficiency and reduce GHG emissions. NHTSA issued CAFE standards under the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA), and EPA issued GHG emissions standards under the Clean Air Act. These rules require a combined average fleet-wide fuel economy of 34.1 mpg and 250 grams per mile of CO_2 for MY 2016 light duty vehicles. Vehicles covered by these standards are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. The program is projected to reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (NHTSA 2010 citing EPA 2009).
- **NHTSA and EPA Forthcoming Proposal for Model Year 2017 – 2025 Light-Duty Vehicle Standards.** Following the first phase of the National Program, NHTSA and EPA plan to propose fuel economy and GHG emissions standards for MY 2017–2025 light duty vehicles. On October 1, 2010, NHTSA and EPA issued a Notice of Intent (NOI) announcing their plans for setting light-duty vehicle standards for MY 2017 and beyond. On May 10, 2011, NHTSA published in the Federal Register a NOI announcing the development of the EIS for the forthcoming proposal.[14]
- **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, which went into effect 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). Also during this 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 propose a rulemaking for facilities with emissions of at least 50,000 tpy 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

[14] 76 *FR* 26996 (May 10, 2011).

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, which went into effect July 1, 2010, 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 2010). 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 2010).
- **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. This target is contingent on passage of U.S. energy and climate legislation. Recent Federal actions that may reduce GHG emissions 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.

International Actions

- **United Nations Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol, and the December 2010 Conference of the Parties (COP)-16.** UNFCCC is an international treaty signed by many countries around the world (including the United States[15]), 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). For the first time, at COP-15 (held in 2009) all major developed and developing countries agreed to pledge specific emission reductions. At COP-16, in December 2010, a draft accord pledged to limit global temperature increase to less than 2 °C (3.6 °F) above pre-Industrial global average temperature. As of April 27, 2011, 141 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.

[15] 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 that had 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).

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 discussion and conclusions drawn in that section apply to this cumulative impact analysis as well. 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

Using the methodology described in Section 4.4.3.1, NHTSA estimated the emissions resulting from the proposed HD Fuel Efficiency Improvement Program. GHG emissions from MY 2050-2100 HD vehicles were then scaled using GCAM assumptions regarding the growth of U.S. transportation fuel consumption (*See* Section 3.4.3.1).

Cumulative emission reductions from each action alternative increase with the increasing stringency of the alternatives, with Alternative 2 having the lowest cumulative emission reductions and Alternative 5 having the highest cumulative emission reductions. Table 4.4.4-1 shows total GHG emissions and emission reductions projected to result from new U.S. HD vehicles from 2014–2100 under each action alternative. Between 2014 and 2100, projections of cumulative emission reductions due to the proposed action and other reasonably foreseeable future actions ranged from 5,600 to 10,900 $MMTCO_2$. Compared to cumulative global 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 0.3 percent from their projected levels under the No Action Alternative.

Table 4.4.4-1

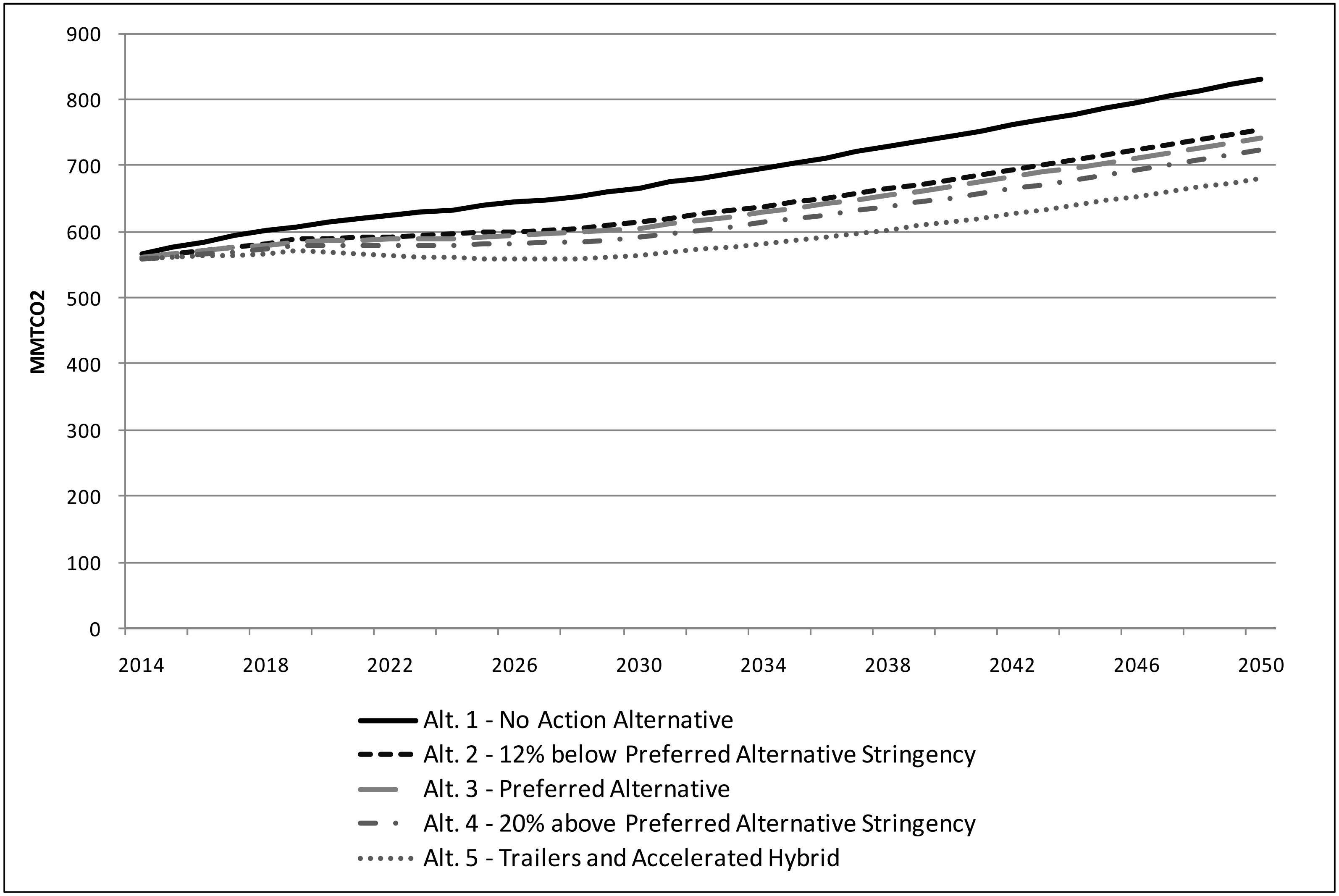
Cumulative Effects of CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles from 2014 to 2100 by Alternative a/

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative	Emissions Reductions Compared to No Action Alternative (%)
Alt. 1 - No Action Alternative	66,000	0	
Alt. 2 - 12% below Preferred Alternative Stringency	60,400	5,600	8%
Alt. 3 - Preferred Alternative	59,600	6,400	10%
Alt. 4 - 20% above Preferred Alternative Stringency	58,100	7,900	12%
Alt. 5 - Trailers and Accelerated Hybrid	55,100	10,900	17%

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.

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. HD vehicles in the United States currently account for approximately 6.6 percent of U.S. CO_2 emissions. With the action alternatives reducing U.S. HD vehicle CO_2 emissions by 8–17 percent over 2014–2100 under the cumulative impacts analysis presented in this chapter, the proposed action would contribute to reducing total U.S. CO_2 emissions relative to the no action case. 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 and reasonably foreseeable future increases in fuel efficiency would reduce total U.S. CO_2 emissions by 1.6 to 3.1 percent in 2100. Figure 4.4.4-1 shows projected annual emissions from U.S. HD vehicles for MY 2014–2018 when combined with reasonably foreseeable future actions.

Figure 4.4.4-1. Cumulative Annual CO_2 Emissions from U.S. HD Vehicles Under the MY 2014–2018 Standards and Other Reasonably Foreseeable Future Actions (MMTCO_2)



As Table 4.4.4-2 shows, 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 turn over.

Table 4.4.4-2

Emissions of Greenhouse Gases ($MMTCO_2e$ per year) from U.S. HD Vehicles by Alternative, Cumulative Effects Analysis

GHG and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon dioxide (CO_2)					
2014	567	561	561	559	558
2020	614	590	587	579	568
2030	666	613	605	591	564
2050	831	754	742	723	681
2080	821	745	733	714	672
2100	764	693	682	664	625
Methane (CH_4)					
2014	18.07	17.71	17.69	17.65	17.59
2020	20.32	18.99	18.90	18.69	18.41
2030	19.04	16.48	16.28	15.91	15.20
2050	22.47	18.89	18.61	18.14	17.13
2080	22.20	18.66	18.39	17.92	16.92
2100	20.65	17.36	17.10	16.66	15.74
Nitrous oxide (N_2O)					
2014	1.92	1.91	1.91	1.91	1.91
2020	1.56	1.54	1.54	1.54	1.54
2030	1.22	1.14	1.14	1.12	1.10
2050	1.40	1.27	1.26	1.25	1.22
2080	1.38	1.26	1.25	1.23	1.20
2100	1.29	1.17	1.16	1.15	1.12

Under all of the alternatives, growth in the number of HD vehicles in use throughout the United States is projected to result in growth in total HD VMT. As a result, despite increases in fuel efficiency under each action alternative, total fuel consumption and CO_2 emissions by HD vehicles in the United States are projected to increase, 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 1.1 percent of total global emissions of CO_2 in 2005 (EPA 2011, WRI 2011).[16] Although substantial, this source is still a small percentage of global emissions. The proportion of global CO_2 emissions attributable to 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 emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. As described above, in 2007, Arizona, California, New Mexico, Oregon, and Washington formed the WCI to develop regional strategies to address climate change. As of early 2011, seven U.S. states and four Canadian provinces have partnered under the WCI to collaboratively reduce their GHG emissions. In 2010, WCI released its "Design for the Regional WCI Program," in which WCI explains its commitment to, and strategy for, reducing GHG emissions within the WCI region by 15 percent below 2005 levels by 2020, which would yield cumulative reductions of 719 $MMTCO_2$ equivalent over the 2012-2020 period (WCI 2010b). By comparison, this rulemaking is expected to reduce CO_2 emissions by 105 to 193 $MMTCO_2$ between 2014 and 2020. In the Northeast and Mid-Atlantic, ten States have formed RGGI to reduce CO_2 emissions from power plants in the Northeast by 10 percent by 2018 (RGGI 2011). The Program was projected in 2006 to reduce emissions by 268 $MMTCO_2$ from 2006 to 2024 (RGGI 2006).[17] By comparison, NHTSA forecasts that this rulemaking will reduce CO_2 emissions by 235 to 447 $MMTCO_2$ 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 by their target dates compared to the beginning of the actions; in contrast, emissions from HD vehicles are projected to increase despite NHTSA's proposed action 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.

4.4.4.2 Social Cost of Carbon

The social cost of carbon (SCC) is an estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions. Readers should consult Section 3.4.3.2 for a description of 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.

Table 4.4.4-3 presents the cumulative impacts of the HD Fuel Efficiency Improvement Program, 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 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 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

[16] Includes land-use change and forestry and excludes international bunker fuels.
[17] 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.

Table 4.4.4-3

Reduced Monetized Damages of Climate Change for each Action 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)
Alt. 2 - 12% below Preferred Alternative Stringency	$9,650	$64,900	$117,000	$197,000
Alt. 3 - Preferred Alternative	$11,100	$74,600	$135,000	$226,000
Alt. 4 - 20% above Preferred Alternative Stringency	$13,700	$91,800	$166,000	$278,000
Alt. 5 - Trailers and Accelerated Hybrid	$18,800	$127,000	$229,000	$384,000

percent, and 2.5 percent), rather than the 3-percent and 7-percent discount rates applied to other future benefits.[18] Consistent with the SCC table in Section 3.4.3.2 (Table 3.4.3-1) 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 Indicators

The approach to estimating the cumulative effects of climate change from the MY 2014–2018 HD Fuel Efficiency Improvement Program actions mirrors that used to estimate the direct and indirect effects of the proposed action and alternatives, with the exception of assumptions on (a) continuation of fuel efficiency improvements and (b) the global emissions scenario used. As described above, for the analysis reported in this chapter, NHTSA assumes that the overall fuel efficiency of new vehicles under the action alternatives continues to improve until 2050 at a pace consistent with AEO Early Release 2011, extended after 2035 (*see* Section 4.1.2). NHTSA also assumes fuel-efficiency increases consistent with the AEO projections under the No Action Alternative. The proposed HD Fuel Efficiency Improvement Program would apply only to new vehicles, therefore this assumption results in emission reductions and fuel savings that continue to grow as new vehicles meeting the increased fuel consumption requirements are added to the fleet in each subsequent year.

Using the methodology described above, Sections 4.4.4.3.1 through 4.4.4.3.5 describe cumulative effects of the alternatives on climate change in terms of atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise. The impacts of the proposed action and alternatives – in combination with 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.[19] Although relatively small – primarily due to the global and multi-sectoral nature of the climate problem – the impacts occur on a global scale and are long-lived.

[18] 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.

[19] These conclusions are not meant to express the 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's obligations in this regard.

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 3.4.4.3.1 for a comparison of MAGICC 5.3v2 results and reported results from the IPCC Fourth Assessment Report.

The GCAM6.0 scenario, described in Section 4.4.3.3 above, was used to represent the No Action Alternative 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 the No Action Alternative and the four 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 action alternatives produce a reduction in the increase in projected CO_2 concentration and temperature, but the reduction is a small fraction of the total increase in CO_2 concentrations and global mean surface temperature.

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 5 to 677.8 ppm under the No Action Alternative. For 2030 and 2050, the corresponding ranges are even smaller. Because CO_2 concentrations are the key driver of all other climate effects, the small changes in CO_2 leads to small differences in climate effects.

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/

Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C) b/			Sea-level Rise (cm) b/		
	2030	2050	2100	2030	2050	2100	2030	2050	2100
Totals Under Alternative HD Fuel Efficiency Improvement Program Standards									
Alt. 1 - No Action Alternative	440.1	506.5	677.8	0.838	1.397	2.564	7.90	14.15	33.42
Alt. 2 - 12% below Preferred Alternative Stringency	440.0	506.3	677.3	0.838	1.396	2.561	7.90	14.14	33.40
Alt. 3 - Preferred Alternative	440.0	506.3	677.2	0.838	1.396	2.561	7.90	14.14	33.40
Alt. 4 - 20% above Preferred Alternative Stringency	440.0	506.3	677.1	0.838	1.396	2.560	7.90	14.14	33.39
Alt. 5 - Trailers and Accelerated Hybrid	440.0	506.2	676.8	0.838	1.395	2.559	7.90	14.14	33.38
Reductions Under Alternative HD Fuel Efficiency Improvement Program Standards									
Alt. 2 - 12% below Preferred Alternative Stringency	0.1	0.2	0.5	0.001	0.001	0.002	0.00	0.01	0.02
Alt. 3 - Preferred Alternative	0.1	0.2	0.6	0.001	0.001	0.003	0.00	0.01	0.02
Alt. 4 - 20% above Preferred Alternative Stringency	0.1	0.3	0.7	0.001	0.001	0.003	0.00	0.01	0.03
Alt. 5 - Trailers and Accelerated Hybrid	0.1	0.3	1.0	0.001	0.002	0.004	0.00	0.01	0.04

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/ The values for global mean surface temperature and sea-level rise are relative to levels in the year 1990.

Figure 4.4.4-2. Cumulative Effects on CO_2 Concentrations (ppm)

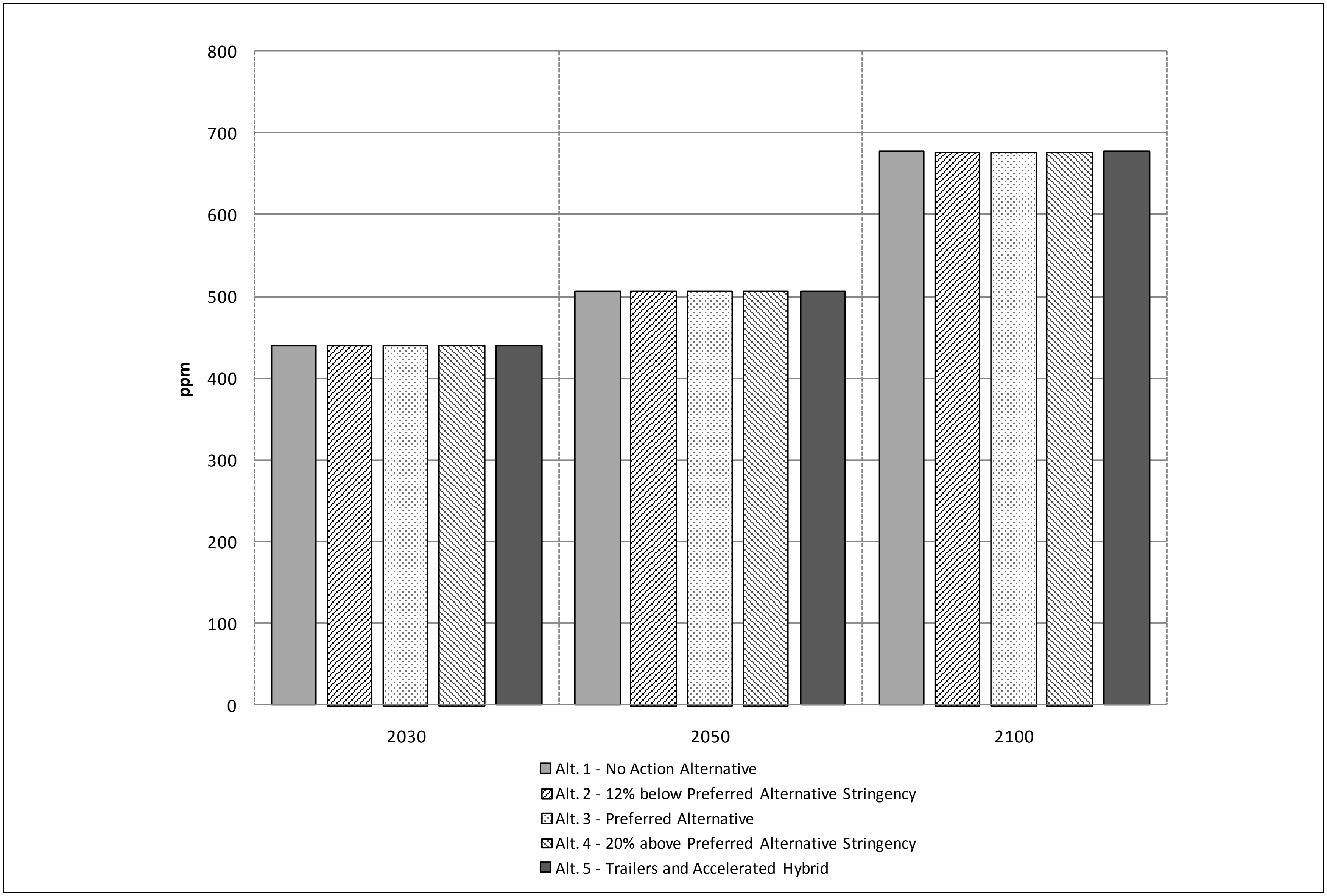


Figure 4.4.4-3. Cumulative Effects on Global Mean Surface Temperature Increase (°C)

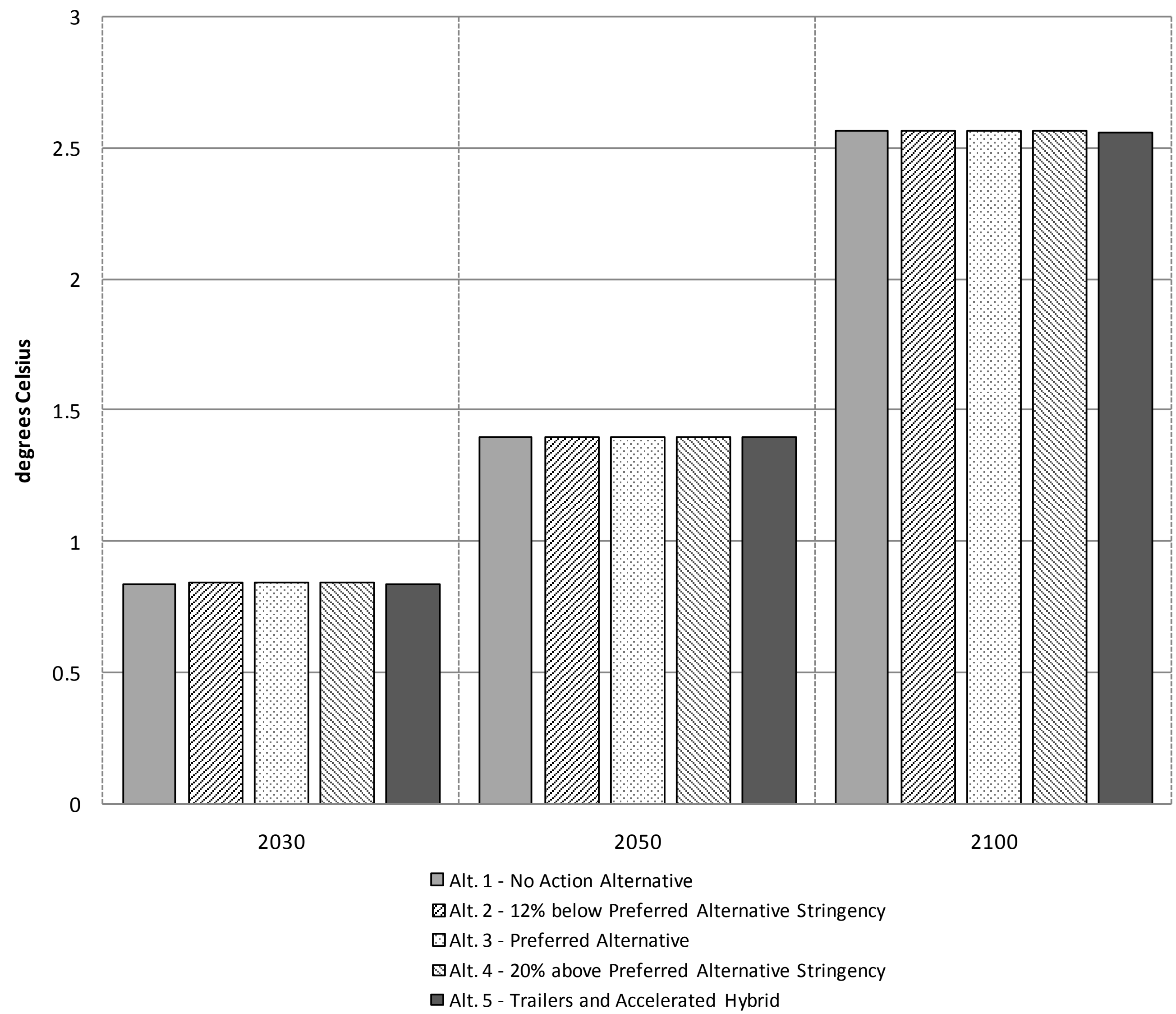


Figure 4.4.4-4. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

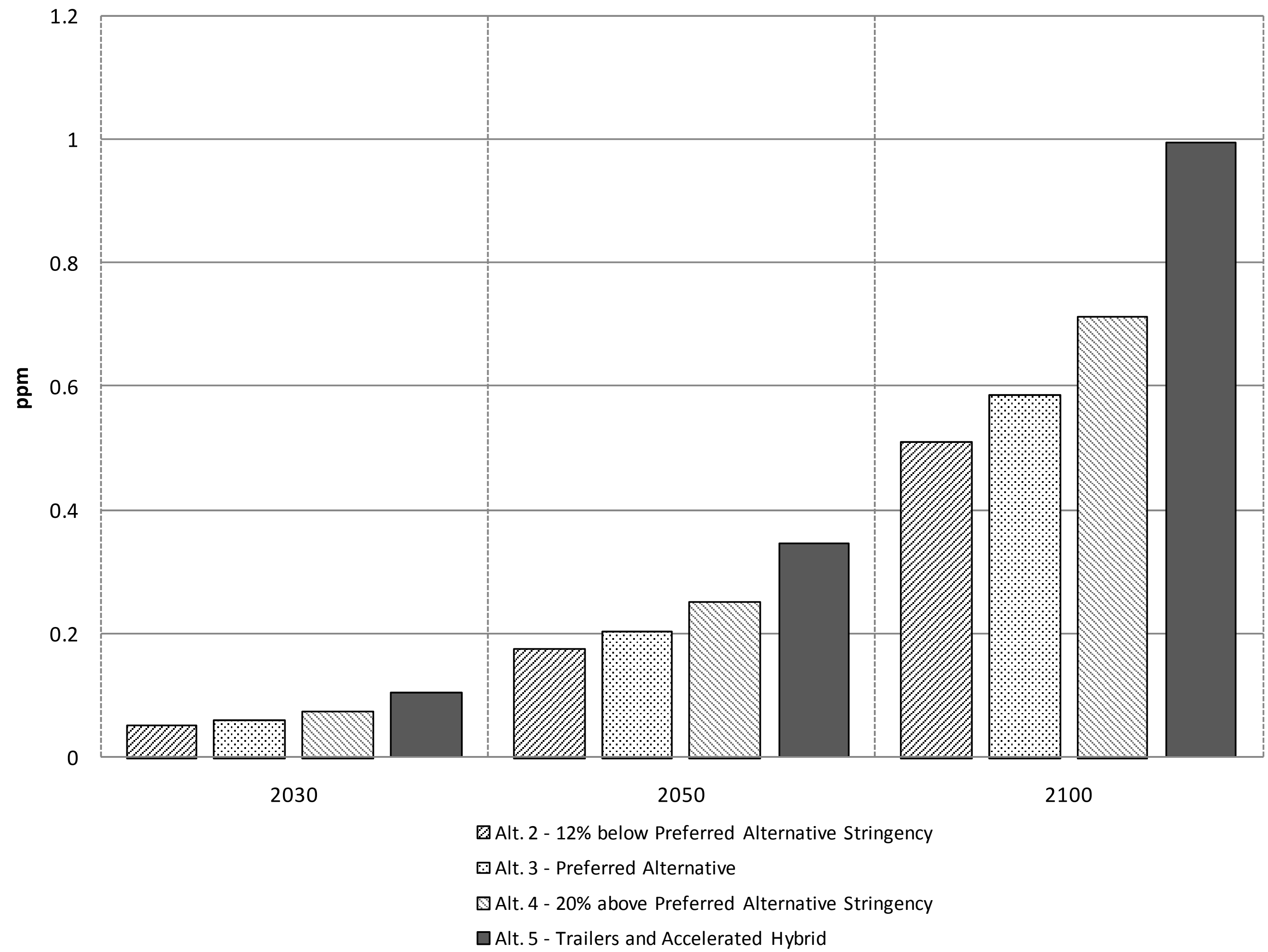
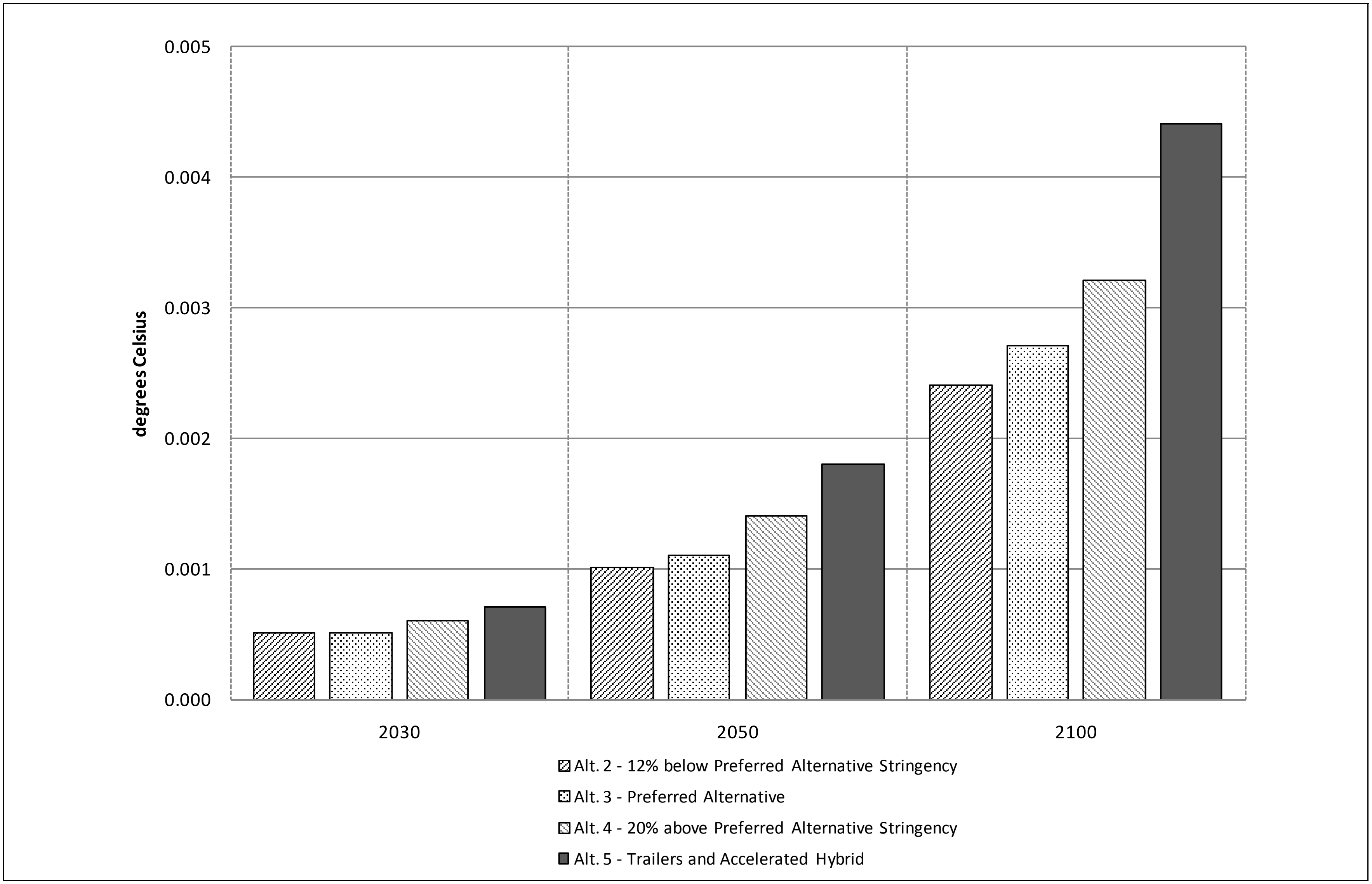


Figure 4.4.4-5. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)



4.4.4.3.2 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.[24] 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 0.002 °C (0.004 °F) under Alternative 2 to 0.004 °C (0.007 °F) under Alternative 5.

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 3.4.4-6 in Section 3.4.4.3.2.

4.4.4.3.3 Precipitation

The effects of higher temperatures on the amount of precipitation and the intensity of precipitation events, as well as the IPCC scaling factors to estimate global mean precipitation change, are discussed in Section 3.4.4.3.3. 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.

Table 4.4.4-5

Cumulative Effects on Global Mean Precipitation (Percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°C) for the GCAM6.0 Scenario by Alternative			
Alt. 1 - No Action Alternative	0.583	1.533	2.386
Alt. 2 - 12% below Preferred Alternative Stringency	0.583	1.532	2.384
Alt. 3 - Preferred Alternative	0.583	1.532	2.384
Alt. 4 - 20% above Preferred Alternative Stringency	0.583	1.531	2.383
Alt. 5 - Trailers and Accelerated Hybrid	0.583	1.531	2.382
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (Compared to No Action Alternative) b/			
Alt. 2 - 12% below Preferred Alternative Stringency	0.000	0.001	0.002
Alt. 3 - Preferred Alternative	0.000	0.001	0.002
Alt. 4 - 20% above Preferred Alternative Stringency	0.000	0.002	0.003
Alt. 5 - Trailers and Accelerated Hybrid	0.000	0.002	0.004

[24] 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 oceans.

Table 4.4.4-5 (continued)

Cumulative Effects on Global Mean Precipitation (Percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC a/

Scenario	2020	2055	2090
Global Mean Precipitation Increase (%)			
Alt. 1 - No Action Alternative	0.85%	2.31%	3.89%
Alt. 2 - 12% below Preferred Alternative Stringency	0.85%	2.31%	3.89%
Alt. 3 - Preferred Alternative	0.85%	2.31%	3.89%
Alt. 4 - 20% above Preferred Alternative Stringency	0.85%	2.31%	3.88%
Alt. 5 - Trailers and Accelerated Hybrid	0.85%	2.31%	3.88%
Reduction in Global Mean Precipitation Increase by Alternative (% Compared to No Action Alternative)			
Alt. 2 - 12% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 3 - Preferred Alternative	0.00%	0.00%	0.00%
Alt. 4 - 20% above Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 5 - Trailers and Accelerated Hybrid	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/ Precipitation change in year 2020 is non-zero but is smaller than the precision being reported.

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. Also, the various AOGCMs produce results that are regionally consistent in some cases but 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.

4.4.4.3.4 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 shows sea-level rise in 2100 ranging from 33.42 centimeters (13.16 inches) under the No Action Alternative to 33.38 centimeters (13.14 inches) under Alternative 5, for a maximum reduction of 0.04 centimeter (0.02 inch) by 2100.

4.4.4.3.5 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. 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 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 has the greatest impact in the global emissions scenario with the highest CO_2 emissions (GCAMReference 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 0.5–0.7 ppm. The Preferred Alternative using the GCAM6.0 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of a 0.6 ppm reduction compared to the No Action Alternative.

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								
Alt. 1 No Action Alternative	1.5	436.909	486.311	511.774	0.430	0.706	0.918	16.09
	2.0	437.545	488.046	517.125	0.533	0.886	1.199	19.98
	2.5	438.097	489.576	522.109	0.622	1.044	1.461	23.46
	3.0	438.580	490.933	526.739	0.700	1.184	1.704	26.56
	4.5	439.720	494.204	538.729	0.881	1.517	2.330	34.18
	6.0	440.542	496.619	548.354	1.009	1.760	2.825	39.94
Alt. 3 Preferred Alternative	1.5	436.849	486.112	511.271	0.430	0.705	0.916	16.07
	2.0	437.484	487.845	516.612	0.533	0.885	1.197	19.96
	2.5	438.036	489.375	521.587	0.622	1.043	1.458	23.43
	3.0	438.519	490.730	526.208	0.699	1.183	1.701	26.54
	4.5	439.659	493.999	538.176	0.880	1.515	2.326	34.15
	6.0	440.481	496.412	547.784	1.009	1.758	2.820	39.90
Reduction Under Preferred Alternative Compared to No Action Alternative								
	1.5	0.060	0.199	0.503	0.000	0.001	0.002	0.02
	2.0	0.061	0.201	0.513	0.000	0.001	0.002	0.02
	2.5	0.061	0.201	0.522	0.000	0.001	0.003	0.03
	3.0	0.061	0.203	0.531	0.000	0.001	0.003	0.03
	4.5	0.061	0.205	0.553	0.001	0.001	0.004	0.03
	6.0	0.061	0.207	0.570	0.001	0.002	0.005	0.04

4.4 CLIMATE

This section focuses on the cumulative impacts on climate of the proposed action and alternatives and covers many of the same topics as in Section 3.4 and Section 3.5.3. To minimize the repetition of background information on climate science or modeling methodologies, this section refers the reader to Section 3.4 where appropriate.

The climate analysis in Chapter 4 is broader than the corresponding analysis in Chapter 3 because Chapter 4 addresses the effects of the HD Fuel Efficiency Improvement Program proposed standards together with those of past, present, and reasonably foreseeable future actions. The HD vehicle fleet's emission trajectory through 2050 is described in Section 4.1.2. That section describes how NHTSA models reasonably foreseeable increases in fuel efficiency of the HD vehicle fleet for each alternative from 2018 to 2050 based on AEO projections. As described below, 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).

4.4.1 Introduction – Greenhouse Gases and Climate Change

Section 3.4.1 provides a discussion of the science of climate change, including 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. 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, readers are referred to Section 3.4.2 for a discussion of this topic.

4.4.3 Methodology

The methodology used to characterize the effects of the proposed action and alternatives on climate has three key elements:

- *First*, NHTSA estimates GHG emissions under each alternative (including the No Action Alternative). The methodology for estimating GHG emissions is described in Section 4.4.3.1.
- *Second*, NHTSA estimates the monetized damages associated with carbon dioxide (CO_2) emissions (the social cost of carbon) and the reductions in those damages that would be attributable to each regulatory alternative. The methodology for estimating the social cost of carbon is described in Section 3.4.3.2.
- *Third*, NHTSA analyzes how the estimated GHG emissions might affect the climate system (climate effects). The methodologies for analyzing how GHG emissions affect global climate parameters are described in Section 4.4.3.3.

4.4.3.1 Methodology for Modeling Greenhouse Gas Emissions

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. To estimate the emissions resulting from the proposed action, NHTSA used the MOVES and GREET models (*see* Section 3.1.4 for descriptions of the models) and scaled the estimates to take into account projected annual gains in fuel efficiency derived from the AEO Early Release 2011 forecast.[8] These CO_2 emission estimates also include upstream emissions, which occur from the use of fossil carbon-based energy during crude oil extraction, transportation, and refining, and in the transportation, storage, and distribution of refined fuel. Because CO_2 accounts for such a large fraction of total GHGs emitted during fuel production and use (more than 95 percent, even after accounting for the higher global warming potentials of other GHGs), NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel use that accompany higher fuel efficiency.[9]

The methodology for modeling GHG emissions is described in Section 3.4.3.1. As described there, the MOVES model provides estimates of fleet CO_2 emissions until only 2050. In order to present longer-term projections of the cumulative impacts of this action, NHTSA used a scaling methodology to project the impact of MY 2051-2100 HD vehicles using Global Change Assessment Model (GCAM) assumptions regarding the growth of U.S. transportation fuel consumption.

To estimate the impact of the proposed action on global CO_2 emissions, NHTSA calculated the difference between the No Action Alternative described in Section 4.1 and the total fleet CO_2 emissions under each action alternative. NHTSA then subtracted this GHG emissions reduction from the GCAM6.0 scenario (described below) to generate modified global-scale emissions scenarios, which show the effect of the various alternatives on the global emissions path.

4.4.3.2 Social Cost of Carbon

Please *see* Section 3.4.3.2 for a description of 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.

4.4.3.3 Methodology for Estimating Climate Effects

This EIS estimates and reports four effects of climate change driven by alternative scenarios of projected changes in 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 GHG emissions is a direct effect of the improvements in fuel efficiency associated with the alternatives; the four effects on climate change may be considered to be indirect effects.

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 climate effects. MAGICC 5.3.v2 uses the

[8] In Chapter 3, NHTSA modeled the projected direct and indirect impacts of the proposed standards by isolating the impacts of the proposal. There, NHTSA assumed that the fuel efficiency of new HD vehicles under each action alternative would remain constant at the required 2018 level during all subsequent model years unless market forces would have pushed fuel efficiency higher. In contrast, in this chapter, NHTSA addresses the effects of the HD Fuel Efficiency Improvement Program together with those of reasonably foreseeable future actions. Thus, as discussed in Section 4.1.2, NHTSA assumes that further gains in fuel efficiency growth beyond 2018 implied by the AEO forecast will be achieved in the aftermath of the proposed action.

[9] Although this section includes only a discussion of CO_2 emissions, the climate modeling discussion in Section 4.4.4 assesses the cumulative impacts associated with emissions reductions of multiple gases, including CO_2, CH_4, N_2O, SO_2, CO, NO_x, and VOCs.

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.

4.4.3.3.1 MAGICC Version 5.3v2

For a description of MAGICC, *see* Section 3.4.3.3.1.

4.4.3.3.2 Reference Case Modeling Runs

In the cumulative impacts analysis presented in this chapter, NHTSA assumed that global emissions under the No Action Alternative would follow the trajectory provided by the GCAM6.0 scenario, rather than the GCAMReference scenario used in Chapter 3. Whereas the GCAMReference Scenario assumed no explicit policies to limit carbon emissions in the future, the GCAM6.0 scenario represents a Reference Case which takes into account significant future global actions to address climate change. The approach for the Reference Case modeling runs for the cumulative effects analysis was based on the same approach described in 3.4.3.3.2, with the only difference being the choice of global emission scenarios. Section 4.4.4 presents the results of the Reference Case modeling runs.

4.4.3.3.3 Sensitivity 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. The approach for the sensitivity analysis in this chapter was based on the same approach described in Section 3.4.3.3.3. Unlike the Chapter 3 analysis, which did not assess the sensitivity around different global emissions scenarios, for the results presented in this chapter, NHTSA assumed multiple global emissions scenarios including GCAM6.0 (678 ppm in 2100); RCP4.5 (522 ppm in 2100); and GCAMReference scenario (785 ppm in 2100). Section 4.4.4.3.5 presents the results of the sensitivity analysis for these different global emission scenarios.

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, such as, population growth, economic development, and policy change. 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 3.4.3.4 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.[10] This Reference Case global emissions scenario serves as a baseline against which the

[10] The RCP4.5 scenario is another, more aggressive, stabilization scenario that provides an illustration of the climate system response to stabilizing the anthropogenic components of radiative forcing at 4.5 W/m^2 in the year 2100. The RCP4.5 scenario "assumes that climate policies, in this instance the introduction of a set of global greenhouse gas emissions prices, are invoked to achieve the goal of limiting emissions, concentrations and radiative forcing" (Thomson *et al.* 2011). This scenario is a "stabilization scenario" – i.e., one that stabilizes the atmospheric concentration of CO_2 – with a pathway that minimizes cost. In other words, the RCP4.5 scenario "assumes that all nations of the world undertake emissions mitigation simultaneously and effectively, and share a common global price that all emissions to the atmosphere must pay with emissions of different gases priced according to their

climate benefits of the various HD Fuel Efficiency Improvement Program alternatives can be measured. NHTSA chose the GCAM6.0 scenario to represent reasonably foreseeable actions.

The GCAM6.0 scenario is the GCAM representation of the radiative forcing target (6.0 watts per square meter 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 assumes a moderate level of global GHG reductions. It is based on a set of assumptions about drivers such as population, technology, socioeconomic changes, and global climate policies that correspond to stabilization, by 2100, of total radiative forcing[11] and associated CO_2 concentrations at roughly 678 parts per million by volume (ppmv).[12] More specifically, GCAM6.0 is a scenario that incorporates declines in overall energy use, including fossil fuel use, as compared to the reference case. In addition, GCAM6.0 includes increases in renewable energy and nuclear energy, with the proportion of electricity-supplied total final energy increasing due to fuel switching in the end-use sectors. Carbon dioxide capture and storage (CCS) also plays an important role that allows for continued use of fossil fuels for electricity generation and cement manufacture while limiting CO_2 emissions. Although GCAM6.0 does not explicitly include specific climate change mitigation policies within the scenario, it does represent a plausible future pathway of global emissions in response to significant global action to mitigate climate change. GCAM scenarios were developed more than ten years after 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.

NHTSA used the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects but used the RCP4.5 scenario and the GCAMReference emissions scenario (an updated version of the MiniCAM model scenario) to evaluate the sensitivity of the results to alternative emissions scenarios.

Separately, each action 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 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 614 million metric tons of CO_2 ($MMTCO_2$); emissions in 2020 under the Preferred Alternative are 587 $MMTCO_2$ (*see* Table 4.4.4-2). The difference of 27 $MMTCO_2$ (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 27 $MMTCO_2$ less than this reference level, or 37,495 $MMTCO_2$ 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 2011 Early Release (EIA 2011) and International Energy Outlook (IEO) 2010 (EIA 2010), 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 GCAMReference scenario.

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hundred-year global warming potentials" (Thomson *et al.* 2011). Although RCP4.5 does not explicitly include specific climate change mitigation policies, it represents a plausible future pathway of global emissions in response to more significant global action to mitigate climate change than the GCAM6.0 scenario.

[11] *See* Section 3.4.1.7.3 for an explanation of the term "radiative forcing."

[12] Based on 3.0 °C climate sensitivity.

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.

4.4.3.4.1 Past, Present, and Reasonably Foreseeable Future Actions Related to the Cumulative Impacts Analysis

NHTSA chose the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects for this chapter because regional, national, and international initiatives and programs now in the planning stages and underway indicate that some reduction in the rate of global GHG emissions is reasonably foreseeable in the future. The initiatives and programs discussed below are those NHTSA has tentatively concluded are past, present, or reasonably foreseeable 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, a scenario that takes into account moderate reductions in the rate of global GHG emissions, such as the GCAM6.0 scenario, can be considered reasonably foreseeable under NEPA.

United States: Regional Actions[13]

- **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 2009). 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 2009). 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 2009; RGGI 2011). 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 Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec), along with 16 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

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

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 2010a). The second phase begins in 2015, when the program expands to include transportation fuels and residential, commercial, and industrial fuels not otherwise covered (WCI 2010a). When fully implemented in 2015, the program will cover nearly 90 percent of GHG emissions in the 11 WCI partner States and provinces.

United States: Federal Actions

- **NHTSA and EPA Joint Rule on Fuel Efficiency and GHG Emissions Standards for Light-Duty Vehicles.** In April 2010, NHTSA and EPA issued a joint Final Rule establishing a new National Program to regulate MY 2012–2016 passenger cars and light trucks to improve fuel efficiency and reduce GHG emissions. NHTSA issued CAFE standards under the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA), and EPA issued GHG emissions standards under the Clean Air Act. These rules require a combined average fleet-wide fuel economy of 34.1 mpg and 250 grams per mile of CO_2 for MY 2016 light duty vehicles. Vehicles covered by these standards are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. The program is projected to reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (NHTSA 2010 citing EPA 2009).
- **NHTSA and EPA Forthcoming Proposal for Model Year 2017 – 2025 Light-Duty Vehicle Standards.** Following the first phase of the National Program, NHTSA and EPA plan to propose fuel economy and GHG emissions standards for MY 2017–2025 light duty vehicles. On October 1, 2010, NHTSA and EPA issued a Notice of Intent (NOI) announcing their plans for setting light-duty vehicle standards for MY 2017 and beyond. On May 10, 2011, NHTSA published in the Federal Register a NOI announcing the development of the EIS for the forthcoming proposal.[14]
- **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, which went into effect 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). Also during this 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 propose a rulemaking for facilities with emissions of at least 50,000 tpy 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

[14] 76 *FR* 26996 (May 10, 2011).

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, which went into effect July 1, 2010, 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 2010). 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 2010).
- **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. This target is contingent on passage of U.S. energy and climate legislation. Recent Federal actions that may reduce GHG emissions 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.

International Actions

- **United Nations Framework Convention on Climate Change (UNFCCC) – The Kyoto Protocol, and the December 2010 Conference of the Parties (COP)-16.** UNFCCC is an international treaty signed by many countries around the world (including the United States[15]), 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). For the first time, at COP-15 (held in 2009) all major developed and developing countries agreed to pledge specific emission reductions. At COP-16, in December 2010, a draft accord pledged to limit global temperature increase to less than 2 °C (3.6 °F) above pre-Industrial global average temperature. As of April 27, 2011, 141 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.

[15] 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 that had 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).

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 discussion and conclusions drawn in that section apply to this cumulative impact analysis as well. 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

Using the methodology described in Section 4.4.3.1, NHTSA estimated the emissions resulting from the proposed HD Fuel Efficiency Improvement Program. GHG emissions from MY 2050-2100 HD vehicles were then scaled using GCAM assumptions regarding the growth of U.S. transportation fuel consumption (*See* Section 3.4.3.1).

Cumulative emission reductions from each action alternative increase with the increasing stringency of the alternatives, with Alternative 2 having the lowest cumulative emission reductions and Alternative 5 having the highest cumulative emission reductions. Table 4.4.4-1 shows total GHG emissions and emission reductions projected to result from new U.S. HD vehicles from 2014–2100 under each action alternative. Between 2014 and 2100, projections of cumulative emission reductions due to the proposed action and other reasonably foreseeable future actions ranged from 5,600 to 10,900 $MMTCO_2$. Compared to cumulative global 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 0.3 percent from their projected levels under the No Action Alternative.

Table 4.4.4-1

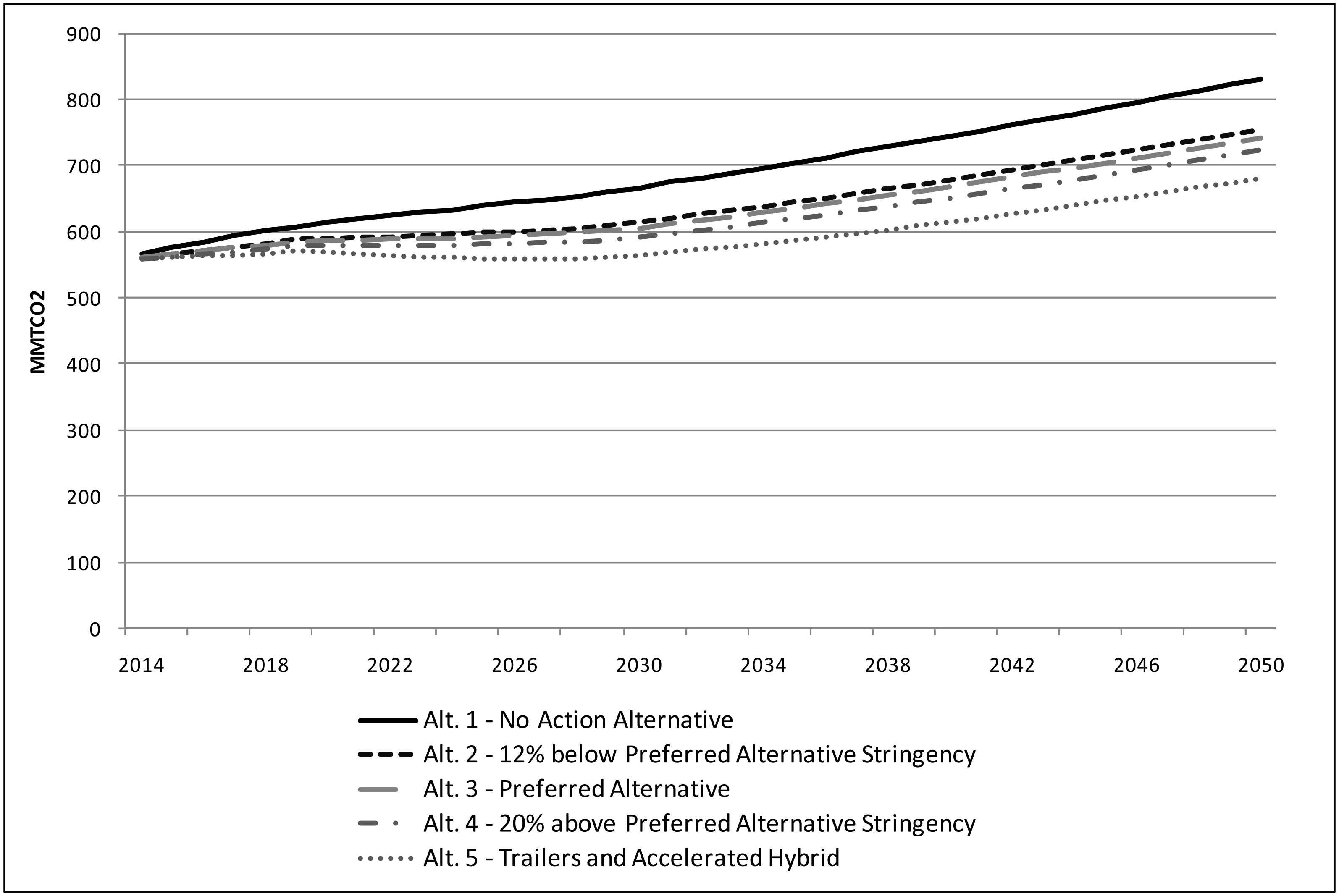
Cumulative Effects of CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles from 2014 to 2100 by Alternative a/

Alternative	Emissions	Emissions Reductions Compared to No Action Alternative	Emissions Reductions Compared to No Action Alternative (%)
Alt. 1 - No Action Alternative	66,000	0	
Alt. 2 - 12% below Preferred Alternative Stringency	60,400	5,600	8%
Alt. 3 - Preferred Alternative	59,600	6,400	10%
Alt. 4 - 20% above Preferred Alternative Stringency	58,100	7,900	12%
Alt. 5 - Trailers and Accelerated Hybrid	55,100	10,900	17%

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.

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. HD vehicles in the United States currently account for approximately 6.6 percent of U.S. CO_2 emissions. With the action alternatives reducing U.S. HD vehicle CO_2 emissions by 8–17 percent over 2014–2100 under the cumulative impacts analysis presented in this chapter, the proposed action would contribute to reducing total U.S. CO_2 emissions relative to the no action case. 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 and reasonably foreseeable future increases in fuel efficiency would reduce total U.S. CO_2 emissions by 1.6 to 3.1 percent in 2100. Figure 4.4.4-1 shows projected annual emissions from U.S. HD vehicles for MY 2014–2018 when combined with reasonably foreseeable future actions.

Figure 4.4.4-1. Cumulative Annual CO_2 Emissions from U.S. HD Vehicles Under the MY 2014–2018 Standards and Other Reasonably Foreseeable Future Actions ($MMTCO_2$)



As Table 4.4.4-2 shows, 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 turn over.

Table 4.4.4-2

Emissions of Greenhouse Gases ($MMTCO_2e$ per year) from U.S. HD Vehicles by Alternative, Cumulative Effects Analysis

GHG and Year	Alt. 1 No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon dioxide (CO_2)					
2014	567	561	561	559	558
2020	614	590	587	579	568
2030	666	613	605	591	564
2050	831	754	742	723	681
2080	821	745	733	714	672
2100	764	693	682	664	625
Methane (CH_4)					
2014	18.07	17.71	17.69	17.65	17.59
2020	20.32	18.99	18.90	18.69	18.41
2030	19.04	16.48	16.28	15.91	15.20
2050	22.47	18.89	18.61	18.14	17.13
2080	22.20	18.66	18.39	17.92	16.92
2100	20.65	17.36	17.10	16.66	15.74
Nitrous oxide (N_2O)					
2014	1.92	1.91	1.91	1.91	1.91
2020	1.56	1.54	1.54	1.54	1.54
2030	1.22	1.14	1.14	1.12	1.10
2050	1.40	1.27	1.26	1.25	1.22
2080	1.38	1.26	1.25	1.23	1.20
2100	1.29	1.17	1.16	1.15	1.12

Under all of the alternatives, growth in the number of HD vehicles in use throughout the United States is projected to result in growth in total HD VMT. As a result, despite increases in fuel efficiency under each action alternative, total fuel consumption and CO_2 emissions by HD vehicles in the United States are projected to increase, 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 1.1 percent of total global emissions of CO_2 in 2005 (EPA 2011, WRI 2011).[16] Although substantial, this source is still a small percentage of global emissions. The proportion of global CO_2 emissions attributable to 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 emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. As described above, in 2007, Arizona, California, New Mexico, Oregon, and Washington formed the WCI to develop regional strategies to address climate change. As of early 2011, seven U.S. states and four Canadian provinces have partnered under the WCI to collaboratively reduce their GHG emissions. In 2010, WCI released its "Design for the Regional WCI Program," in which WCI explains its commitment to, and strategy for, reducing GHG emissions within the WCI region by 15 percent below 2005 levels by 2020, which would yield cumulative reductions of 719 $MMTCO_2$ equivalent over the 2012-2020 period (WCI 2010b). By comparison, this rulemaking is expected to reduce CO_2 emissions by 105 to 193 $MMTCO_2$ between 2014 and 2020. In the Northeast and Mid-Atlantic, ten States have formed RGGI to reduce CO_2 emissions from power plants in the Northeast by 10 percent by 2018 (RGGI 2011). The Program was projected in 2006 to reduce emissions by 268 $MMTCO_2$ from 2006 to 2024 (RGGI 2006).[17] By comparison, NHTSA forecasts that this rulemaking will reduce CO_2 emissions by 235 to 447 $MMTCO_2$ 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 by their target dates compared to the beginning of the actions; in contrast, emissions from HD vehicles are projected to increase despite NHTSA's proposed action 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.

4.4.4.2 Social Cost of Carbon

The social cost of carbon (SCC) is an estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions. Readers should consult Section 3.4.3.2 for a description of 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.

Table 4.4.4-3 presents the cumulative impacts of the HD Fuel Efficiency Improvement Program, 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 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 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

[16] Includes land-use change and forestry and excludes international bunker fuels.
[17] 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.

Table 4.4.4-3

Reduced Monetized Damages of Climate Change for each Action 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)
Alt. 2 - 12% below Preferred Alternative Stringency	$9,650	$64,900	$117,000	$197,000
Alt. 3 - Preferred Alternative	$11,100	$74,600	$135,000	$226,000
Alt. 4 - 20% above Preferred Alternative Stringency	$13,700	$91,800	$166,000	$278,000
Alt. 5 - Trailers and Accelerated Hybrid	$18,800	$127,000	$229,000	$384,000

percent, and 2.5 percent), rather than the 3-percent and 7-percent discount rates applied to other future benefits.[18] Consistent with the SCC table in Section 3.4.3.2 (Table 3.4.3-1) 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 Indicators

The approach to estimating the cumulative effects of climate change from the MY 2014–2018 HD Fuel Efficiency Improvement Program actions mirrors that used to estimate the direct and indirect effects of the proposed action and alternatives, with the exception of assumptions on (a) continuation of fuel efficiency improvements and (b) the global emissions scenario used. As described above, for the analysis reported in this chapter, NHTSA assumes that the overall fuel efficiency of new vehicles under the action alternatives continues to improve until 2050 at a pace consistent with AEO Early Release 2011, extended after 2035 (*see* Section 4.1.2). NHTSA also assumes fuel-efficiency increases consistent with the AEO projections under the No Action Alternative. The proposed HD Fuel Efficiency Improvement Program would apply only to new vehicles, therefore this assumption results in emission reductions and fuel savings that continue to grow as new vehicles meeting the increased fuel consumption requirements are added to the fleet in each subsequent year.

Using the methodology described above, Sections 4.4.4.3.1 through 4.4.4.3.5 describe cumulative effects of the alternatives on climate change in terms of atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise. The impacts of the proposed action and alternatives – in combination with 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.[19] Although relatively small – primarily due to the global and multi-sectoral nature of the climate problem – the impacts occur on a global scale and are long-lived.

[18] 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.
[19] These conclusions are not meant to express the 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's obligations in this regard.

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 3.4.4.3.1 for a comparison of MAGICC 5.3v2 results and reported results from the IPCC Fourth Assessment Report.

The GCAM6.0 scenario, described in Section 4.4.3.3 above, was used to represent the No Action Alternative 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 the No Action Alternative and the four 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 action alternatives produce a reduction in the increase in projected CO_2 concentration and temperature, but the reduction is a small fraction of the total increase in CO_2 concentrations and global mean surface temperature.

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 5 to 677.8 ppm under the No Action Alternative. For 2030 and 2050, the corresponding ranges are even smaller. Because CO_2 concentrations are the key driver of all other climate effects, the small changes in CO_2 leads to small differences in climate effects.

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) b/			Sea-level Rise (cm) b/		
Alternative	2030	2050	2100	2030	2050	2100	2030	2050	2100
Totals Under Alternative HD Fuel Efficiency Improvement Program Standards									
Alt. 1 - No Action Alternative	440.1	506.5	677.8	0.838	1.397	2.564	7.90	14.15	33.42
Alt. 2 - 12% below Preferred Alternative Stringency	440.0	506.3	677.3	0.838	1.396	2.561	7.90	14.14	33.40
Alt. 3 - Preferred Alternative	440.0	506.3	677.2	0.838	1.396	2.561	7.90	14.14	33.40
Alt. 4 - 20% above Preferred Alternative Stringency	440.0	506.3	677.1	0.838	1.396	2.560	7.90	14.14	33.39
Alt. 5 - Trailers and Accelerated Hybrid	440.0	506.2	676.8	0.838	1.395	2.559	7.90	14.14	33.38
Reductions Under Alternative HD Fuel Efficiency Improvement Program Standards									
Alt. 2 - 12% below Preferred Alternative Stringency	0.1	0.2	0.5	0.001	0.001	0.002	0.00	0.01	0.02
Alt. 3 - Preferred Alternative	0.1	0.2	0.6	0.001	0.001	0.003	0.00	0.01	0.02
Alt. 4 - 20% above Preferred Alternative Stringency	0.1	0.3	0.7	0.001	0.001	0.003	0.00	0.01	0.03
Alt. 5 - Trailers and Accelerated Hybrid	0.1	0.3	1.0	0.001	0.002	0.004	0.00	0.01	0.04

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/ The values for global mean surface temperature and sea-level rise are relative to levels in the year 1990.

Figure 4.4.4-2. Cumulative Effects on CO_2 Concentrations (ppm)

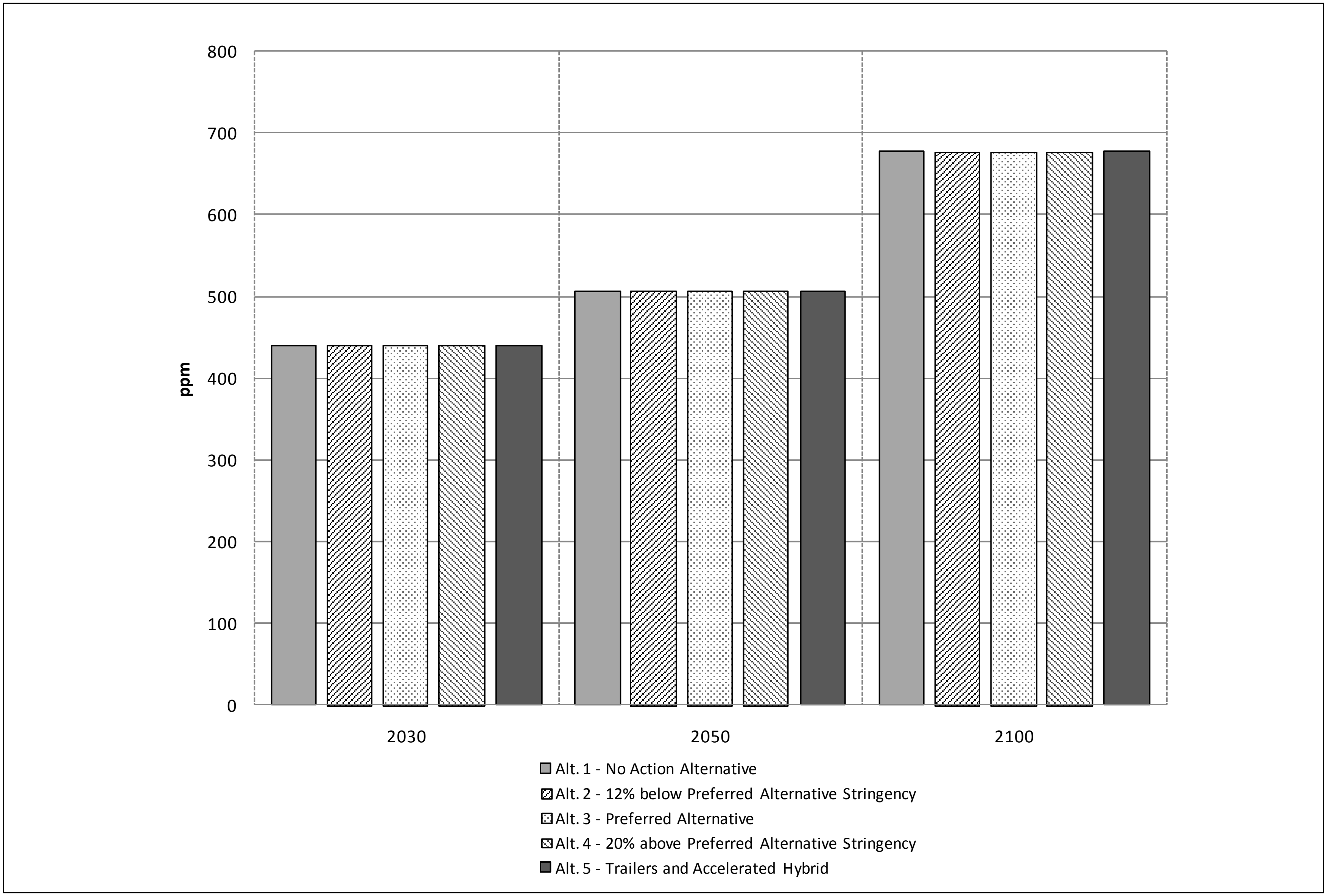


Figure 4.4.4-3. Cumulative Effects on Global Mean Surface Temperature Increase (°C)

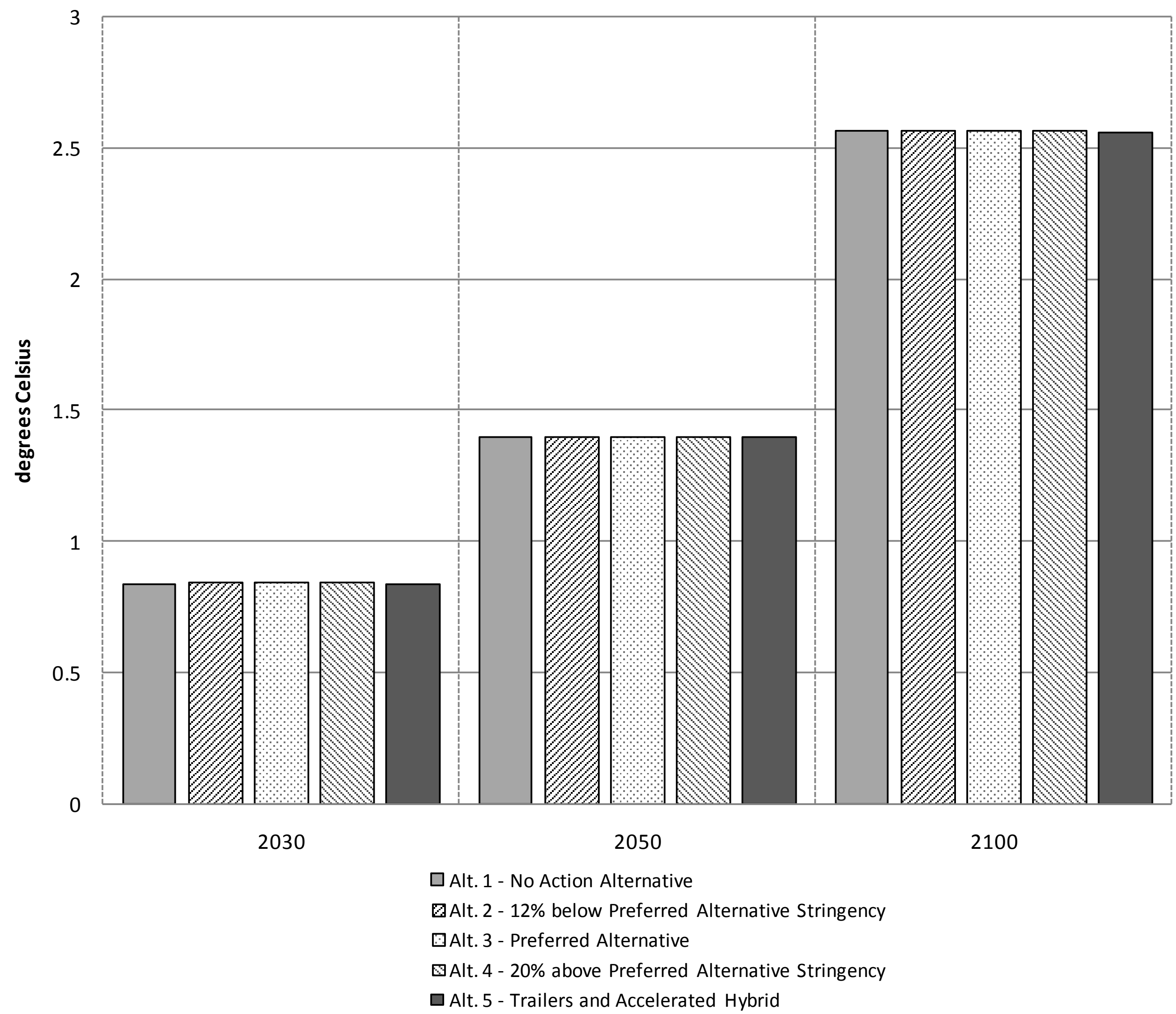


Figure 4.4.4-4. Cumulative Effects on CO_2 Concentrations (Reduction Compared to the No Action Alternative)

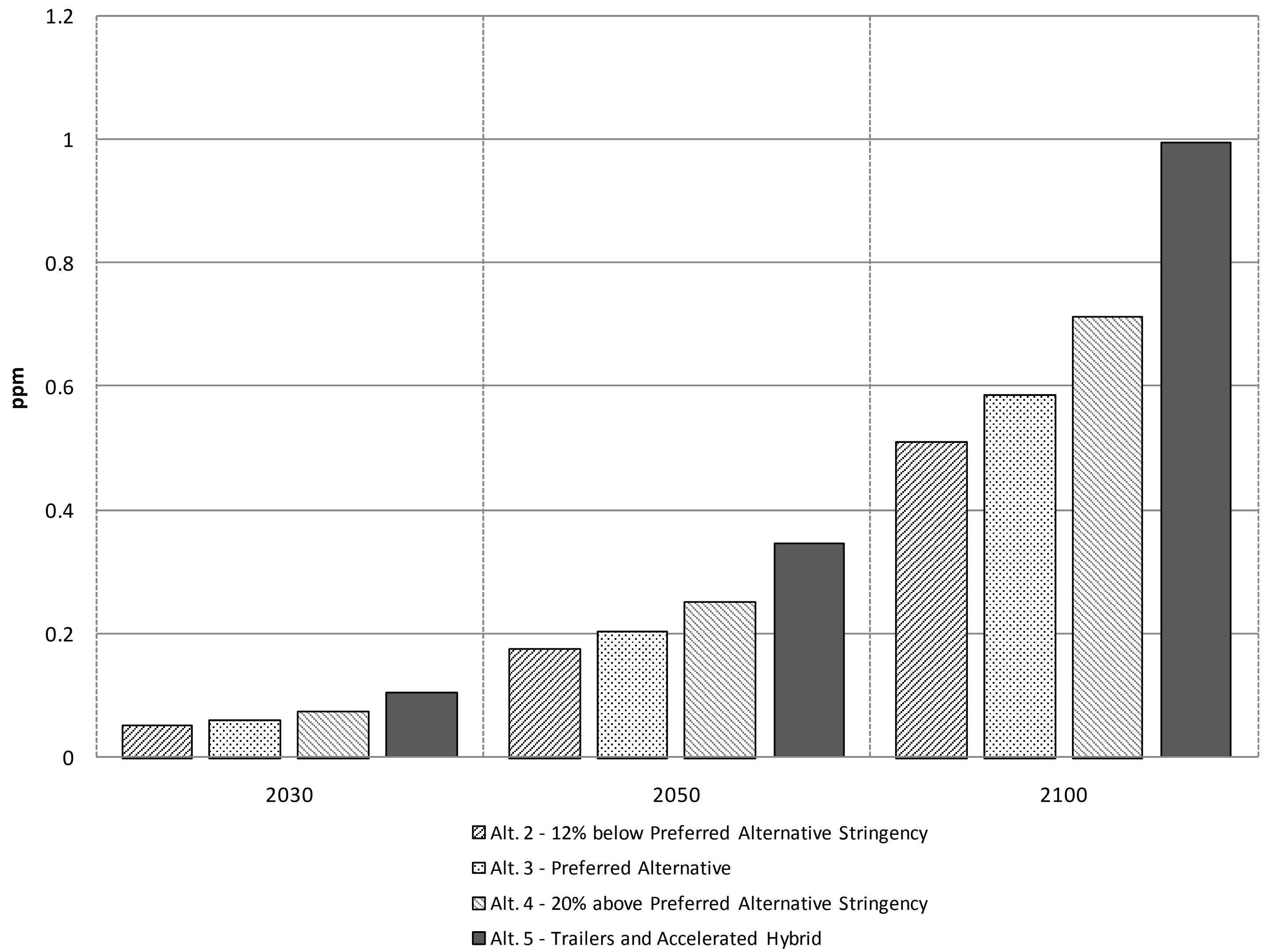
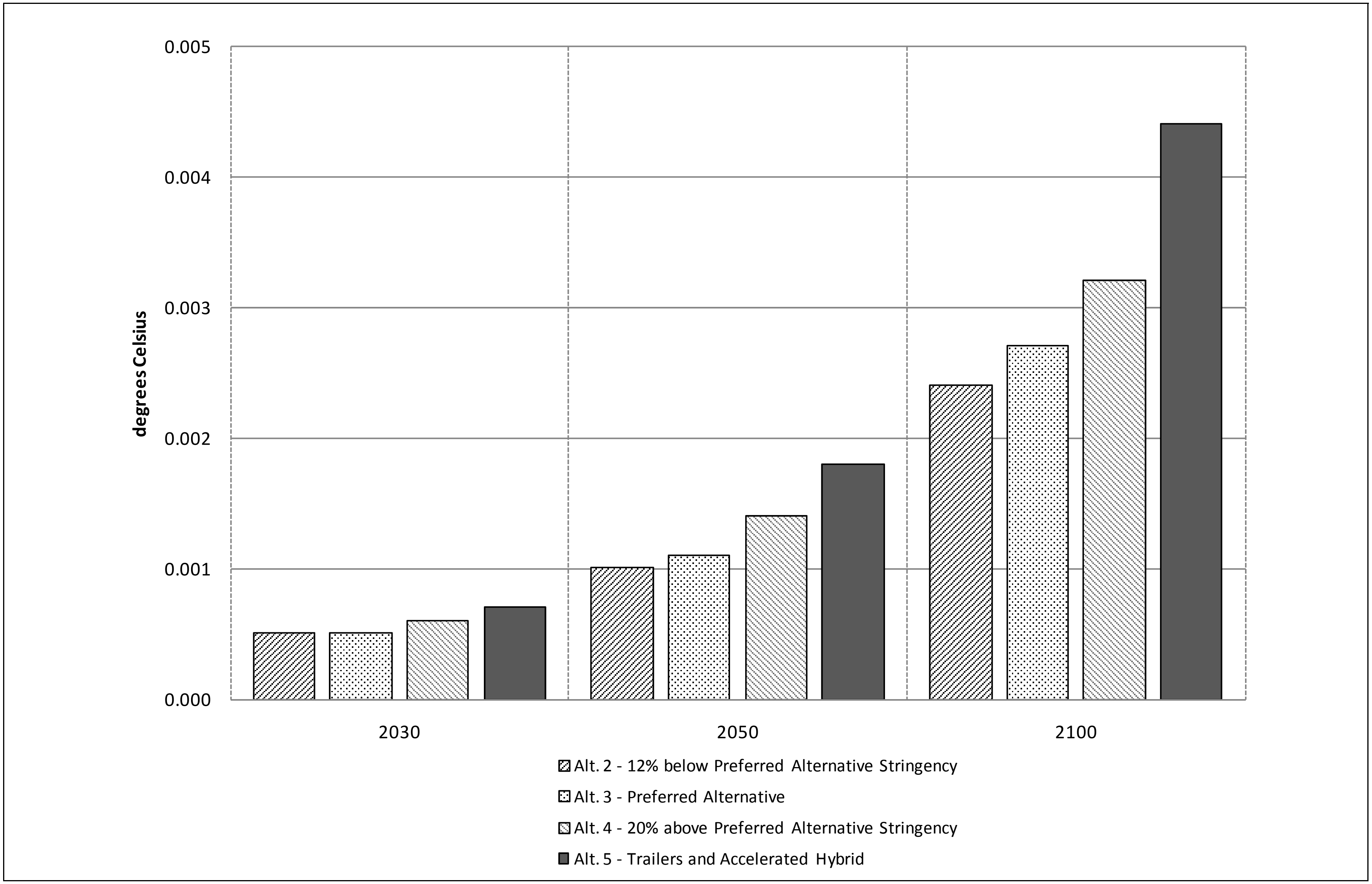


Figure 4.4.4-5. Cumulative Effects on Global Mean Temperature (Reduction Compared to the No Action Alternative)



4.4.4.3.2 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.[24] 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 0.002 °C (0.004 °F) under Alternative 2 to 0.004 °C (0.007 °F) under Alternative 5.

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 3.4.4-6 in Section 3.4.4.3.2.

4.4.4.3.3 Precipitation

The effects of higher temperatures on the amount of precipitation and the intensity of precipitation events, as well as the IPCC scaling factors to estimate global mean precipitation change, are discussed in Section 3.4.4.3.3. 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.

Table 4.4.4-5

Cumulative Effects on Global Mean Precipitation (Percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC a/

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980-1999 Levels (°C) for the GCAM6.0 Scenario by Alternative			
Alt. 1 - No Action Alternative	0.583	1.533	2.386
Alt. 2 - 12% below Preferred Alternative Stringency	0.583	1.532	2.384
Alt. 3 - Preferred Alternative	0.583	1.532	2.384
Alt. 4 - 20% above Preferred Alternative Stringency	0.583	1.531	2.383
Alt. 5 - Trailers and Accelerated Hybrid	0.583	1.531	2.382
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (Compared to No Action Alternative) b/			
Alt. 2 - 12% below Preferred Alternative Stringency	0.000	0.001	0.002
Alt. 3 - Preferred Alternative	0.000	0.001	0.002
Alt. 4 - 20% above Preferred Alternative Stringency	0.000	0.002	0.003
Alt. 5 - Trailers and Accelerated Hybrid	0.000	0.002	0.004

[24] 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 oceans.

Table 4.4.4-5 (continued)

Cumulative Effects on Global Mean Precipitation (Percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC a/

Scenario	2020	2055	2090
Global Mean Precipitation Increase (%)			
Alt. 1 - No Action Alternative	0.85%	2.31%	3.89%
Alt. 2 - 12% below Preferred Alternative Stringency	0.85%	2.31%	3.89%
Alt. 3 - Preferred Alternative	0.85%	2.31%	3.89%
Alt. 4 - 20% above Preferred Alternative Stringency	0.85%	2.31%	3.88%
Alt. 5 - Trailers and Accelerated Hybrid	0.85%	2.31%	3.88%
Reduction in Global Mean Precipitation Increase by Alternative (% Compared to No Action Alternative)			
Alt. 2 - 12% below Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 3 - Preferred Alternative	0.00%	0.00%	0.00%
Alt. 4 - 20% above Preferred Alternative Stringency	0.00%	0.00%	0.00%
Alt. 5 - Trailers and Accelerated Hybrid	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/ Precipitation change in year 2020 is non-zero but is smaller than the precision being reported.

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. Also, the various AOGCMs produce results that are regionally consistent in some cases but 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.

4.4.4.3.4 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 shows sea-level rise in 2100 ranging from 33.42 centimeters (13.16 inches) under the No Action Alternative to 33.38 centimeters (13.14 inches) under Alternative 5, for a maximum reduction of 0.04 centimeter (0.02 inch) by 2100.

4.4.4.3.5 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. 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 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 has the greatest impact in the global emissions scenario with the highest CO_2 emissions (GCAMReference 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 0.5–0.7 ppm. The Preferred Alternative using the GCAM6.0 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of a 0.6 ppm reduction compared to the No Action Alternative.

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								
Alt. 1 No Action Alternative	1.5	436.909	486.311	511.774	0.430	0.706	0.918	16.09
	2.0	437.545	488.046	517.125	0.533	0.886	1.199	19.98
	2.5	438.097	489.576	522.109	0.622	1.044	1.461	23.46
	3.0	438.580	490.933	526.739	0.700	1.184	1.704	26.56
	4.5	439.720	494.204	538.729	0.881	1.517	2.330	34.18
	6.0	440.542	496.619	548.354	1.009	1.760	2.825	39.94
Alt. 3 Preferred Alternative	1.5	436.849	486.112	511.271	0.430	0.705	0.916	16.07
	2.0	437.484	487.845	516.612	0.533	0.885	1.197	19.96
	2.5	438.036	489.375	521.587	0.622	1.043	1.458	23.43
	3.0	438.519	490.730	526.208	0.699	1.183	1.701	26.54
	4.5	439.659	493.999	538.176	0.880	1.515	2.326	34.15
	6.0	440.481	496.412	547.784	1.009	1.758	2.820	39.90
Reduction Under Preferred Alternative Compared to No Action Alternative								
	1.5	0.060	0.199	0.503	0.000	0.001	0.002	0.02
	2.0	0.061	0.201	0.513	0.000	0.001	0.002	0.02
	2.5	0.061	0.201	0.522	0.000	0.001	0.003	0.03
	3.0	0.061	0.203	0.531	0.000	0.001	0.003	0.03
	4.5	0.061	0.205	0.553	0.001	0.001	0.004	0.03
	6.0	0.061	0.207	0.570	0.001	0.002	0.005	0.04

Table 4.4.4-6 (continued)

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

HD Fuel Efficiency Improvement Program Alternative	Climate Sensitivity (°C for 2xCO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C) b/			Sea-level Rise (cm) b/
		2030	2050	2100	2030	2050	2100	2100
Emissions Scenario: GCAM6.0								
Totals								
Alt. 1 No Action Alternative	1.5	437.772	500.695	655.075	0.510	0.834	1.443	20.25
	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	50.02
Alt. 3 Preferred Alternative	1.5	437.712	500.496	654.522	0.510	0.833	1.442	20.23
	2.0	438.586	502.670	662.666	0.635	1.045	1.850	25.15
	2.5	439.348	504.598	670.221	0.743	1.232	2.222	29.51
	3.0	440.016	506.316	677.224	0.838	1.396	2.561	33.40
	4.5	441.597	510.483	695.335	1.060	1.790	3.413	42.88
	6.0	442.737	513.578	709.862	1.220	2.077	4.073	49.99
Reduction Under Preferred Alternative Compared to No Action Alternative								
	1.5	0.060	0.199	0.553	0.000	0.001	0.002	0.02
	2.0	0.061	0.201	0.565	0.000	0.001	0.002	0.02
	2.5	0.061	0.203	0.575	0.001	0.001	0.002	0.02
	3.0	0.061	0.204	0.587	0.001	0.001	0.003	0.02
	4.5	0.061	0.207	0.611	0.001	0.001	0.003	0.03
	6.0	0.061	0.210	0.631	0.001	0.002	0.004	0.03
Emissions Scenario: GCAMReference								
Totals								
Alt. 1 No Action Alternative	1.5	441.253	512.770	757.689	0.538	0.912	1.761	22.80
	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	55.59
Alt. 3 Preferred Alternative	1.5	441.191	512.567	757.104	0.538	0.911	1.759	22.79
	2.0	442.090	514.887	766.860	0.669	1.139	2.238	28.25
	2.5	442.872	516.940	775.891	0.781	1.339	2.670	33.08
	3.0	443.557	518.766	784.249	0.880	1.515	3.062	37.37
	4.5	445.176	523.188	805.822	1.110	1.934	4.034	47.78
	6.0	446.341	526.466	823.089	1.274	2.239	4.776	55.55

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. Section 4.5 of the MY 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 MY 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 MY 2012–2016 CAFE Standards FEIS. The reader is directed to the MY 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. 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 MY 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 MY 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, less than one hundredth of one percent change in the rate of precipitation increase, and less than one 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 large 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.[25]

4.5.2 Methodology

Each sector-specific discussion opens with a summary of information presented in the MY 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 MY 2012–2016 CAFE Standards FEIS also refers to peer-reviewed literature that has not been assessed or synthesized by an expert panel, but which supplements the findings of the panel-reviewed reports.

Following the summary of information from the MY 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 that 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

[25] *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"); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1997), *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).

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 MY 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 3.4.4.1). 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 MY 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.

<u>Snow and Ice Cover</u>: 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 project 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 MY 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 MY 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 MY 2012-2016 CAFE Standards FEIS. Because there is so much agreement between these synthesis reports and the ones cited in the MY 2012–2016 CAFE Standards FEIS, 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.

Precipitation, Runoff, and Surface Waters: A new report confirms the trends in precipitation discussed in the MY 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) projected that summer precipitation will decrease across the central Northeast, but increase in the most northern and southern parts of the region. Evaporation is projected 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.

Snow and Ice Cover: 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 ± 9 days in autumn).

In a recent study, Flanner *et al.* (2011) used a variety of remote sensing and field measurements to investigate the radiative forcing and the albedo feedback[26] of snow cover and sea ice in the Northern

[26] Albedo is a measure of the fraction of incoming solar raditation reflected by a surface. Snow and ice have a high albedo (i.e., these surfaces reflect a large portion of incoming solar radiation) while land and water have a lower

Hemisphere. The authors estimate that the albedo feedback corresponding to the decline of the North Hemisphere cryospheric cooling from 1978 to 2008, measured at the top of the atmosphere, is between 0.3 and 1.1 W m^{-2} K^{-1} – substantially larger than estimates obtained from the climate models used in the IPCC AR4. On this basis, the authors concluded that these models likely underestimate the recent surface albedo feedback.

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 also 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). A recent analysis of glaciers in the greater Himalyas between 2000-2008 using remotely-sensed data found that more than 65% of monsoon-influenced glaciers had retreated (Scherler 2011). 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. In a recent study, Tedesco *et al.* (2011) concluded that, on the Greenland ice sheet, 2010 set new records for surface melt, albedo, runoff, and the number of days when bare ice was exposed. They found that early melt onset in spring 2010 triggered

albedo. The albedo feedback effect occurs when warming temperatures cause snow and ice to melt, exposing ocean and land, which absorb more solar radiation, further increasing warming.

premature bare ice exposure, which—alongside warm summer conditions and below-average summer snowfall—prolonged the melting season. This analysis corroborates other studies indicating that feedbacks can accelerate the rate of mass loss in ice sheets.

Water Quality and Water Supply: A recent 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).

Climate change may affect not only water quality but also water supply. McDonald *et al.* (2011) a used a detailed hydrologic model, demographic projections, and climate change scenarios to estimate per-capita water availability for major cities in the developing world at present and at 2050. They estimated that currently 150 million people live in cities with water shortages, defined as having less than 100 L per person per day. Model projections indicated that by 2050, climate change could cause water shortages for an additional 100 million urban dwellers.

Extreme Events – Floods and Droughts: New findings of storm intensity and heavy precipitation have become available, in comparison to studies cited in the MY 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 the contribution of 1-day extreme precipitation events to total precipitation has been increasing since 1990, with 8 of the top 10 years of extreme single-day precipitation events observed since 1990. Other related extreme weather events include flooding, which EPA states will likely become more intense. 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).[27]

A recent review of drought studies found that global aridity has increased substantially since the 1970s due to recent drying over Africa, southern Europe, East and South Asia, and eastern Australia. Coupled climate models used in the IPCC AR4 project increased aridity in the twenty-first century over most of Africa, southern Europe and the Middle East, most of the Americas, Australia, and Southeast Asia. Model projections indicate that regions like the United States that have not experienced prolonged droughts during the last 50 years because of natural climate variations could see persistent droughts in the next 20–50 years (Dai 2011).

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 projected 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 moderate emission scenario (A1B) and used a hurricane model to simulate storm development in response to projected warming. Simulation results projected 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

[27] Because data from the U.S. Drought Monitor are only available for the most recent decade, there is no clear long-term trend in this indicator. With continued data collection, future versions of this indicator should be able to paint a more complete picture of long-term trends in drought.

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 could 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 MY 2012–2016 CAFE Standards FEIS discusses the observed and projected impacts of climate change on ecosystems including terrestrial communities, aquatic communities, and wetlands. This section summarizes that information.

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 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 project increased ecosystem disturbance from floods, drought, wildfires, insects, ocean acidification, and other drivers of global change; they also project declines in keystone species, which could result in ecological cascade effects and exacerbate other ecosystem threats, such as habitat destruction and invasive species problems. 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 projections identified in Section 4.5.4 of the MY 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 MY 2012-2016 CAFE Standards FEIS and affirm much of the findings. To reduce redundancy with the information already provided in the MY 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. In addition, a recent study suggests that ecosystems have a slow inertial response and can be committed to shifts or loss of vegetation even before any changes in habitat structure have been observed. (Jones *et al*. 2009).

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 projections 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 project 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 impacts to phenology; species' range and ecosystem shifts; local/regional extirpation or global extinction; and trophic interactions, as discussed below.

Phenology: Recent studies support the conclusions of earlier work; they indicate that the phenology of plant and animal species will continue to change in regions that experience warmer annual average temperatures and earlier spring weather. In one new study of flowering plant species in southwestern Ohio, the authors found that nine of the fifteen species studied have exhibited statistically significant earlier blooming over the course of a 28-year study period, from 1976 to 2003. Several of the species that typically flower earliest in the year (*Galanthus sp.* and *Crocus sp.*) exhibited the greatest changes in flowering dates. This appears related to the clearly observable warming trends in the area; the minimum average January and February temperatures in southwestern Ohio increased significantly over the study period (McEwan *et al*. 2011).

Species' Range and Ecosystem Shifts: New findings are consistent with earlier studies' observations of a general trend of species movement poleward and to higher elevations in response to rising temperatures. One new study suggests that up to half of the Earth's land could be highly to very highly vulnerable to climate change-induced vegetation shifts. The most vulnerable systems are temperate mixed forest, boreal conifer, and alpine biomes, while tropical evergreen and desert biomes are least at risk. Projections of vegetation included in this study, modeled using three different SRES scenarios (B1,A1B, and A2), suggest that entire biomes could shift poleward as much as 400 km (Gonzalez *et al.* 2010). 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 the lower bound of the elevation range of half of the 28 mammal species first studied a century ago in Yosemite National Park, California, moved approximately 500 meters upward since the initial study. This is apparently consistent with the observed increase in local minimum temperatures of 3 °C (5 °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 Plant Hardiness Zone designation of 5b (plant hardiness minimum temperatures of -26 °C to -23 °C (-15 °F to -9 °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. As of 2010, forests had higher background mortality rates[28] compared to historical 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 one study, in which vegetation coverage in the Amazon was modeled, the authors indicate that by the time forest die-back due to changes in climate is detectable in 2050, the forest will already be committed to losing 50 percent of its area even with no further increases in climate forcing. There is a threshold temperature (marked by a global average increase of 2 °C over pre-industrial average), below which the equilibrium in the forest can be maintained. Above this temperature, the authors indicate that some die-off is inevitable (Jones *et al*. 2009). In another new study, the authors suggest that in northern and western Europe, greater atmospheric CO_2 concentration and warmer surface temperatures will allow for greater growth in the near term, but that the longer-term outlook suggests that continued increases in temperature and the associated drought and disturbances (such as pests and wildfire) will negatively impact forests. In southern Europe, negative impacts of climate change by the end of the century are likely to outweigh the potential benefits (Lindner *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 projections 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 projected 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 projects a mismatch between birds and their food sources as the climate warms. The losses might be even more pronounced 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

[28] Background mortality refers to the rate of tree death in a forest (or group of forests) that is not linked to a specific event, such as fire or pest infestation (DeRose *et al.* 2008).

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 projects 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 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 projects “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.

Species have been adapting to environmental changes since life began on Earth. However, climate change could require species to adapt on greater and faster scales than current species have been able to successfully achieve in the past (EPA 2010a). 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 MY 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[29] and coastal[30] ecosystems around the globe has been substantially degraded or lost altogether. Despite the lack of high-quality data available to quantify changes in these

[29] 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).
[30] 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."

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.[31] 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 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 and shell-producing ocean creatures. (*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.

[31] 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).

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 MY 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 MY 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 MY 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 MY 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 (Fussel 2009). 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 (Fussel 2009). 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 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).[32] 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 projected by IPCC (2007a) and cited by EPA (2009) and the MY 2012–2016 CAFE Standards FEIS, with much of the difference attributable to the fact that the IPCC (2007a) projections did not quantify the effect of melting associated with the ice sheet processes. *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 are likely to exacerbate storm surges and flooding (NRC 2010b, Hoffman *et al.* 2010). 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).

[32] 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.

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 MY 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 MY 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 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: New findings continue to support the observed relationship between the reduction in primary productivity and the warming of surface waters discussed in the MY 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 MY 2012–2016 CAFE FEIS regarding observed and projected climate change impacts on food, fiber, and forest products.

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.

Forests: 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.

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. 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[33] 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

[33] 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.

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 could very likely be reduced due to higher temperatures, but livestock production during winter months could increase, again due to the projected increase in temperatures.

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 MY 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 MY 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. Areas in which these reports overlap with the information provided in the MY 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 MY 2012–2016 CAFE Standards FEIS are provided by topic category.

Forests: Climate change will alter the growth and distribution of forests, but the response of forests to climate change will depend on complex interactions among local processes. For example, 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 can all influence forest response to a changing climate (Way and Oren 2010). As a result, the expected responses of forests to projected climate change impacts vary significantly across the country. 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). 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 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). While forests in the northern and eastern areas of the United States are projected to experience positive or mixed growth, forests in warm and arid regions may experience significant decreased growth. For example, a recent study analyzed tree ring patterns and found that if temperature and precipitation patterns change as projected, forest growth in the southwestern United States will decrease substantially (Williams *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 projected 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 MY 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) projected that projected increases in drought frequency in northeastern forests could impact maple syrup production and the coloration of autumn foliage, with adverse economic consequences for the northeastern United States.

Recent 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, while research on mechanisms of tree mortality due to drought is ongoing, one such study suggests that historical periods of aridity and high temperatures have contributed to the recent increase in fires and bark-beetle outbreaks in the southwestern United States (Williams *et al.* 2010). In addition, 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).

<u>Agriculture and Croplands</u>: Complex interactions between soil moisture, temperature, atmospheric CO_2, nitrogen availability, ozone, and the timing of short-term heat and flooding events can 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 projecting 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[34] 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 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 projects 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 projected 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 changes in the length of growing season could have both negative and positive impacts: crop and pasture yields in mid- to high-latitude regions may benefit from moderate warming, while conversely, yields in seasonally dry and low

[34] 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).

latitudes may be negatively impacted by just a slight warming (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.

Fisheries: 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 projected 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 projected 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 MY 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 projecting 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 MY 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 mitigate 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 MY 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 MY 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 projected changes in climate. Adopting the organization used by the IPCC, this sector is broken down into five categories.

<u>Industry</u>: 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.

<u>Services/Economic</u>: 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.

<u>Utilities and Infrastructure</u>: 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 projected 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. Human settlements are also vulnerable to extreme events in which precipitation and high wind speeds may damage structures.

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, projected 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 project 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[35] for instability in volatile regions of the world. Climate change-driven conflicts could begin around the world, 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 MY 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 MY 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 MY 2012–2016 CAFE Standards FEIS. This section does not repeat any information already provided in the MY 2012-2016 CAFE Standards FEIS. However, new information provided by NRC's *Climate Stabilization Targets* is presented here. This

[35] "Threat multiplier" refers to an action that further intensifies the instability of a system that poses a security concern.

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.

Industries: 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 would increase maintenance costs for the transportation sector.

Transit systems are also vulnerable to the same projected 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 (Johnson 2011, Mills 2009).

Climate change is also anticipated to have broad economic impacts. For example, climate change may impact the tourism industry on the U.S. Eastern Seaboard as shorelines and coasts are affected (Hughes 2011). Ciscar *et al.* (2011) estimated that if the climate of the 2080s were to occur today, household welfare in the European Union (EU) could reduce by 0.2-1% annually based on low (B2) and moderately-high (A2) emission scenarios, halving the EU's annual welfare growth. These declines in welfare would be primarily due to impacts on coastal systems, agriculture, and river flooding.

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 (Gasper *et al.* 2011, 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. In subtropical climates, climate change is projected to increase annual building energy use by 6.6 to 8.1 percent, compared to the average for the period from 1979 to 2008, by the end of the twenty-first century (2091-2100) (Wan *et al.* 2011).

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.

<u>Human Settlements</u>: Food and water security are additional climate-related risks to human settlements (Gasper *et al.* 2011). 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 projected to lose 11 percent yield per degree of warming, representing a major threat to international food security (NRC 2010b). Food security will be particularly at risk in Africa as crop systems are impacted by climate change (Müller *et al.* 2011). These food shortages will impact human settlements and may force communities to migrate. One study suggests that climate-driven reductions in crop yields would increase emigration from Mexico to the United States for populations aged 15 to 65 years by 2% for every 10% reduction in crop yields (Feng *et al.* 2010).

Climate change is also projected to cause water shortages. McDonald *et al.* (2011) project that change will cause water shortages in urban settings for an additional 100 million people, in addition to the 1 billion people projected to experience water scarcity due to population growth by 2050. This study made projections using an average of the four Millennium Ecosystem Assessment climate scenarios, which cover a wider range of possible emissions than the IPCC AR4 scenarios (McDonald *et al.* 2011). Overall, risks to human settlements are projected to be greatest in Central America, central South

America, the Arabian Peninsula, Southeast Asia, and much of Africa, based on projections of climate change and human population density (Samson *et al.* 2011).

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 (Stevenson *et al.* 2010, DOD 2010, NIC 2008). Examples of potential destabilizing conditions are water scarcity in the Middle East and flooding due to sea level rise in Bangladesh (Stevenson *et al.* 2010).The national security impacts to the United States will be primarily indirect, as climate change impacts will exacerbate existing problems in other countries and increase the risk of domestic instability and intra-state conflict (Fingar 2008, NIC 2008).

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 projected effects of global climate change. With the information available on projected 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 MY 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 since publication of the MY 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 MY 2012–2016 CAFE Standards FEIS and corroborate the findings discussed in the summary section above. To reduce redundancy, information already provided in the MY 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. Another recent report, UNEP's *Environmental Effects of Ozone Depletion and its Interactions with Climate Change: 2010 Assessment*, synthesizes current research on the synergistic effects of changes in solar ultraviolet (UV) radiation and higher temperatures on human health (Norval *et al.* 2010). This section also includes new findings of recently released peer-reviewed journal articles. The topics listed above (e.g., 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.

Heat Events: 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 MY 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, three 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,[36] 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).

Air Quality: Several studies have found increasing levels of ground-level ozone, which can exacerbate respiratory ailments and affect lung efficiency (Kim *et al.* 2011, NRC 2010a, NRC 2010b, Jackson *et al.* 2010). 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

[36] 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.

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 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). Sea-level rise due to climate change could increase the areal extent of saline and brackish water bodies in coastal areas and consequently increase the incidence of vector-borne diseases due to an increase in the populations of salinity-tolerant mosquitoes and other disease vectors. (Ramasamy and Surendran 2011). The risk to human health is likely to increase since more than half of the world's population currently lives within 37 miles of the coast, and population density in coastal areas is expected to increase by almost 55 percent from 2000 to 2050 (Ramasamy and Surendran 2011 citing UNEP 2007).

Chronic Disease: 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, Ren *et al*. 2011, and Spickett *et al.* 2011). 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). One recent study found that for the same level of UV radiation exposure, higher temperatures associated with climate change are more likely to cause an increase in skin cancer incidence for fair-skinned populations in the U.S. (Norval *et al.* 2010 citing van der Leun *et al.* 2008). For each one degree Celsius increase in temperature, basal cell carcinoma and squamous cell carcinoma increased by an estimated three and six percent, respectively (Norval *et al.* 2010). Additionally, high temperatures and humidity may suppress human immunity to infectious diseases and skin cancers by increasing the damaging effects of UV-B radiation (Norval *et al.* 2010 citing Ilyas 2007).

Indirect Impacts on Health: The indirect impacts of climate change include water scarcity and food security problems. Water scarcity is already a major global issue but climate change is likely to further reduce access to freshwater in some areas. Early melting of winter snowpack, melting glaciers, coastal inundation and salt water intrusion into freshwater aquifers will reduce supply of freshwater in some regions; in others, increased precipitation may increase water availability. Climate change may reduce food supply by compromising agricultural yields and nutritional quality as a result of decreasing water supply increasing ground-level ozone, and greater heat stress. Given that the demand for potable water and food is rapidly increasing due to population growth, these indirect impacts of climate change could have an extensive effect on global human health (Myers and Bernstein 2011).

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, Bell 2011, and Harley *et al.* 2011). 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 (Shea and 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, expanding air quality monitoring to additional areas, use of regional risk assessment and preparedness tools to identify and assist vulnerable populations during extreme events, strengthening of infrastructure to withstand extreme weather events, preparing the healthcare workforce to understand and deal with the impacts of climate change, and improved water management practices and drainage systems (Frumkin 2008, Harley *et al.* 2011, and Bell 2011). Bell (2011) proposes a holistic approach for preparing the health sector to deal with climate change by addressing governance and culture, health service delivery, workforce development, materials and infrastructure, and finance. Both Bell (2011) and Harley *et al.* (2011) note the current scarcity and major need for effective region-specific reaction plans that cover multiple mitigation and adaptation goals. 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. Developing countries and various geographic regions within developed countries would greatly benefit from knowledge sharing practices within and between developed and geographically close developing countries.

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 below is based on a survey of tipping points and abrupt climate change presented in Section 4.5.9 of the MY 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[37] 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 projections. 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 projections. 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 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

[37] The climate system is composed of the atmosphere, oceans, land, cryosphere, and biosphere.

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):[38] 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),[39] 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):[40] ENSO has substantial and large-scale effects on the global climate system.[41] The changes that might lead to increasingly persistent (and frequent) El Niño (or La Niña) conditions are particularly uncertain. Increases in ocean heat content could have an effect on ENSO conditions, but future 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.

[38] 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.

[39] 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.

[40] 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.

[41] 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.).

The IPCC does not project passing a threshold[42] 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[43] 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.

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

[42] An albedo greater than roughly 50 percent is necessary to simulate the collapse of the monsoon in a simple model.
[43] 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.

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, (5) the effects of delaying mitigation of GHG emissions, and (6) 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 MY 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 or associated with slow, subtle changes. For example, paleoclimate records contain evidence of both steady, linear changes in climate as well as abrupt changes where a small degree of warming resulted in non-linear climate system changes that persisted for millennia (Molina *et al.* 2009). When thresholds are crossed, ecological change is accelerated due to nonlinear reactions, positive feedbacks, or synergies among several stressors (Harley and Paine 2009, Lindsay and Zhang 2005, NRC 2010c, Rockström *et al.* 2009). 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, Röckstrom *et al.* 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." Smith *et al.* (2009) estimate that risks of tipping points (referred to as "Large-Scale Discontinuities") will not be substantial until the global mean temperature rises more than 4°C (7.2°F) or 5°C (9.0°F) above the 1990 mean.

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 project or analyze their likelihood (NRC 2010a). One new study, based on eliciting subjective probability estimates from experts, attempts to estimate the risks to the global economy from crossing specific climate system tipping points. The results indicate that there remains low confidence in experts' ability to accurately predict low-probability, high-impact events (Kriegler *et al.* 2009). 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). Lindsay and Zhang (2005) suggest that a tipping point for the Arctic ice-ocean system was reached in 1989, leaving Arctic sea ice in a state of continual thinning.

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). Under a moderately-high (A2) emission scenario, the area covered by the Amazon rainforest could be reduced by 70 percent in 2100, and the likelihood of severe droughts is projected to increase such that the current 1-in-20 year drought is projected to be 18 times more likely to occur by 2060 (Fussel 2009, citing Cook and Vizy 2008 and Cox *et al.* 2008).

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 projections in the quantity of future dust production range from significant increases to reductions near zero (Washington *et al*. 2009).

The Effects of Delaying Mitigation: Several studies have shown that delaying mitigation of GHG emissions results in a greater accumulation of CO_2 in the atmosphere, thereby increasing the risk of crossing tipping points and triggering abrupt changes. Based on historical and current rates of CO_2 emissions, Lowe *et al.* (2009) find that key global temperature thresholds are likely to be crossed in the next few decades and that the timescales for recovery from crossing climate thresholds may be as long as several centuries. Ramanathan and Feng (2008) demonstrate that GHG emissions since the preindustrial era have already committed the planet to an additional 1.6°C (2.9°F) of warming from today; the authors conclude that "even the most aggressive CO_2 mitigation steps […] can only limit further additions to the committed warming." New *et al.* (2011) similarly conclude that "the chances of shifting the global energy system fast enough to avoid [a global average temperature increase of] 2°C [3.6°F] are slim." The authors regard temperature increases above 2°C [3.6°F] to be more likely to trigger tipping points that result in severe climate impacts. Mignone *et al.* (2008) and Vaughan *et al.* (2009) find that delays in reducing CO_2 emissions will require more stringent reductions in the future, and that delays on the order of two or more decades may reduce the possibility of limiting atmospheric CO_2 concentrations to levels that are less likely to trigger tipping points.

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 decision-making. 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

In compliance with EO 12898, this section includes a qualitative analysis of the cumulative effects of the proposed action with regard to air pollutant discharges and climate change on "environmental justice populations."[44] This analysis supplements the direct and indirect effects environmental justice analysis presented in Section 3.6.6.

4.6.1 Affected Environment

See Section 3.6.6.1 for a discussion of the environmental justice affected environment.

4.6.2 Environmental Consequences

Cumulative impacts to environmental justice populations are qualitatively the same as the direct and indirect impacts discussed in Section 3.6.6. Cumulative impacts to resource areas would generally be smaller under the action alternatives than under the No Action Alternative. This is also true of impacts to air quality on a nationwide basis. However, emissions of $PM_{2.5}$ and DPM would increase in some nonattainment areas under the action alternatives. Tables 4.3.3-4 and 4.3.3-8 (in Section 4.3) and Appendix D present detailed information about emissions changes for each pollutant in specific nonattainment areas.

In addition to air quality impacts, there are a number of other potential impacts to environmental justice populations that are cumulative in nature - resulting from the proposed action together with other past, present, and reasonably foreseeable future actions. These impacts, described below, are largely a result of energy use and climate change.

4.6.2.1 Fossil Fuel Extraction and Processing

Because the proposed action has ramifications for transportation energy use in the United States, there may be cumulative impacts to fossil fuel extraction and processing. Thus, 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. Oil extraction and refining poses a heightened threat 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.

4.6.2.2 Effects of Climate Change in the United States

Environmental justice populations in the United States, as defined by EO 12898, would experience the same general impacts as a result of global climate change 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

[44] *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). For a definition of "environmental justice populations," *see* Section 3.6.6.

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."

4.6.2.2.1 Land Use

This section discusses, qualitatively, the most substantial areas of potential disproportionate impacts for environmental justice populations in the United States.

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

In the following sections, NHTSA provides a qualitative analysis of non-climate cumulative impacts of CO_2.[45] As with the climatic effects of CO_2, the changes in non-climatic impacts associated with the alternatives are difficult to assess quantitatively. Nonetheless, it is clear that a reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce non-climate impacts of CO_2, such as the ocean acidification effect and the CO_2 fertilization effect described below.

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, it is considered unlikely that there was a significant decrease in ocean pH. This is because the rate at which atmospheric CO_2 changed in the past was much slower than at present, and during slow natural changes, the carbon system in the oceans has time to reach a steady state with sediments. If the ocean starts to become more acidic, 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

[45] *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"); 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).

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 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).

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). Orr *et al.* (2005) used 13 climate models of the ocean-carbon cycle to assess calcium carbonate saturation under the IPCC IS92a "business as usual" scenario (one of the six IPCC emission scenario alternatives developed in 1992, Leggett *et al*. 1992). Under these model runs, Southern Ocean surface waters would begin to become undersaturated with respect to aragonite (a form of calcium carbonate) as early as 2050; by 2100 all of the Southern Ocean south of 60 degrees south and portions of the Subarctic North Pacific could become undersaturated (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 al.* 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. Some scientists have suggested that critical thresholds at which adverse effects occur as a result of elevated CO_2 could be relatively low for many animals (Pörtner *et al.* 2005). Veron *et al.* (2009) argue that that CO_2 levels below 350 ppm are needed to protect coral reef ecosystems from collapse. 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, Haugan *et al.* 2006 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, though 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). High CO_2 is also a bleaching agent for corals and crustose coralline algae under high irradiance, and acts synergistically with warming to lower thermal bleaching thresholds (Anthony *et al.* 2008). 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. In addition, the researchers observed that lowered seawater pH and hypoxia will have a synergistic effect on organisms that will be exacerbated by the combination of stressors they face, including ocean acidification, land-use change, and nutrient enrichment. As a result, affected organisms may reach the limits of their physiological tolerances and cross critical thresholds, with abrupt and major changes to ecosystem health.

Coldwater Corals. As the aragonite saturation horizon (the limit between water that is saturated with aragonite and 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 IS92a ("business as usual") scenario, which assumes countries do little to curb emissions (Nakicenovic and Stewart 2000), 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[46] 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

[46] Recruitment rate refers to the number of new individuals added to a biological population.

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). Changes in pH upset acid-base regulation in many animals, including crustaceans and fish, and affect processes that are important for growth and the control of neurotransmitter concentrations such as ion exchange, oxygen transport, and metabolic equilibria (Pörtner *et al.* 2004).

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 (Dixson *et al*. 2010). Other studies suggest that high CO_2 in seawater can lead to cardiac mortality in some fish (Ishimatsu *et al.* 2004). 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. While indirect effects via transmission through the food web is important, Haugan *et al.* (2006) reviewed a number of studies that show that there are also direct effects of elevated CO_2 on the growth, reproduction, and activity of higher tropic level organisms. For example, there is evidence that even a small decrease in pH has a dramatic effect on the oxygen carrying capacity of squid (Turley *et al.* 2005).

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 IPCC IS92a emissions 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 Quéré *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 (Le Quéré *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. Le Quéré *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 (Le Quéré *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).[47] 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.

[47] 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.

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 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, 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).

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 agency does not have to formulate and adopt a complete mitigation plan,[1] 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 the No Action Alternative neither NHTSA nor EPA would issue a rule regarding fuel efficiency improvement or GHG emissions for MYs 2014–2018. Compared to the No Action Alternative, each of the four action alternatives would result in a decrease in CO_2 emissions and associated climate change effects and a decrease in energy consumption.

As described in this EIS, emissions of criteria and toxic air pollutants would generally decrease for all action alternatives and analysis years as compared to their levels under the No Action Alternative. The only exceptions to this decline are emissions of $PM_{2.5}$, DPM, and 1,3 butadiene under some alternatives and analysis years. Specifically, $PM_{2.5}$ is projected to increase in year 2018 under Alternative 3. $PM_{2.5}$ and DPM are both projected to increase in year 2018 under Alternative 2 and in years 2030 and 2050 under Alternatives 2 through 5. Emissions of 1,3 butadiene would increase slightly in year 2050 under Alternatives 2 through 4. The maximum projected increases in emissions compared to the No Action Alternative are 5.9 percent for $PM_{2.5}$ (under Alternative 2 in 2050), 8.0 percent for DPM (under Alternative 2 in 2050), and 0.2 percent for 1,3-butadiene (under Alternative 4 in 2050). Under the Preferred Alternative, increases in emissions in 2030 compared to the No Action Alternative would be 1,284 tons (3.9 percent) for $PM_{2.5}$, 1,213 tons (4.8 percent) for DPM, and less than one ton of 1,3-butadiene (0.03 percent). Overall, negative health impacts associated with criteria and toxic air pollutant

[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) (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).

emissions are expected to be reduced (*see* Tables 3.5.2-9 and 3.5.2-10), and the emissions under the four action alternatives would have few unavoidable adverse impacts.

Increases in $PM_{2.5}$, DPM, and 1,3-Butadiene emissions could also occur under the action alternatives in some nonattainment areas due to increases in VMT. These increases would represent a slight decline in the rate of reduction otherwise achieved by implementation of Clean Air Act standards.

5.2 MITIGATION MEASURES

Under the proposed action, some increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the HD standards. Notably, however 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 2009b). Also, vehicle manufacturers can choose which technologies to employ to reach the new HD fuel efficiency requirements. Some technology choices result in higher or lower impacts for these emissions.

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. 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.

In regard to air quality, Federal transportation funds administered by the Federal Highway Administration (FHWA) could be available to help support 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. 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 of criteria and toxic air pollutants as EPA promulgates new regulations.

Each action alternative would reduce energy consumption and GHG emissions compared to the No Action Alternative, resulting in a net beneficial effect. Nonetheless, 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[2]. The current proposed standard[3] 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 estimates that the greater volumes of biofuel mandated by proposed standards would reduce GHG emissions from transportation by approximately 150 million tons CO_2 equivalent (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 2009a). 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. In 2009, 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 2010).

In a joint NHTSA and EPA rulemaking published in May 2010, NHTSA and EPA set the first national coordinated fuel economy and CO_2 vehicle emission regulations, covering 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 (NHTSA 2010). The agencies estimate that the joint program will reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (NHTSA 2010). The agencies have announced plans to build on the first stage of this coordinated program with forthcoming fuel economy and GHG emissions standards for light duty vehicles for MY 2017 and beyond.[4]

In May 2010, EPA issued rules to address GHG emissions from stationary sources under Clean Air Act permitting programs.[5] Under the first step to phase in this rule, which started 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

[2] Renewable Fuel Standard for 2009, Issued Pursuant to Section 211(o) of the Clean Air Act, 73 *FR* 70643 (November 21, 2008).
[3] Final Rule: Regulations of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 *FR* 14670 (March 26, 2010).
[4] Notice of Upcoming Joint Rulemaking to Establish 2017 and Later Model Year Light Duty Vehicle GHG Emissions and CAFE Standards, 75 *FR* 62739 (Oct. 13, 2010).
[5] Final Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 *FR* 31514 (June 3, 2010).

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 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.[6] 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 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.[7] 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 final guidance for Federal GHG reporting and accounting onOctober 6, 2010, establishing government-wide procedures for calculating and reporting GHG emissions associated with Federal agency operations.[8]

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.[9] 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.[10]

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[6] Federal Leadership in Environmental, Energy, and Economic Performance, Exec. Order No. 13514, 74 *FR* 52117 (Oct. 8, 2009).
[7] *See* http://www.whitehouse.gov/the-press-office/president-obama-sets-greenhouse-gas-emissions-reduction-target-federal-operations (Accessed: June 12, 2011).
[8] *See* http://www.federalregister.gov/articles/2010/10/18/2010-26139/final-guidance-federal-greenhouse-gas-accounting-and-reporting (Accessed: June 12, 2011).
[9] 42 U.S.C. § 13385(b).
[10] *See* http://www.whitehouse.gov/blog/2010/01/28/president-obama-delivers-american-high-speed-rail (Accessed: June 12, 2011).

Also within DOT, 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.

In addition, 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.

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 2011).

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. However, NHTSA's setting of fuel efficiency standards will reduce the rate at which these emissions will increase. 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. 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.

Chapter 6 Responses to Public Comments

The National Highway Traffic Safety Administration (NHTSA) submitted to the U.S. Environmental Protection Agency (EPA) a draft Environmental Impact Statement (DEIS) to disclose and analyze the potential environmental impacts of the agency's newly proposed HD Fuel Efficiency Improvement Program standards for Model Years (MYs) 2014-2018 and reasonable alternative standards pursuant to National Environmental Policy Act (NEPA) implementing regulations issued by Council of Environmental Quality (CEQ), U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations. On October 29, 2010, a Notice of Availability of the DEIS was published in the *Federal Register* (*FR*). In accordance with CEQ NEPA regulations, the Notice of Availability of the DEIS triggered a public comment period. The public was invited to submit comments on the DEIS until January 3, 2011. NHTSA mailed approximately 200 copies of the DEIS to interested parties, including federal, state, and local officials and agencies; elected officials, environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 8 of the DEIS.

On Tuesday, November 30, 2010, EPA and NHTSA published in the *Federal Register* (*FR)* the Proposed Rulemaking for *Greenhouse Gas and Fuel Efficiency Standards For Medium and Heavy Duty Engines and Vehicles; Proposed Rule*. The publication of the proposed rule opened a 60-day comment period and the public was invited to submit comments on or before January 31, 2011 by posting to either the EPA or NHTSA docket (EPA-HQ-OAR-2010-0162 or NHTSA-2010-0079).

In preparing this final Environmental Impact Statement (FEIS), NHTSA reviewed comments received in both dockets, in which a combined total of 3,048 public submissions were received. NHTSA and EPA also held public hearings on November 15, 2010 in Chicago, IL and on November 18, 2010 in Cambridge, MA to receive comments on the rulemaking. NHTSA received 76 written comments from interested stakeholders on the DEIS. In addition, NHTSA received 40 oral statements and 10 written submissions at the hearing in Chicago and 47 oral statements and 4 written submissions at the hearing in Cambridge. In this chapter of the FEIS, NHTSA has quoted substantive excerpts from these comments and responded to the comments received, as required by NEPA (40 CFR § 1503.4).

NHTSA considered and evaluated all written and oral comments received during the public comment period in the preparation of this FEIS. The agency incorporated changes into this FEIS, in part, in response to comments on the DEIS. NHTSA also changed the EIS as a result of updated information that became available after issuance of the DEIS.

NHTSA has taken the following approach to the comments it received in both the EPA and NHTSA dockets:

- The agencies received a significant number of comments directly addressing or otherwise related to the proposed rule. After reviewing all of the comments received, NHTSA has addressed below only those comments considered substantive to the EIS. Comments directly addressing or related to the proposed rule, and which do not directly address the EIS, will be addressed by the final rule and its associated documents.
- The agencies received 396 oral or written comments stating general support for the proposed rule and 46 oral or written comments stating general opposition to the proposed rule. NHTSA appreciates those comments, but because they do not raise specific issues or concerns pertaining to this EIS, no response is provided. Comments that were specific to the EIS or that substantively addressed analytical methods or approaches taken in the EIS have been responded to below.

- NHTSA received multiple comments that were substantively similar or identical to each other. In cases where the quantity of such comments was voluminous, representative comments were selected for presentation.[1] In all cases, these representative comments are considered to comprehensively summarize the issues raised. Where this occurs, the agency has indicated that it has taken this approach.
- Where the same commenter provided several substantially similar comments on a particular topic, NHTSA has included in this document one representative version of the comment.

The transcript from the public hearing and written comments submitted to NHTSA are part of the administrative record and are available on the Federal Docket, which can be found online at http://www.regulations.gov, Reference Docket No.: NHTSA-2010-0079. Table 6-1 lists the topics addressed in this chapter. Sections 6.1 through 6.6 provide comments on the DEIS and NHTSA's responses to those comments. Comment docket numbers in this chapter include only the last four digits of the docket number, excluding the initial "NHTSA-2010-0079," which begins all docket submissions. All "TRANS-Cambridge" comments are taken from the transcript associated with the Cambridge, MA public hearing (NHTSA-2010-0079-0084); "PAPER-Cambridge" comments are taken from paper letters submitted at the public hearing (NHTSA-2010-0079-0084); TRANS-Chicago comments are taken from the transcript associated with the Chicago, IL public hearing (NHTSA-2010-0079-0088); PAPER-Chicago comments are taken from paper letters submitted at the public hearing (NHTSA-2010-0079-0088).

[1] CEQ regulations permit an agency to attach summaries of substantive comments received on a draft environmental impact statement if the response has been "exceptionally voluminous." *See* 40 CFR § 1503.4(b).

Table 6-1

Outline of Issues Raised in Public Comments on the DEIS

6.1 PURPOSE AND NEED

6.1.1 Purpose and Need Statement

Comments

NHTSA received several comments highlighting the potential benefits of the proposed rule and how they aligned with the purpose and need of the proposed action. Commenters often raised substantially similar points. Representative comments are presented below:

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

We concur with the National Academy of Science's assessment that the upcoming MD/HD vehicle rulemaking "is an important juncture for the nation. The choices that will be made over the course of the next few years will establish the regulatory design for [MD/HD vehicle] fuel consumption standards for the next several decades at least." For that reason, the agency must base its rulemaking and EIS analysis on the most updated and relevant scientific evidence available.

Docket Number: 0079
Commenter: John Walsh, South Carolina Department of Transportation

The energy independence/security implications [of the rule] are less controversial and potentially more important than possible climate change and health effects.

Docket Number: PAPER-Chicago
Commenter: Miranda Carter, Environment Illinois

Improving the fuel economy of our nation's medium and heavy duty trucks is . . . an essential step to reducing our dependence on oil. Trucks drive more miles than any other vehicle on the road, and because there has never been any regulation requiring trucks to use fuel-efficient technologies, the average fuel economy of trucks is a shockingly low 6.1 miles per gallon.

Our nation can and must do much better than that. Gas guzzling trucks not only produce air pollution, but also increase the cost of transporting goods for consumers and businesses. Strong regulations to increase the fuel efficiency of trucks will have widespread benefits for both our environment and our economy.

The proposed regulations are an important first step towards greater fuel efficiency for our heavy duty vehicles.

Docket Number: TRANS-Cambridge
Commenter: Gary Oshnock, Chrysler Group LLC

Chrysler unequivocally agrees, the rules proposed by this NPRM (Notice of Proposed Rulemaking) for the 2014 and 2018 model year, will reduce greenhouse gas emissions, enhance energy security and offer greater regulatory certainty for vehicle manufacturers.

Docket Number: PAPER-Chicago
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

There is no question that truck users are sensitive to fuel prices. Nonetheless there are currently big obstacles to bringing efficiency technologies into the market: there is no standardized way of documenting the benefits of these technologies; volatile fuel prices undermine the confidence of manufacturers and buyers to invest in them; and trucks are often sold after just a few years on the road. Given this situation, a fuel efficiency standard is an important tool for promoting the development of new technologies and ensuring their rapid deployment.

Docket Number: TRANS-Cambridge
Commenter: Gina Coplon-Newfield, Sierra Club-Green Transportation Department

The CO_2 emissions from trucks are disproportionately higher than those from cars. The massive oil spill in the Gulf of Mexico is only the most recent reminder of how dirty and dangerous is our nation's addiction to oil.

Docket Number: TRANS-Cambridge
Commenter: Martin Suhrke

I'm saying this out of my own concern for the global environment, and I think you should act for the same reason. And if not for that reason, you should act based on long-term economical implications of lagging behind in a changing world; or based on considerations about public health issues related to air pollution; or based on your obligation to take part in a serious universal matter; or based on any one of the many bad things that come out of dependency upon oil. Eventually, it all comes down to quality of life for everyone.

Docket Number: TRANS-Cambridge
Commenter: David Heimann

[W]ithout fuel economy standards, . . .U.S. car-makers and truck-makers, will fall way behind competition, because they are doing something out there, Japanese vehicles, European vehicles, Chinese vehicles, they are starting. . . .[W]e can't afford to fall behind the competition, because that would cost valuable jobs, stall innovation, increase our dependence on oil, . . . a whole lot of bad things, if we do that. So we have got to keep up, and one way of doing that is make our own playing field level, so that truckers and manufacturers are encouraged to [purchase and manufacture] good trucks, and the only way to do that, really, is by standards.

Docket Number: TRANS-Cambridge
Commenter: Roger Shamel

Improved fuel efficiency will reduce our dependence on imported oil, also reducing our need to spend defense dollars in other parts of the world in order to protect these foreign oil reserves and have untold other benefits, in terms of health and other impacts.

Docket Number: TRANS-Chicago
Commenter: Corey Jones

And doing the right thing for the public, whether it be investing in the research and technology and improving the technology of the vehicles on the road, of doing—make smart choices, some common-sense choices that really pay off in the long-term—I think that's really where I think the role of the EPA comes in, because that's where the gap is. No one is looking in that direction right now. That's where we need leadership. We need leadership for the long-term vision. And there is no long-term vision in the industry.

Docket Number: TRANS-Cambridge
Commenter: Mary Ellen Kustin, National Wildlife Federation

First, this proposed rule underscores the value of setting standards for greenhouse gas under the Clean Air Act. And like the 2012 to 2016 greenhouse gas and fuel economy standards for light-duty vehicles, which, as I'm sure you know, gained the buy-in of all major stakeholders, these new heavy-duty standards have been publicly supported by engine manufacturers, fleet companies, major retailers, states and, of course, environmental workers. The wide support reflects the reality that these standards are a win-win for consumers, the national economy and the environment.

Docket Number: PAPER-Chicago
Commenter: Anita Green, General Board of Pension and Health Benefits of The United Methodist Church

Many companies have told us that without clear policy signals from Washington, innovation stalls and capital sits on the sidelines. Setting strong standards will be the signal companies are looking for to begin production that incorporates new technologies. In turn, this will boost production and innovation throughout the supply chain, and allow manufacturers to bring new and more efficient products to revitalize a stagnant market. . . .Furthermore, many companies include transportation emissions in their GHG assessments, and tighter fuel standards will help companies achieve their own GHG reduction goals.

* * * * *

The fuel savings I have described would, according to the Union of Concerned Scientists, reduce GHG emissions by a total of 140 million metric tons by 2030 - equivalent to removing 21 million of today's cars and trucks from the road. . . . It is critical to address heavy duty truck emissions now, given that it accounts for about 17% of transportation oil use. . . .

* * * * *

The United States' reliance on trucks underscores a need to mitigate our vulnerability to the rising price of fuel. The Ohio Business Council for a Clean Economy states that we depend on the trucking industry for 70% of U.S. shipping needs. America's dependence on trucks to supply our economy has grown by over 50% since the early 1990s, and continues to grow. Efficiency standards that require the use of existing and emerging fuel reduction technologies would reduce our dependence on oil; and save a total of 100 billion gallons of fuel in the next 20 years. Annual fuel savings in 2030 alone could top 11 billion gallons.

Docket Number: TRANS-Chicago
Commenter: Peter Zalzal, Environmental Defense Fund

Third: Pollution reduction, energy security, and national security. The agencies' proposed standards will also address these closely intertwined goals. Over the lifetime of the vehicles sold between 2014 and 2018, these proposed standards will reduce greenhouse gas emissions by 250 million metric tons of CO_2 equivalent and reduce fuel consumption by more than 500 million barrels, or projected daily oil savings comparable to entirely offsetting our nation's Iraqi oil imports by 2030. This rule is an important step toward breaking our dependence on foreign oil and curbing our contribution to climate change.

Docket Number: TRANS-Cambridge
Commenter: Kelly Gallagher

EPA's estimate that these standards could reduce greenhouse gas emissions by 250 million metric tons is very important, and to put that in perspective, these savings would be equal to all of Africa's projected transportation sector emissions in 2020, the entire continent, according to the new World Energy Outlook produced by the International Energy Agency.

Docket Number: TRANS-Cambridge
Commenter: Jonathan Gensler

At home, we face vulnerable coastlines, heat waves, drought, water shortage and wildfires, all of which endanger lives and cost billions of dollars to respond to. For example, Hurricane Katrina cost nearly 2,000 lives and more than $80 billion in damages.

* * * * *

[I] believe that our nation's oil addiction and our contribution to climate change severely threaten our national security. I believe that the proposal to reduce greenhouse gas emissions from our nation's fleet of heavy-duty trucks and buses is a vitally important step toward reducing that threat and protecting our troops.

Docket Number: TRANS-Cambridge
Commenter: Branden Bell, Union of Concerned Scientists, Clean Vehicles Program

According to the analysis by UCS, cutting fuel use from new long-haul tractors pulling van trailers 35 percent by 2017, and other trucks by 20 percent, would result in 5.6 billion gallons of oil saved annually by 2030. Those fuel savings would reduce heat-trapping global warming pollution by a total of 70 million metric tons, which is the equivalent of removing about 10 million of today's cars and light trucks [from] the road.

Docket Number: TRANS-Chicago
Commenter: Tony Garcia, International Union UAW

The UAW is also strongly supportive of the proposed rule because of the substantial progress that will be achieved through meeting the nation's need to conserve oil and reduce greenhouse gas emissions. The UAW believes that every sector of our economy should contribute to the solution to the vexing problems of energy security and climate change. With the implementation of the proposed rules, the on-road vehicle sector will extend its contribution to these solutions and maintain its position as the sector doing more, much more than any other sector to advance these causes.

Docket Number: 0142
Commenter: Janice Nolan, Hilary Sinnamon, Peter Zalzal, Katie Patterson, and Britt Groosman - American Lung Association and Environmental Defense Fund

The United States consumes more than 19 million barrels of oil a day, which is nearly a quarter of the oil consumed in the entire world, and more than all European Union nations combined. Over half of the oil we use each day is imported from foreign countries, and more than 70 percent of the oil we consume is used for transportation. . . .

The nation's fleet of trucks and buses consumes more than 100 million gallons of fuel per day - 13 percent of total U.S. petroleum consumption. . . . To put this in perspective, the BP oil spill is estimated to have leaked nearly 200 million gallons of crude into the Gulf of Mexico. Our commercial trucks and buses use the same amount of oil in 2 days as was leaked from the entire Deepwater Horizon rig disaster. . Reducing our consumption of oil will save consumers money and reduce the harmful impact on our environment.

* * * * *

Oil dependence has serious consequences. Extracting oil fouls land and water, kills wildlife, and destroys habitat—as we've seen too grimly in the recent BP oil spill in the Gulf of Mexico. Refining oil creates air pollution and water pollution. Combustion of oil—burning oil and oil-based fuels in engines—releases CO_2, which causes global warming (about 42 percent of the world's energy-related CO_2 emissions come from oil). Emissions from oil refining and combustion also contribute to ozone, which worsens asthma, causes premature death and contributes to other health problems. [Footnotes omitted.]

Docket Number: PAPER-Chicago
Commenter: Steve Perlman

It will ultimately mean that our country will save billions of gallons of oil in the next two decades. That means billions of gallons that will not need to be imported from the Middle East, helping improve the United States' import/export trade balance. As Lisa Jackson is quoted saying in the New York Times, "Overall, this program will save $41 billion and much of it will stay home in the U.S. economy rather than paying for imported oil."

Fewer imports also mean a stronger national security, as our country will be less and less vulnerable to the actions of the countries from which the U.S. must depend on to supply the oil for our country's trucks.

Docket Number: TRANS-Cambridge
Commenter: Wade Barnes

You may hear testimony today about technical and economic challenges involved in meeting the proposed standards. But none of these so-called "challenges" are as hard as the threats our troops face on a daily basis. I transited the Strait of Hormuz about 40 times during my three deployments to the Middle East. Each time my ship was challenged or maneuvered against by the ships and aircraft of the Iranian Revolutionary Guard Corps. I submit that it is high time that the weapons that empower nations like Iran begin to rust and decay, and the first step in achieving this goal is to drive down the global price of oil by reducing U.S. demand. Fuel efficiency standards are a proven means to achieve this end.

Docket Number: TRANS-Cambridge
Commenter: Catherine Pargeter, Trillium Asset Management Corporation

In addition, our energy security will be increased. The United States' reliance on trucks underscores a need to mitigate our vulnerability to the rising price of fuel.

Docket Number: TRANS-Chicago
Commenter: Christopher Miller, Operation Free

Another number I wanted you to remember is 24. According to Navy Secretary Ray Mabus, every 24th military convoy downrange results in the death of a U.S. service member. I led missions every day in Baghdad, many of which included hauling fuel for our unit to operate. Up to 80% of the loads of some convoys are fuel. More efficient vehicles mean less fuel needed, which means less of our troops being killed. That means more of them get to go home. The technology to improve vehicle fuel efficiency is available. Cleaner vehicles more than pay for themselves in lower fuel costs. And the cleaner trucks required by this rule will reduce our oil addiction, improve our national security, and, above all, save American lives.

Docket Number: TRANS-Chicago
Commenter: Yvette Pena-Lopez, BlueGreen Alliance

This also means sending less money overseas for foreign oil. According to a statement by Ed Markey, a senior member on several House committees, "With just five years of new vehicles sold under this proposed program, America will eliminate the same amount of oil that we import from Russia and Nigeria in a year." And the unions care about this greatly, as do the BlueGreen Alliance to Operation Free who spoke earlier.

Docket Number: TRANS-Chicago
Commenter: Ashkan Bayatpour

Our country cannot be this weak and vulnerable based on one single fuel source. However, the reality is, as it stands today, that we most certainly are.

Docket Number: TRANS-Chicago
Commenter: Rose Gomez

We have paid what are heavy prices, our troops that are across in another country that are paying and have paid very high costs. On top of that, billions of dollars have been expended, billions, billions that can never be brought back in addition to the sons and daughters that have been lost in this trafficking service sending people across to another country in which we have already lost a lot.

Docket Number: PAPER-Cambridge
Commenter: Carol Lee Rawn, Ceres and the Investor Network on Climate Risk (INCR)

Strict standards are also critical to national energy security. We are increasingly dependent on trucking, so need to minimize our vulnerability to the rising price of fuel. Standards requiring the use of existing and emerging technologies would significantly reduce our dependence on oil. According to a UCS report, cutting fuel use using existing and emerging technologies would save a total of 100 billion gallons of fuel from 2010-2030.

Docket Number: TRANS-Chicago
Commenter: Rinda West

Currently our pricing structure does not consider the downstream costs of remediating the damage done by our fixation on short-term gain. Everything from the BP oil spill to climatic disasters like Hurricane Katrina, which are all part of the downstream costs of our addiction to oil. Higher standards for greenhouse gas emission and fuel efficiency constitute an investment in our children, our country, and our future.

Docket Number: TRANS-Chicago
Commenter: Georgina Salgado-Chavez

Our dependence on oil is so much to the point that we can are destroying nature and from that point of view, our soil, our water, our air, our food is contaminated.

Substantively similar comments were received from: Clare Robbins (TRANS-Cambridge); Therese Langer, American Council for an Energy-Efficient Economy (TRANS-Chicago); Ashkan Bayatpour (TRANS-Chicago); Miranda Carter, Environment Illinois (TRANS-Chicago); Roger Shamel (PAPER-Cambridge); Steve Perlman (PAPER-Chicago); Jason Mathers, Environmental Defense Fund (TRANS-Cambridge); and John Boesel, CALSTART (0134).

Response

These commenters discussed the broad range of potential benefits this rulemaking offers the Nation—in terms of economic competitiveness, national security, and the environment. As the agencies stated in the NPRM, the proposed rules would create a strong and comprehensive National Program designed to address the closely intertwined challenges of dependence on oil, energy security, and global climate change. We agree with commenters that the proposed National Program would also enhance American competitiveness and job creation.

NHTSA is charged with evaluating the environmental impacts of this rule under the National Environmental Policy Act (NEPA). The broad sector that NHTSA and EPA have proposed to regulate—ranging from large pickups to sleeper-cab tractors—is responsible for about 18% of U.S. oil consumption. All of the action alternatives that NHTSA has evaluated for the purpose of this EIS would result in substantial fuel savings and associated GHG emissions reductions.

Comments

NHTSA received several comments highlighting potential economic savings as well as benefits to job creation and the economy that would be realized because of the proposed rule and how they aligned with the purpose and need of the proposed action. Commenters often raised substantially similar points. Representative comments are presented below:

Docket Number: 0058
Commenter: Andrenika Randle

Additionally, the changes would save the consumer and the company billions of dollars over time that will assist with our nation's economy and saving money to strengthen our economy will assist with the increase of employment in this nation instead of outsourcing for cheap labor and products. The overall benefit from this proposal is the impact on the environment. A clean environment will breed better health. The cost savings from this proposal is staggering and worth the time and effort to incorporate.

Docket Number: 0110
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

Improving the fuel economy of our nation's trucks will provide long-lasting benefits to consumers, businesses, and the economy as a whole, by reducing the costs for transporting goods and for the many other services that utility and vocational vehicles provide.

Docket Number: PAPER-Chicago
Commenter: Richard Stuckey

The energy savings from increased miles per gallon will save trucking companies a significant percentage of their fuel costs over the life of their vehicles.

The trucking companies will produce trucks that will be more attractive to customers here and overseas.

Docket Number: PAPER-Chicago
Commenter: Anita Green, General Board of Pension and Health Benefits of The United Methodist Church

1. Job Creation and Economic Growth

In a joint report called "Delivering Jobs: The Economic Costs and Benefits of Improving Fuel Economy of Heavy Duty Vehicles," the Union of Concerned Scientists and CALSTART concluded that a 38% reduction in truck fuel use would result in the creation of 124,000 new jobs by 2030, in every state. Under their analysis, Illinois would gain 5,440 jobs by 2030.

The report demonstrates that investments in advanced truck technologies would create jobs across the truck manufacturing sectors—from engineers to assembly line workers. As operating costs come down due to more fuel efficient trucks, business owners and consumers will be able to make additional investments in other goods and services throughout the economy, including more fuel efficient trucks. These job increases would greatly offset any job losses stemming from a declining demand for fuel. The report estimates that GOP would expand $4 billion by 2020 and $10 billion by 2030.

2. Save Businesses Money

Advanced fuel efficient trucks will more than pay for themselves over a typical ownership period. The organization Go60MPG estimates that in just two years, an over the road owner-operator could recoup the initial technology investment to reduce fuel use by 35%—and accumulate net savings of more than $50,000 in the first five years of operation. This revenue is critical to the owner-ops that have struggled to survive under the double hit of a recessionary decrease in freight and an increase in fuel costs.

With a 75% gain in fuel efficiency, package delivery fleets can expect to save $11,000-$26,000 per truck over 12 years. Based on a 65% efficiency gain, long-haul fleets could save about $120,000 per truck over 8 years of service.

3. Retain Our Position as Leaders in Efficient Truck Manufacturing

The United States is currently the world leader in the development, production and use of energy efficient and hybrid trucks. To retain our position, we need clear policy signals.

According to CALSTART, at least 15,000-30,000 jobs in truck manufacturing can be retained and 25,000 additional high efficiency truck technology jobs can be created, if US leadership in this field is preserved. [Footnotes omitted].

Docket Number: TRANS-Cambridge
Commenter: Jason Mathers, Environmental Defense Fund

(1) Job Growth. The agencies' proposed standards are good for American business. The clear, common-sense regulatory structure will help companies develop clean technology and efficiently take those technology innovations to market. In a recent op-ed that Brian mentioned, Environmental Defense Fund's President, Fred Krupp, and the CEO of Cummins, Tom Linebarger, recognized the critical role these standards play in "getting innovations to market that will create economic opportunity for American companies and jobs for American workers." American truck and engine manufacturers, like Cummins, are poised to reap the economic benefits of these standards, ensuring that American manufacturers are both leading innovation here at home and leading exporters of advanced clean-truck technologies.

(2) Financial Savings. Technologies to reduce greenhouse gas emissions from medium- and heavy-duty vehicles is cost-effective for America's fleet and truck owners. For instance, a new "18-wheeler" meeting the proposed standards will yield a net savings of up to $74,000 in avoided fuel costs over the truck's useful life. And some fleets aren't waiting around for the new rules to take effect to start saving money. For example, fleets like Sysco, Staples, Poland Spring and Wal-Mart, have already implemented available technologies, like hybrid drivetrains, idle reduction software, transmission adjustments and aerodynamic tractors and trailers, because of the cost savings. As fuel rivals depreciation as the top cost for fleet vehicles, fleets everywhere will benefit from more efficient trucks.

Docket Number: TRANS-Cambridge
Commenter: Brendan Bell, Union of Concerned Scientists - Clean Vehicles Program

In addition to the environmental and energy security benefits, strong standards can deliver important economic benefits as well. Strong standards will deliver significant fuel savings for truck owners and operators, and create markets for new technology to help keep America's truck manufacturing sector competitive in an increasingly global marketplace. According to UCS analysis, the economic impact of substantially increasing the fuel efficiency of the nation's trucking fleet over the next 20 years, using technology available today and in development, will create more than 63,000 jobs by 2020 in both the truck manufacturing sector and the U.S. economy as a whole, and that's both due to direct investments in truck manufacturing and also in the fuel savings, as a growth for the entire economy. By 2030, our analyses show that continued advances in fuel efficiency would create more than 120,000 jobs.

Establishing strong medium- and heavy-duty vehicle standards for fuel efficiency and greenhouse gases is a critical step to making all of these benefits a reality. They will spur the U.S. truck manufacturing sector to continue to innovate, invest in next generation technologies, and deploy fuel saving technologies across the entire trucking fleet, while delivering cost savings to truck owners. Standards will also help overcome barriers that have hindered investments in truck fuel efficiency technologies by both truck buyers and manufacturers, such as fuel price uncertainty, short-periods of truck ownership, lack of standardized information on truck fuel efficiency, split tractor-trailer ownership, and other market failures.

Docket Number: TRANS-Cambridge
Commenter: Catherine Pargeter, Trillium Asset Management Corporation
[Portions of this comment that are substantively similar to other comments have been omitted.]

In addition, we will be able to retain our position as leaders in efficient truck manufacturing. The United States is currently the world leader in the development, production and use of energy efficient and hybrid trucks. To retain our position, we need clear policy signals.

According to CALSTART, at least 15,000 to 30,000 jobs in truck manufacturing can be retained, and 25,000 additional high efficiency truck technology jobs can be created, if the U.S. leadership in this field is preserved.

Docket Number: TRANS-Cambridge
Commenter: Luke Tonachel, Natural Resources Defense Council

The Heavy-Duty National Program is a historic step forward for protecting the environment, for saving truck operators money at the pump and for boosting jobs. The standards are good for truck manufacturers, because it gives them certainty and lays the foundation for them to be more sustainable businesses in a future world of volatile fuel prices and intensifying global warming. It is good for workers because a stronger industry and lower operating costs mean more, better-paying jobs. The standards are also good for consumers, because they help reduce the cost of shipping goods that all of us buy.

Docket Number: TRANS-Chicago
Commenter: Christopher Miller, Operation Free

The benefits are widespread. I've already mentioned the benefits to national security and our troops. But what about the $74,000 that a trucker could save over the life of a truck, and the $41 billion in savings to American families.

Manufacturers are helping our nation by producing vehicles that reduce our dependence on oil and save American lives abroad. More than 150 U.S. companies are already employing a variety of trucks that make fuel and pollution reductions far beyond the requirements of the proposal being considered today. And individual truck owners who buy cleaner vehicles will save money at the pump that will pay for the upgrade in only a few years. It's time that these more fuel efficient vehicles become the norm.

Docket Number: TRANS-Chicago
Commenter: Mark Kraemer

And increased fuel efficiency in trucks will also help everyone by helping keep gas prices low. And I know this myself because my last two vehicle purchases were hybrid sedans that decreased my fuel consumption by . . . at least half from what I was driving before. And I know that . . . by driving these cars I'm helping to reduce demand at the gas pump. I know that just on an individual level because I don't go to the gas station as much as I used to. I go two to three weeks between gas fill-ups. And when I reduce demand, I'm helping to reduce gas prices, and that helps everyone.

Docket Number: TRANS-Chicago
Commenter: Charles Frank

Insurance costs will be reduced for all of us and for businesses. And there are more obvious benefits of less global warming, pollution, less dependence on imported oil, and our need to go to war over keeping the shipping lanes open for oil tankers, and reduced pollution from those oil tankers as well, when we don't need to keep the lanes open bringing oil over to our country and around the world. Lower fuel costs for trucking reduce the shipping costs for our goods are another benefit.

Docket Number: TRANS-Chicago
Commenter: Michael Ciaccio, International Brotherhood of Teamsters

These new standards will provide an important economic benefit. More efficient trucks could and should improve earnings for drivers because they'll lower the cost of transmitting goods. This will benefit all truck drivers, especially those without union representation, who've seen their real wages decrease more than 30 percent over the past 30 years.

Docket Number: PAPER-Cambridge
Commenter: Carol Lee Rawn, Ceres and the Investor Network on Climate Risk (INCR)
[Portions of this comment that are substantively similar to other comments have been omitted.]

Stricter standards will ultimately save businesses money, since advanced fuel efficient trucks will more than pay for themselves over a typical ownership period. The UCS/CALSTART report concluded that these benefits would accrue to the greater economy; as operating costs come down due to more fuel efficient trucks, business owners and consumers could invest that money in goods and services throughout the economy. According to the report, under stricter standards GDP would expand by $10 billion by 2030. [Footnote omitted].

* * * * *

Finally, companies in a variety of sectors are increasingly interested in tracking Scope 3 emissions, including GHG emissions associated with transportation and freight movement, as part of their publicly disclosed GHG assessment. Thus, a growing number of companies support policies such as strict truck standards that would help them achieve their own GHG emission reduction goals as well as save money.

Docket Number: TRANS-Cambridge
Commenter: Kelly Gallagher

By reducing domestic oil consumption, oil imports are likely to be reduced, and to the extent that these imports are reduced, the U.S. trade deficit would be lessened as well. Based on my research on energy-technology innovation, I also believe that these standards would help to induce innovation in vehicle fuel efficiency technologies and, therefore, possibly result in the development of improved or lower-cost engines and vehicle technologies. If this occurs, these advanced vehicle technologies could be exploited in the U.S. domestic market, as well as exported to other countries. If increased exports of U.S. technologies are achieved, it would improve the manufacturing base here in the United States, which could result in more U.S. jobs as well as further reducing the trade deficit with other countries beyond what would be achieved through having to import less oil.

Docket Number: TRANS-Cambridge; PAPER-Cambridge
Commenter: Mary Ellen Kustin, National Wildlife Federation

We welcome these vehicle rulemakings not just as an essential step forward on climate change, but as a critical driver to replace our oil dependency with made-in-America oil-saving vehicle technology and manufacturing. U.S. manufacturers are making rapid strides to develop highly efficient cars and trucks, and these rules help ensure that American manufacturers can continue to build jobs, improve our trade balance, and assist in an economic recovery.

* * * * *

Standards are critical to capture the full potential benefits in this sector. We applaud EPA and DOT for their work to set these standards, and for including all classes of medium and heavy duty trucks in the standard. Despite the diversity of this sector, recent National Academy of Sciences analysis shows that technologies available today and over the next few years exist to meet these standards, and even to exceed them in many parts of the sector. While US manufacturers are leaders in many parts of advanced truck design and manufacturing, there have been a variety of barriers to investments in truck fuel efficiency technologies by both truck buyers and manufacturers, including: fuel price uncertainty, short-periods of ownership, lack of standardized information on truck fuel efficiency, split tractor-trailer ownership, and others. The new standards can help overcome these barriers, providing truck owners with more options, with cost-effective fuel efficiency technologies and with greater savings, while providing significant environmental and economic benefits to the public.

Docket Number: TRANS-Chicago
Commenter: Thomas Stover, Eaton Corporation

There are many stakeholders in the commercial vehicle market that are pressed by commercial and social responsibilities to improve performance, reduce fuel consumption, and reduce greenhouse gas emissions. What brings us all together is the realization that reducing emissions and fuel burn is good business.

If the new standards are carefully chosen and implemented, they can drive benefits to a broad spectrum of stakeholders by reducing the total cost of operations in the trucking industry, reducing the nation's dependence on foreign oil, fostering innovation, and creating high value jobs while fundamentally improving our environment.

Docket Number: TRANS-Chicago
Commenter: Yvette Pena-Lopez, BlueGreen Alliance
[Portions of this comment that are substantively similar to other comments have been omitted.]

These standards enhance American competitiveness and job creation as domestic truck manufacturers ramp up production of a cleaner fleet of heavy-duty trucks.

* * * * *

Second, complementary truck efficiency programs should take into account trucking's unique market structure and encourage the acquisition of cleaner vehicles by owner-operators and fleets. These supportive measures can help minimize deferral of vehicle purchases, create and sustain more quality jobs, maximize economic benefits to American vehicle component manufacturers, and accelerate gains in fuel efficiency and pollution reduction.

Substantively similar comments were received from: Steve Perlman (PAPER-Chicago); Dan Proctor (TRANS-Cambridge); Peter Zalzal, Environmental Defense Fund (TRANS-Chicago); Rich Stuckney (TRANS-Chicago); Danielle Korpalski, National Wildlife Federation - Great Lakes Office (TRANS-Chicago); James McCaffrey, Massachusetts Sierra Club (TRANS-Cambridge); Don Anair, Union of Concerned Scientists (TRANS-Chicago); and Jonathan Glassman (TRANS-Cambridge).

Response

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 (White House 2010a). In it, the President requested that NHTSA implement fuel efficiency standards and EPA implement GHG emission standards that strengthen the industry and enhance job creation in the United States.

The above comments stress the cost savings that businesses could expect under the proposed rule and its alternatives. Some commenters also noted the potential benefits to the U.S. trade deficit,

economic growth, and job creation. In the NPRM, NHTSA and EPA estimated that fuel savings under the Preferred Alternative would exceed the cost of any additional technology used by manufacturers to comply with the proposed rule. These cost savings could potentially produce additional profits for the HD vehicle industry, strengthening the industry and enhancing job creation in the United States, consistent with the President's directive and the purpose and need of the proposed rule and its alternatives. Similarly, decreased reliance on foreign sources of petroleum could be expected to produce economic benefits for the Nation as well.

Comments

Docket Number: TRANS-Cambridge
Commenter: Catherine Pargeter, Trillium Asset Management Corporation

The report demonstrates that investments in advanced truck technologies would create jobs across the truck manufacturing sectors, from engineers to assembly line workers. As companies incur lower operating costs, due to more fuel efficient trucks, business owners and consumers will be able to make additional investments in other goods and services throughout the economy, including more fuel efficient trucks. The report estimates that the GDP would expand $4 million by 2020 and $10 billion by 2030.

* * * * *

Many companies have said that without clear policy signals from Washington, innovation stalls and capital sits on the sidelines. Setting strong standards will be the signal companies are looking for to begin production that incorporates new technologies. In turn, this will boost production and innovation throughout the supply chain, and allow manufacturers to bring new and more efficient products to revitalize a stagnant market.

Docket Number: TRANS-Cambridge
Commenter: Carol Lee Rawn, Investor Network on Climate Risk

Strict standards will catalyze investment in high efficiency truck technologies, thereby serving to retain the U.S. leadership position in this sector, save businesses money, promote energy security and reduce climate risk.

Docket Number: TRANS-Cambridge
Commenter: Ugo Nwoke, Tochi Technologies and Ohio Business Council for Clean Energy

In every challenge there is an opportunity. I think currently facing us is a great opportunity, really. A greater fuel economy standard will drive up investment in new vehicle technologies and push the envelope in novel materials. Greater efficiency also has direct economic benefits; increasing fuel economy of the medium- and heavy-trucks by 3.5 miles per gallon can save up to $24 billion in 2030, after factoring, obviously, the costs of efficiency technologies. The graph, which is attached to our submission, which is on this document, it shows that with an increase in fuel economy by just 30 percent, when you consider a price range of $2.50 and $6.00 per gallon, a vehicle that was previously getting six miles per gallon will save up to $1,000 for every 15,000 miles driven.

(Graph titled "Miles Driven to $1,000 Saved" shows a near-term market solution based on Miles on the y-axis and Pre-Retrofit MPG on the x-axis.)

Furthermore, more than eight million jobs are riding on the U.S. auto-industry innovations, including the ones that we intend to create. The auto-industry supply—the auto-manufacturers, suppliers, dealers and an array of new industry partners contribute to a jobs multiplier effect of more than four additional jobs for one job in the auto-industry. This number grows when jobs associated with truck manufacturing are included.

Improving the fuel economy of new medium- and heavy-duty trucks could create more than 120,000 new jobs nationwide by 2030, with all 50 states experiencing net job growth

Docket Number: TRANS-Cambridge
Commenter: Matthew Todaro, Boston College Environmental Law Society

The EPA and DOT must not allow the American trucking industry to suffer [competitively]. Instead, EPA and DOT should enact the strongest possible standards to help our truck industry innovate, create new jobs here in America, and develop the technology that can help America lead the world truck industry into an efficient fuel economy, in a fuel-efficient manner.

Docket Number: TRANS-Cambridge
Commenter: Susan Shamel

New fuel standards will foster innovation within America's transportation industries, creating new companies and jobs.

Standards will also help overcome barriers that have hindered investments in truck fuel efficiency technologies by both truck buyers and manufacturers.

Docket Number: TRANS-Chicago
Commenter: Mark Kraemer

But I also believe that when we make our truck fleet more modern and fuel efficient, we are acting in our own best interest both for truckers who will save money on fuel and for truck manufacturers who will have a new, more efficient product to sell to the world. In future years, there will be a strong demand for trucks that conserve fuel and reduce the cost of shipping. If U.S. manufacturers are able to offer the most fuel-efficient trucks to the world market, the automotive industry will reap the benefits and good-paying manufacturing jobs that always follow innovation in America.

Docket Number: TRANS-Chicago
Commenter: Yvette Pena-Lopez, BlueGreen Alliance

This will also create opportunities throughout the U.S. supply chain in producing improved aerodynamics, more efficient engines, hybrid electric drive systems and idling controls that will help achieve fuel efficiency gains.

Docket Number: TRANS-Chicago
Commenter: Thomas Stover, Eaton Corporation

The proposed is a good foundation for what the new regulations can be—giving clear, achievable objectives that spur innovation and deployment while avoiding negative impact on the economy and promoting leadership in commercial vehicle fuel efficiency.

Docket Number: TRANS-Chicago
Commenter: Peter Zalzal, Environmental Defense Fund

The agencies' proposed standards are good for American business. The clear, common-sense regulatory structure will help companies develop clean technology and efficiently get technological innovations to market. In a recent op-ed, Cummins's CEO Tom Linebarger recognized the critical role these standards play in "getting innovations to market that will create economic opportunity for American companies and jobs for American workers." American truck and engine manufacturers are poised to reap the economic benefits of these standards, ensuring that American manufacturers are both leading innovation here at home and leading exporters of advanced green truck technologies.

Docket Number: TRANS-Chicago
Commenter: Danielle Korpalski, National Wildlife Federation- Great Lakes Office

The new standards can help overcome these barriers, providing truck owners more options with cost-effective fuel efficiency technologies and with greater savings while providing significant environmental and economic benefits to the public.

Docket Number: TRANS-Chicago
Commenter: Tony Garcia, International Union UAW

The proposed rule will affect the products manufactured by every one of these members. We believe that the impact on our members will be positive and will help secure the long-term future of manufacturing employees in this sector. The additional technology needed to increase fuel efficiency and reduce greenhouse gas emissions in medium-and heavy-duty vehicles will require additional content. The engineering and manufacture of this additional content will increase employment. This formulation of additional technology requiring more content per vehicle and in turn requiring more employment to produce that content means that the proposed rule will have a positive effect on our manufacturing sector and our nation's economy for many years to come.

Docket Number: TRANS-Chicago; PAPER-Chicago
Commenter: Steve Perlman

And in the long run, it's going to create jobs as well because we can own the technology and own the innovation to push this forward. Then we're going to be a more competitive country. I mean, I can talk about all the environmental benefits, which I am sure have all been noted very well. But the more we look at it from a smart business investment, which is another way to look at it, and I think it's been noted by others, but it creates more national security and lesser dependence on imports and also more efficiency for running our trucks in the future. It's just a smart business decision.

* * * * *

Without strong fuel efficiency standards, American auto makers will fall behind world competition, costing valuable jobs, stalling innovation, and hurting our country's overall transportation efficiency.

Response

As stated in Section 1.4 of the FEIS, the purpose and need of the proposed action is to require the maximum feasible improvement in fuel efficiency for HD vehicles. NHTSA recognizes that manufacturers' adoption of fuel efficiency technologies in response to this rule will spur greater penetration of existing technologies throughout the HD fleet and may lead to the design and

manufacture of new technologies. The technologies likely to be used are considered cost-effective, and this is consistent with the President's directive that the fuel efficiency standards should spur economic growth and create and enhance job creation in the United States.

6.1.1.1 Statutory Interpretation

Comments

Docket Number: 0133
Commenter: Alec Zacaroli, Volvo Group

NEPA, the statutory basis for the EIS requirement, does not apply to EPA activities conducted pursuant to its authority under the Clean Air Act. See 15 U.S.C. 793(c)(1). In the context of this rulemaking, therefore, NEPA only would apply to NHTSA activities. Since NHTSA's program does not independently contribute to GHG/FE improvement and its environmental impacts, however, the EIS is unnecessary.

Response

In setting fuel efficiency standards for HD vehicles, NHTSA and EPA are acting under independent statutory authorities. NHTSA has proposed fuel efficiency standards pursuant to the Energy Policy and Conservation Act (EPCA), 49 U.S.C. § 32901 <u>et seq.</u>, as amended by the Energy Independence and Security Act of 2007 (EISA), and EPA has proposed GHG emission standards under the Clean Air Act (CAA), 42 U.S.C. § 7521(a). NHTSA's authority requires that the agency implement "a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program designed to achieve the maximum feasible improvement." *See* 49 U.S.C. § 32902(k)(2). NHTSA's mandate to promote energy efficiency is independent of EPA's mandate to protect public health and welfare, as the Supreme Court held in <u>Massachusetts v. EPA</u>. 549 U.S. 497, 532 (2007). The joint HD Fuel Efficiency Improvement Program promises to deliver environmental and energy benefits, cost savings, and administrative efficiencies on a nationwide basis that might not be available under a less coordinated approach.

As the commenter recognizes, the National Environmental Policy Act (NEPA) does not apply to EPA's action under the CAA. *See* 15 U.S.C. § 793(c)(1). However, because NHTSA has independent authority to regulate HD vehicles under EPCA, and because NHTSA's action is subject to NEPA, an EIS is necessary to inform NHTSA's action. 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). 42 U.S.C. § 4332. 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 preferred alternative and other proposed alternative actions pursuant to Council on Environmental Quality (CEQ) NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.

Comments

Docket Number: 0079
Commenter: John Walsh, South Carolina Department of Transportation

Controversy exists with the climate change and impact studies upon which much of the climate change analysis is based. NASA's recently published PM2.5 map (http://www.nasa.gov/topics/earth/features/health-sapping.html) indicates US particulate matter density is as much as four times less than other areas of the world where there is more pollution from coal burning, blowing sand, and biomass burning. Are the areas of the world with higher PM2.5 concentrations as diligent as the US in planning to reduce their GHG and other emissions? If not, the only market for more fuel efficient engines and truck related technologies will be in the US. Will the US be at an economic disadvantage by enacting these efficiency improvements?

Response

Under the Energy Independence and Security Act of 2007 (EISA), NHTSA is required to implement "a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program designed to achieve the maximum feasible improvement." ***See*** **49 U.S.C. § 32902(k)(2). EPA has also proposed GHG emission standards under the Clean Air Act (CAA).** ***See*** **42 U.S.C. § 7521(a). These statutory authorities apply regardless of whether other countries take action to address their $PM_{2.5}$ emissions. Furthermore, the fact that other regions may emit significantly larger quantities of $PM_{2.5}$ does not lessen the importance of curbing emissions here in the United States; nor does it reduce the need to address the environmental impacts of those emissions.** ***See Massachusetts v. EPA*****, 549 U.S. 497, 523-26 (2007).**

NHTSA believes that the proposed rule will not put the U.S. at an economic disadvantage. The costs and benefits of the proposed rule were discussed at length in the NPRM and will be addressed again in the forthcoming final rule and its associated documents. We note again that the agencies projected in the NPRM and draft RIA that the fuel savings resulting from the proposed rule would exceed the expected increase in cost per vehicle. Furthermore, as discussed in Chapters 3 and 4 of this FEIS, the agencies predict significant fuel savings, air quality benefits, climate benefits, and improved health outcomes as a result of this rulemaking.

6.1.2 Joint Rulemaking

Comments

Docket Number: TRANS-Cambridge
Commenter: Gary Oshnock, Chrysler Group LLC

Chrysler strongly believes that a single national fuel economy and greenhouse gas program will place more clean and efficient vehicles on the road quickly and at lower costs. Our resources are best utilized when applied with one single national standard, versus differing state level fuel economy and greenhouse gas requirements.

Docket Number: TRANS-Cambridge
Commenter: Ronald Minsk, Securing America's Energy Future (SAFE)

This administration has decided to tie fuel economy regulations to greenhouse gas emission regulations. SAFE wants to point out that addressing climate and energy security are both important national goals, but they are not the same thing. One can address climate issues without addressing energy security issues. And there are separate and different energy security benefits that one can achieve beyond the benefits of addressing climate change. This, however, is one area where the issues are particularly closely aligned. If the proposed rule goes final, consistent with its current structure, increasing the fuel economy of the nation's fleet of medium- and heavy-duty vehicles will reduce their carbon emissions, allowing us to pursue two important national goals at once.

Docket Number: 0121
Commenter: Jed Mandel, Engine Manufacturers Association

In addition, it is vitally important, as the Agencies have recognized, that there be one, and only one, HD National Program. The market for HD vehicles and engines, and the manner in which they are built, sold and operated, simply cannot accommodate any differing or disparate GHG/FE standards.

Docket Number: 0129
Commenter: Robert Jorgensen, Cummins Inc.

Alignment between the EPA CO_2-based standards and the NHTSA fuel consumption-based standards is critical in achieving a single national program. Cummins believes the proposal achieves this alignment through its proposed method of measuring CO_2 then converting to fuel consumption.

Response

NHTSA agrees with the comments that a single National Program to regulate the closely related issues of fuel efficiency and GHG emissions of HD vehicles is important. The HD Fuel Efficiency Improvement Program promises to deliver 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 and inconsistent Federal programs.

6.2 THE PROPOSED ACTION AND ALTERNATIVES

6.2.1 Proposed Action

Comments

Docket Number: 0134
Commenter: John Boesel, CALSTART

We believe that greater fuel and emission reductions in the early years are possible. We understand why EPA has taken the deliberative approach it has to phase in the rule, but would encourage all actions possible to achieve earlier reductions from innovative technologies, fuels or approaches.

Docket Number: 0126
Commenter: Charles Uthus, American Automotive Policy Council

The agencies' proposed standards for heavy-duty pickup trucks and vans would result in greenhouse gas (“GHG”) and fuel consumption reductions of 10 percent for gasoline-powered vehicles and 15 percent for diesel-powered vehicles. Although some commenters at the public hearings . . . stated that the stringency of these standards should be increased, there are multiple reasons supporting the agencies’ approach to this rulemaking: … [Footnote omitted].

Docket Number: TRANS-Cambridge
Commenter: Jed Mandel, Engine Manufacturers Association and Truck Manufacturers Association

[W]e do think that the standards that the agencies proposed are pretty aggressive in the timeframe, and we want to be careful not to make it impractical to implement in that timeframe. Obviously, we, and our customers have long been interested in fuel efficiency, so anything that can be done to improve fuel efficiency is desirable.

Docket Number: 0090
Commenter: Tracey Norberg, Rubber Manufacturers Association

During the EIS process, NHTSA should evaluate the various options available for the metric of the regulation. NHTSA should ask, “What is the measure of efficiency?” In this country, the traditional metric for assessing light-duty vehicle fuel efficiency is miles per gallon. However, in the light-duty context, the variability of vehicle load is much narrower, and the regulated vehicles are largely consumer vehicles. NHTSA should consider whether other metrics are more appropriate in the context of medium and/or heavy trucks. For example, NHTSA should evaluate the appropriateness of a metric related to the vehicle load, such as tons of freight hauled per gallon, or some similar metric. Another candidate may be gallons per ton-mile, which is commonly used in Europe.

However, if NHTSA chooses to use a metric not related to load, NHTSA should evaluate on what load would be appropriate to base the metric. In other words, if miles per gallon or gallons per mile is chosen, NHTSA should specify a realistic percent of maximum vehicle load or other similar metric so that all vehicles are evaluated under the same load assumption.

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

In light of the urgency of taking action to avoid the worst results of climate change, the standards should go into effect as soon as the law allows, i.e., four years after finalization of the proposed rule in 2011 (thus, beginning with MY 2015). Further, NHTSA's laudable plan to develop an optional voluntary compliance standard before mandatory standards take effect should begin with Model MY 2011-2014, not MY 2014-2015. [Footnote omitted].

Response

EISA requires NHTSA to institute a fuel efficiency improvement program that achieves the "maximum feasible" improvement based upon considerations of appropriateness, cost-effectiveness, and technological feasibility. *See* 49 U.S.C. § 32902(k)(2). NHTSA has balanced these factors to derive a range of alternatives analyzed in this EIS. NHTSA believes that the Preferred Alterantive reflects a reasonable and appropriate balancing of the statutory factors. For further explanation of NHTSA's balancing of the statutory factors, *see* section III of the NPRM.

Regarding the comment that NHTSA should determine the appropriate metric for this rulemaking, the agency agrees that vehicle load plays a much greater role in the context of medium- and heavy-duty vehicles than for light-duty vehicles. Thus, NHTSA and EPA have proposed test metrics that express fuel consumption and GHG emissions relative to the most important measures of heavy-duty truck utility for each segment, consistent with the recommendation of the 2010 NAS Report.

For heavy-duty pickup trucks and vans, EPA and NHTSA proposed standards on a per-mile basis (g/mile for the EPA standards, gallons/100 miles for the NHTSA standards). For heavy-duty trucks, both combination and vocational, the agencies proposed standards expressed in terms of the key measure of freight movement, tons of payload miles or, more simply, tonmiles. Hence, for EPA the proposed standards were in the form of the mass of emissions from carrying a ton of cargo over a distance of one mile (g/ton-mi)). Similarly, the proposed NHTSA standards were in terms of gallons of fuel consumed over a set distance (one thousand miles), or gal/1,000 ton-mile. Finally, for engines, EPA proposed standards in the form of grams of emissions per unit of work (g/bhp-hr), the same metric used for the heavy-duty highway engine standards for criteria pollutants today. Similarly, NHTSA proposed standards for heavy-duty engines in the form of gallons of fuel consumption per 100 units of work (gal/ 100 bhp-hr). This EIS analyzes and discloses the environmental impacts associated with the proposed standards. For more information about the proposed standards, *see* Section II of the NPRM.

As stated above, the agencies received numerous comments relating to the proposed rule; those comments will be addressed in the forthcoming rulemaking documents. While comments regarding the timing of the proposed regulation are more germane to the proposed rule, a similar comment was specifically addressed to the EIS. NHTSA appreciates the suggestion that the standards go into effect beginning with MY 2015, with voluntary standards beginning earlier as well. However, the agency interprets such action to be contrary to EISA's intent to provide "not less than . . . four model years of regulatory lead time." *See* 49 U.S.C. § 32902(k)(3). For more information regarding the timeframe of the agency's proposed rule, please consult the NPRM or the forthcoming rulemaking documents.

6.2.2 Vehicle Classes 2B and 3: 8,501-14,000 lbs (Heavy Duty Pickups)

Comments

Docket Number: NHTSA-2010-0079-0110-8, 0110-17
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

The agencies' proposal to reduce fuel consumption by 10% from gasoline vehicles and 15% from diesel vehicles by 2018 can and should be strengthened in order to maximize the benefits of improved fuel economy and reduced GHG emissions in this sector, using commercially viable technologies. We support the agencies' approach to require full vehicle emissions and fuel consumption testing for the class 2b and 3 vehicles. However, based on the findings of the NAS study, we believe the potential reduction for this sector could be greater than required under the proposed rule. The NAS study found that a 30 percent reduction could be achieved without hybridization in Class 2b trucks between 2015 and 2020. We encourage the agencies to consider more stringent standards for this class of vehicles for the 2018 timeframe.

Docket Number: 0142
Commenter: Janice Nolan, Hilary Sinnamon, Peter Zalzal, Katie Patterson, and Britt Groosman - American Lung Association and Environmental Defense Fund

In addition, the proposed package for gasoline pickups and vans did not include cost-effective technologies like cylinder deactivation and coupled cam phasing, which are capable of reducing CO_2 by 4 to 8 percent. Adding these two technologies to the agencies' proposed gasoline package would provide a reduction of 15 percent, according to EPA's Lumped Parameter Model. (Footnote 18: Based an analysis by ACEEE). The revised package offers a payback in less than 4 years, which is less than the payback period for the agencies' original package. Therefore, we request the agencies require gasoline pickups and vans to achieve at least a 15 percent reduction over 2010 levels by 2018.

Docket Number: TRANS-Cambridge
Commenter: Coralie Cooper, Northeast States for Coordinated Air Use Management

We ask the agencies to consider increasing the stringency of the standards in each of the three vehicle categories included in the rule: Tractor trailers, vocational vehicles and Class (2b) and Class (3) vehicles.

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And then, at last on Class (2b) and Class (3) vehicles. We support the agencies' approach to require full vehicle emissions and fuel consumption testing for the Class (2b) and Class (3) vehicles. Furthermore, we concur with the assumption that technologies used to comply with the 2012 to 2016 light-duty vehicle standards will be used to comply with the Class (2b) and Class (3) category standards. The agencies have proposed a 15 percent reduction in fuel consumption and emissions for diesel vehicles, and a 10 percent reduction for gasoline vehicles in 2017. Based on the findings of the National Academy of Sciences '09 study, we believe the potential reduction for this sector could be greater. The Academy study found that a 30 percent reduction could be achieved without hybridization in Class (2b) trucks between 2015 and 2020. Thus, we encourage the agencies to consider more stringent standards for this class of vehicles for the 2017 timeframe.

Docket Number: TRANS-Cambridge
Commenter: David Marshall, Clean Air Task Force

With respect to heavy pickups and vans, the National Academy of Sciences report found that fuel consumption in the Class (2b) sector could be reduced by about 45 percent in the 2015 to 2020 timeframe. EPA's proposal calls only for a 10 to 15 percent reduction by 2018, and appears to be based on technologies supporting EPA's light-duty standards for the 2012 to 2016 timeframe. We believe EPA should not only tighten the standards for these pickups and vans, but also fully phase them in by 2016, in the same timeframe as the light-duty fleet.

Docket Number: TRANS-Chicago
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

Regarding work trucks, here again we agree that there are additional opportunities for savings that have not been captured by the proposed stringency. And I would just observe that the proposed level of those standards almost—for 2018—almost exactly matches the projected fuel efficiency of work trucks in the Energy Information Administration forecast in a business-as-usual scenario; so that is to say that in the absence of regulation, the EIA is projecting that same 11 percent reduction from 2010 levels. And we also think that at a minimum, that work truck standards proposed for 2018 should be fully phased in by 2016 to allow for further increases in the succeeding years.

Docket Number: TRANS-Chicago
Commenter: Ann Mesnikoff, Sierra Club - Green Transportation Campaign

For class 2B trucks, we believe that both agencies are setting too low a bar. The proposed rule recognizes that the primary manufacturers of these vehicles—work trucks, large pickup trucks—are GM, Ford, and Chrysler, and these are the companies that are already making improvements to these vehicles for the 2012 to 2016 standards in smaller or less heavy of the work truck vehicles. In the final rule, DOT and EPA should accelerate the timeline for improving these vehicles and ensure that the full range of available technologies are considered to maximize the oil savings and emission reductions for work trucks and vans.

Docket Number: 0126
Commenter: Charles Uthus, American Automotive Policy Council

The NAS Report justifies the level of standard stringency proposed by the agencies and does not support significantly more stringent standards.

During the Public Hearings, several commenters representing various NGOs and private citizen members of those NGOs commented that they believed that the recent NAS report supported greater levels of CO_2 and fuel consumption improvements than those proposed for Class 2b-3 complete and cab-complete vehicles. However, these commenters failed to consider several issues:

The baseline vehicles upon which the NAS Report is formulated had significantly lower technology levels than those used by the agencies for a baseline fleet, making larger improvements appear possible. In general, the vehicles used as a baseline in the NAS report represented 2008 or earlier model year vehicles as compared to the 2010-2011 model year baseline fleet used by the agencies. The NAS approach resulted in “potential” improvements that are already included in the agencies’ baseline fleet. For example, the NAS baseline vehicle utilized a 4-speed automatic transmission whereas the agencies’ baseline vehicles commonly utilized 5- to 6-speed transmissions. Further examples of improvement technologies used by the NAS in their evaluation, but already commonly available in the agencies’ baseline fleet were friction reduction, variable valve timing, aerodynamic improvements, and advanced diesel after-treatment systems.

Although the NAS Report considered hybridization of Class 2b-3 vehicles as part of its evaluation (showing a potential benefit of 18%), such high cost technologies are generally not an economically viable option for consumers and manufacturers. For example, the NAS Report finds that if hybridization is included, the estimated break-even fuel price for Class 2b pickup improvements is $4.80/gallon. According to the U.S. Energy Information Administration, estimated 2020 fuel prices ($2009) are $3.382/gal and $3.526/gal for gasoline and diesel fuels respectively.

The NAS Report states that "some of the technologies evaluated in this report may be available later than expected, or at a lower level of performance than expected… regulators will need to allow for the fact that some technologies may not mature as expected."

Response

The proposed standards for Class 2b and 3 heavy-duty pickups and vans are based on a set of vehicle, engine, and transmission technologies expected to be used to meet the recently established fuel economy standards for MY 2012-2016 light-duty vehicles, with full consideration of how these technologies are likely to perform in heavy-duty vehicle testing and use. In developing the proposed standards for heavy-duty pickups and vans, NHTSA evaluated over 35 technologies that manufacturers could use to improve the fuel consumption of their vehicles during MY 2014-2018. The technologies considered in the agency's analysis fall into five broad categories: engine technologies, transmission technologies, vehicle technologies, electrification/accessory technologies, and hybrid technologies. *See* Chapter 2 of the draft RIA. These technologies are either in use or have been announced for upcoming model years in some light-duty vehicle models, and some are in use in a portion of heavy-duty pickups and vans as well.

After reviewing the technology assessments from the NAS report, the joint light-duty MY 2012-2016 CAFE rulemaking, and information provided by the commenters about the stringency of these standards, NHTSA believes that the proposed standards and alternatives are reasonable considering the available lead time and costs to bring the necessary technologies to market and NHTSA's assessments of the efficacy of the technologies when applied to heavy-duty pickup trucks and vans. The agency believes the range of alternatives, and the technologies reflected therein, properly bracket where the "maximum feasible" standards would fall for these vehicles.

Since the manufacturers of heavy-duty pickups and vans generally have only one basic pick-up truck and van with different versions (*i.e.*, different wheel bases, cab sizes, two-wheel drive, four-wheel drive, etc.) and do not have the flexibility of the light-duty fleet to coordinate model improvements over several years, changes to heavy-duty pickups and vans to meet new standards must be carefully planned with the redesign cycle taken into account. The opportunities for large-scale changes (e.g., new engines, transmission, vehicle body and mass) thus occur less frequently than in the light-duty fleet, typically at spans of eight (8) or more years. However, opportunities for gradual improvements not necessarily linked to large scale changes can occur between the redesign cycles. Examples of such improvements are upgrades to an existing vehicle model's engine, transmission, and aftertreatment systems. Given this long redesign cycle and NHTSA's understanding of where the different manufacturers are in that cycle, NHTSA believes the range of alternatives properly bracket the "maximum feasible improvement" that may be obtained by these vehicles.

6.2.3 Vehicle Classes 7 and 8: 26,000+ lbs (Tractors)

Comments

Docket Number: TRANS-Cambridge
Commenter: Gina Coplon-Newfield, Sierra Club-Green Transportation Department

Sierra Club joined with our allies to ask the Administration to cut fuel consumption in freight trucks by 35 percent. We urge the agencies to achieve this goal. Our work as part of the Go60MPG dot org coalition will continue as we urge the Administration to set strong standards for all vehicles.

Docket Number: TRANS-Chicago
Commenter: Rita Billon

The technology exists today to ensure a 35-percent reduction in fuel consumption of long-haul tractors pulling trailers by 2018. The standards set by [the] Environmental Protection [Agency] and DOT should ensure that we don't aim lower than what's technically possible today. A 35-percent reduction in oil use by long-haul freight trucks along a 20-percent reduction in oil use by other trucks covered in this rule would result in 5.6 gallons of oil saved annually by 2030.

Response

EISA requires that NHTSA consider and balance three statutory factors (*i.e.*, appropriateness, cost-effectiveness, and technological feasibility) when setting maximum feasible fuel economy standards for commercial medium- and heavy-duty on-highway vehicles and work trucks. 49 U.S.C. § 32902(k)(2). The agency has carefully balanced these factors in setting forth the alternatives under consideration in this EIS, with the goal of setting standards at the maximum feasible level.

For Class 7 and 8 tractors, NHTSA has proposed setting standards separately for the tractor cab and engine that is installed in the tractor. Together these proposed standards would achieve reductions of up to 23 percent from tractors by MY 2017 when compared to a baseline 2010 model year tractor. The technologies that the agency is analyzing to set the final tractor standards include improvements in aerodynamic design, lower rolling resistance tires, extended idle reduction technologies, and lightweighting of the tractor. NHTSA believes that Class 7 and 8 engine standards should reflect technological improvements in combustion and overall engine efficiency through technologies such as engine friction reduction, aftertreatment optimization, and turbocompounding.

The agency believes that the alternatives under consideration for Class 7 and 8 tractors properly bracket the range within which the maximum feasible standards would fall and within the balance required to be struck by EISA. Although commenters did not identify which technologies are available to achieve 35 percent reductions in this vehicle class, NHTSA believes that requiring increased technology penetration beyond what the agency has modeled would exceed maximum feasibility.

6.2.4 Vocational Vehicles (All Classes)

Comments

Docket Number: 0110
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

The proposed standards for vocational trucks consider only the benefits from engine efficiency improvements and low-rolling-resistance tires. We urge the agencies to strengthen the standards for this vehicle category to reflect the potential for other viable technologies, such as improved aerodynamics, mass reduction, advanced transmissions, and hybridization. A 2010 National Academy of Sciences (NAS) study found that fuel consumption could be reduced by up to 50% for some types of vocational vehicles using a combination of these advanced technologies.

Moreover, Pike Research projects medium- and heavy-duty hybrid sales of 300,000 vehicles annually, equal to about 7 percent of total projected sales, by 2015.

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The proposed rule would require a 7 to 10 percent reduction in GHG emissions from vocational trucks by 2017. However, assuming modest gains from hybridization and other improvements consistent with the NAS study, we believe that substantial additional savings will be achievable in the same timeframe. We urge the agencies to require vocational trucks to reduce emissions by at least an additional 5 percent for light and medium vehicles, and an additional 3 percent for heavy vehicles by 2017 in order to promote the production of hybrids and the faster uptake of advanced technologies.

Docket Number: PAPER-Chicago
Commenter: Miranda Carter, Environment Illinois

Additional technologies beyond engine and tire improvements, including hybrid engines (20-40 percent), advanced transmissions (2-4 percent), and weight savings (2-4 percent), should be considered in setting vocational vehicle standards.

Docket Number: TRANS-Cambridge
Commenter: Coralie Cooper, Northeast States for Coordinated Air Use Management

The agencies proposal for medium- and heavy-duty vocational vehicles is technically feasible in the timeframe proposed, but further improvements could be realized in this sector as well. A 2010 National Academy of Sciences study on technologies to reduce medium- and heavy-duty truck fuel consumption found that 38 to 50 percent of some vocational vehicle fuel consumption, bucket trucks, for example, could be reduced with hybridization, engine improvements, weight reduction and transmission improvements. Without hybridization, the Academy's study found that approximately 18 percent of fuel consumption can be reduced in the 2015 to 2020 timeframe. The EPA/NHTSA proposal requires a seven to ten percent reduction in the same timeframe for these types of vehicles. In the EPA/NHTSA proposal, a number of technologies can be used to earn credits through the advanced technology and innovative provisions, but the standards will not require the use of these technologies. NESCAUM and NACAA urge the agencies to establish more stringent standards in the final rulemaking for this class of vehicles that will require the introduction of these technologies

Docket Number: TRANS-Cambridge
Commenter: David Marshall, Clean Air Task Force

Second, hybrid technology and other drivetrain technologies, such as advanced transmissions, can provide significant additional fuel economy benefits, especially for vocational trucks that experience a fair amount of start and stop driving. EPA's standards for vocational trucks should reflect the availability of these technologies.

Docket Number: TRANS-Cambridge
Commenter: Luke Tonachel, Natural Resources Defense Council

The vocational truck standards should be strengthened to include technologies beyond engine and tire improvements, such as hybrid powertrains, advanced transmissions and advanced, lightweight materials. The agencies note that these technologies deliver fuel savings far beyond those required by the standards, and are cost-effective in certain applications today.

Docket Number: 0112
Commenter: Vera Pardee, Center for Biological Diversity

In the case of vocational vehicles in particular, the Agencies have gravely shortchanged the process. They limit performance improvements to just two types of technologies – tire resistance and engine technologies – but leave out entire categories ("[a]erodynamics technology, weight reduction, drive train improvement, and hybrid powertrains") because grappling with setting standards based on these technologies would be "difficult." While it is true that the number of different types of vocational vehicles and their manufacturers increase the complexity of this vehicle segment, these circumstances do not excuse the Agencies from requiring the use of available, feasible, and cost-effective technologies. Aerodynamics, regenerative breaking/acceleration, idling reduction, hybrid powertrains and the use of advanced materials to reduce weight could achieve tremendous additional improvements – between 20 to 50 percent fuel use reductions in the case of hybrid powertrains alone.

Docket Number: TRANS-Cambridge
Commenter: Mary Ellen Kustin, National Wildlife Federation

These proposed rules are a critical first step, and we see a number of opportunities for even greater improvements…it's been referred to already, encouraging greater use of hybrids, advanced transmissions and weight reduction in vocational trucks…

Docket Number: 0079
Commenter: John Walsh, South Carolina Department of Transportation

The draft environmental impact statement alternative 8 analysis did not include other viable energy storage technologies such as "ultra capacitors, high-speed flywheels, and hydraulic accumulators". Consequently, alternative 8 costs and risk are probably overstated. For vocational truck applications, these are technologies that can supplement or replace hybrid electric technologies already in production for passenger vehicles and may have the greatest potential of increasing vocational truck fuel economy.

Response

NHTSA assessed the technologies suggested by the commenters for vocational vehicles and has concluded that although these technologies may have the potential to reduce fuel consumption, the agency has not been able to estimate baseline fuel consumption for each type of vocational vehicle

and for each type of technology given the wide variety of models, configurations, and uses of vocational vehicles. For example, idle reduction technologies such as auxiliary power units and cabin heaters can reduce workday idling associated with vocational trucks. However, characterizing idling activity for the vocational segment in order to quantify the benefits of idle reduction technology is complicated by the variety of duty cycles found in the sector. Idling in school buses, fire trucks, pick-up trucks, delivery trucks, and other types of vocational vehicles varies significantly. Similarly, for advanced drivetrains and advanced transmissions, determining a baseline configuration, or a set of baseline configurations, is extremely difficult given the variety of trucks in this vehicle segment.

NHTSA does not believe that the agency can base standard stringency on the use of technologies for which the agency cannot identify baseline configurations, because baseline emissions and fuel consumption are the benchmarks against which standards are developed. For some technologies, such as weight reduction and improved auxiliaries (e.g., electrically driven power steering pumps) the need to limit technologies to those under the control of the chassis manufacturer restricted the agency's options for incorporating the technologies into the proposed standards. For example, lightweight components that are under the control of chassis manufacturers are limited to very few components, such as frame rails.

Considering the fuel efficiency benefits that will be achieved by finalizing the rule in the timeframe proposed, rather than delaying it in order to gain more information to include additional technologies in the complex and varied universe of vocational vehicles, NHTSA proposed standards that do not assume the use of technologies suggested by the commenters.

NHTSA disagrees with the comment that the costs were overstated for Alternative 5 (Alternative 8 in the DEIS), as the agency based its cost estimates for each vehicle class from the National Academy of Sciences (NAS) Report findings. Specifically, the agency assumed that a hybrid powertrain would provide a 32 percent reduction in fuel consumption for a vocational vehicle at a projected cost of $26,667 per vehicle, based on the average of the NAS report findings for box trucks, bucket trucks, and refuse vehicles. NHTSA projected a cost of $9,000 per vehicle for pickup trucks and vans with an effectiveness of 18 percent. Lastly, the effectiveness of hybrid powertrains installed in tractors was assumed to be 10 percent at a cost of $25,000.

6.2.5 Adoption of More Aggressive Alternatives

Comments

NHTSA received several general comments regarding the stringency of the proposed action and alternatives. Commenters often raised substantially similar points. Representative comments are presented below:

Docket Number: PAPER-Chicago
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

We also believe however that the proposal can and should be strengthened to capture more of the available fuel savings, to ensure support for the program among regulated entities and the public, and to establish precedents that will facilitate future improvements in the program.

Docket Number: TRANS-Cambridge
Commenter: David Marshall, Clean Air Task Force

We also support separate standards for engines, although we think the standards proposed could be strengthened.

Docket Number: TRANS-Cambridge
Commenter: James McCaffrey, Massachusetts Sierra Club

We urge DOT and EPA to issue the strongest possible standards by 2018, a 35 percent reduction in oil use from long-haul tractors pulling van trailers, and a 20 percent reduction in oil use from all other trucks, and make vehicle standards part of a national transportation plan that moves our nation beyond oil.

Docket Number: PAPER-Cambridge
Commenter: Roger Shamel

A huge misinformation campaign by the corporate giants has unfortunately left many Americans clueless about this issue. It is imperative that those of us who understand do everything in our power to begin to transition us away from our dependence on fossil fuels. I urge the EPA and DOT to move forward with the strongest fuel standards possible for medium and heavy-duty trucks.

Docket Number: TRANS-Chicago
Commenter: Ann Mesnikoff, Sierra Club – Green Transportation Campaign

The Sierra Club welcomes the proposed rule but urges that both agencies ensure that standards deliver on both the urgency of reducing global warming pollution and the need to end our dangerous addiction to oil. There are clear opportunities to increase stringency of these standards for all of the trucks covered, and additional steps such as trailer standards must be taken.

Sierra Club joins with the Union of Concerned Scientists, National Resources Defense Council, Environment America, and other groups in asking the Administration to cut fuel consumption in freight trucks by 35 percent. We urge the agencies to achieve this goal in a combination with car standards of at least 60 miles per gallon in 2025 and deliver as much as 49 billion gallons of oil savings in 2030. Our work as part of go60mpg.org coalition will continue as urge the Administration to set strong standards for all vehicles.

Docket Number: TRANS-Chicago
Commenter: Don Anair, Union of Concerned Scientists

One area where the proposal could be improved is on stringency. As proposed, the standards would capture many of the benefits of technology available today but fall short of what is possible in the 2014 to 2018 timeframe. To meet the President's goals and to meet the requirements of the Clean Air Act, standards should maximize oil savings and emissions reductions based on improvements available across the entire vehicle. They should also be stringent enough to spur investments in next-generation technology.

Docket Number: PAPER-Cambridge
Commenter: Mary Ellen Kustin, National Wildlife Federation

These standards are a critical first step, and we see a number of opportunities for even greater improvements. These opportunities include setting efficiency standards for the trailer portion of long haul tractor trailers; encouraging greater use of hybrids, advanced transmissions and weight reduction in vocational trucks, and for the 2B work trucks, taking full and more rapid advantage of the technologies that are being developed to meet the 2012-2016 light duty vehicles rule.

Substantively similar comments were received from: Miranda Carter, Environment Illinois (PAPER-Chicago); Gina Coplon-Newfield, Sierra Club – Green Transportation Department (TRANS-Cambridge); David Heimann (TRANS-Cambridge)

Response

In proposing fuel consumption standards for HD vehicles, NHTSA is acting pursuant to the Energy Independence and Security Act of 2007 (EISA), which requires the agency to consider three factors when determining "maximum feasible" fuel efficiency improvement for the HD sector – "appropriateness, cost-effectiveness, and technological feasibility." 49 U.S.C. § 32902(k)(2). NHTSA has balanced these considerations and believes that the alternatives under consideration properly bracket the range within which the maximum feasible standards would fall. Furthermore, the agency has balanced those factors in a way that achieves substantial fuel economy gains. Setting more aggressive standards beyond what the agency has modeled would exceed maximum feasibility. NHTSA also notes that electing to impose more aggressive standards would impose substantial additional costs on the heavy-duty industry. Overly aggressive standards would not achieve the result intended by EISA, *i.e.*, meeting the overarching goal of energy conservation while also weighing cost-effectiveness and technological feasibility.

6.2.5.1 Maximum Feasible Standard (*i.e.*, Technology-forcing Alternative)

Comments

Docket Number: 0025; 0081; 0112
Commenter: Vera Pardee, Center For Biological Diversity

NHTSA should present alternatives that are truly technology forcing. In its Notice, NHTSA describes four alternative approaches (plus a business-as-usual or baseline approach) to achieving maximum fuel efficiency, each increasing in stringency by applying what appear to be currently available fuel efficiency improvement technologies to an increasing number of emission sources within the MD/HD Vehicles class (engines, tractors, trucks, and trailers). Given the urgency of the issue as demonstrated by the best available science, and given the statutory mandate that NHTSA achieve the "maximum feasible improvement", 442 U.S.C. § 32902(k)(2), it is inconceivable that Alternatives 2, 3 or 4 should be given any weight, and that anything less than Alternative 5 could be justified. We agree with the NAS Study's conclusion that "selectively regulating only certain vehicle classes would lead to very serious unintended consequences and would compromise the intent of the regulation," NAS Study at S-13, adding only that all vehicle classes as well as engines and trailers should be simultaneously regulated.

Moreover, the Center is concerned that none of the alternatives appear to be truly technology forcing, in that the forthcoming standards, even though they are some five years away from implementation, do not seem to anticipate technological improvements by setting performance standards in excess of what existing technologies can produce.

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The Agencies have not included alternatives that truly represent the maximum technologically feasible fuel efficiency improvement achievable during the rulemaking period, and have also rejected technology-forcing measures from consideration. We urge the Agencies to present and fully analyze such alternatives, a step we believe is mandated by the National Environmental Policy Act ("NEPA").

* * * * *

The DEIS fails to present and discuss a fuel efficiency improvement alternative that incorporates all technical fuel efficiency improvements that can feasibly be implemented during the rulemaking period. Because, under the applicable statutes, the proposed HD vehicle rule (the "HD Vehicle Rule") must implement fuel efficiency standards that achieve the maximum feasible improvement in HD Vehicle fuel efficiency, the environmental impact statement for the rulemaking must, at a minimum, present, discuss, and analyze at least one alternative that actually incorporates all improvements that are technically feasible during the rulemaking period, including technology-forcing measures. The DEIS, however, does not present such an alternative, and therefore does not discuss the relevant environmental impacts its implementation would entail. [Footnote omitted].

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[W]hile NHTSA must consider whether the standards it sets are appropriate for the vehicles at issue, are cost-effective, and are technologically feasible, the resulting standards cannot fail to deliver "the maximum feasible improvement."

Center for Biological Diversity v. NHTSA established that, in fulfilling its duties under Section 32902(a), NHTSA "cannot set fuel economy standards that are contrary to Congress's purpose in enacting the EPCA – energy conservation," it cannot act arbitrarily and capriciously; it cannot advance conclusions unsupported by the evidence; if it conducts cost-benefit analyses, it may not assign values of zero to benefits that can be ascertained within a range; and it cannot bias its cost-benefit analysis. Section 32902(k) imposes the same requirements. In addition, fuel efficiency standards under EPCA and EISA must be technology-forcing. [Footnotes omitted].

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The Environmental Impact Statement ("EIS") accompanying a rulemaking under EPCA, EISA, and the Clean Air Act must therefore include at least one alternative that does encompass the maximum technologically feasible improvement achievable, must include technology-forcing measures, and must bring their environmental impact (and those of other alternatives discussed), into sharp focus.

* * * * *

For HD Vehicles, technologies exist or can feasibly be developed within the rulemaking period to reduce emissions up to 50% in model year 2017. The DEIS should analyze and discuss the alternatives that can reach that result, even if they are not the Agencies' preferred alternative. In each case, the amount of reductions in emissions of greenhouse gases and other pollutants and the fuel savings left on the cutting table because a more efficient alternative was not chosen should be clearly identified and monetized.

The need to discuss a truly technology-forcing alternative that includes all technologies that exist or can be developed during the rulemaking period is especially urgent since, as the Agencies point out, vehicle miles traveled ("VMT") are expected to continue to increase during the rulemaking period, and indeed more than offset the fuel efficiency gains projected under all of the alternatives the Agencies have so far chosen to analyze. As the DEIS points out, EPA's criteria pollutant regulations have decreased total pollution by up to 97 percent even while vehicle miles traveled have continued to increase. The Agencies' analysis showing that even the most stringent alternative they have so far considered increases greenhouse gas emissions by up to 13.6 percent in 2020 underscores the fact that the HD Vehicle Rule fails the legislative mandate. We urge the Agencies to remedy this defect in the Final Environmental Impact Statement ("FEIS") (and final HD Vehicle Rule).

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Even if presently some measure of doubt exists as to whether the technology can be fully implemented by 2017, the technology-forcing mandates of EPCA, EISA and the Clean Air Act urge its inclusion.

But regardless of the final decision the Agencies will make in the rulemaking, the DEIS must include bottom cycling as part of a presentation of a truly "maximum feasible" efficiency improvement option, along with all other such fuel improvement technologies. Omission of these technologies from consideration deprives the decision-maker and the public of the opportunity to fully assess the environmental impacts that could be avoided, and the benefits in improved fuel efficiency and reduced pollution that could be achieved, and thus runs counter to NEPA's mandate.

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The Agencies' failure to drive toward maximum feasible results, and its substitution of inappropriate, non-statutory goals to lead its decision-making is apparent in many instances. For example, they state that "[b]y focusing on existing technologies and well-developed regulatory tools, the agencies are able to propose rules that we believe will produce real and important reductions in GHG emissions and fuel consumption within only a few years". Constructing standards based on existing and well-developed technologies takes no account of the technology-forcing mandate of EPCA, EISA and the CAA. The relevant statutes do not call for fuel efficiency improvements that are "real and important," but for maximum feasible improvements [Footnote 11: See also id. at 74213 ("This proposal is based on the need to obtain significant oil savings and GHG emissions reductions from the transportation sector, and the recognition that there are appropriate and cost-effective technologies to achieve such reductions feasibly") (emphasis added); and passim]. [Footnote omitted].

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The Agencies Fail to Present an Alternative That Represents the Maximum Feasible Emission Reductions and Fuel Consumption Improvement. None of the ten alternative stringencies the Agencies present in the Proposed Rule and the accompanying DEIS contains all of the available technologies to reduce fuel consumption and greenhouse gas emissions. Although Alternative No. 8 – presented as the most stringent alternative – adds hybrid powertrain technologies for vocational vehicles and heavy-duty pickups and vans, it excludes, at a minimum, both the use of bottoming cycles for Class 7 and 8 tractors and weight reduction of 10 percent for heavy-duty pickups and vans (technology additions assumed for Alternative 6b). Also excluded, inter alia, are the four technology categories rejected for vocational vehicles]. Moreover, the Agencies have not calculated the monetized net benefits associated with either Alternative 6b or Alternative 8. This omission deprives the public and decision-makers of crucial information required to compare and weigh the Agencies' preferred alternative (Alternative 6) against either of these two alternatives, both of which would achieve significantly better greenhouse gas emissions and fuel efficiency. We urge the Agencies to provide complete information and a truly technology-forcing alternative. [Footnote omitted].

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The need to reduce greenhouse gas emissions and increase HD Vehicles' fuel efficiency to the maximum feasible extent, and to do so as quickly as possible, has never been greater. Current global efforts put future temperature rises on a path that easily exceeds dangerous levels – as the Agencies' forecast of some 670 ppm of CO2 by 2100 fully attests. To do their part to forestall these effects, the Agencies must do far more than the Proposed Rule envisions. The statutory mandates, the availability of technology that is either on the shelf already or that can be implemented within the rulemaking years, and the overwhelming cost-benefit imbalance that results from the present proposal must propel the Agencies to revise their standards upwards by up to 50 percent.

Docket Number: TRANS-Chicago
Commenter: Ann Mesnikoff, Sierra Club – Green Transportation Campaign

Importantly, the Clean Air Act allows for technology-forcing standards. We also greatly appreciated NHTSA's authority under the 2007 Energy Independence and Security Act, which is tied to the urgent need to reduce our dependence on foreign oil and the security and financial consequences it has for our country. Given the challenges of oil dependence and climate change, we urge both EPA and NHTSA to finalize stringent technology-forcing standards for each category of truck covered under the rule.

Docket Number: TRANS-Cambridge
Commenter: Carol Lee Rawn, Investor Network on Climate Risk

EPA and NHTSA are to be commended for the proposals under consideration, but by using existing and emerging technologies, we could realize even greater benefits in terms of economic growth and oil savings. We, thus, urge EPA and NHTSA to take into account all available technologies across the vehicle in setting the standards.

Docket Number: TRANS-Cambridge
Commenter: Luke Tonachel, Natural Resources Defense Council

The Heavy-Duty National Program should capture all cost-effective efficiency improvements and greenhouse gas emissions reductions.

Docket Number: TRANS-Chicago
Commenter: Miranda Carter, Environment Illinois

While we applaud the proposed fuel efficiency standards for medium-and heavy-duty trucks as an important and historic first step, the standards proposed by the EPA and NHTSA fail to maximize available technologies to increase the fuel efficiency of trucks. The National Academy of Sciences recently concluded that current technologies could allow trucks of certain vehicle classes to increase fuel efficiency between 30 and 50 percent for different truck classes. The draft proposal, however, fails to enact all of the recommendations of our leading scientists.

Docket Number: TRANS-Cambridge
Commenter: David Marshall, Clean Air Task Force

Although we support much in EPA's proposal, we do not believe that it takes full advantage of the technologies available to improve the efficiency of the heavy-duty highway fleet between now and 2018. Significant additional reductions in fuel use and greenhouse gas emissions could be obtained with a stronger rule. Delaying these reductions until after 2018 will only make it harder to obtain the very steep reductions needed thereafter. We, therefore, urge EPA first to:

(1) Strengthen the requirements for the 2014 to 2018 model year vehicles by:

Setting standards for long-haul tractor trailers. Tightening the proposed standards for vocational trucks. Tightening the proposed standards for heavy-duty pickups and vans, and fully implementing them by 2016. And tightening the proposed engine standards.

* * * * *

We urge EPA to strengthen its proposal by taking full advantage of the technology options to reduce fuel consumption and greenhouse gas emissions from heavy-duty highway vehicles that are described in the recent comprehensive report by the National Academy of Sciences.

* * * * *

We urge EPA to follow through with these critical regulatory efforts, and to develop standards that are technology-forcing, rather than technology-following.

Docket Number: TRANS-Chicago
Commenter: Rich Stuckney

The standards set by the EPA and Department of Transportation should ensure that we achieve at least a part of a 35-percent reduction. The 35-percent reduction in large trucks, a 30-percent reduction by other trucks, a billion gallons of fuel saved by 2030. In summary, these are some of the reasons for issuing the strongest possible fuel standards for heavy-duty trucks. And I urge you to do so at the earlier possible opportunity.

Docket Number: PAPER-Chicago
Commenter: Steve Perlman

I want to encourage the EPA and the Department of Transportation to issue the strongest standards possible for large truck emissions, and help lessen our nation's dependence on oil.

Docket Number: PAPER-Chicago
Commenter: Cory Jones

Please set the strongest standards possible and make vehicle standards for trucks part of a national transportation plan that moves us beyond oil.

Docket Number: TRANS-Cambridge
Commenter: Jonathan Rosenthal

And when I say "the strongest standards that are possible," I do not mean the strongest standards that are possible politically, or the strongest standards that are possible economically; I mean the strongest standards that are possible physically and possible technologically.

Docket Number: TRANS-Cambridge
Commenter: Matthew Todaro, Boston College Environmental Law Society

The standard set by EPA and DOT should ensure that we do not aim lower than what is possible with today's technology. A 35 percent reduction in oil use by long-haul freight trucks, along with a 20 percent reduction of oil use in other trucks covered under this rule, would result in 5.6 billion gallons of oil saved annually by 2030. Enacting the strongest standards possible will help our trucking industry avoid the same pitfalls that our automobile industry has already suffered

Docket Number: TRANS-Chicago
Commenter: Yvette Pena-Lopez, BlueGreen Alliance

First, advanced vehicle technology should be utilized to make annual progress on increasing efficiency and reducing transportation sector oil dependence and pollution to the highest degree that is technically and economically feasible.

Docket Number: TRANS-Chicago
Commenter: Rinda West

I urge you to support the highest possible standards for fuel efficiency and greenhouse gas reduction.

Docket Number: 0110
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

Because of these important economic, environmental, and security benefits, we encourage the agencies to adopt the most stringent standards that are both technically and economically feasible.

Docket Number: TRANS-Chicago
Commenter: Cynthia Linton

I urge you now to write the strictest rules possible to reduce oil use in trucks under the Clean Air Act, long-haul trucks by 35 percent, and others by 20 percent. Doing so will, as you have heard from many people, cut 250 million metric tons of dangerous carbon dioxide pollution. Technologies are available to substantially reduce trucks' tailpipe emissions.

Response

NHTSA recognizes that Congress intended EPCA (and by extension, EISA, which amended it) to be technology-forcing. However, NHTSA believes it is important to distinguish between setting “maximum feasible” standards, as EPCA/EISA requires, and “maximum technologically feasible” standards, as the commenters suggest.

The agency must weigh all of the statutory factors in setting fuel efficiency standards, and therefore may not weigh one statutory factor in isolation. Neither EPCA nor EISA define “maximum feasible” in the context of setting fuel efficiency standards. Instead, NHTSA is directed to consider three factors when determining what the maximum feasible standards are – “appropriateness, cost-effectiveness, and technological feasibility.” 49 U.S.C. § 32902(k)(2). It is within the agency’s discretion to weigh and balance the factors laid out in 32902(k) in a way that is technology-forcing, as evidenced by the alternatives analyzed in this EIS, but that stops short of requiring the application of all available technology or technology not yet in existence, as some commenters suggested.

The agency has balanced the statutory factors in setting forth alternatives under consideration in this EIS, with the goal of setting standards at the maximum feasible level. In doing so, NHTSA determined appropriate engine and vehicle technologies for each vehicle sector that would achieve the maximum feasible level within the regulatory timeframe covered by this rulemaking. The agency believes that the alternatives selected in this EIS represent a reasonable range of

alternatives and that the technologies reflected therein properly bracket where the "maximum feasible" standards would fall. For a discussion of the alternatives, *see* Section 2.3 of the DEIS and this FEIS. NHTSA believes that requiring increased technology penetration beyond what the agency has modeled would exceed maximum feasibility.

Further, for most fuel efficiency technologies that NHTSA evaluated in its analysis, the agency applied phase-in constraints that made less limited assumptions, while continuing to recognize that most technologies must still be applied as part of a vehicle freshening or redesign. NHTSA believes that the phase-in schedule provides an appropriate balance between the technology-forcing purpose of the statute and EISA-mandated considerations of economic practicability. NHTSA is sensitive to the unique production demands of manufacturers of medium- and heavy-duty engines and vehicles, and believes that a phase-in schedule is necessary in order to provide manufacturers enough flexibility to incorporate the proposed technologies into their production schedules.

6.2.6 Comparison of Alternatives and Context of Analysis

Comments

Docket Number: 0025; 0081
Commenter: Vera Pardee, Center for Biological Diversity

NHTSA should analyze and discuss alternatives that contribute to the reduction of greenhouse gas emissions from MD/HD Vehicles to levels that allow the U.S. to reduce its overall emissions to sustainable levels.

* * * * *

Therefore, even if NHTSA intends to present the same general NEPA analysis in connection with the MD/HD Vehicle rulemaking as it did in the LD Vehicle FEIS, we request, at a minimum, that it undertake a different analysis as well, as set forth below.

Specifically, NHTSA should not fail to perform an analysis that shows what it must do to curb emissions from MD/HD vehicles that proportionally contribute to reaching sustainable emissions targets because it has (erroneously) concluded that no actions by other nations to curb their greenhouse gas emissions to reach that same goal are reasonably foreseeable. NEPA and CEQ implementing regulations require NHTSA to consider the foreseeable actions of others: "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." LD Vehicle FEIS at 2-40. While we agree that the currently enacted regulations and the future policies and promises of third parties remain inadequate to address the problem, this does not allow NHTSA to avoid presenting alternatives that would lead MD/HV Vehicles to contribute their proportionate share of overall U.S. greenhouse gas reductions to avoid unsustainable environmental change.

* * * * *

The EIS should analyze what must be done to cut emissions fom MD/HD vehicles to a sustainable level. We request that NHTSA perform a back-casting analysis of alternative fuel efficiency standards that either assumes that other actors also engage in conduct that avoids catastrophic climate change, or that disregards what others might to and focuses only on the U.S. proportionate responsibility. Specifically, NHTSA should determine the total greenhouse gas emissions reductions from MD/HD Vehicles that would allow the sector to reach its proportionate share of the maximum global allowable emissions necessary to reach atmospheric greenhouse gas concentrations low enough to avoid catastrophic climate change. That, in a nutshell, is what NEPA commands. We request that the MD/HD Vehicle EIS include an analysis of the extent to which the proposed alternatives would contribute to a reduction of U.S. greenhouse gas emissions to 17% below 2005 levels by 2020, to 25–40% below 1990 levels by 2020, and to 45% below 1990 levels by 2020. We also believe that NHTSA should project reductions reached by 2020, 2050, 2080 and 2100. [Footnote omitted].

* * * * *

We thank the Agencies for including in this DEIS information and a graphic description of how its proposed action compares to President Obama's stated goal to reduce U.S. emissions by 17% over 2005 levels by 2020. The public and decision-makers can now clearly appreciate that even the most stringent proposed alternative not only fails to contribute to reaching this goal, but actually makes its accomplishment much more difficult because HD Vehicle greenhouse gas emissions are allowed to increase to between 8.2 [percent] and 13.6 percent above 2005 levels by 2020.

Although climate change is a global problem, proportional reductions required by each country, and in turn from each emission source, can be calculated that together would reach sustainable global emission levels. [Footnote 78: It is true, as the Agencies assert, that President Obama's directive did not require every emitting sector to contribute equally proportional emission reductions. See DEIS, 3-102. The fact that the Agencies may determine that this outcome cannot be attained does not affect the Agencies' duty under NEPA to disclose and analyze the effort that would be required to reach the goal.] Even if the Agencies conclude that these goals cannot be reached by means of the tools available to them (including the full panoply of technology-forcing options that can feasibly be deployed during the rulemaking period), the presentation of that information, including the costs of implementation and the benefits both obtained and foregone, is the essential function of an adequate NEPA analysis.

Response

The environmental analysis presented in this EIS is consistent with the requirements of NEPA and CEQ implementing regulations. This FEIS informs decisionmakers and the public of a range of reasonable alternatives and the environmental impacts associated with each alternative.

Under NEPA, agencies are required to examine reasonable alternatives, and not those that are a "worst case scenario." Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 354-55 (1989). An agency is not required to consider alternatives "whose effect cannot be reasonably ascertained, and whose implementation is deemed remote and speculative." Headwaters, Inc. v. Bureau of Land Mgmt., Medford Dist, 914 F.2d 1174, 1180 (9th Cir. 1990) (quoting Life of the Land v. Brinegar, 485 F.2d 460 (9th Cir. 1973), cert. denied, 416 U.S. 961 (1974)). CEQ guidance on this point is similar. "Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (Mar. 23, 1981) (emphasis added).

NHTSA is charged with developing a Fuel Efficiency Improvement Program for medium- and heavy-duty vehicles that achieves the "maximum feasible" improvement in fuel efficiency in consideration of three statutory factors. Specifically, the program must be "appropriate, cost-effective, and technologically feasible." 49 U.S.C. § 3209w(k)(2). In setting fuel economy standards, NHTSA also takes into account other relevant factors such as safety and environmental concerns. Consistent with EPCA's overall purpose – energy conservation – NHTSA sought to balance the

statutory factors noted above in articulating the range of alternatives analyzed in this EIS. Environmental benefits are one consideration in the development of reasonable alternatives analyzed in this EIS. While each of the alternatives would avert significant GHG emissions in comparison to the No Action Alternative, NEPA does not require that NHTSA develop alternatives designed to achieve specific GHG reduction targets.

The "rule of reason" guides the choice of alternatives and the extent to which the EIS must discuss each alternative. *See, e.g.*, City of Carmel-by-the-Sea v. U.S. Dep't of Transp., 123 F.3d 1142, 1155 (9th Cir. 1997). *See* also American Rivers v. FERC, 201 F.3d 1186, 1200 (9th Cir. 2000) (quoting City of Carmel-by-the-Sea, 123 F.3d at 1155). Under the rule of reason, an agency "need not consider an infinite range of alternatives, only reasonable or feasible ones." Id. (citing 40 CFR § 1502.14(a)-(c)).

NHTSA recognizes the White House goal of reducing U.S. GHG emissions in the range of 17% below 2005 levels by 2020 and, as the commenter notes, has included a discussion of the magnitude of CO_2 emission reductions under this action in terms of the relative contribution of the heavy duty vehicle sector toward that goal. As the commenter notes, the White House goal does not require that every emitting source contribute equally proportional emission reductions to the 17% reduction of 2005 levels by 2020 goal. The selected alternatives were chosen by NHTSA based on the statutory factors specified in EISA, rather than the policy goals identified by the commenter. As discussed in the FEIS, the alternatives do not result in absolute reductions with respect to 1990 levels. However, the selected alternatives represent the range over which the agency believes the statutory factors may appropriately be balanced and therefore they consistute a reasonable range of alternatives to obtain the maximum feasible improvement in this sector. As for the commenter's request to project GHG reductions reached by 2020, 2050, 2080, and 2100, NHTSA provides this information in Table 3.4.4-2.

The commenter expressed a concern that NHTSA has "concluded that no actions by other nations to curb their greenhouse gas emissions to reach that same goal are reasonably foreseeable." At this time, multilateral agreements and actions to limit global warming to 2 °C above historic levels are not concluded. Furthermore, Congress has not yet taken action to implement this commitment by the President, and has not yet established the regulatory structure or allocated the budget to do so. The timing of the impacts of this commitment is uncertain. Nonetheless, NHTSA believes that the regional, national, and international initiatives and programs established to reduce GHG emissions and/or energy use illustrate an existing and continuing trend of U.S. and global awareness, emphasis, and efforts toward significant GHG reductions. For this reason, in the analysis of cumulative impacts presented in this FEIS, NHTSA assumes a moderate level of global GHG reductions, resulting in a global atmospheric CO_2 concentration of 678 ppm by 2100. *See* Section 4.4.3.3. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA. Addressing climate change to limit global warming to 2 °C above historic levels would require much greater actions from the United States and the global community.

Comments

Docket Number: 0025; 0081
Commenter: Vera Pardee, Center for Biological Diversity

NHTSA should analyze the alternatives it discusses in a manner that does not artificially minimize the true impact the more stringent alternatives can have by misleadingly implying that because NHTSA does not control all sources of greenhouse gas emissions, the impact of its rulemaking will be negligible.

* * * * *

Because NHTSA has indicated that it will "focus on the impacts [of climate change] in much the same manner as it did in the prior EIS," 75 Fed. Reg. 33568, we here address what we believe were critical inadequacies of that prior analysis, and request that NHTSA remedy them.

In particular, in our comment letter to NHTSA concerning the LD Vehicle FEIS (the "Comment Letter"), we discussed the manner in which NHTSA presented the effects of the proposed greenhouse gas emission reductions on what it claimed was their foreseeable cumulative result in terms of CO_2 levels, temperature and sea level rise and other consequences. We noted that a temperature increase of 1.4ºC over 1990 levels (or an increase of 2ºC over preindustrial levels), corresponding to a CO_2 stabilization level of approximately 450 ppm, will create a fifty/fifty chance that severe and irreversible impacts from global warming will occur. Yet, the LD Vehicle FEIS showed that in the year 2100, even the most stringent alternative presented would result in global CO_2 concentrations of 653.4 ppm and a temperature increase of 2.592ºC above today's level, and provided no alternative analysis. LD Vehicle FEIS, 4-57. Although NHTSA and EPA asserted that catastrophic climate impacts at 450 ppm (most likely corresponding to a 2ºC temperature increase) or even 550 ppm (most likely corresponding to about 3ºC of warming) remain too uncertain to quantify, there is no such uncertainty at CO_2 levels of 653 ppm – these levels would cause environmental catastrophes under any scenario. NEPA and its implementing regulations direct federal agencies to "[u]se the NEPA process to identify and assess the reasonable alternatives to proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment," and "[u]se all practicable means . . . to restore and enhance the quality of the human environment and *avoid or minimize any possible adverse effects of their actions upon the quality of the human environment*." 40 C.F.R. § 1500.2(e) and (f) (emphasis added). An environmental impact assessment that seeks to justify agency action even though its "most stringent" implementation results in an outcome unsustainable for life as we know it is unreasonable *per se*. [Footnotes omitted].

* * * * *

The LD Vehicle FEIS' analysis did serve to prove that the LD Vehicle Rule's greenhouse gas reductions are insufficiently stringent. But the manner in which this conclusion was presented also created the incorrect impression that the environmental outcome would not change regardless of what course of action the agencies pursued. … Thus, we request that in the forthcoming EIS, NHTSA refrain from justifying any decision not to demand truly maximum feasible fuel efficiency by depicting the ultimate outcome of all regulatory efforts as *de minimis*, and instead conduct a meaningful alternative analysis as suggested herein.

* * * * *

Because these emissions are closely related to the amount of fuel the vehicles consume, setting fuel efficiency standards at the maximum feasible level is among the most significant actions the U.S. government can take to reduce America's overall greenhouse gas emissions. Thus, it is imperative that the FEIS fully and effectively disclose the consequences of the proposed actions by means of meaningful comparisons and clear statements of their effects and consequences. We ask that the Agencies present and evaluate alternatives in a manner that allows the decision-makers and the public to understand and compare their impacts in the context of the role HD Vehicle fuel efficiency can play in combating climate change.

* * * * *

Lastly, the Agencies must identify their preferred alternative, and bring into focus why they believe that alternative delivers the maximum feasible improvement achievable in light of the environmental impacts, costs and benefits at stake. [Footnote omitted].

* * * * *

Levels of 678 ppm predicted under the HD Vehicle DEIS (most likely to correspond to ~3ºC of warming above pre-industrial levels) would cause environmental catastrophes under any scenario. A CO_2 level of 678 would result in a mean global temperature rise of 2.56°C by 2100 according to the DEIS, presumably in relation to 1980-1999 levels, which corresponds to a 3.06°C temperature rise relative to pre-industrial (1850-1899) levels. In addition, as noted in the DEIS, the 2.56°C temperature rise does not include the full temperature impact of 678 ppm due to time lags in the warming commitment, and thus the full temperature response from 678 ppm will be higher.

* * * * *

Because no other alternative is presented, the DEIS creates the incorrect impression that the environmental outcome would not change regardless of what course of action the agencies pursued. When the difference in the effects of all alternatives presented amounts to single digits in parts per million of CO_2 concentrations or fractions of a single digit in temperature and sea level rise, it appears that efforts to improve fuel efficiency are futile. Such reasoning, when not accompanied by the proportional-reductions analysis we believe is required, can bolster the misconception that programs to curb greenhouse gas pollution accomplish nothing and are never worth the price, whatever it may be. This line of reasoning was condemned by the Supreme Court in *Massachusetts v. EPA*, when it took EPA to task for characterizing achievable greenhouse gas reduction measures as insignificant. *Massachusetts v. EPA*, 549 U.S. 497, 523-26 (2007). [Footnotes omitted].

Response

Climate change is a global phenomenon. GHGs can persist in the atmosphere for decades to centuries, and the effects of a given level of emissions in one location can occur globally. NHTSA has presented emissions data in a number of contexts but believes that it is appropriate to evaluate the effects of this rulemaking in terms of its relation to global emissions and global climate conditions using year 2100 as an endpoint. This is a common approach for climate modeling.

NHTSA recognizes the important role that transportation plays in addressing global climate change issues and does not believe that environmental outcomes would be the same regardless of what course of action the agencies pursued. The projected beneficial impacts of the proposed standards are significant. To get a sense of the relative impact of the projected emissions reductions resulting from fuel efficiency standards,[2] it can be helpful to consider the relative importance of emissions from HD vehicles as a whole. Emissions from these vehicles constitute about 22.4 percent of total U.S. transportation sector emissions. U.S. transportation sector emissions are about 30.6 percent of total annual U.S. CO_2 emissions. Because U.S. emissions constitute 17.4 percent of global CO_2 emissions, U.S. medium and heavy duty vehicle emissions (those that NHTSA has the authority to regulate under EISA) account for roughly 1.2 percent of global annual CO_2 emissions.

[2] For example, in 2018, emissions reductions that would result from the Preferred Alternative are equivalent to the annual emissions from over one million HD vehicles. See Section 3.4.4 for more information.

Despite the fact that this action alone will not stop global climate change, the agency does not minimize its contribution to reducing GHG emissions. Throughout this FEIS, NHTSA indicates the important role that transportation plays in addressing global climate change issues, and attempts to put the impacts of the alternative standards in the context of HD vehicle emissions. *See* FEIS Sections 2.4, 3.4.2, and 3.4.4.1. NHTSA also includes graphs and figures to place the impacts of the agency's action in the context of total U.S. GHG emissions, and in the context of total U.S. transportation sector emissions. *See* FEIS Summary. The agency has emphasized context discussions in the EIS Summary so that they are readily available to readers. To allow the public and decisionmakers to clearly compare the impacts of the action alternatives under consideration, NHTSA has presented this information in easy to read tables in Section 2.4 of this FEIS. NHTSA believes that such comparisons present the proposed action and the impacts of the alternatives under consideration in perspective for the public and decisionmakers.

Under EISA, NHTSA has the authority to create a fuel efficiency improvement program for ''commercial medium- and heavy-duty on-highway vehicles and work trucks'' designed to achieve "maximum feasible improvement." The agency has analyzed four action alternatives that it believes to be within the range of "maximum feasible." NHTSA considers alternatives that would eliminate CO_2 emissions from this sector, as well as the proposed proportional reduction alternatives, to be outside the scope of "maximum feasible" as defined under EISA.

NHTSA disagrees with the commenter's statement that this EIS is unreasonable "per se" because the global concentration of CO_2 is forecast to increase significantly by 2100 under all of the alternatives. While Sections 3.4 and 4.4 of the EIS show small differences in climate effects (CO_2 concentration, temperature, sea-level rise, precipitation) when expressed in terms of climate endpoints, *i.e.*, the results at the end of an analysis period, NHTSA believes that this is likely true for any given short-term GHG emission mitigation action when taken alone. A suite of many GHG emission reduction policies in many countries and economic sectors would need to be implemented to mitigate climate change substantially. Global climate change is occurring despite NHTSA's action; this action alone cannot "avoid or minimize any possible adverse effects" (*See* 40 C.F.R. § 1500.2) caused by GHG emissions. Rather, a long-term commitment to the HD Fuel Efficiency Improvement Program, in addition to policies in many countries and economic sectors, is necessary to have a significant effect in reducing fuel consumption and CO_2 emissions.

Comments

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

In response to specific requests for comments contained in the Notice, we believe that (a) NHTSA should evaluate environmental impacts in the following time frames: 2020, 2050, 2080 and 2100; and (b) that NHTSA's analysis should include potential upstream impacts (changes in fuel use and emissions levels resulting from the extraction, production, storage, and distribution of fuel).

Response

NHTSA has chosen to report environmental impacts in the short term (2030), the medium-term (2050), and the long-term (2100). NHTSA believes that presenting impacts for these time frames gives decisionmakers and the public sufficient information to understand the relative environmental impacts of the alternatives, and that providing additional years (e.g., 2020 or 2080) would not substantially increase this understanding. However, as noted in response to a comment

in Section 6.2.6, the agency has reported projections for GHG reductions in 2020 and 2080 in Table 3.4.4-2.

NHTSA's analysis does include potential upstream impacts from changes in fuel use and GHG emissions, resulting from the extraction, production, storage, and distribution of fuel. As NHTSA states in Section 3.4.3.1 of the FEIS, "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."

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

We appreciate the Agencies' citations to several emission reduction efforts currently underway by third parties, such as the Regional Greenhouse Gas Initiative and the Western Climate Initiative, as well as similar global initiatives and laws. To these examples the Agencies should add the recently announced "Massachusetts Clean Energy and Climate Plan for 2020," which aims to reduce emissions to 25 percent below their 1990 levels by 2020. As the Agencies note, these actions – contrary to the proposed HD Vehicle rule – actually seek *to reduce* total greenhouse gas emissions. Thus, neither the EIA 2010 Reference Case nor the GCAM6.0 scenario (which also suffers from additional inconsistencies pointed out by the Agencies), is "harmonious with implementation of these policies and initiatives." Thus, the cumulative impacts analysis remains improperly skewed to forecasting much smaller global CO_2 emission reduction gains than are reasonably foreseeable. These errors exacerbate the false impression that emission reductions achieved by the HD Vehicle Rule have negligible effects. [Footnotes omitted].

Response

A number of states have enacted climate legislation, including Massachusetts. In response to this comment, NHTSA has added text to Section 4.4.3.4.1 of the FEIS to note that 23 states have issued executive orders or enacted legislation setting statewide GHG emissions reductions goals.

The commenter expressed concern that neither EIA 2010 nor the GCAM6.0 reference scenario is representative of efforts to reduce GHG emissions. In its analysis of cumulative impacts, NHTSA assumes a level of global GHG reductions sufficient to result in a global atmospheric CO_2 concentration of 678 ppm by 2100; this is lower than the reference case emission scenario used in the direct impacts analysis, which results in a global atmospheric CO_2 concentration of 785 ppm by 2100. *See* FEIS Section 4.4.3.3 and 3.4.3.3. NHTSA believes that the regional, national, and international initiatives and programs established to reduce GHG emissions and/or energy use illustrate an existing and continuing trend of U.S. and global awareness, emphasis, and efforts toward significant GHG reductions. Together they imply that future commitments for reductions are probable and, therefore, reasonably foreseeable under NEPA. For this reason, NTHSA uses the GCAM6.0 reference scenario in the cumulative impacts analysis.

The commenter also states that the EIS creates the impression that emission reductions achieved by the proposal are minimal. The choice of global GHG emissions scenarios is important to put the GHG reductions into context and to show the relative magnitude of the environmental impact of the alternatives. However, as shown by the sensitivity analyses (*see* FEIS Section 4.4.4.3.4), the

choice of global emissions scenario does not have a significant effect on the incremental changes in climate endpoints (e.g., CO_2, temperature, and sea level) associated with the different alternatives.

Comments

Docket Number: 0142
Commenter: Janice Nolan, Hilary Sinnamon, Peter Zalzal, Katie Patterson, and Britt Groosman - American Lung Association and Environmental Defense Fund

The proposed rule provides for a 10 percent and 15 percent reduction in CO_2 emissions from 2010 levels from gasoline and diesel fueled pickups and vans, respectively, in 2018. However, the 2010 Annual Energy Outlook (AEO) projects that heavy-duty pickups and vans will achieve virtually the same fuel efficiency in 2018 absent regulation, because these vehicles will take advantage of the technologies brought to market by the 2012-2016 light-duty rule. Therefore, to accelerate the take-up of these available technologies, we request that the final rule require the proposed improvements by 2016. [Footnotes omitted.]

Docket Number: TRANS-Chicago
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

Regarding work trucks, here again we agree that there are additional opportunities for savings that have not been captured by the proposed stringency. And I would just observe that the proposed level of those standards almost—for 2018—almost exactly matches the projected fuel efficiency of work trucks in the Energy Information Administration forecast in a business-as-usual scenario; so that is to say that in the absence of regulation, the EIA is projecting that same 11 percent reduction from 2010 levels. And we also think that at a minimum, that work truck standards proposed for 2018 should be fully phased in by 2016 to allow for further increases in the succeeding years.

Response

In response to comments comparing the action alternatives to the HD vehicle annual energy consumption forecast produced by the U.S. Energy Information Administration (EIA) and describing that forecast, known as the Annual Energy Outlook (AEO), as "business as usual," NHTSA added a market forecast analysis to the FEIS as Section 3.5. The AEO takes into account predicted changes to the HD fleet based on the uptake of technologies in response to market forces. While the AEO forecasts do reflect current law and regulations, they do not incorporate proposed laws or regulations, including the proposed HD Fuel Efficiency Improvement Program.

Selecting an appropriate baseline against which to compare this proposal and the alternatives is challenging. NHTSA understands that market forces may independently result in changes to the future HD fleet even in the absence of the proposed rule, and that, to the extent they can be estimated, those changes should be incorporated into the baseline. Nonetheless, the broad range and many types of HD vehicles in the fleet, the lack of prior regulation of fuel efficiency for this sector, and economic uncertainty make estimating fuel efficiency of future HD vehicles particularly difficult.

Market-based forecasts of fuel economy rely on inherently uncertain measures, such as future oil prices, and therefore cannot perfectly predict future fuel economy. With these cautions in mind, NHTSA nevertheless believes that a market forecast of changes in fuel efficiency is the appropriate baseline for the evaluation of the environmental impacts of the proposed action and alternatives. NHTSA further believes that AEO represents the best available market-based forecast of future

fuel efficiency and fuel consumption by HD vehicles that would occur in the absence of this rule. The EIA is the primary source of data used by government agencies and private organizations to analyze and model energy systems.

To address the comments to the DEIS, Section 3.5 of the FEIS compares the environmental impacts of the action alternatives to those of a baseline derived from the AEO 2011 Early Release Reference Case, the AEO forecast available at the time the modeling for this section was performed.

6.2.7 Suggestions for New Alternatives

6.2.7.1 Alternative 6B + Alternative 8 + Additional Technologies

Comments

Docket Number: 0112
Commenter: Vera Pardee, Center for Biological Diversity

We strongly urge the Agencies to adopt an alternative not depicted here: a combination of Alternative 6b with the additional technologies added in Alternative 8 and other technologies discussed here and in our earlier comment letters but which have been rejected by the Agencies. A full cost-benefit analysis which does not improperly put the thumb on one side of the scale will undoubtedly prove that alternative to remain highly cost-effective.

Response

Alternative 4 (Alternative 6b in the DEIS) sets proposed fuel efficiency standards for heavy-duty pickup trucks and vans, Class 2b through 8 vocational vehicles, and combination tractors and the engines installed in them. That alternative represents a stringency level which is 20 percent more stringent than the agency's Preferred Alternative standard. To achieve this stringency, the proposed combination tractor standard would be derived from the addition of Rankine waste heat recovery and 100 percent application of Bin IV aerodynamics to high roof sleeper cab combination tractors. For heavy-duty pickup trucks and vans, the standard would be derived from the addition of turbo downsized gasoline engine technology, and for vocational vehicles, the standard would be derived from the addition of hybrid powertrains to 6 percent of the vocational vehicles.

Alternative 5 (Alternative 8 in the DEIS) also sets proposed fuel efficiency standards for heavy-duty pickup trucks and vans, Class 2b through 8 vocational vehicles, and combination tractors and the engines installed in them, but also includes the regulation of trailers. This Alternative adds hybrid powertrains to the heavy-duty pickup trucks and vans, vocational vehicles, and tractors. In addition, NHTSA applied aerodynamic technologies to commercial box trailers, along with tire technologies for all commercial trailers.

The agency has balanced the statutory factors in setting forth alternatives under consideration in this EIS, with the goal of identifying alternatives that properly bracket where the "maximum feasible" standards would fall for these vehicles. In doing so, NHTSA weighed appropriate engine and vehicle technologies for each vehicle sector that would achieve the maximum feasible level within the regulatory timeframe covered by this rulemaking. NHTSA believes that an alternative that includes technologies beyond those already included in Alternative 5, as suggested by the commenter, would fall outside of maximum feasibility, following a reasonable balancing of the statutory factors. The agency believes that the alternatives selected in this EIS represent a reasonable range of alternatives and that the technologies reflected therein properly bracket where

the "maximum feasible" standards would fall. For a discussion of the alternatives, *see* Section 2.3 of the DEIS and this FEIS.

6.2.7.2 Alternative 6B, 7, or 8 and Alternative 8 as a Voluntary Compliance Program

Comments

Docket Number: 0092
Commenter: Togiola T.A. Tulapono, American Samoa

1. American Samoa would prefer the implementation of Alternatives 6b, 7, or 8 given the increased reduction in the amount of Green House Oases (GHG), specifically CO_2 over NHTSA's Preferred Alternative 6.

* * * * *

5. If NHTSA goes forth with implementing Preferred Alternative 6, the NHTSA should integrate Alternative 8 through a voluntary compliance program via incentives to manufactures.

6. We would further urge that NHTSA initiate a voluntary compliance program for manufactures to encourage them to implement the most stringent Alternative, number 8, on their own.

Response

The agency has balanced the statutory factors in setting forth alternatives under consideration in this EIS, with the goal of setting standards at the maximum feasible level. In doing so, NHTSA has selected engine and vehicle technologies for each vehicle sector that the agency believes would achieve the maximum feasible level within the regulatory timeframe covered by this rulemaking. The agency believes that the alternatives selected in this EIS represent a reasonable range of alternatives and that the technologies reflect therein properly bracket where the "maximum feasible" standards would fall. For a discussion of the alternatives, *see* Section 2.3 of the DEIS and this FEIS.

NHTSA does not anticipate initiating a voluntary compliance program to encourage manufacturers to implement technologies included in an FEIS Alternative other than that selected as the agency's action.

6.2.7.3 Regulation of All Vehicle Classes

Comments

Docket Number: 0092
Commenter: Togiola T.A. Tulapono, American Samoa

NHTSA should apply standards across all vehicle classes, 2b through 8, in the Alternative selected.

Docket Number: TRANS-Chicago
Commenter: Don Anair, Union of Concerned Scientists

We strongly support the Agencies' inclusion of all classes of medium and heavy-duty vehicles in the standards, from pickup trucks and vans to the largest and heaviest of vehicles. Many technologies are already available today to improve the efficiency of these vehicles. That is why we strongly support the proposal to implement standards starting no later than model year 2014 for all classes of trucks.

Docket Number: TRANS-Chicago
Commenter: Drew Kodjak, International Council on Clean Transportation

In almost all cases, the rule proposal is consistent with the recommendations and findings of the NAS panel. In my opinion, the principle findings of the NAS were that there is a substantial opportunity for improvement in the fuel efficiency of these vehicles ranging from 35 to 50 percent within the 2015 to 2020 timeframe. And then in order to capture the full extent of this opportunity, the agencies should regulate the whole sector and the full vehicle.

Response

The agency agrees and has removed from consideration alternatives that do not include all vehicle classes (*i.e.*, heavy-duty pickup trucks and vans, combination tractors, and vocational vehicles). All alternatives in the FEIS now include all vehicle classes except trailers. The regulation of trailers is included in Alternative 5 (Alternative 8 in the DEIS), and would provide additional fuel consumption reduction opportunities. However, the Preferred Alternative does not include standards for trailers because NHTSA intends to work with EPA to do more research on how to appropriately regulate the trailer industry.

6.2.7.4 Alternatives to Petroleum

Comments

Docket Number: TRANS-Chicago
Commenter: Rose Gomez

We have the technology, and there are so many other alternatives that are available other than oil.

Response

Through this rule, NHTSA addresses the urgent and closely intertwined challenges of energy independence and security. The agency has proposed flexibility provisions that include credits for advanced technology vehicles such as electric vehicles. This regulation also proposes steps to recognize benefits of flexible-fueled vehicles and dedicated alternative-fueled vehicles through credit incentives. However, NHTSA projects in this EIS that the fuel consumed by HD vehicles will continue to be predominantly petroleum-based (both diesel and gasoline) in the foreseeable future.

6.2.8 Technology Assumptions

6.2.8.1 Electrification

Comments

Docket Number: 0144
Commenter: Jutta Solano, Florida Power & Light Co.

We concur with and support NHTSA and EPA's decision to exclude upstream (i.e. power plant) emissions when computing electric vehicle emissions. FPL concurs with your judgment that in the overall scope of this rulemaking, the best approach for encouraging the expansion of electric vehicle technology is to exclude emissions related to the source of the electricity from the emission calculation. On December 23, 2010, EPA announced that it will finalize New Performance Standards for greenhouse gas emissions that will apply to new power generating units, major modifications, and eventually to existing units, with a final rule to be issued by May of 2012. Furthermore, we feel that it would be extremely difficult, given the diverse nature of power generation technologies and resulting diverse emissions in different areas of the country, to develop a valid methodology to apply generating unit emissions to electric vehicles. Our Company also supports the position of the Edison Electric Institute regarding this issue.

Docket Number: TRANS-Cambridge
Commenter: Gina Coplon-Newfield, Sierra Club - Green Transportation Department

Secondly, there should be a robust plan for the electrification of trucks and to address the upstream emissions from charging electric vehicles. The Sierra Club will join together with others to ensure that a massive shift to electric vehicles, with no tailpipe emissions, will dramatically reduce global warming pollution and our dependence on oil. While electrification of heavy-duty trucks is not currently feasible, in the vocational truck category, there could be increasing potential for plug-in trucks that may well come to the market during the years covered by this rule.

Sierra Club continues to urge that EPA fairly account for the emissions associated with charging electric cars and trucks. While there are no tailpipe emissions from electric vehicles, there are certainly emissions associated with the electricity that charges these vehicles.

Docket Number: TRANS-Cambridge
Commenter: Susan Robinson, Waste Management

We believe that electric, electrification of cars and trucks can be a major part of emission reduction strategies in this country. Of course, the technology is there right now, much more for cars than for trucks, but there are currently technologies available for some types of trucks, particularly smaller kinds. And Ford is about to come out with a new plug-in truck, as I'm sure we all know, so we think it can be a major part of the strategy.

Response

NHTSA agrees that promoting transportation electrification is an important step toward reducing emissions and achieving energy independence. To provide an incentive for the commercialization of this promising technology, under the proposed rules, manufacturers that incorporate electrification would be eligible for special credits that could be applied to heavy-duty vehicles or engines.

The issue of whether to account for upstream emissions of GHGs in assessing the amount of credit to offer to various types of electric vehicles (EVs) is important. Although these vehicles produce zero tailpipe emissions, they are powered by electricity whose generation, depending on the source, may itself cause significant GHG emissions. Although such emissions would not be accounted for if electric vehicle GHG emissions are assessed at zero for credit generating purposes, the agencies stated in the proposal that doing so would incentivize this technology. In comparison to light duty vehicles, the agencies expect introduction of EVs into the heavy-duty fleet to be less frequent. While NHTSA anticipates increasing deployment of HD electric vehicles, this EIS does not take into account upstream emissions of these vehicles, reflecting current levels of EV deployment for this sector. Where appropriate, however, this EIS does assume decreased upstream emissions associated with petroleum extraction and transportation, and with the refining, storage, and

distribution of transportation fuels, due to changes in the volumes of gasoline and diesel produced and consumed under each action alternative.

6.2.8.2 Hybridization

Comments

Docket Number: 0134
Commenter: John Boesel, CALSTART

We are particularly concerned about the unintended consequences that the rule could have on advanced technologies that provide emissions reductions beyond those required for compliance. If these technologies are not required or otherwise incentivized, the market may lose momentum and technology deployment may slow down. The new rule may leave achievable early reductions and fuel savings "on the table" and might not adequately spur innovative technologies, fuels or approaches.

As an example, hybrid power systems are commercially available, providing real world GHG and fuel economy to vocational trucking fleets across the country and are increasingly available in the market. Hybrid-electric drive train systems in medium- and heavy-duty vehicles are already demonstrating fuel economy improvements of 20% to 50% in early commercial operations. Hydraulic-hybrid systems are in testing and pilot production as well, with promise for fuel economy, performance and low cost. These drive trains are now available from major manufacturers.

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

Although these proposed rules are making a necessary and important step in reducing fuel consumption by the medium-and heavy-duty truck transportation sector, the industry should be encouraged to innovate and to seek ways to reduce fuel consumption further. Although NHTSA and EPA have chosen Alternative 6 (Engines, Tractors and Class 2b Through 8 Trucks) as the preferred alternative, New York State would like, at a minimum, to see the alternative expanded to include incentives for greater penetration of advanced hybrid powertrain technology for vocational vehicles, pickups and vans as addressed in Alternative 8.

Alternative 8 is the only alternative that includes the application of hybrid drive trains. In Alternative 8, the market penetration of hybrid drive trains into the heavy-duty pickup and vocational vehicle classes is 50 percent and the penetration rate for the combination truck sector is 0 percent. EPA and NHTSA acknowledge that it is not possible to achieve hybrid technology penetration rates at or even near these levels in the time frame of this rule-making. Accordingly, New York State requests that EPA and NHTSA explain why other hybrid drive train penetration rates (such as 10-25 percent for pickup and vocational and 0-10 percent for combination trucks) are not considered to be feasible alternatives. While the cost analyses suggest the hybrid technology will involve higher incremental costs than more conventional technologies, hybrid technologies are demonstrated to achieve significant fuel economy and greenhouse gas emission benefits. These benefits are clearly demonstrated. A greater use of hybrid technology in vocational vehicles also would reduce occupational exposure to diesel exhaust, and hybrid school buses would reduce the exposure of school children to particulate matter emitted by idling.

New York State recognizes that the application of hybrid technologies is a compliance option for the industry in the proposed regulation. The industry can obtain fleet credit through hybrid technologies (or other advanced and innovative technologies) through the advanced and innovative technology credit process. New York State recommends that NHTSA and EPA use this information and market penetration of the technologies to set future standards that are in line with Alternative 8.

Docket Number: TRANS-Cambridge
Commenter: Gina Coplon-Newfield, Sierra Club – Green Transportation Department

Hybrid technology should inspire stronger standards. Hybrid trucks can and should be a part of the near-term emissions solution, particularly for a range of vocational trucks. There are quite sophisticated hybrid technologies that already exist today, and these technologies will greatly increase in the years to come. The new truck standards should include a bolder stringency to reflect and spur this current and future hybrid technology.

Docket Number: TRANS-Cambridge
Commenter: Brendan Bell, Union of Concerned Scientists – Clean Vehicles Program

The third issue is that the standards should support the adoption of advanced vehicle technologies. Advanced vehicle technologies, as was mentioned before, such as hybrid-electric drivetrains, can deliver significant improvements in fuel efficiency. The current generation of hybrid systems being sold today has achieved fuel consumption reductions of as much as 35 percent in certain applications. The new standards should support the continued development and deployment of advanced technology in order to maintain the United States' current leadership in the industry.

Docket Number: TRANS-Chicago
Commenter: Tony Garcia, International Union UAW

We concur in the assessment that while hybrid technologies under development and in limited production today will become more widespread in time, the cost and functionality of these vehicles does not warrant their inclusion in the assessment of what currently is achievable.

We are entirely supportive of the incentives for the production of these vehicles in the proposed rule and believe that these provisions will lead to a quicker introduction of hybrid technology in the vocational fleet.

Docket Number: 0112
Commenter: Vera Pardee, Center for Biological Diversity

As to hybrid powertrains, the Agencies state that their decision to exclude them as a mandatory measure – even though hybrid powertrains are already in use – is motivated by a desire not to "overestimate" the number of hybrids that are likely to be introduced into the market; instead, they propose to encourage production of hybrids through credits alone. This approach completely misperceives the Agencies' mandate: rather than applying a conservative approach, the Agencies must push for technological breakthroughs through the use of ambitious goals. The Agencies cannot simply exclude a presently available technology that delivers considerable fuel efficiency improvements because they cannot precisely estimate future market penetration or fear potentially slower uptakes. The law requires exactly the opposite approach. The Agencies estimate that a 25 percent utilization rate of hybrid powertrains in MY 2017 vocational vehicles might increase the cost per vehicle by $30,000. Even if this estimate were correct, it alone cannot justify dismissing these improvements absent a full cost-benefit analysis, which the Agencies have not provided. As to weight reduction efforts, the Agencies have simply skipped the economic analysis of the costs and benefits to be achieved.

Docket Number: TRANS-Cambridge
Commenter: Brian Mormino, Cummins Inc.

Some of the technologies are here, right now, and I think this rulemaking will capture those, and make sure that they will be widespread, and others are being developed, and I think can be more widespread in the future. So a good example with the Department of Energy is waste heat recovery technology that can really be the so-called "hybrid" of tractor trailer standards, and provide the biggest benefit for that fleet. That technology is not ready for the market, it is one that we are working very hard on, as well as industry partners, and I think it will be able to be deployed in the market. I think some of the incentives that are provided within the regulation provide incentives for us to make sure we get that on the market as soon as possible, so I think that is a good tool that we have. But we are also working closely on hybrids, and a variety of other technologies. I think that the regulation strikes the right balance, in terms of promoting that technology, getting technologies on the market, and at the same time waiting, or allowing that technology to develop, for it to be applied in the right applications.

Response

NHTSA notes that hybrid powertrain development in Class 7 and 8 tractors has been limited. More time is needed to develop hybrid systems and battery technology for tractors that operate primarily in highway cruise operations. However, one benefit of hybrid technology in this vehicle class is less fuel consumption during idling. The National Academy of Sciences (NAS) Report estimated that hybrid systems could provide a potential fuel consumption reduction of 10 percent, of which 6 percent is idle reduction. The agency's proposed standards and alternatives include the use of extended idle reduction technology by other means. As a result, NHTSA believes that this 6 percent reduction can be achieved through other idle reduction technologies, and that the addition of hybrid technology in setting tractor standards would duplicate many of the emission reductions attributable to extended idle reduction.

The agency is considering hybrid technology in setting heavy-duty pickup and van standards; however, NHTSA believes that the development, design, and tooling effort needed to apply this technology to this entire fleet would not prove cost-effective in the timeframe covered by this rulemaking. One reason is the small sales volumes of heavy-duty hybrid pickups and vans relative to the light-duty sector. The smaller engines that facilitate much of hybrid technology's benefit are typically at odds with the importance heavy-duty pickup truck buyers place on engine horsepower and torque for vehicle performance.

Several types of vocational vehicles, including utility or bucket trucks, delivery vehicles, refuse haulers, and buses, are well suited for hybrid powertrains. The vocational vehicle industry is currently developing three types of hybrid powertrain systems – hydraulic, electric, and plug-in electric. The hybrids developed to date have seen fuel consumption reductions between 20 and 50 percent in the field. However, there are still key issues that restrict the penetration of hybrids for vocational vehicles, including overall system cost, battery technology, and lack of cost-effective electrified accessories. NHTSA did not include hybrid technology in its proposed vocational vehicle standards because this technology is still undergoing development, and the agency anticipates a very small fraction of hybrid vocational vehicle sales to include this technology (*i.e.*, 1 to 2 percent) in the timeframe covered by this rulemaking.

Given the status of hybrid technology development and the promise of future advancements in hybrid technologies for the heavy-duty fleet, NHTSA believes that creating credit flexibilities for manufacturers for this first phase of the HD National Program is fully consistent with the agency's obligation to develop a fuel efficiency improvement program designed to achieve the maximum

feasible improvement. EISA gives NHTSA broad authority to develop “compliance and enforcement protocols” that are “appropriate, cost-effective, and technologically feasible,” and the agency believes that compliance flexibilities such as the opportunity to earn and use credits along with the other compliance provisions are a reasonable and appropriate interpretation of that authority.

6.2.8.3 Trailer Fuel Efficiency Improvements

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center For Biological Diversity

(b) Technologies Exist or Can Be Implemented During the Rulemaking Period That Can Improve Fuel Efficiency Gains By Up To 50%

Technologies exist, or can feasibly be developed and implemented during the rulemaking period, that are appropriate for HD Vehicles and that can sharply increase their fuel efficiency gains. As will be discussed below, because the benefits of these technologies are extremely likely to outweigh their costs by orders of magnitude under any accurate cost-benefit accounting, alternatives implementing such technologies will also prove to be highly cost effective (and may even prove to be profitable). The DEIS should therefore include alternatives incorporating these technologies and analyze their environmental impacts.

(1) Trailer Fuel Efficiency Improvements

In the NPRM, the Agencies have tentatively decided not to apply fuel efficiency improvements to trailers used with Class 7 and Class 8 tractors, not because these technologies are unavailable, but because of the diversity of trailer manufacturers and models and manufacturers’ inexperience with fuel efficiency regulations. These reasons for rejecting trailer regulations cannot withstand scrutiny: not only do they have no relation to the factors the Agencies must consider under Section 32902(k) (appropriateness for the vehicles at issue, cost effectiveness, and technical feasibility), but they deliberately ignore those factors. Not utilizing readily available fuel improvement technologies for Class 7 and Class 8 tractor trailers is especially egregious because these vehicles consume the largest fraction of fuel among the HD Vehicle category.

Indeed, the Agencies themselves recognize the many presently existing opportunities for improvements in trailer fuel efficiency, including aerodynamic drag, rolling resistance, and overall weight, and cite studies showing that fuel consumption could be reduced by up to 18 percent through improved aerodynamics and tire resistance alone. The Agencies further recognize that, as stated in the relevant National Academy of Sciences report, the trailer market’s split incentives present a clear barrier to market forces alone driving fuel improvement, providing even greater impetus for taking regulatory action as quickly as possible. The Agencies’ analysis and discussion of the feasibility, cost-effectiveness, and availability of fuel efficiency improvements for trailers makes a compelling case for the implementation of such regulations, and, contrary to the Agencies’ assertions otherwise, demonstrate the Agencies’ expertise in the subject matter. The claim that the industry should not yet be regulated because it has not already “been subject to either emissions or fuel economy regulations” obviously misses the mark, as that claim will be as true five years from now, or indeed at any time in the future, as it is at present unless regulation in fact begins. The Agencies are obligated by statute and Presidential directive to devise and implement fuel efficiency regulations, and the fact that regulation has not yet commenced cannot be cited as the reason for not commencing it. Lastly, while the trailer manufacturing industry might be fractionated and complex, so is the HD Vehicle industry as a whole, and yet the Agencies have been able to devise efficiency standards.

In short, there is no excuse for the failure to commence trailer fuel efficiency improvement regulations as part of the final HD Vehicle rule.

Docket Number: TRANS-Cambridge
Commenter: Mary Ellen Kustin, National Wildlife Federation

These proposed rules are a critical first step, and we see a number of opportunities for even greater improvements. These opportunities include setting efficiency standards for the trailer portion of the long-haul tractor trailers…

Response

The agency solicited comments in the NPRM on achieving fuel efficiency improvements through regulation of trailers. In the NPRM, NHTSA discussed relatively conceptual approaches on how a future trailer regulation could be developed, but did not provide a proposed test procedure or proposed standard. Nevertheless, NHTSA has included an alternative (Alternative 5) in this FEIS that would regulate the fuel efficiency of trailers in addition to the vehicle components that would be regulated under the other action alternatives.

NHTSA notes that regardless of the agency's final decision in this rulemaking, the SmartWay Transport Partnership Program continues to encourage the development and use of technologies to reduce fuel consumption from trailers.

6.2.8.4 Tire Fuel Efficiency Improvements

Comments

Docket Number: 0090; 0136
Commenter: Tracey Norberg, Rubber Manufacturers Association

RMA understands the various alternatives evaluated in the EIS would result in an overall vehicle fuel efficiency regulation and the final regulation would likely identify the various component technologies available to truck manufacturers to employ in meeting the overall vehicle requirement.

During the assessment of the available component technologies NHTSA should evaluate the balance of tire performances necessary in truck tires - particularly the tread wear and traction aspects of tire performance, as well as fuel efficiency (i.e. rolling resistance). Trucks, especially those used in long haul applications, are expected to perform well in a variety of weather, in a broad geographical region, over varied topographies. Tires play a critical role in a truck's ability to perform under these circumstances, and the demands on a truck tire should be considered in the evaluation of the extent to which rolling resistance can be improved to assist in meeting an overall vehicle standard

NHTSA should also recognize in the EIS the broad use of retreaded truck tires in this country. In fact, nearly half of all replacement truck tires are retreads. A truck tire typically sees a small percentage of its useful life with its original tread. After a new tire's tread wears sufficiently, the tire is sent to a retread facility for retreading. The tire is buffed to remove any remaining tread. The resulting tire casing is then prepared to receive a new tread. Tire casings are valuable commodities to fleets that typically retain and retread their own casings, considering the casings as company assets. Retreading a tire is environmentally friendly – a new tire takes about 22 gallons of petroleum to produce, but a retread takes only about seven gallons of oil to manufacture. In certain applications, some tire casings can be retreaded several times, allowing a fleet to amortize its investment and achieve cost efficient environmental benefits.

Furthermore, NHTSA should consider the retreadability of various tire options in the EIS. Some tire types in some applications may be able to be retreaded more times than other tire types. A differential in retreadability has environmental effects, because a tire that can be retreaded more times conserves raw materials, allows fewer scrap tires to be generated and saves energy used in tire manufacturing. A tire that can be retreaded fewer times has a negative impact on the environment due to the added materials and energy used to make new tires, as well as generating more scrap tires. Even if some tires promise energy benefits while in service on vehicles due to lower rolling resistance, it is important to understand and assess a tire's other performance and environmental aspects, including retreadability, in the final EIS. Finally, NHTSA may wish to consider the rolling resistance of retreads themselves, since they constitute a significant percentage of the truck tires on the road. Such discussions are already progressing with the EPA SmartWay program.

* * * * *

It is well documented that vehicle inflation pressure plays a significant role in vehicle fuel efficiency. In developing the EIS, NHTSA should consider fuel efficiency losses associated with under-inflated tires in assessing environmental benefits achievable under the various alternatives outlined in the Federal Register notice. As well, NHTSA should consider technologies available to monitor and maintain tire inflation pressure on trucks, and the environmental impacts of such technologies.

* * * * *

In the NPRM, EPA and NHTSA provide proposed technology application rates for aerodynamics, steer tires, drive tires, weight reduction, extended idle reduction and vehicle speed limiter. With regard to steer tires and drive tires, EPA and NHTSA do not assume 100 percent application rates of SmartWay™ or Advanced SmartWay™ tires. According to Table III_4, EPA and NHTSA propose that between 50 and 70 percent of both steer and drive tires be SmartWay™ verified products, while 10 to 20 percent of the market should be comprised of Advanced SmartWay™ tires. *[Footnote 2: 75 Fed.Reg. at 74224.]*

However, the proposed standards do not take into account which models of tires are currently SmartWay™ verified technologies. In fact, the vast majority of current mileage drive tires, regional steer and drive tires, and traction drive tires do not meet the targets for the SmartWay ™ verified technologies program. These tire classes include some of the highest volume tires in the marketplace.

It is important to note that the SmartWay™ verified technologies program was designed to address tires in one market segment – the long haul Class 8 vehicle segment. Tires that meet SmartWay™ targets are appropriate for this class of vehicles, not the other subcategories of Class 7 and Class 8 vehicles that EPA and NHTSA are proposing to regulate using SmartWay™ verified technologies program data as a basis. It is inappropriate to use SmartWay ™ verified technologies program data as a basis for standards for vehicle segments other than Class 8 long haul, since verified tires are not appropriate for these vehicles. Tires for long haul Class 8 vehicle applications have been the focus of rolling resistance design innovation, since the fuel economy payback on these vehicles is significant due to the typical long haul drive cycle, due to the significant percentage of highway miles these vehicles see. Other regional and local Class 7 and Class 8 vehicles see fewer highway miles, and demands on tires focus more on wear and traction attributes, since these vehicles see high scrub, stop and go drive cycles. These vehicles will see more significant fuel losses due to engines losses, and the tire contribution is less significant.

The SmartWay™ verified technologies program has recognized that more data is needed to characterize the tire market for non-long haul tire applications for Class 2B through Class 7. SmartWay™ verified technologies program has conducted tire testing in these vehicle segments for the last several months to begin to understand tire rolling resistance performance in these segments. RMA members believe that due to the significantly different demands required of non-long haul tires, EPA should only base standards for Class 8 long haul applications on current SmartWay TM verified technologies program data. For other non-long haul applications, EPA should coordinate with SmartWay TMverified technologies program to incorporate the new data they have collected for non-long haul applications. As well, EPA should revise its application rates for non-long haul applications to reflect the fact that there is currently little if any market focus on low rolling resistance tires, either by tire manufacturers or tire purchasers, due to the other performance needs of these vehicles.

Docket Number: 0108
Commenter: Timothy Robinson, Bridgestone Americas Tire Operation

Retreadability of various tires cited in the EIS needs to be studied. Some tire types may not be able to be retreaded as many times as other tire types.

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Bridgestone Americas recommends that NHTSA and the EPA conduct a total life cycle analysis study to fully understand the environmental impacts of:

- Tires with various performance levels, and any trends discovered using data from recommendation #1.
- Retreadability of various tire options cited in the EIS.

We highly recommend the use of a globally recognized total cycle analysis such as ISO14040:2006 and ISO 14044:2006. Bridgestone Americas is willing to support and participate in any way we can.

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

Although the proposed rule-making will not provide guidelines or tire maintenance inspection protocols, recommendations should be made to the states to develop and to implement applicable tire inflation and inspection protocols. Automatic tire inflation would be an important technological feature as a means to keep tires properly inflated and ensure proper load distribution with the pavement surface in addition to fuel savings. New York State recommends that automatic tire inflation be included in the host of technology measures under the proposed rules.

Response

NHTSA appreciates the commenter's recommendations to more closely analyze the environmental impacts associated with tire performance. Reducing a tire's rolling resistance will reduce fuel consumption and lower emissions of CO_2 and other greenhouse gases. The agency accounts for low rolling resistance tire performance in the proposed standards. To quantify tire rolling resistance and the emission reductions associated with reduced rolling resistance, EPA conducted independent testing of tire rolling resistances and their applicability for each vehicle sector. Each of the alternatives contains targets for reductions in rolling resistance that would lead to overall increases in vehicle fuel efficiency. NHTSA also considered other factors of tire performance, including durability, traction control, vehicle handling, comfort, and retreadability.

NHTSA recognizes that proper tire inflation pressure can be maintained with a rigorous tire inspection and maintenance program or with the use of tire pressure and inflation systems. While

the agency recognizes that such devices could have a beneficial effect on fuel efficiency, their use is not included in this regulatory framework. NHTSA will continue to rely on the SmartWay program, which provides information on proper tire inflation pressure and on tire inflation pressure monitoring systems. Most fleet operators require pre-route vehicle inspections by drivers. These inspections typically include air pressure checks to not only help with the fuel efficiency benefits of proper tire inflation pressures, but to also help ensure safe vehicle operational characteristics.

6.2.8.5 Vehicle Speed Limiters

Comments

Docket Number: 0112; 0081
Commenter: Vera Pardee, Center for Biological Diversity

In our January 3, 2011 Comment Letter, we have already urged the Agencies to set standards based on the use of speed governors, whose potential to limit fuel consumption is highly significant since fuel consumption and CO_2 emissions increase proportional to the square of vehicle speed. Moreover, speed governors are already used in the industry and are inexpensive. The Agencies base their decision not to assume the use of speed governors on their stated concern that they lack jurisdiction to require them; however, we note here that the Agencies already require speed limiters' use where manufacturers seek to qualify their tractors as "off-road" to qualify them for an exemption to the rulemaking . . . If the Agencies can mandate the use of a technology as a condition to obtaining a statutory exemption, they can adopt standards that are premised on their use as well.

* * * * *

We note that in rejecting consideration of the 60 mile-per-[hour] speed regulator, the Agencies have indicated that they believe they lack the statutory authority to require manufacturers to reduce vehicle speed. However, the statute contains no such restriction. Instead, it instructs NHTSA to examine the fuel efficiency of HD Vehicles and determine "the range of factors, including, without limitation, design, functionality, use, duty cycle, infrastructure, and total overall energy consumption and operating costs that affect [HD Vehicles'] fuel efficiency," and then to implement "fuel economy standards" that are "appropriate, cost-effective, and technologically feasible" for HD Vehicles. Speed undoubtedly is a "factor" in fuel efficiency, and a speed regulator is a technology that is feasible (and already in use), cost effective, and appropriate, and will create immediate and significant fuel efficiency gains. But even if the Agencies simply require a regulator set at existing maximum speed limits to avoid any jurisdictional concerns, speeding and its attending fuel consumption would be eliminated. We urge the Agencies to reconsider their position and adopt a speed limitation technology. [Footnotes omitted].

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

Speed governor technologies are 1) cost effective, 2) proven to reduce fuel consumption and emissions and 3) appear to be generally acceptable to the trucking industry. New York State believes that the use of vehicle speed limiters in Class 8 sleeper cab trucks would be an effective tool in reducing fuel consumption as these trucks travel long distances and could easily be set to a truck speed limit without compromising operational logistics.

Docket Number: TRANS-Chicago
Commenter: Jed Mandel, Engine Manufacturers Association and Truck Manufacturers Association

We recognize that in the goods movement arena, the opportunity to reduce fuel consumption and therefore improve greenhouse gases is way beyond the four wheels, if you will, of the vehicle itself. Depending on what the public policy of the United States would be, we can provide data to you that shows you that for each mile of reduction in average speed there is a concomitant improvement in fuel efficiency. There's a direct relationship. Obviously that has to be enforced as well as implemented.

Response

NHTSA agrees that fuel efficiency benefits may be realized through the incorporation of speed limiters. One commenter mistakenly thought that the agencies were rejecting consideration of VSLs due to perceived jurisdictional obstacles. In fact, both the CAA and EISA allow consideration of VSL technology, and the agencies considered the appropriateness of basing standards on performance of the technology. The NPRM proposed to allow combination tractors that use vehicle speed limiters (VSL) to include the maximum governed speed value as an input to the GEM model for purposes of determining compliance with the vehicle standards. *See* 75 FR at 74223. Governing the top speed of a vehicle can reduce fuel consumption and GHG emissions, because fuel consumption and CO_2 emissions increase exponentially with the vehicle speed. Limiting the speed of a vehicle reduces the fuel consumed, which in turn reduces the amount of CO_2 emitted. The NPRM proposed to use the maximum speed programmed in the VSL as an input into GEM to determine the fuel economy benefit.

The forthcoming rulemaking documents will discuss in detail the technologies that may be used to meet the final standards.

6.2.8.6 Bottom Cycling Technology

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center For Biological Diversity

Bottom cycling is an emerging technology that can provide significant reductions in CO_2 emissions compared with many other technology options. A bottoming cycle is a system of "waste heat recovery" in which heat that is generated as a byproduct of providing power to run a vehicle is captured and used to drive a secondary turbine to create more energy. The potential for bottoming cycle emissions reduction is greater than that of many other technologies or configurations. The fuel savings are comparable to the fuel savings for a parallel electric hybrid powertrain at two-thirds of the cost. In comparison to other technologies that use or reduce waste heat, bottoming cycles are far superior: a mechanical turbocompound can reduce CO_2 emissions by 2.9%; electrical turbocompound by 4.2%; variable valve actuation by 1%; and advanced exhaust gas recirculation by 1 to 2%. In contrast, a bottoming cycle can reduce CO_2 emissions by up to 10%.

Although bottoming cycle technology has not yet been used in vehicles, it is common in power plants. Moreover, a recent report by the Northeast States Center for a Clean Air Future and the International Council on Clean Transportation ("NESCCAF/ICCT report") clearly considers the bottoming cycle a viable future technology that can feasibly be implemented in 2017, and includes a bottoming cycle in two of the emissions reductions "packages" simulated to show what level of whole-vehicle reductions are possible. One way to accelerate implementation is to use a less aggressive bottoming cycle that would be easier and cheaper to achieve by 2017, with a CO_2 reduction potential of 8%. The NPRM also notes that a report to the National Academy of Sciences panel reviewing fuel efficiency improvement opportunities for HD Vehicles included waste heat recovery in the engine package for MD 2016-2020.

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The NPRM has so far concluded, despite these studies, that bottom cycling will not be ready for production by the 2017 model, and has therefore excluded it from the rulemaking. This reasoning cannot withstand scrutiny: exclusion is sure to result in a standard that represents less than the “maximum feasible” improvement, even though the technology is (a) technically feasible within the rulemaking’s time frame, (b) appropriate for the vehicle, and (c) cost effective.

Response

NHTSA disagrees with the commenter’s assessment that bottom cycling technology is technically feasible within the regulatory timeframe. NHTSA believes that bottom cycling technologies are still in the development phase and will not be ready for production by MY 2017. For example, TIAX noted in their report to the NAS panel that the engine improvements beyond MY 2015 included in the NAS report were highly uncertain. For this reason, the agency did not include bottom-cycling technologies in determining the stringency of the proposed standards for heavy-duty engines. However, NHTSA considers this technology a significant opportunity to reduce fuel consumption in the future, and NHTSA plans to explore the creation of incentives for manufacturers to continue to invest to develop this technology through an advanced technology credit program that is intended to encourage the development of technologies that are not yet commercially available for the heavy-duty fleet.

6.2.8.7 ‘Suite’ of Technologies

Comments

Docket Number: 0112
Commenter: Vera Pardee, Center for Biological Diversity

(b) Technologies Exist or Can Be Implemented During the Rulemaking Period That Improve Fuel Efficiency Gains By Up To 50%

In our January 3, 2011 Comment Letter, we discussed technologies that either exist or can feasibly be developed and implemented during the rulemaking period, that are appropriate for HD Vehicles, and that can sharply increase their fuel efficiency gains, but that the Agencies have excluded from their preferred choice (Alternative 6). Specifically, we urged the Agencies to impose fuel efficiency regulations on trailers used with Class 7 and Class 8 tractors, to require the use of bottoming cycle technology within the rulemaking years, and to adopt other viable fuel efficiency improvements. We here add the following comments.

In several instances, the Agencies present a “suite” of presently available and feasible technologies, but expressly do not require that each technology within the “suite” be applied. For example, in discussing the use of idle reduction technologies, the Agencies state that, “as with all technology inputs discussed in this section, the agencies are not mandating the use of idle reductions or idle shutdown, but rather allowing their use as one part of a suite of technologies feasible for reducing fuel consumption and meeting the proposed standards." In other words, the Agencies allow manufacturers to choose among some proven, available, feasible and efficiency improvements measures, leaving some of them unused (or used only to obtain voluntary credits). However, in every instance where such “optional” technologies would add to a vehicle’s fuel efficiency, the failure to require their implementation violates the mandates of EPCA and EISA to produce the “maximum feasible” fuel efficiency improvements. We urge the Agencies instead to adopt efficiency standards that incorporate the use of every one of the technologies now allocated to an optional technology “suite”, excepting only those that create no additionality.

Docket Number: PAPER-Cambridge
Commenter: Carol Lee Rawn, Ceres and the Investor Network on Climate Risk (INCR)

We thus urge EPA and NHTSA to take into account all available technologies across the vehicle in setting standards.

Docket Number: TRANS-Chicago
Commenter: Mark Kraemer

But technology exists right now that can achieve substantial fuel reductions in tractors and in other trucks as well, and these efficiency gains could be made in a few short years.

Docket Number: TRANS-Chicago
Commenter: Tony Garcia, International Union UAW

We recognize that the technologies available now or in the near future make the substantial contribution possible and believe it is entirely appropriate that regulations be enacted that reflect what can be achieved.

Response

NHTSA disagrees that the agency must implement all available technologies when setting heavy-duty standards. NHTSA believes it is important to distinguish between setting “maximum feasible” standards, as EPCA/EISA requires, and “maximum technologically feasible” standards.

The agency must weigh all of the statutory factors in setting fuel efficiency standards, and may not weigh one statutory factor in isolation. Neither EPCA nor EISA defines “maximum feasible” in the context of setting heavy-duty standards. Instead, NHTSA is directed to consider three factors when determining what the maximum feasible standards are – “appropriateness, cost-effectiveness, and technological feasibility.” 49 U.S.C. § 32902(k)(2). It is within the agency’s discretion to weigh and balance the factors laid out in 32902(k) in a way that is technology-forcing, as evidenced by the alternatives analyzed in this EIS, but that stops short of requiring the application of all available technology to all vehicle categories.

The agency has carefully balanced the statutory factors in setting forth alternatives under consideration in this EIS, with the goal of setting standards at the maximum feasible level. In doing so, NHTSA determined appropriate engine and vehicle technologies for each vehicle sector that would achieve the maximum feasible level within the regulatory timeframe covered by this rulemaking. The agency believes that the alternatives selected in this EIS represent a reasonable range of alternatives and that the technologies reflected therein properly bracket where the “maximum feasible” standards would fall. For a discussion of the alternatives, *see* Section 2.3 of the DEIS and this FEIS.

6.2.8.8 HD Engines

Comments

Docket Number: TRANS-Chicago
Commenter: Don Anair, Union of Concerned Scientists

We also support establishing both engine standards and full vehicle standards. Engine improvements are critical for reducing fuel consumption across all vehicle classes and vocations.

* * * * *

Finally, EPA and DOT should strengthen the proposed engine standards to more closely reflect the potential improvements in engine technologies available by 2017. The National Academy's evaluation indicates that incremental improvements in combustion efficiency, electrification of accessories, improved emission control systems, and turbo-compounding can deliver up to twice the proposed fuel savings for heavy-duty engines in 2014 and 2017.

Docket Number: TRANS-Chicago
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

I want to comment on the question of the stringency of the standards, and I want to first indicate my support for some of the comments of the Union of Concerned Scientists in this area and add a few specifics for the engine category. We also think that the stringency could be improved somewhat.

Response

The engine technologies projected for gasoline heavy-duty engine standards are technologies used in the Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Joint Technical Support Document. These technologies include: engine friction reduction, coupled cam phasing, cylinder deactivation, and stoichiometric gasoline direct injection. For diesel engine standards, NHTSA evaluated the following technologies: combustion system optimization, turbocharging and air handling systems, engine parasitic and friction reduction, integrated aftertreatment systems, electrification, and waste heat recovery.

NHTSA carefully evaluated the research supporting the NAS report and its recommendations and incorporated them to the extent practicable in the development of the HD Fuel Efficiency Improvement Program. While the NAS report suggests that greater engine improvements could be achieved by the use of technologies such as improved emission control systems and turbo-compounding, NHTSA believes the alternatives under consideration represent the most stringent technically feasible for diesel engines used in tractors and vocational vehicles in the 2014 to 2017 timeframe.

The NAS study concluded that tractor engine fuel consumption can be reduced by approximately 15 percent in the 2015 to 2020 timeframe and vocational engine fuel consumption can be reduced by approximately 10 to 17 percent in the same timeframe. Based on a review of existing studies, NAS study authors found that a range of reduction potential exists for improvements in combustion efficiency, electrification of accessories, improved emission control systems, and turbocompounding. The study found that improvements in combustion efficiency can provide reductions of 1 percent to 4 percent; electrification of accessories can provide reductions of 2 percent to 5 percent in a hybridized vehicle; improved emission control systems can provide a 1

percent to 4 percent improvement (depending on whether the improvement is to the EGR or SCR system); and a 2.5 percent to 10 percent reduction is possible with mechanical or electrical turbocompounding. While the reductions under consideration in this regulation are lower than those published in the NAS study, NHTSA believes that they are consistent with the findings of the NAS study. The reasons for this are as follows.

First, some technologies cannot be used by all manufacturers. For example, improved SCR conversion efficiency was projected by NAS to provide a 3 percent to 4 percent improvement in fuel consumption. Conversely, low temperature EGR was found to provide only a 1 percent improvement. While the majority of manufacturers do use SCR systems and will be able to realize the 3 percent to 4 percent improvement, not all manufacturers use SCR for NO_X aftertreatment. Manufacturers that do not use SCR aftertreatment systems would only be able to realize the 1 percent improvement from low temperature EGR. The agencies took into consideration the entire market in setting forth the stringency of the proposed standards and alternatives and thus did not assume that all manufacturers would be able to use all technologies.

Second, significant technical advances may be needed in order to realize the upper end of estimates for some technologies. For example, studies evaluated by NAS on turbocompounding found that a 2.5 percent to 10 percent reduction is feasible. However, only one system is available commercially and this system provides reductions on the low end of this range. Little technical information is available on the systems that achieve reductions in the upper range for turbocompounding. These systems are based on proprietary designs, and improvement results have not yet been replicated by other companies or organizations. NHTSA is assuming that all tractor engine manufacturers will use turbocompounding by 2018 in response to its proposed standards. This will require a significant change in the design of heavy-duty tractor engines, one that likely represents the maximum technically feasible standard even at the low end of the assumed improvement spectrum.

Finally, different duty cycles used in the evaluation of medium- and heavy-duty engine technologies can affect reported fuel consumption improvements. For example, some technologies are dependent on high load conditions to provide the greatest reductions. The duty cycles used to evaluate some of the technologies considered by NAS differed significantly from that used by the agencies in the modeling for this rulemaking. Maximum and average speed was higher in some of the cycles used in the studies, for example, and one result was demonstrated on a nonroad engine cycle. The effectiveness of turbocompounding when evaluated on a duty cycle with higher engine load can show a greater reduction potential than when evaluated with a lower engine load. NHTSA selected the duty cycles for this analysis that the agency believes best suits tractors and vocational engines.

6.2.8.9 Northeast States Center for a Clean Air Future, International Council on Clean Transportation (NESCCAF/ICCT) Report

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center For Biological Diversity

According to the NESCCAF/ICCT report, heavy-duty long haul truck emissions could be reduced by up to 50% in MY 2017 through a combination of technologies (e.g., aggressive aerodynamics and rolling resistance reductions, parallel hybrid powertrain, bottoming cycle, Rocky Mountain double trailer, and a 60 mile-per-gallon governor). (Some of these technologies are also feasible for other segments within the H[D] Vehicle category). The NESCCAF/ICCT report indicates that this package falls within a "reasonable technological risk," and over a 15-year payback period owners would reap a cost savings of $42,000 (assuming a fuel price of $2.50/gal). The payback period for the 50% reduction package ("Package 14") is stated at 4.7 years. Although these technologies exist or can feasibly be deployed by 2017 to reduce emissions of long-haul tractor trailers up to 50%, the Agencies have rejected many of them, including hybrid powertrains, idle reduction technologies, and bottoming cycles. Instead, the Agencies state they plan to utilize only technologies that are currently available. As stated above, this approach ignores the statutory mandate to devise a standard that represents maximum feasible improvements and is technology forcing.

* * * * *

Further, we note that, while the Agencies have rejected technologies such as bottom cycle engines, hybrid drive trains and full electric vehicles because they are not currently available for HD Vehicles, they have included other technologies, such as advanced exhaust gas recirculation which still faces some technological hurdles before it can be implemented. We urge the Agencies to implement in the later model years of the rulemaking all technologies reasonably estimated to be ready for implementation at that time.

Response

NHTSA reviewed the findings and recommendations of the NESCCAF/ICCT report when developing the proposed rule. In conducting its analysis of the NESCCAF/ICCT report, NHTSA adopted some of its key recommendations in implementing the new program but not all of them. The agency believes it is important to distinguish between setting "maximum feasible" standards, as EPCA/EISA requires, and "maximum technologically feasible" standards, as the commenter suggests. The agency must weigh all of the statutory factors in setting fuel efficiency standards, and may not weigh one statutory factor in isolation. Neither EPCA nor EISA define "maximum feasible" in the context of setting CAFE standards. Instead, NHTSA is directed to consider three factors when determining what the maximum feasible standards are – "appropriateness, cost-effectiveness, and technological feasibility." 49 U.S.C. § 32902(k)(2). It is within the agency's discretion to weigh and balance the factors laid out in 32902(k) in a way that is technology-forcing, as evidenced by the alternatives analyzed in this EIS, but that stops short of requiring the application of all available technology.

6.2.8.10 National Academy of Sciences (NAS) Report

Comments

Docket Number: TRANS-Cambridge
Commenter: Luke Tonachel, Natural Resources Defense Council

NRDC considers the model year 2014 to 2018 proposal to be part of the first of multiple future medium- and heavy-truck rulemakings that will continue to cut pollution and improve efficiency. The National Academies have detailed technology pathways that go beyond those required by the standard, including hybrid drivetrains, advanced bottoming-cycle engines and plug-in electric drive vehicles.

Docket Number: TRANS-Cambridge
Commenter: Jason Mathers, Environmental Defense Fund

Moreover, truck and engine manufacturers can comply with the agencies' standards, and Americans can realize these significant cost-cutting benefits by broadly deploying currently available technologies. In fact, a recent report by the National Academy of Sciences found that a variety of technologies are available today to improve fuel efficiency and reduce pollution even beyond what is proposed in the rule.

These standards provide a clear path forward for fleets already utilizing advanced technologies as well as those looking to integrate advanced technologies into their fleets.

Response

Consistent with EISA's direction, The National Academy of Sciences (NAS) submitted a report evaluating medium- and heavy-duty fuel economy standards to NHTSA in March of 2010. NHTSA reviewed the findings and recommendations of the NAS report when developing the proposed rule, but also conducted an independent study. In conducting its analysis of the NAS report, several key recommendations, such as the use of fuel efficiency metrics, were found to be the best approach to implementing the new program. However, the results of its own study, along with EPA's, led NHTSA to develop a different approach with respect to the inclusion of certain technologies in setting standards as noted by the commenter.

The purpose of NHTSA's study was to bring together the NAS recommendations and the agency's independent analysis to determine the basis for the proposed standards. While hybrid technology was not included in setting the agency's proposed standards, NHTSA believes that an incentive structure would be beneficial to encourage the penetration of this technology into the heavy-duty fleet. NHTSA anticipates that the inclusion of other technologies such as advanced bottom-cycling engines and plug-in electric drive vehicles could be considered in a future rulemaking.

6.2.9 Non-Technological Improvements

Comments

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

In addition, the NAS Study cites to the significant fuel efficiency improvements that can be brought about by driver training and education. . . . Setting standards higher than technological improvements alone can achieve will provide the incentive to put non-technological solutions such as these into practice.

Docket Number: 0094
Commenter: Dominic Cardella

Returning to the topic of tractor-trailer vehicles, the American Trucking Associations (ATA) lists several recommendations that should be also be considered. The recommendations include reducing national speed limits to 65mph, governing the top speed of later model trucks to 65mph, initiatives to reduce discretionary engine idling, more efficient traffic management and roadway design, and innovative management techniques to increase the amount of cargo hauled per truck and per gallon of fuel. As a leading voice of the trucking industry, ATA believes that many of these recommendations are practical and can be readily implemented for immediate benefit.

Docket Number: 0138
Commenter: Douglas Greenhaus, NADA

In its report, the NAS discussed numerous other approaches to increasing fuel efficiency, including comprehensive driver training, the use of higher productivity vehicles (e.g., longer combinations), congestion mitigation, more efficient vehicle deployment and routing, and rigorous maintenance practices. NADA/ATD recognizes the limited authority EPA and NHTSA have to regulate vehicles in-use. Nonetheless, agency resources should be devoted to promoting these and other effective fuel efficiency improvement strategies.

Docket Number: TRANS-Cambridge; TRANS-Chicago
Commenter: Jed Mandel, Engine Manufacturers Association and Truck Manufacturers Association

Three, significant opportunities for fuel efficiency improvement exist both outside the engine and/or vehicle manufacturers' control and, indeed, beyond anything that EPA and NHTSA are currently proposing. Speed limitation, highway weight and length requirements, infrastructure improvements, congestion control and the like, should all be considered as opportunities for additional improvements

* * * * *

In a similar way, in the United States, various states have various different requirements . . . for the weight and length of tractors or trucks that are allowed on the highway. If longer and heavier trucks were allowed, we would greatly improve the fuel efficiency associated with the movement of goods that those trucks carry.

* * * * *

We know that congestion in our nation's highways—and there are certain specific spots that are notorious for congestion—lead to inefficient operation of—throughout the goods movement system. And if we can improve that, get rid of those bottlenecks and improve that congestion, we know again that there are demonstrable improvements in fuel [efficiency] that, again, directly translate to improved greenhouse gas emissions.

* * * * *

Some of them are beyond the scope of, certainly, the EPA's authority and in some degree, NHTSA's as well. But by working together as we worked together to this point, I'm hoping that we can identify additional opportunities for improvement.

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

The preamble describes the complexities of the truck market, ranging from engine manufacturers, truck owners, trailer manufacturers, trailer owners, shipping companies, trucking operators, trade and others. Although the medium-and heavy-duty truck market could have increased its profit margin greatly through fuel-saving technologies, to date, truck buyers and operators have not taken advantage of opportunities to make investments in these types of technologies. Availability of reliable information regarding performance of new technologies may be one reason why truck buyers are not making more fuel-efficient purchases. Information availability, therefore, is a critical component toward steering this market to greater fuel efficiency. … Since lack of information availability has been a contributing factor in not steering the truck market towards improved fuel efficiency, every effort should be made to fill this information gap.

Response

Several commenters proposed specific technologies, non-technological improvements, or driver behavioral modifications as potential sources of fuel efficiency improvement. Under EISA, NHTSA is instructed to set "fuel economy standards" for HD vehicles and work trucks. Although NHTSA recognizes that such solutions may offer emissions reductions, the agency does not have the statutory authority to impose or require liberalized highway weight and length requirements, infrastructure improvements, congestion controls, improved vehicle deployment or routing, or more rigorous maintenance practices. Complementary operational measures like driver training, which are promoted by EPA's SmartWay program, will continue to provide efficiency benefits for the nation's truck fleet. The SmartWay program will also continue to provide reliable information on fuel efficient, low-carbon technologies and operational practices to help accelerate their deployment.

6.2.10 Economic Assumptions

6.2.10.1 Rebound Effect

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center For Biological Diversity

The Agencies admit that in the case of HD Vehicles, the rebound effect has not been studied extensively, and that the National Academy of Sciences has determined that it is "'not possible to calculate with a great deal of confidence what the magnitude of the 'rebound' effect is for heavy-duty trucks.'" At least until the Agencies can estimate the rebound effect on HD Vehicle drivers – if any – with some confidence, the fuel savings of the proposed rulemaking should not be discounted.

Docket Number: 0083
Commenter: Robert Stout, State of Missouri Department of Natural Resources

The DEIS makes the argument that most, if not all, fuel efficiency and emissions reductions that would be realized as a result of HD vehicles getting better mileage per gallon will be offset by more miles traveled, a process referred to as the "rebound effect". The study used values of 5 percent (tractors), 10 percent (HD pickups and vans) and 15 percent (vocational vehicles) for the rebound effect. The theory behind the rebound effect is that vehicles with higher fuel mileage will be driven more than the older vehicles they replaced, thus increasing their vehicle miles traveled (VMT). This increase in VMT is theorized to increase fuel consumption and increase emissions from actual driving to nearly the same level as the no action alternative.

The department agrees that it is reasonable to assume that consumers driving passenger vehicles may drive more if their vehicles get better gas mileage. They may be less motivated to economize, combine trips or carpool. The report failed to provide any compelling evidence to explain why tractors and other work trucks would be expected to increase VMT solely based on improved fuel savings. Improving fuel efficiency should not provide an incentive to increase VMT, but should rather provide an incentive to improve profitability. The report also fails to fully explain the rationale for the use of 5 percent, 10 percent or 15 percent estimated increases. The department suggests that NHTSA clarifies and supports the assumption that this effect will result in marginal fuel savings or overall emissions reductions from implementation of the New Medium-and Heavy-Duty Fuel Efficiency Improvement Program.

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

New York State commends the agencies' modeling effort for calculating a potential rebound effect. A rebound is likely to occur due to fuel savings achieved through the proposed measures. If moving freight by truck is to become cheaper and reduced fuel cost is passed on to customers, increased demand on truck freight could ensue and could cause a spike in truck traffic. New York State strongly recommends a consideration of strategies to prevent a shifting of shipping from rail to highway trucking services. New York State's Draft Climate Action Plan Interim Report presents policy options to shift freight to non-highway modes. The potential trucking rebound would be counter to this option and would not align with the transportation goal of reducing congestion and increasing freight movement efficiencies.

Response

According to the National Academy of Sciences (NAS) study, it is "not possible to provide a confident measure of the rebound effect," for heavy duty vehicles, yet NAS concluded that a rebound effect likely exists and that "estimates of fuel savings from regulatory standards will be somewhat misestimated if the rebound effect is not considered." While NHTSA agrees that the medium- and heavy-duty rebound effect needs to be studied in more detail, NHTSA has attempted to capture the potential impact of the rebound effect in its analysis so as not to misestimate fuel savings as cautioned by the NAS.

To derive an estimate of the rebound effect for use in assessing the fuel savings and other impacts of more stringent fuel consumption standards, NHTSA assessed multiple methodologies which produce a large range of potential values of the rebound effect, including aggregate, econometric, sector-specific, and other modeling methodologies. For the purposes of quantifying the rebound effect for this program, NHTSA's estimates of the rebound effect were derived from econometric analysis of national and state VMT data. Specifically, the estimates of the rebound effect reported in the draft RIA are ranges of estimated short-run and long-run elasticities of annual VMT by vocational vehicles (single-unit) and combination trucks with respect to fuel cost per mile driven. (Fuel cost per mile driven during each year is equal to average fuel price per gallon during that year divided by average fuel economy of the truck fleet during that same year.) These estimates were derived from time-series regression of annual national aggregate VMT for the period 1970-2008 on measures of nationwide economic activity, including aggregate GDP, the value of durable and nondurable goods production, and the volume of U.S. exports and imports of goods, and variables affecting the price of trucking services (driver wage rates, truck purchase prices, and fuel costs), and from regression of VMT for each individual state over the period 1994-2008 on similar variables measured at the state level.

Since long-run state data estimates under the econometric analysis are generally more consistent with the aggregate estimate methodology, NHTSA selected a rebound effect for vocational vehicles (single unit trucks) of 15%, which is within the range of estimates from both the econometric and aggregate methodologies. Similarly, NHTSA chose a rebound effect for combination tractors of 5%. To date, no estimates of the HD pickup truck and van rebound effect have been cited in relevant literature. Since this class of vehicles encompasses a wider range of applications than heavy-duty vocational vehicles, it is not appropriate to apply rebound estimates for vocational vehicles to HD pickup trucks and vans. These vehicles are more similar in use to large light-duty vehicles, so for the purposes of our analysis, NHTSA chose to apply the light-duty rebound effect of 10% to HD pickups and vans.

NHTSA disagrees with the statement by one commenter that most, if not all, fuel efficiency and emissions reductions due to the proposed rule would be offset by the rebound effect. As described above, the rebound effect selected by the agency ranges from 5% to 15% depending on the class of vehicles. As explained in Section 3.1 of this EIS, fuel consumption and CO_2 emissions are projected to decline under each of the action alternatives in comparison to the No Action 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.

NHTSA does not agree with the characterization, by one commenter, of the agency's assumption for the rebound effect for tractors and vocational vehicles as based solely on fuel savings. As described above, the agency's estimates for the rebound effect analyze other variables beyond fuel costs, including driver wage rates and truck purchase prices.

For the purposes of this EIS, the agency has not taken into account any potential impact on fuel savings or GHG emission reductions from the rail sector due to mode shifting.

6.2.10.2 Cross Border Trucking

Docket Number: TRANS-Chicago
Commenter: Michael Ciaccio, International Brotherhood of Teamsters

Successful implementation of these standards, however, should not be compromised by regulatory loopholes. For example, environmentally hazardous trucks from Mexico cross into American commercial zones 5 million times a year. If the cross-border trucking requirements aren't implemented, many trucks that don't have to meet the standards will be allowed to travel throughout the United States. U.S. drivers would suffer financially from competition with low wage Mexican drivers, and truck manufacturing would be harmed by diminished demand.

I'll give you have another example. There are about 100,000 environmentally hazardous trucks at our nation's ports. As we develop an emission standard, we must also pass legislation like the Clean Ports Act so that solutions like the Port of Los Angeles' Clean Truck Program can be fully implemented.

Docket Number: 0141
Commenter: Stanley Gee, Acting Commissioner, State of New York Department of Transportation

Reducing fuel consumption of the heavy-duty engines and vehicles could also benefit Canadian, Mexican, and other foreign trucking firms, if they utilize the new engine and related technologies as well. Our agencies recommend that these impacts be considered as part of an overall National Freight Plan that balances freight and environmental needs, especially important in light of projected increases in freight movement.

Response

The Federal Motor Carrier Safety Administration, a cooperating agency to this EIS, is establishing a Pilot Program on North America Free Trade Agreement (NAFTA) Long-Haul Trucking Provisions. *See* 76 FR 20807. This pilot program addresses requirements, including environmental controls, needed to engage in long-haul trucking across the U.S. border. As of June 2011, FMCSA is working to develop an environmental assessment to evaluate the environmental impacts associated with this program. NHTSA notes that any impacts that occur as a result of the adoption

of fuel efficiency technologies in trucks manufactured for use outside the United States in response to the proposed rule is beyond the scope of this EIS.

6.3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

6.3.1 Air Quality

Comments

Docket Number: TRANS-Cambridge
Commenter: Jeanette MacNeille

I don't think, in my lifetime, I am going to see really clean air, but I think our children, or our grandchildren might, because of what's being done here. It actually matters. And I think, also, that if we allow the status quo to remain as it is, what we are then doing is building our transportation, and our energy and our commercial enterprises on the broken health of our children, and the elderly, and everybody in between.

Docket Number: TRANS-Chicago
Commenter: Mark Kraemer

And studies have found that adopted these standards could result in improvement to public health as well. That is a public health issue as well as a fuel efficiency issue.

* * * * *

We must act now to ensure that our children and our grandchildren will live in a world that is as healthy or even healthier, hopefully, as the one we live in right now. It is within our power to accomplish this within just a few years if we act now in the best interest of our environment and make trucks that use less gasoline.

Docket Number: TRANS-Chicago
Commenter: Charles Frank

[M]y wife suffers from asthma, and I know that with higher fuel economy standards, trucks will burn less fuel and emit less soot and other particulate matter into the air we all breathe, and she and so many others that suffer directly from this hazard will have a healthier life. Health care costs will go down; and the number one reason for school children missing school, asthma, will be better controlled, reducing absenteeism and improving productivity, even at GM, from parents that have to stay home from work to take care of sick children or families.

Docket Number: PAPER-Chicago
Commenter: Richard Stuckey

When your recommendations for higher fuel economy standards and reduced emissions are implemented trucks will burn less fuel and emit less soot and other particulates into the air and [my daughters] and others that suffer from these hazards may breathe better and have healthier li[v]es. When your recommendations are implemented the greatest reason for school children to miss school, asthma, will be better controlled, reducing absenteeism and loss of productivity from parents who have to stay home to care for their children. Health care costs will go down and health insurance costs will be reduced.

Docket Number: TRANS-Chicago
Commenter: Michael Ciaccio, International Brotherhood of Teamsters

In addition to the benefits to our environment, cleaner, more efficient trucks will represent a dramatic improvement to the working conditions of truck drivers as their exposure to dangerous diesel fumes will be greatly reduced.

Docket Number: TRANS-Cambridge
Commenter: Jessica Feldish

I think that there is nothing more important than finding innovative ways to reduce fuel consumption and air pollution than to raise the fuel economy standards for trucks. I too, from living in a very high traffic area, have suffered allergies and seasonal issues from the air pollution that has surrounded my community with trucking. And I think that reducing our dependence on oil would create a healthier and more equitable and sustainable future for my peers and I to prosper within, as we grow and create lives of our own in this great country.

Docket Number: TRANS-Cambridge
Commenter: Susan Shamel

I have an adorable three-year-old grandson, who has recently been diagnosed with asthma. There's no history of this in our family, and it is quite possible to attribute his disease to excessive tropospheric ozone. In addition, ozone is also killing plants, with a $2 billion loss to the soybean crop in the U.S. this past year being attributed to high ozone levels. Regulations designed to address fuel standards on trucks would cut emissions and help to lower these ozone levels.

Docket Number: TRANS-Chicago
Commenter: Rich Stuckney

When your recommendations are implemented, the greatest reason for schoolchildren who miss school, asthma, will be better controlled and reduce absenteeism and lost productivity from parents who stay at home care to care for their children and will be addressed in health costs which will go down and insurance costs will be reduced.

Docket Number: PAPER-Cambridge
Commenter: Roger Shamel

It is also imperative to consider the health effects of reducing fossil fuel use. Currently, ozone levels in the lower atmosphere are way above acceptable standards, a direct result of excessive fossil fuels burning. This is leading to increased respiratory distress, esp[ecially] among the young and elderly, and especially in hot weather. Asthma rates in this country are rapidly rising as a result, with 40,000 deaths annually.

Docket Number: TRANS-Cambridge
Commenter: Mike Gildesgame, Appalachian Mountain Club

And we concur with the EPA notes in the preamble to the proposed regulations that were circulated, and urge that the studies that were noted there be carried out, be completed. And I'm quoting here, “It is important to qualify the health and environmental impacts associated with the proposed standards because a failure to adequately consider these ancillary co-pollutant impacts could lead to an incorrect assessment of their net costs and benefits. Moreover, co-pollutant impacts tend to accrue in the near term, while any effects from reduced climate change mostly accrue over a timeframe of several decades or longer. EPA typically quantifies and monetizes the health and environmental impacts related to both PM, (particulate matter), and ozone in its regulatory impact analyses (RIAs), when possible. However," as you noted, "EPA was unable to do so in time for this proposal." We hope that those studies are carried out.

Docket Number: TRANS-Cambridge
Commenter: Kate Maas, Board of Health in Chelsea, Massachusetts

I would like to address the impact that climate change will have on air quality in communities such as the one where I live, whose air quality is already severely compromised. Diesel pollution right now is a serious public health issue in our community. Being an urban industrial center, right across the harbor from Boston, much of Chelsea serves as a transport center delivering all grades of oil, road salt, products and produce to communities all over New England. With thousands of diesel trucks crisscrossing our city on a daily basis, Chelsea constantly must contend with diesel exhaust that compromises our air quality and the public health of our citizens. Health conditions related to diesel emissions are: Strokes, coronary heart disease, asthma/asthma-related hospitalizations. And Chelsea already ranks in the highest category in the state for all of these conditions.

* * * * *

We are actively trying to do something about our diesel pollution problem and the related health concerns, but we are equally aware that as we mitigate, climate change exacerbates. So I would like to reiterate what I said in the beginning. Issuing fuel economy requirements at a national level, which will result in reductions in global warming tailpipe emissions is immensely important for communities such as ours and so, we, in Chelsea urge the EPA and the DOT to set the strongest standards possible in order to mitigate our pollution exposure.

Docket Number: TRANS-Chicago
Commenter: Gordon Shelter

I think enacting the strongest standard possible is important. CAFE standards for cars have spurred industry innovation and have benefitted American consumers for decades. According to recent studies, workers with the greatest lifetime exposure to diesel exhaust had a 31-percent higher risk of lung cancer than people with no such occupational exposure. The particulate matter in diesel exhaust also exacerbates conditions like asthma. During a year I spent as a furniture mover, often spending hours loading and unloading idling trucks, I developed a persistent cough. My family affectionately referred to it as a "mover's cough," that didn't end until I found other employment. I wouldn't try to establish causation from my experiences, but a growing body of research suggests particulate exposure has deleterious health consequences. Truck standards will provide far-reaching benefits for everyone.

Response

As a number of commenters indicated, one important benefit of the proposed standards is the health effects of reducing fossil fuel use. As this EIS indicates, the action alternatives would result in substantial fuel savings – and associated emissions reductions – as compared to the No Action Alternative.

The proposed standards would affect air pollutant emissions and air quality, which in turn could affect public health and welfare and the natural environment. For this EIS, 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. All of the action alternatives, including the Preferred Alternative, are projected to result in fewer emergency room and work-loss days for conditions like asthma and less incidence of chronic bronchitis. Sections 3.5.2 and 4.3.3 of the DEIS provide further information on the health benefits of the proposed standards.

A number of commenters stated that the proposed standards would benefit specific groups of individuals and specific communities. For example, one comment indicated that workers exposed to truck exhaust would benefit from the rule. NHTSA expects that people whose employment exposes them to truck exhaust will benefit from reduced truck exhaust emissions. In addition, to the extent new, more fuel efficient vehicles are operated in specific areas, NHTSA expects that the emissions reductions and health benefits would occur in those areas as well.

In response to the comment seeking additional analysis of the health benefits of the proposal, for this FEIS, NHTSA has conducted a detailed photochemical air quality modeling study to refine the estimates of health benefits and monetized health benefits. *See* Appendix F.

Comments

Docket Number: 0083
Commenter: Robert Stout, State of Missouri Department of Natural Resources

Localized Calculation of Emissions Reductions
The study also examined the effects of the proposed fuel efficiency rule on nonattainment and maintenance areas. The study concluded that localized results show that very little emissions reductions would result in nonattainment or maintenance areas from the proposed rule. This is based on assumptions that most of these areas have no petroleum production or refining within their boundaries and that petroleum was not transported through urban areas. Impacts to nonattainment and maintenance areas are of particular concern because of the air quality status of the two largest urban areas in Missouri. St. Louis is currently designated as nonattainment for ozone and PM. Kansas City is designated as a maintenance area for ozone. The specific criteria pollutants of concern in Kansas City and St. Louis are outlined below:

Ozone -Kansas City
The Kansas City Metropolitan Area is a maintenance area under the previous one-hour ozone standard, and was designated attainment for the 1997 8-hour ozone standard. Also, the area has numerous local controls implemented as a result of the previous ozone violations under the one-hour ozone standard. These controls are found in the Kansas City Ozone portion of the Missouri State Implementation Plan, and in Title 10, Division 10, Chapter 2 of the Missouri Code of State Regulations. The 8-hour ozone maintenance plan for the Kansas City Maintenance Area was approved by EPA in 2007. This plan includes additional local control measures that are required to be implemented in two phases when triggered. The first phase was triggered by the quality assured violation of the 8-hour ozone standard during the 2007 ozone season. This phase includes a heavy-duty diesel idle reduction measure that has already been put in place and emissions reductions from large point sources that fall under the Clean Air Interstate Rule. The 8-hour ozone standard was revised in 2008. Air quality data showed that the Kansas City Area would be nonattainment under this new, lower standard. The Missouri portion of the Kansas City nonattainment area was recommended to include Platte, Clay, Clinton, Jackson and Cass counties. In 2010, the EPA proposed a reconsideration of the 2008 ozone standard to an even lower range. The reconsidered ozone standard is not expected to have any effect on our recommendation for counties designated nonattainment in the Missouri portion of the Kansas City area.

Ozone -St. Louis
The St. Louis area counties of Jefferson, Franklin, St. Charles, and St. Louis and St. Louis City are an ozone nonattainment area under the 1997, 8-hour ozone standard. As such, the area is required to have emission reduction plans to achieve attainment. The area also has numerous local emissions controls on various types of emission sources, which are found in the St. Louis portion of the Missouri State Implementation Plan. Under the revised 2008 ozone standard, Lincoln County was added to these same counties and city for the nonattainment designation recommendation. The ongoing reconsideration of the 2008 standard is not anticipated to affect our nonattainment recommendation for the St. Louis area.

Particulate Matter -St. Louis
The St. Louis Area contains the only part of the state designated as nonattainment for particulate matter under the 1997 annual PM 2.5 Standard. The St. Louis particulate matter nonattainment area includes the City of St. Louis and the counties of St. Louis, St. Charles, Franklin, and Jefferson.

Response

The commenter states that the emissions projected by the DEIS in nonattainment and maintenance areas are of concern because of the air quality status of the two largest urban areas in Missouri, and also notes that the St. Louis area is currently designated as a nonattainment area for ozone and PM.

Particulate Matter – Kansas City
Kansas City is designated as a maintenance area for ozone. The data presented in Appendix D of the FEIS show that emissions of $PM_{2.5}$ in the Kansas City ozone maintenance area are predicted to increase by a maximum of less than 16 tons per year. The total 2005 emissions of $PM_{2.5}$ in the Kansas City ozone maintenance area were 14,127 tons (EPA 2010a). The maximum predicted increase in $PM_{2.5}$ emissions represents approximately 0.11 percent percent of the area's total $PM_{2.5}$ emissions. Because the maximum predicted increase in $PM_{2.5}$ emissions represents a relatively small proportion of the area's total $PM_{2.5}$ emissions, the proposed HD vehicle standards would not jeopardize the Kansas City area's status as attainment for the $PM_{2.5}$ standards.

Ozone – Kansas City
The data given in Appendix D of the FEIS show that emissions of NO_x and VOC, the precursor emissions of ozone, in the Kansas City ozone maintenance area are predicted to decrease under every action alternative for all analysis years. *See* Section 3.3.1.2.1 for more information on ozone.

Ozone – St. Louis
The data given in Appendix D of the FEIS show that emissions of NO_x and VOC in the St. Louis ozone nonattainment area are predicted to decrease under every action alternative for all analysis years.

Particulate Matter – St. Louis
The data given in presented in Appendix D of the FEIS show that emissions of $PM_{2.5}$ in the St. Louis $PM_{2.5}$ nonattainment area are predicted to decrease under every action alternative for all analysis years. Accordingly, the proposed HD vehicle standards would not jeopardize the area's progress toward attainment of the $PM_{2.5}$ standard.

Air quality chemistry is complex, and projected changes in emissions do not account for meteorology, pollutant transport, pollutant formation in the atmosphere, and other local factors. Nevertheless, the projected changes in emissions under the action alternatives provide an indication

that there would be no adverse impacts on attainment in the St. Louis and Kansas City nonattainment areas.

Comments

Docket Number: 0087
Commenter: Hilary Sinnamon, Environmental Defense Fund

Finally, we recommend ways the Agency can better estimate the monetized health benefits of air quality improvements resulting from each proposed alternative.

* * * * *

As explained in the DEIS, NHTSA calculated the premature-mortality-related effect coefficients that underlie the benefits-per-ton estimates from both the American Cancer Society cohort (Pope et al. 2002) and the Harvard Six Cities cohort (Laden et al. 2006), and notes that "both studies should be used to generate benefits estimates." DEIS, page 3-37. However, the DEIS goes on to explain that, for the current analysis, "…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." DEIS, page 3-37.

EDF requests that the Agency develop a benefit-per-ton value derived from either the more rigorous Laden study or present the results based on both the Pope et. al. and the Laden studies to ensure that a more transparent and comprehensive estimate of the monetized health benefits of air quality improvements are developed.

Response

Both Table 3.3.3-9 (changes in health outcomes in cases per year by alternative) and 3.3.3-10 (monetized health benefits in dollars per year by alternative) in the DEIS presented the results based on both the Pope *et al*. and the Laden *et al*. studies. However, the DEIS did not present values derived from the Laden *et al*. study in Tables 3.3.2-3 or 3.3.2-4. In response to this comment, the benefit-per-ton values based on the Laden *et al*. study have been added to Table 3.3.2-3 in this FEIS and the incidence-per-ton values based on the Laden *et al*. study have been added to Table 3.3.2-4 in this FEIS to improve the clarity of the analysis.

Comments

Docket Number: 0142
Commenter: Janice Nolan, Hilary Sinnamon, Peter Zalzal, Katie Patterson, and Britt Groosman - American Lung Association and Environmental Defense Fund

EPA should promulgate more stringent PM emissions standards for APUs to protect public health. Auxiliary power units (APUs) are among the technologies available today to reduce fuel use from sleeper cab tractors due to idling. We request the agencies adopt more protective health-based diesel particulate matter (PM) emissions standards for these units to bring them in line with the truck engines they are relieving.

Reducing idling is an important step in reducing fuel consumption, GHG emissions and other airborne contaminants from diesel engines in sleeper cabs because they are estimated to idle 6-8 hours a day, as many as 250-300 days a year. EPA estimates that APUs can reduce fuel consumption and CO2 emissions from these engines by 6 percent. We support the inclusion of APUs as a technology option manufacturers can use to meet the proposed standards for sleeper cab trucks.

However, the diesel PM standards for diesel APUs, established under the nonroad rule, are not as protective as the truck engine standards for MY 2007 and later trucks, which require the use of diesel particulate filters (DPFs) or comparable alternative. This disparity allows diesel APUs to emit more than 5 times as much harmful diesel PM as a MY 2007 or later diesel sleeper cab engine. This increase in PM emissions will be particularly significant at idling "hotspots" like truck stops, travel centers, rest areas, distribution centers and port areas. Idling in these areas can create high concentrations of harmful diesel PM, threatening the health of drivers, truck stop, port and rest area workers and residents of neighboring communities, many of whom are often low income. In addition to the health impacts, diesel PM is made of primarily of black carbon, which is a potent greenhouse gas. We therefore request that the agencies put in place more protective PM emissions standards for these units to protect public health and the environment from the harmful impacts of diesel PM.

The California Air Resources Board recently established more protective standards for diesel APUs that require the use of diesel particulate filters or a comparable alternative, which reduce PM by as much as 85 percent and make APUs as clean as the truck engines they are attached to. CARB concluded that the technology to make these reductions is available and cost-effective. CARB has verified three diesel particulate filters that can be added to existing APUs and one new diesel APU that includes a DPF. [Footnotes omitted].

Response

NHTSA agrees that emissions of PM and PM precursors from heavy-duty vehicles contribute to ambient air pollution that poses significant health concerns. Section 3.3.1.2 of this EIS details the health effects associated with $PM_{2.5}$.

Under the Clean Air Act, APUs are considered nonroad engines, subject to different statutory provisions than those covering the highway motor vehicles and engines dealt with in this rulemaking. Nonroad engines, including those used in APUs, are subject to stringent Tier 4 PM standards that were set in 2004 (Nonroad Tier 4 Standard Rule, *available at:* http:www.epa.gov/nonroad-diesel/2004fr.htm), and are now being phased in. More stringent PM standards for nonroad engines are not within the scope of this rulemaking. EPA continually monitors the potential for new technology to further reduce harmful emissions and may take further action on nonroad engines used in APUs in the future.

Comments

Docket Number: 0112
Commenter: Vera Pardee, Center for Biological Diversity

We include here studies showing…. the higher-than previously-estimated risk of lung damage due to ozone pollution, and ask the Agencies to include them in their analysis of climate change impacts. [Footnote 40: *Chong S. Kim et al., Lung Function and Inflammatory Responses in Healthy Young Adults Exposed to 0.06 ppm Ozone for 6.6 Hours*, AMERICAN JOURNAL OF RESPIRATORY AND CLINICAL CARE MEDICINE , Jan. 7, 2011, DOI:10.1164/rccm.201011-1813OC, available at: http://ajrccm.atsjournals.org/cgi/content/abstract/201011-1813OCv1.]

Response

In response to the commenter, NHTSA has included the Kim *et al*. (2011) study in the FEIS and acknowledges the human health threats posed by rising near-surface ozone levels, noting that "Several studies have found increasing levels of ground-level ozone, which can exacerbate respiratory ailments and affect lung efficiency (Kim *et al.* 2011, NRC 2010a, NRC 2010b, Jackson *et al*. 2010)." *See* Section 4.5.8 for a full discussion.

6.3.2 Climate

6.3.2.1 Introduction to GHGs and Climate Change

Comments

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

Recent observations of climate change, improved analyses, and modeling studies indicate that several key risks from anthropogenic climate change are substantially greater than assessed in the IPCC AR4, including risks that would be categorized as "dangerous anthropogenic interference with the climate system" under the language of the United Nations Framework Convention on Climate Change (Fussel 2009, Smith et al. 2009). Climate is changing more quickly than projected by earlier IPCC reports; climate impacts are occurring at lower surface temperatures than previously estimated; temperature change and sea level rise during this century will be greater than previously projected; and the climate is approaching tipping points beyond which the climate system will switch to a different state more quickly than previously projected (Fussel 2009, Lenton et al. 2008, McMullen and Jabbour 2009, Richardson et al. 2009).

Recent scientific studies have also increased the understanding of several processes that delay the full impacts of greenhouse gases and make climate change impacts extremely longlasting: (1) the climate commitment (i.e. future warming and sea-level rise resulting from greenhouse gas concentrations that are already in the atmosphere); (2) the irreversibility of climate change and ocean acidification from CO2 emissions; (3) the triggering of tipping points; and (4) the enhancement of positive feedback cycles that amplify climate change. These scientific studies indicate that current warming and the climate commitment presently constitute 'dangerous anthropogenic interference' with the climate system, and that the safe upper limit for atmospheric CO2 needed to avoid 'dangerous climate change' is at most 350 ppm. They demonstrate that a reasonable probability of avoiding dangerous climate change cannot be achieved unless immediate and significant reductions of CO2 and other greenhouse gases occur.

Response

NHTSA agrees that climate change science is rapidly evolving, and accordingly it has worked hard to assess the regulatory alternatives in light of recent synthesis reports and peer-reviewed literature. The FEIS includes findings from several of the studies suggested by the commenter and others, including Füssel (2009), Smith *et al*. (2009), Lindsay and Zhang (2005), Lowe *et al*. (2009), Mignone *et al*. (2008), Rockstrom *et al*. (2009), and Vaughan *et al*. (2009). An analysis of tipping points, abrupt climate change, and potential thresholds is provided in this EIS in section 4.5.9 based on the climate change science synthesis report. As stated in section 3.4.3.5, 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.

As the commenter notes, new studies indicate greater dangers related to the effects of climate change. In preparing this EIS, we have specifically considered several of the newer studies referenced by the commenter. Specifically, elements of Füssel's (2009) and Smith *et al.*'s (2009) updates of IPCC's (2007) "reason for concern" have been addressed in Sections 3.4 and 4.5 of the FEIS, where relevant. Some of the sources suggested by the commenter (e.g., McMullen and Jabbour (UNEP 2009) and Richardson, *et al*. (2009)) were previously included in the DEIS and remain in this FEIS.

Comments

Docket Number: 0025; 0112
Commenter: Vera Pardee, Center for Biological Diversity

Thermal inertia in the climate system causes a time lag between the emission of greenhouse gases and the full physical climate response to those emissions. Thus, the climatic changes experienced so far are only part of the full response expected from the greenhouse gases already in the atmosphere (Hansen et al. 2008). The delayed effects from existing emissions are known as the "climate commitment." The magnitude of committed warming from past greenhouse gas emissions is now estimated to be higher than reported in the IPCC AR4 (Fussel 2009). Based on the greenhouse gases already emitted, the planet is most likely committed to additional warming over pre-industrial levels estimated at 1.6 degrees C (most of which is expected to be experienced in this century due to the unmasking of the aerosol cooling effect by air pollution abatement laws) (Ramanathan and Feng 2008) and up to 2 degrees C in the long-term (Hansen et al. 2008), rather than the 0.6°C increase estimated in the IPCC AR4 (Meehl et al. 2007). In addition, sea-level rise will continue for centuries due to continuing thermal expansion of the oceans and melting of the Greenland and West Antarctic ice sheets (Richardson et al. 2009). Any greenhouse gases added to the atmosphere exacerbates the climate commitment.

* * * * *

Since the time of our January 3, 2011 Comment Letter, additional studies have been published that add to the overwhelming evidence that climate change is currently underway and that the failure to reduce greenhouse gases will cause catastrophic consequences. We include here studies showing record melts from the Greenland ice sheet in 2010; the bigger-than estimated impact on climate from the melting Arctic; and the higher-than previously-estimated risk of lung damage due to ozone pollution, and ask the Agencies to include them in their analysis of climate change impacts. [Footnotes omitted].

Response

Section 3.4.4.3.2 of the FEIS discusses the thermal inertia issue raised by the commenter and acknowledges the commenter's point regarding the lasting effect of greenhouse gases already in the atmosphere. There we state that "[t]he 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." This issue is also discussed in Section 4.4 of the FEIS.

In addition, the FEIS includes findings from several of the studies suggested by the commenter and others, including Füssel (2009), Smith *et al.* (2009), Lenton *et al*. (2008), Smith *et al*. (2009), Lindsay and Zhang (2005), Lowe *et al*. (2009), Mignone *et al*. (2008), Rockstrom *et al*. (2009), Vaughan *et al*. (2009), and Kim *et al*. (2011). In the FEIS, highlights of some of the studies suggested by the commenter have been included. As noted above, elements of Füssel's (2009) update of IPCC's (2007) "reasons for concern" have been addressed in Sections 3.4 and 4.5 of the FEIS, where relevant. Hansen *et al*.'s (2008) points on climate commitment have not been included as the source

is not peer-reviewed or panel-reviewed; however, Ramanathan and Feng's (2008) findings have been added to Section 4.5.9. Richardson *et al*. (2009) was previously included in the DEIS and is also included in the FEIS.

Comments

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

Climate changes caused by increases in CO_2 concentrations, including temperature increases and sea-level rise, are largely irreversible for 1,000 years after emissions cease (Archer and Brovkin 2009, Solomon et al. 2009), while increases in ocean acidification will persist for hundreds of thousands to millions of years (Richardson et al. 2009). An important contributing factor is the long atmospheric lifetime of CO_2 compared to other greenhouse gases. A significant fraction of anthropogenic CO_2, ranging from 20–60 percent, remains airborne for a thousand years or longer after emissions cease (Archer and Brovkin 2008, Solomon et al. 2009). Approximately 25 percent of emitted CO_2 will have an atmospheric lifetime of more than 5000 years (Montenegro et al. 2007).

Some of the anthropogenic CO_2 is removed from the atmosphere by deep ocean mixing; however, global average temperatures are not projected to drop significantly for at least 1,000 years after the cessation of emissions because the removal of CO_2 by deep-ocean mixing is largely compensated by heat emission from the ocean (Matthews and Caldeira 2008, Solomon et al. 2009). Studies suggest that two-thirds of the maximum temperature anomaly from CO_2 emissions will persist for longer than 10,000 years (Eby et al. 2009). Anthropogenic CO_2 also causes irrevocable sea-level rise. Long-lasting warming from persistent CO_2 causes the oceans to continue to expand and the continued melting of the glaciers and ice sheets, which in turn contribute to millennia of sea-level rise (Solomon et al. 2009). In addition, the long tail of fossil fuel CO_2 in the atmosphere may trigger slow processes and feedbacks including methane hydrate release from the ocean and methane release from melting permafrost (Archer and Brovkin 2008). As summarized by Matthew and Caldeira (2008), "fossil fuel CO_2 emissions may produce climate change that is effectively irreversible on human timescales."

As stated in one study:

It is sometimes imagined that slow processes such as climate changes pose small risks, on the basis of the assumption that a choice can always be made to quickly reduce emissions and thereby reverse any harm within a few years or decades. We have shown that this assumption is incorrect for carbon dioxide emissions, because of the longevity of the atmospheric CO_2 perturbation and ocean warming. Irreversible climate changes due to carbon dioxide emissions have already taken place, and future carbon dioxide emissions would imply further irreversible effects on the planet, with attendant long legacies for choices made by contemporary society.

Solomon et al. (2009) at 708-1709. And, according to another study:

The notion is pervasive in the climate science community and in the public at large that the climate impacts of fossil fuel CO_2 release will only persist for a few centuries. This conclusion has no basis in theory or models of the atmosphere/ocean carbon cycle, which we review here. The largest fraction of the CO_2 recovery will take place on time scales of centuries, as CO_2 invades the ocean, but a significant fraction of the fossil fuel CO_2, ranging in published models in the literature from 20–60 percent, remains airborne for a thousand years or longer. Ultimate recovery takes place on time scales of hundreds of thousands of years, a geologic longevity typically associated in public perceptions with nuclear waste. The glacial/interglacial climate cycles demonstrate that ice sheets and sea level respond dramatically to *millennial-timescale changes in climate forcing. There are also potential positive feedbacks in the carbon cycle, including methane hydrates in the ocean, and peat frozen in permafrost, that are most sensitive to the long tail of the fossil fuel CO_2 in the atmosphere.*

Archer and Brovkin (2008) at 283.

Response

NHTSA recognizes that climate change is long lasting, and thus the FEIS includes projections of temperature and sea level rise through 2100. Given uncertainties in emission profiles and the climate system, this timeframe is typically used in climate simulations. NHTSA understands the importance of long-term impacts extending beyond 2100 and has addressed the atmospheric longevity of greenhouse gases and associated potentially irreversible impacts to ice, methane hydrates, and sea level qualitatively in Sections 3.4 and 4.5 of the FEIS. The FEIS includes findings from several of the studies suggested by the commenter. Richardson *et al*. (2009) was included in the DEIS and is also included in the FEIS. The additional studies suggested by the commenter regarding atmospheric lifetime of carbon have now been incorporated in Section 3.4.1.6 of the FEIS (including Archer and Brovkin (2008), Eby *et al*. (2009), Matthews and Caldeira (2008), Montenegro *et al*. (2007), and Solomon *et al*. (2009)).

6.3.2.1.1 Black Carbon

Comments

Docket Number: 0081; 0112
Commenter: Vera Pardee, Center for Biological Diversity

Black carbon will increase as shown by DEIS PM results; EPA should set a “cap” or standard for black carbon like those for N_2O and CH_4, and account for black carbon reductions in considering alternative emission reduction measures.

* * * * *

The DEIS improperly fails to discuss alternatives that reduce black carbon emissions from HD vehicles. Even though HD Vehicles are a significant source of black carbon emissions, the DEIS fails to discuss any alternative that reduces these emissions. . . . Black carbon is both a component of PM2.5 and an extremely effective climate warming agent, and while not yet officially declared an air pollutant in its individual capacity by EPA, it certainly meets that definition. Moreover, its deleterious health effects are unquestionable. For all of these reasons, the DEIS should take black carbon emission reductions into account in presenting and discussing alternative emission reduction measures. Further, the DEIS’ discussion of black carbon includes a number of scientific errors. We request that the FEIS discuss alternatives that reduce black carbon emissions from HD Vehicles and correct the errors noted. [Footnotes omitted].

* * * * *

The DEIS also states that the impact of black carbon cannot be compared to that of other greenhouse gases. This statement is misleading. Typically, a global warming potential (GWP) is derived for a given greenhouse gas, which is multiplied by the volume emitted to allow a comparison between the strength of warming caused by different greenhouse gases. While is it true that no single value has emerged for the global warming potential (GWP) of black carbon, all estimates indicate that it is extremely powerful, especially over short time spans. Bond and Sun estimate the GWP of black carbon relative to CO_2 to be 680 for a 100 year period. . . . Reddy and Boucher estimate the GWP of black carbon at 480 for a hundred year period, with a range of 374 to 677, depending on the different atmospheric residence time and amount of insolation. . . . Jacobson estimates the GWP for black carbon at significantly higher levels – 1500-2400 for black carbon and 840-1280 for fossil fuel soot. . . . Although these values vary depending on the assumptions involved, the message is clear: black carbon is an extremely effective climate warming agent when compared to carbon dioxide and methane. The Agencies do not require an exact value for comparing black carbon's deleterious effect to that of other greenhouse gases to know that black carbon must be reduced. The key information is unquestionable: black carbon is emitted in large quantities by diesel engines, black carbon is an extremely potent warming agent, and technologically feasible, appropriate and cost-effective measures exist to reduce these emissions. [Footnotes omitted].

* * * * *

Although MAGICC, the model the Agencies use to simulate climate effects, does not include a user-manipulated black carbon variable at this time, black carbon is included in the basic model. If MAGICC is deemed insufficient for the task, the Agencies can obtain other models that estimate the climate effects of black carbon. An example of the use of such a model is contained in Ramanathan and Xu. . . . Even if no currently available model can estimate the exact magnitude of black carbon's climate effect, however, enough scientific data exists for the Agencies to determine that black carbon must be addressed aggressively to reduce the damages caused by global warming. [Footnotes omitted].

* * * * *

In light of the highly significant black carbon emissions from HD Vehicles, we also urged the Agencies in our January 3, 2011 Comment Letter to include these emissions in their environmental impact statement and their decision-making process in selecting appropriate technologies and HD Vehicle standards.

Response

NHTSA agrees that black carbon is a potent climate forcing agent. Nonetheless, significant scientific uncertainties remain regarding black carbon's total climate effect, as do concerns about how to treat the short-lived black carbon emissions alongside the long-lived, well-mixed GHGs in a common framework. 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, NHTSA believes including quantification of black carbon climate impacts in an analysis of the proposed standards would be premature at this time. NHTSA provides a qualitative discussion of the potential climate impacts of black carbon in Section 3.4.

With regard to the comment regarding the global warming potential of black carbon, the GWP of black carbon is highly uncertain, as illustrated by the studies cited which provide 100-year GWPs ranging from 374 to 2400. The scientific community has yet to support a single GWP estimate for black carbon. Section 3.4.1.7 of the FEIS discusses the uncertainty in current estimates of the climate effects of black carbon.

With regard to the comment about the agencies' use of MAGICC, while this model simulates climate change effects based on interactions across all gases and particles including black carbon,

the impact of the regulatory alternatives on black carbon is uncertain and is not quantified. Although the state-of-the-science is not sufficiently mature to allow the EIS to quantify the effects of changes in black carbon emissions on climate, NHTSA believes that it has used the best available models and supporting data to allow evaluation of the regulatory options and their environmental effects in terms of climate change. The models used for the FEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the assumptions the FEIS makes regarding uncertain conditions reflect the best available information and are appropriate for this analysis.

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

The DEIS' discussion of the net radiative forcing of black carbon creates the misleading impression that there are instances in which black carbon can exert a cooling influence on the atmosphere. This is untrue. The DEIS cites Ramanathan and Carmichael as demonstrating that, when solar radiation is absorbed by black carbon, some of the radiation will not reach the surface, causing "dimming." While this is true, the enhanced atmospheric warming due to black carbon will always be greater than any dimming and global mean radiative forcing increases regardless of changes at the Earth's surface. . . . In fact, Ramanathan and Carmichael specifically indicate that it is not appropriate to compare surface dimming with GHG forcings because the net atmospheric forcing of black carbon is still positive. [Footnotes omitted].

* * * * *

The DEIS black carbon discussion also appears at times to conflate aerosols and black carbon. For instance, it states that "the magnitude of aerosol effects can vary immensely with location and season of emissions." . . . Similarly, the DEIS discusses "atmospheric brown clouds" or "ABCs." ABCs, however, are the result of combined aerosols emitted in various regions, and include black carbon as well as other lighter-colored aerosols. . . . The analysis of such other aerosols is not relevant to the analysis of the specific impacts of black carbon. Black carbon is the only aerosol that consistently leads to atmospheric heating, whereas other aerosols may have cooling or mixed effects. These errors must be corrected so that the DEIS reflects only data related specifically to black carbon. [Footnotes omitted].

* * * * *

The difference in the impact of black carbon compared with other aerosols makes the immediate reduction of black carbon crucial. It is estimated that greenhouse gas pollution has contributed about 3 W/m^2 of heating to the atmosphere since the Industrial Revolution. . . . Yet, observed warming has been only about 30% of what would be expected for this amount of radiant energy. . . . It is believed that while some energy has been stored in the oceans, about 50% of the energy is "masked" by the cooling effect of non-black carbon aerosols. Because these other aerosols are a public health hazard, they are in decline and will continue to decline. This means that atmospheric heating will increase substantially. One way to combat this "unmasking" is to reduce black carbon. . . . Ramanathan and Xu estimate that black carbon has contributed about 0.9 W/m^2 of warming since the Industrial Revolution. . . . Thus, significant reductions in black carbon could also substantially reduce the consequences of aerosol "unmasking." [Footnotes omitted].

Response

The DEIS introduces black carbon as a type of aerosol; NHTSA agrees that black carbon does not have the same climate effects as aerosols in general. As noted by the commenter, the net radiative impact of black carbon suspended over a surface is generally likely to be positive, while other aerosols may have cooling or mixed effects depending on circumstances. Text has been added to Footnote 46 in the FEIS to distinguish between the net radiative impact of black carbon and other aerosols.

The commenter is incorrect that the DEIS discusses "atmospheric brown clouds" or "ABCs." The DEIS does not mention ABCs. As the commenter points out, ABCs are the result of combined aerosols emitted in various regions and include black carbon as well as other lighter-colored aerosols. ABCs, as such, are not emitted from HD vehicles.

As the commenter states, the latest scientific literature suggests that the cooling associated with aerosols such as sulfates and nitrates reduces the realized warming associated with greenhouse gases, and that black carbon, also an aerosol, is a warming agent. The climate modeling analysis for the FEIS accounts for reductions in cooling that would occur with reductions in levels of aerosols such as sulfates and nitrates.

NHTSA agrees with the comment that the net radiative forcing of black carbon will result in warming. The text of this FEIS has been clarified by adding a statement that the net radiative impact of black carbon suspended over a surface is always positive and leads to a net warming effect.

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

The DEIS appears to assume that the existence of regulations reducing $PM_{2.5}$ relieve the Agencies of their duty to address black carbon in the DEIS and proposed rulemaking. This is incorrect. Because particulate matter is composed of multiple aerosol compounds, the overall PM level from a given source can be reduced by decreasing any one or more of its constituent pollutants – without, however, necessarily reducing the black carbon component in equal proportion. For example, diesel oxidation catalysts can reduce diesel PM emission as a whole by approximately 20 to 40%, yet they do not decrease the carbonaceous component of the PM. . . . While black carbon is the predominant component of diesel PM, sulfates are the other major contributor. Measures that aim to reduce sulfates, such as low-sulfur diesel fuel, may reduce PM levels, but do not necessarily maximize black carbon reductions, leading some industry experts to recognize that low sulfur fuels may be necessary, but not sufficient to achieve black carbon reductions. . . . Low sulfur fuel is important because it allows for better technology to reduce black carbon, such as the use of diesel particulate filters (DPFs). . . . However, desulphurization of fuels does not guarantee the significant cuts in black carbon that climate scientists recommend. [Footnotes omitted].

Response

This EIS states that black carbon is a component of $PM_{2.5}$ emissions, and that $PM_{2.5}$ emissions are regulated. NHTSA agrees that, depending on emission control technology used, controls on $PM_{2.5}$ emissions may not reduce black carbon emissions to the same extent as regulating black carbon directly. NHTSA also recognizes that low-sulfur fuels enable the use of certain emission control technologies but that low-sulfur fuels alone may not be sufficient to achieve reductions in black

carbon emissions. As a result of regulations already promulgated by EPA under the Clean Air Act, all diesel fuel used for on-road transportation in the United States is required to be ultra-low sulfur. The sulfur content of diesel fuel is not at issue in this rulemaking.

6.3.2.1.2 New Information on Climate Change

Comments

Docket Number: 0025; 0081
Commenter: Vera Pardee, Center for Biological Diversity

In sum, the recent scientific studies highlight the following crucial points that must inform NHTSA's analysis and final choice among the alternatives available to reduce greenhouse gases from MD/HD Vehicles:

– The deleterious effects of climate change, including temperature and sea level rise, have occurred faster than the IPCC AR4 predicted.

– The likelihood that climate change will cause further environmental, economic and societal damage on a global scale, and the severity of that damage, are both substantially greater than described in the IPCC AR4.

* * * * *

With our July 10, 2010 Comment Letter, we submitted substantial scientific material demonstrating that the assumptions underlying the 2007 IPPC Fourth Assessment Report must be updated because the risks from climate change are substantially greater than there assumed. We ask the Agencies to take this updated information, as well as the additional scientific literature cited herein, into account in arriving at their decisions.

Response

As demonstrated by the discussions in Sections 3.4 and 4.5 of this EIS, NHTSA agrees that a number of studies published after the release of the IPCC AR4 in 2007 indicate that atmospheric greenhouse gas concentrations and observed climate changes and associated impacts are occurring more rapidly than previously suggested. Highlights of these studies were included in the DEIS and are again included in the FEIS. In addition, as outlined throughout this section, we have updated this EIS to reflect studies suggested by the commenter where relevant. The FEIS acknowledges more rapid climate change than previously reported by IPCC AR4 (2007) and cites findings from several of the studies suggested by the commenter.

6.3.2.2 Social Cost of Carbon

Comments

Docket Number: 0087
Commenter: Environmental Defense Fund

In addition, we recommend improvements to the methodology for determining the Social Cost of Carbon that do not unduly discount the threat to future generations and that do not fail to account transparently for non-monetized benefits.

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NHTSA Must Enhance the Methodology for Determining Social Cost of Carbon (SCC). It is critical that NHTSA collaborate with other agencies and carry out its responsibilities to accurately account for the Social Cost of Carbon (SCC). *Cf. Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.,*538 F.3d 1172, 1185 (9th Cir. 2008) (finding a NHTSA fuel economy rule arbitrary and capricious where "[t]he value of carbon emissions reduction [was] nowhere accounted for in the agency's analysis, whether quantitatively or qualitatively"). The social cost of carbon is a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions. The SCC 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. EDF commented extensively on the consideration of the SCC in the light-duty greenhouse gas rulemaking and the Notice of Intent for this Draft EIS. It is imperative that NHTSA rigorously and transparently account for the SCC in carrying out its responsibilities under NEPA, EISA, and EPCA. In the DEIS, it is noted that 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. While we support the collaboration and work of the Group, we make suggestions below as to how the approach can and should be improved.

Lower Range of Discount Rates: In light of significant economic and ethical challenges raised by discounting, and the lack of consensus around a single number or even a single conceptual approach to choosing a discount rate, the only appropriate course of action is a fully transparent, exhaustive and rigorous process to determine a range of appropriate discount rates. As described in the DEIS, and based on the Interagency Working Group on Social Cost of Carbon, NHTSA uses discount rates of 5%, 3% and 2.5%. We believe it is not appropriate to include a 5% discount rate and we encourage NHTSA to use a range of discount rates of 3% and below in its SCC analysis, including 1% and 2% discount values, as some analysts suggest values as low as 1.4%. These lower values reflect the scientific, economic, and ethical complexities inherent in inter-generational discounting. We also reiterate our recommendation to use declining discount rates.

Analyzing Burdens on Future Generations: Discount rates are traditionally applied to account for a general preference for immediate benefits as opposed to benefits realized in the future. In the context of climate change, however, benefits accrue not just in the future but to future generations of people. Such inter-generational discounting is more problematic and controversial because it requires us to compare risks faced by different individuals and choose to place more value on one individual's preferences simply because he or she is alive first. Given these issues associated with inter-generational equity, we encourage NHTSA to explore other available analytical tools for defining our moral obligations to future generations. Sustainable development, utilitarianism, corrective-justice, and other ethical theories all offer social decision-makers a model for how to treat future costs and benefits. Choosing among these options is difficult but underscores the fact that our obligation to future generations is fundamentally an ethical question that cannot be resolved by economic analysis alone.

Evaluating Non-Monetized Benefits: GHG reduction policies can significantly undervalue benefits simply because some of these benefits are not easily quantifiable. The White House Office of Management and Budget recognizes that some costs and benefits will be difficult to monetize, but directs agencies to consider other means of quantification. We request that climate impacts omitted from the models should be identified explicitly. A table should be provided that lists, for each economic model, what impacts were not included in the model's estimate of monetized damages. Accompanying text should serve to explain and complement the table entries but not be a substitute for them. [Table and footnotes omitted].

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

The Social Cost of Carbon Is Understated. We applaud the Agencies for the fact that in contrast to the environmental impact statements prepared for earlier vehicle fuel economy standard rulemakings, the DEIS now accounts for upstream as well as downstream carbon emissions. The DEIS has also been improved by including a modest (though insufficient) factor by which the social cost of carbon ("SCC") increases over time. [Footnote 41: The adjustments in value fail to capture the true nature of the increase in SCC over time. As we stated in the July 2010 Comment Letter, studies have shown that delaying mitigation drastically, and possibly irreversibly, increases climate risks and/or long-term costs. In other words, mitigation measures available now that are not implemented because of cost concerns will become much more costly at a later time and, if tipping points are reached, will be unable to alter irreversible damage. For further details, we refer the Agencies to our July 2010 Comment Letter.] However, that increase is offset by the application of a discount rate in all models, a highly questionable exercise where intergeneration transfer issues such as those involved in climate change are at play. In addition, as discussed below, it fails to account for the crossing of tipping points.

Moreover, although the DEIS now includes estimates of the SCC ranging up to $66 per metric ton of CO2, all estimates, including those that arrive at a central value of $22/ton, rely on the work of the Interagency Working Group on the Social Cost of Carbon. Recent scientific literature demonstrates that the assumptions underlying that work are highly questionable and significantly undervalue the SCC value. [Footnote 43: The Agencies themselves note several critical shortcomings of the assumptions underlying the SCC estimates, nearly of which dramatically decrease the SCC value: "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." DEIS at 3-91.] For example, Ackerman and Stanton (2010) present a critique of the Interagency Working Group's methods and conclusions, including the use of only three flawed models, FUND, PAGE, and DICE, to estimate the SCC.

The Interagency Working Group also relied heavily upon flawed Richard Tol's 2009 meta-analysis of estimates of the SCC, which is in fact a highly personal view of the economics literature, with a strong emphasis on Tol's own work. At the same time the Interagency Working Group ignored the Stern Review of the Economics of Climate Change, due only to a limitation to peer-reviewed published literature, ignoring the fact that the Stern Review offered an innovative, rigorous analysis based on a level of professional review that went far beyond the normal peer review process for articles published in academic journals. Overall, the Interagency Working Group's administration's narrow proposed range of SCC values, with a likely "central" estimate of $22, is a function of its choice of a limited range of underlying studies, high discount rates, and insufficient emphasis on the risk of catastrophic climate damage, and contrasts sharply with the United Kingdom's estimated carbon pricing in the rage of $41-$124 per ton of CO_2, with a central case of $83. While cost-effectiveness is one statutory factor the Agencies must consider, the multiple problems inherent in the current SCC estimate highlight the need not only for a more credible monetary analysis, but also the need for a more comprehensive discussion of the true impacts of climate change, a topic which ultimately cannot be captured by economic models or dollar figures alone.

Response

NHTSA appreciates the commenters' recommendations about the SCC estimates, which were developed through an interagency process that included DOT/NHTSA, EPA, and other executive branch entities, and concluded in February 2010. NHTSA and other federal agencies have since used these estimates to estimate the social costs and benefits of various regulatory actions that have

impacts on cumulative global emissions. However, the U.S. government intends to revise these estimates, taking into account new research findings that were not included in the first round. To help inform this process, DOE and EPA are hosting a series of workshops. The first workshop focused on conceptual and methodological issues related to integrated assessment modeling and valuing climate change impacts, along with methods of incorporating these estimates into policy analysis. The second workshop reviewed research on estimating impacts and valuing damages on a sectoral basis. *See* http://yosemite.epa.gov/ee/epa/eerm.nsf/vwRepNumLookup/EE-0564?OpenDocument (Accessed: June 17, 2011) for details about the workshop series.

The interagency group committed to update the SCC estimates as the science and economic understanding of climate change and its impacts on society improves over time. The group set a preliminary goal to revisit the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area.

NHTSA has reviewed the commenter's specific comments about discount rate selection and analyzing effects on future generations and will continue to consider these comments when the current SCC estimates are updated. In the meantime, NHTSA will use the discount rates selected by the interagency group; the basis for this approach is discussed in detail in the SCC Technical Support Document (SCC TSD) (EPA 2010b). In sum, the interagency group applied three constant certainty-equivalent discount rates (2.5, 3, and 5 percent) to the SCC estimates to account for various perspectives about risk and uncertainty. The upper value of 5 percent accounts for the view that there may be a high correlation between climate damages and market returns while the rest of the SCC analysis centers on a discount rate consistent with concerns about risk aversion. NHTSA recognizes the limitations of the discounting approach used in the interagency modeling exercise, but finds it to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach outlined in OMB's existing guidance.

Regarding the comment about the SCC values used in the analysis, the interagency group did not obtain its range of SCC values by sampling the breadth of published SCC values, but rather it used a series of model runs with parameters that are described in the TSD. The Stern review, cited by the commenter, and many other papers were considered in the choice of the range of parameters to use. *See* page 22 of the TSD for more discussion.

Regarding the recommendation to identify non-monetized benefits, it is not possible at this time to provide a precise list of each model's treatment (*i.e.*, included, excluded) of climate impacts. Instead, the SCC TSD presents a robust discussion of this key analytical issue, e.g., how each model estimates climate impacts, the known parameters and assumptions underlying those models, and the implications of incomplete impacts (catastrophic and non-catastrophic) for the SCC estimates. NHTSA notes that the table presented by the commenter does not provide a complete listing for all three models used to estimate the SCC. Moreover, the discussion in the SCC TSD underscores the difficulty in accurately distilling the models' treatment of impacts in table-form. Most notably, the use of aggregate damage functions—which consolidate information about impacts from multiple studies—in two of the models poses a challenge in listing included impacts. For example, within the broad agricultural impacts category, some of the sub-grouped impacts are not explicitly modeled but are highly correlated to other subcategories that are explicitly modeled. Therefore, it may be misleading to identify these kinds of impacts as either "included" or "omitted" from the model. Along those lines, impacts may be included in models but not directly; the Dynamic Integrated Climate and Economy (DICE) model represents adaptation implicitly through the choice of studies used to calibrate the aggregate damage function, and the Climate Framework for Uncertainty,

Negotiation, and Distribution (FUND) model includes adaptation both implicitly and explicitly (*see* the SCC TSD for details).

Accordingly, NHTSA recognizes the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. As noted above, DOE and EPA are hosting a series of workshops to explore the treatment of impacts in the models.

Regarding the comment about the way catastrophic and non-catastrophic impacts are captured by the integrated assessment models, the commenter echoes the interagency working group's caveats about the limitations of the analysis. Recognizing the difficulties in explicitly addressing these challenges in integrated assessment models, the FEIS addresses some of these through complementary discussions. *See* Section 4.5.9 for a discussion of tipping points, thresholds, and catastrophic events; *see* all subsections of 4.5 for brief discussions of adaptation and damages due to high temperatures as they relate to each resource area; and *see* pages 20-22 of the TSD for a discussion of relative risk aversion. Risk aversion is an issue that is being actively debated in the technical literature and a consensus on it has not yet emerged. Since there is substantial uncertainty associated with all of these and other issues, the FEIS states that efforts to quantify and monetize the harm associated with climate change raise important questions about science and economics, and should be viewed as provisional. *See* Section 3.4.3.2. The interagency working group expressly recognized that SCC estimates will be improved in the future and stated that the Federal Government would periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. *See* page 4 of the TSD.

With regard to tipping points, although the damage functions in the models used by the interagency group do not explicitly include thresholds, they do have non-linear relationships between the extent of climate change and the impacts. In other words, the marginal impacts are much greater at high levels of climate change than at low levels. A few integrated assessment models are exploring high-order nonlinearities and threshold behavior, though the quantification of these aspects is quite uncertain. In keeping with the state-of-the-science, the ramifications of exceeding tipping points are discussed in the FEIS, including the likelihood that these thresholds will be exceeded this century. *See* Section 4.5.9. We do not attempt to quantitatively build these highly uncertain aspects into the SCC.

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

In addition, the calculations of the SCC suffer from a defect so fundamental as to render the analysis fatally defective: the SCC estimates are calculated only through 2050, even though other elements of the climate change analysis extend through 2100, and even though the DEIS overall portrays itself as providing a reasonable estimate of damages through that year. This defect is all the more significant because the damages caused by CO_2 emissions last for centuries, if not millennia, and dramatically increase after 2050. In other words, the most significant social costs of carbon are simply left out. A cost-benefit analysis that fails to account for years after 2050, during which the planet will experience much higher temperatures and therefore the most devastating damages caused by global warming, cannot withstand scrutiny. We urge the Agencies to remedy this flaw in the FEIS.

We also wish to draw the Agencies' attention to a number of new studies relevant to the catastrophic effects of climate change that will occur at the CO_2 stabilization level for 2100 (678 ppm) postulated within the DEIS. For instance, one study analyzes how the increase in humidity in regions with high average temperatures will impact human habitability, focusing on heat stress as a function of "wet bulb" temperature. Estimates indicate that with 7°C warming, areas of the earth will exceed wet bulb temperatures to which humans and other mammals are physically capable of adapting, rendering these regions uninhabitable. The costs of these devastating impacts should be included in damage estimates and inform policy decisions regarding dangerous levels of climate change.

In addition, the truncated SCC analysis also omits the damages caused by gases other than CO_2 emissions. Since the Agencies have determined that this omission affects the calculations by understating damages by approximately 5%, this flaw should be easily corrected. Lastly, the DEIS acknowledges that it "probably underestimated the total criteria pollutant benefits," omits analysis of the environmental benefits available from regulating recreational vehicles, fails to quantify the effect on resources such as water and biological resources, and ascribes no value to the human safety and health benefits derived from greenhouse gas emission reductions. The cumulative effect of these decisions is to fatally undervalue the cost-benefits analysis. [Footnotes omitted]

Response

With regard to the comment about the timeframe of NHTSA's SCC analysis, one of the reasons for truncating the analysis in the DEIS at 2050 is that 2050 is the time horizon of the SCC values reported by the interagency working group. As the interagency group acknowledged, the uncertainties associated with the SCC rise dramatically beyond that point. In addition, the net present value of impacts associated with emissions beyond 2050 are quite low as measured using the SCC and a range of discount rates. For example, the net present value of a dollar at a 3% discount rate is only 5 cents 100 years from now. In response to this comment, however, we have added an analysis examining the sensitivity of the results to extrapolating the SCC to 2100. In this simple sensitivity analysis, we found that the net present value of impacts associated with emissions out to 2100 increases, depending on the discount rate, by 19% to 79% in the analysis of direct impacts (as discussed in Section 3.5); and 65% to 119% in the emissions scenario incorporating other foreseeable actions (as discussed in FEIS Section 4.4). Using this simple analysis, we can see that total benefits from CO_2 emissions reductions increase as described above by extending the analysis to 2100, but the relative effectiveness of the alternatives does not change, so a full analysis through 2100 is not warranted.

The commenter notes that the SCC analysis omits the damages caused by gases other than CO_2 emissions and indicates this should be corrected. The interagency group did not estimate the social cost of non-CO_2 GHG emissions and concluded that further analysis was required to link non-CO_2 emissions to economic impacts and to develop social cost estimates for methane specifically. *See* the SCC TSD for detailed discussion. The interagency group hopes to develop methods to value greenhouse gases other than CO_2 in the next round of SCC estimation.

The commenter also notes that the DEIS underestimates the benefits of the action because it omits recreational vehicles, fails to quantify effects on water and biological resources, and does not include the value of human health and safety benefits of GHG reductions. As NHTSA states in Section 1.1, in this EIS the agency does not consider the environmental impacts associated with recreational vehicles because NHTSA's statutory authority requires the agency to set standards for "commercial medium- and heavy-duty on-highway vehicles and work trucks," (49 U.S.C. § 32902(k)(2)), and recreational vehicles are not commercial.

With regard to the health impacts of the proposed action, NHTSA has conducted a full-scale photochemical air quality modeling analysis for this FEIS and has included the results in Appendix F. Photochemical analysis demonstrates the changes in ambient air pollution exposure related to the emission changes associated with each alternative scenario. These ambient concentrations are fed through a health impacts model (e.g., EPA's Environmental Benefits and Mapping Analysis Program – BenMAP) to characterize population exposure and the change in health response associated with various health impact functions derived from the epidemiological literature. This analysis is limited to the criteria air pollutants because health damage estimates are not available for mobile source air toxics.

Although NHTSA has used the best available models and supporting data in this analysis, the agency acknowledges that the estimates omit a number of health and environmental effects where such effects are uncertain. Where information in the analysis included in the FEIS is incomplete or unavailable, the agency has specifically noted the limitations of its analysis, consistent with CEQ regulations. NHTSA believes that the assumptions in the FEIS regarding uncertain conditions reflect the best available information and are valid for this analysis.

The FEIS analysis supports the primary NEPA purposes of informing the selection of an alternative and disclosing potential impacts to the environment. Because the action alternatives are all expected to reduce greenhouse gases and most air pollutant emissions compared to the No Action Alternative (*see* Chapters 3 and 4), the damage to human health is estimated to be similarly reduced. Health benefits are expected to be larger or smaller depending on the alternative selected. The differences in emission reductions (GHGs, criteria pollutants, and air toxics) and in health costs avoided among the alternatives provide ample information for decisionmakers, as required under NEPA. It is reasonable to anticipate that human health impacts will mirror these indicators.

NHTSA has added one study (Hoffman *et al*. 2010) suggested by the commenter to the discussion of impacts of climate change; the study projects the impacts of sea level rise on storm surge and flooding. The other study suggested by the commenter, Sherwood and Huber (2010), is already cited in the DEIS and FEIS as a resource on the potential health effects of climate change, particularly in the form of heat stress.

6.3.2.3 Tipping Points/Abrupt Climate Change

Comments

Docket Number: 0025
Commenter: Vera Pardee, Center for Biological Diversity

- NHTSA should analyze and discuss an alternative that accounts for and avoids, or minimizes the likelihood, of reaching climate change tipping points.

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Growing greenhouse gas emissions have the potential to trigger "tipping points," critical points where the climate system switches rapidly to a qualitatively different state (Lenton et al. 2008, Schellnhuber 2009). Paleoclimatic evidence indicates that abrupt nonlinear changes in the climate system have occurred in the past, in which small increases in average surface temperature produced qualitatively different states of the climate system that were irreversible on a timescale of millennia (Molina et al. 2009). Lenton et al. (2008) reviewed "tipping elements" in the Earth's climate system that could be altered by anthropogenic climate forcing and found several elements that are already close to reaching a tipping point. As reported by Lenton et al. (2008), warming of 0.5-2°C above 1990 levels (which is well within the low end of our current warming commitment) could trigger the total loss of the Arctic summer sea ice, while warming of 1-2 degrees C above 1990 levels could lead to the complete melting of the Greenland ice sheet, resulting in an eventual seven meters of sea level rise. Other climate studies have warned that the Arctic climate system may have already reached a tipping point leading to a rapid transition to a seasonally ice-free Arctic (Lindsay and Zhang 2005).

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Climate forcings can trigger reinforcing positive feedbacks that can further amplify warming. For example, the Arctic ice-albedo feedback loop is already occurring, where the loss of sea ice due to warming reduces the surface albedo and makes the Arctic more vulnerable to future warming. Scientific studies indicate that increased warming will trigger other feedbacks, including the mobilization of carbon in tropical peatlands which are vulnerable to land clearing and drainage, and the release of methane from Arctic permafrost due to warming (Richardson et al. 2009).

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A key objective of the United Nations Framework Convention on Climate Change (UNFCCC) set forth in 1992 is to stabilize greenhouse gas concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system." In regard to species and ecosystems, UNFCCC Articles 2 and 3 specifically stated that "such a concentration stabilization level to avoid DAI should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change" and emphasized avoiding ''threats of serious or irreversible damage" (Solomon et al. 2009) where irreversible is measured on time frames relevant to contemporary society (Richardson et al. 2009). Avoiding dangerous anthropogenic interference (DAI) has been the key international policy goal for protecting the global climate since this objective was set forth in 1992.

The UNFCCC did not define the emissions reductions needed to avoid DAI. The European Union in 1996 set an objective to limit global warming to less than 2°C above preindustrial temperature (1.4°C above 1990 temperature, 1.3°C above 2000 temperature) to avoid DAI, which it reiterated most recently in 2009 (European Council 1996, 2005, 2009). The 2009 Copenhagen Accord, to which the United States is a signatory, recognizes "the scientific view that the increase in global temperature should be below 2 degrees Celsius." This 2°C objective has been widely accepted as "the 2°C guardrail." However, the best available scientific information indicates that a 2°C mean global temperature rise from pre-industrial levels is far in excess of what can reasonably be considered "dangerous" and that much smaller increases in global mean temperature will result in substantial environmental and socio-economic consequences (Hansen et al. 2008, Richardson et al. 2009, Smith et al. 2009).

Numerous scientific studies indicate that current warming and the warming commitment "in the pipeline" already constitute dangerous anthropogenic interference (Hansen et al. 2008, Lenton et al. 2008, Jones et al. 2009, Pimm 2009, Rockstrom et al. 2009, Smith et al. 2009). For example, the updated IPCC Reasons for Concern (RFCs) reflect that current warming is already at a point where significant risks from extreme weather events and risks to species and ecosystems are occurring, and that these risks will become "severe" at a ~1 to 1.5°C rise above preindustrial levels (Smith et al. 2009). The Synthesis Report of the Copenhagen Climate Congress also concluded that the 2°C guardrail (2°C temperature rise above preindustrial temperatures) carries "significant risks of deleterious impacts…for the environment":
In summary, although a 2°C rise in temperature above pre-industrial remains the most commonly quoted guardrail for avoiding dangerous climate change, it nevertheless carries significant risks of deleterious impacts for society and the environment. (Richardson et al. 2009: 16) [Footnotes omitted].

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Hansen et al. (2008) and Rockstrom et al. (2009) presented evidence that the safe upper limit for atmospheric CO_2 needed to avoid 'dangerous climate change' is at most 350 ppm. Hansen et al. (2008) found that our current CO_2 level has committed us to a dangerous warming commitment of ~2 degrees Celsius temperature rise still to come and is already resulting in dangerous changes: the rapid loss of Arctic sea-ice cover, a 4° poleward latitudinal shift in subtropical regions leading to increased aridity in many regions of the earth; the near-global retreat of alpine glaciers affecting water supply during the summer; accelerating mass loss from the Greenland and west Antarctic ice sheets; and increasing stress to coral reefs from rising temperatures and ocean acidification. Hansen et al. (2008) concluded that the overall target of at most 350 ppm CO_2 must be pursued on a timescale of decades since paleoclimatic evidence and ongoing changes suggest that it would be dangerous to allow emissions to overshoot this target for an extended period of time:

If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that. (Hansen et al. 2008: 217)

With atmospheric carbon dioxide at ~390 ppm and worldwide emissions continuing to increase by more than 2 ppm each year, rapid and substantial reductions in CO_2 are clearly needed immediately to safeguard human health and welfare, protect the environment, and avoid the worst impacts of climate change.

Scientific studies have shown that delaying mitigation significantly increases climate risks and/or long-term costs. Vaughan et al. (2009), den Elzen et al. (2010), Mignone et al. (2008), Meinshausen et al. (2009), Allen et al. (2009), Lowe et al. (2009). In other words, mitigation measures available now that are not implemented because of cost concerns will become much more costly at a later time and, if tipping points are reached, will be unable to alter irreversible damage.

The following quotes from the scientific literature demonstrate these facts:

We present a simple conceptual model of anthropogenic CO_2 emissions to highlight the trade off between delay in commencing mitigation, and the strength of mitigation then required to meet specific atmospheric CO_2 stabilization targets. We calculate the effects of alternative emission profiles on atmospheric CO_2 and global temperature change over a millennial timescale using a simple coupled carbon cycle-climate model. For example, if it takes 50 years to transform the energy sector and the maximum rate at which emissions can be reduced is -2.5% year-1, delaying action until 2020 would lead to stabilization at 540 ppm. A further 20 year delay would result in a stabilization level of 730 ppm, and a delay until 2060 would mean stabilizing at over 1,000 ppm. If stabilization targets are met through delayed action, combined with strong rates of mitigation, the emissions profiles result in transient peaks of atmospheric CO_2 (and potentially temperature) that exceed the stabilization targets. Stabilization at 450 ppm requires maximum mitigation rates of -3% to -5% year-1, and when delay exceeds 2020, transient peaks in excess of 550 ppm occur. ***Consequently tipping points for certain Earth system components may be transgressed. Avoiding dangerous climate change is more easily achievable if global mitigation action commences as soon as possible. Starting mitigation earlier is also more effective than acting more aggressively once mitigation has begun.***

Vaughan et al. (2009) at 29 (emphasis added).

Delaying global mitigation action is much more significant than the overall time it takes for the global socio-economic system to make the transition to decarbonisation. ***It is more prudent to begin mitigation***

action soon, than to decarbonise more rapidly at a later date. Furthermore, the greater the delay in global mitigation action the more likely it becomes that an overshoot of a specified stabilization target will occur, and the longer the duration of the overshoot becomes. *These overshoots have particular relevance to concerns regarding 'tipping points' in the Earth system and the potential negative impacts of exceeding certain thresholds. A critical feature of the landscapes generated here is the assumed initial future growth rate in emissions. Our choice of growth rate, based on long term trends, is quite conservative and significantly lower than the actual trend of the last 5 years. Should the most recent trend persist, a much bleaker picture is painted, and early and rapid global mitigation action becomes even more important.*

Id. at 42 (emphasis added).

Substantially postponing the emission reductions, compared to the ranges indicated in IPCC's recent assessment for 2020 as required for meeting the longterm 2 °C target, increases the risk of exceeding this target. ***The costs of a delay strategy are lower in the short term, but lead to higher costs in the longer term. The analysis shows if the emission reductions are postponed to 2030 it is not likely that higher emissions from the earlier years can be fully compensated in future decades in a so-called 'delayed action scenario'.*** *A full compensation would require emission reduction rates in the coming decades that are much higher than those found in the scenario literature. Without compensation, the risk of exceeding the global temperature rise target of 2°C will increase. This confirms that it is not only the reduction commitments for 2050 that determine the risk of exceeding the 2 °C target, but also the path between now and 2050. To meet this 2 °C target, more ambitious 2020 reduction targets are needed for the developed and developing countries than those that have been pledged so far.*

Den Elzen et al. (2010) at 313 (emphasis added).

For example, Meinshausen et al. argue that peaking global emissions before 2020, cutting them at least 50 per cent below 1990 levels by 2050 and continuing reductions thereafter gives us a reasonable chance of staying within a budget consistent with limiting warming to 2 °C, but securing agreement on this will undoubtedly be hard. This is where acknowledging the principle of a cumulative budget could be helpful: the higher emissions are allowed to be in 2020, the lower they will need to be in 2050 to stay within the same overall budget. ***From this perspective, the argument for early emission cuts becomes primarily an economic and technical one: late and rapid reductions are risky, expensive and disruptive, and hence potentially politically infeasible. And the sooner we start, the more flexibility we have to adjust policies as new scientific information becomes available. Cutting emissions later also raises the issue of inter-generational equity, as the costs of very steep emission reductions in the future (assuming these are feasible) could well exceed the economic benefits of postponing mitigation.***

Allen et al (2009) at 57 (emphasis added, footnote omitted).

Climate models provide compelling evidence that if greenhouse gas emissions continue at present rates, then key global temperature thresholds (such as the European Union limit of two degrees of warming since pre-industrial times) are very likely to be crossed in the next few decades. However, there is relatively little attention paid to whether, should a dangerous temperature level be exceeded, it is feasible for the global temperature to then return to safer levels in a usefully short time. We focus on the timescales needed to reduce atmospheric greenhouse gases and associated temperatures back below potentially dangerous thresholds, using a state-of-the-art general circulation model. This analysis is extended with a simple climate model to provide uncertainty bounds. We find that even for very large reductions in emissions, temperature reduction is likely to occur at a low rate. ***Policy-makers need to consider such very long recovery timescales implicit in the Earth system when formulating future emission pathways that have the potential to 'overshoot' particular atmospheric concentrations of***

greenhouse gases and, more importantly, related temperature levels that might be considered dangerous.

Lowe et al. (2009) at 1 (emphasis added).

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- It is now well understood that the climate commitment exposes us to levels of additional warming that is not yet felt but already unavoidable, irreversible and dangerous.
- Without mitigation, triggering points that cause irreversible climate change will occur earlier than predicted and may occur within decades rather than centuries; some may have already occurred.
- Most of the CO_2 now in the atmosphere will remain there for time frames measured in millennia, and its effects will be experienced over those time frames; all CO_2 additions exacerbate the situation.
- The costs of mitigation measures undertaken today are low when compared to their costs at any later date; if trigger points are exceeded, no amount of expense can reverse the damage.
- Risks of catastrophic climate change cannot be avoided unless concentrations of CO_2 are lowered to 350 ppm or less.

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- NHTSA should analyze and discuss an alternative that accounts for and avoids, or minimizes the likelihood, of reaching climate change tipping points.

Response

NHTSA appreciates the discussion of tipping points provided by the commenter. The comment identifies many of the same issues highlighted and discussed in Sections 3.4 and 4.5 of the DEIS (and FEIS). The EIS discusses the impacts on various climate systems of reaching or passing various climate tipping points. *See* FEIS Section 4.5.9.2. That section contains discussions of potential impacts resulting from tipping points being reached for glaciers and ice sheets, the likelihood and persistence of drought, potential impacts on Amazon rainforests, and potential impacts on other climate systems.

The tipping points discussion in Section 4.5.9 of the FEIS has been revised to include findings from many of the sources suggested by the commenter: Lindsay and Zhang (2005), Richardson *et al*. (2009), Smith *et al*. (2009), Rockstrom *et al*. (2009), Vaughan *et al*. (2009), Mignone *et al*. (2008), Meinshausen *et al*. (2009), and Lowe *et al*. (2009). Though Jones *et al*. (2009) and Solomon *et al*. (2009) were already cited in Section 4.5, these discussions have been expanded for the FEIS. These additions clarify that the scientific understanding of tipping points is still developing, but that the risk of reaching these tipping points is increasing as global greenhouse gas emissions continue. The remaining studies suggested by the commenter were not added to the FEIS for the following reasons: Pimm (2009) and Lenton *et al*. (2008) were already cited in Section 4.5.9 of the DEIS; and Hansen *et al*. (2008), Allen *et al*. (2009), and den Elzen *et al*. (2010) were not included because they do not appear to have been extensively peer- or panel- reviewed.

NHTSA does not believe that examining the alternatives in relation to reaching tipping points triggered by CO_2 emissions is practicable. In the context of this EIS, due to the uncertainty

surrounding the precise global temperature change or CO_2 concentration level that would constitute a tipping point, it is not currently practicable to attempt to estimate how this action could delay or mitigate the triggering of tipping points in any quantitative manner. Thus, it would not be possible for NHTSA to relate the reductions in CO_2 emissions, sea-level rise, precipitation changes, and temperatures to tipping-point thresholds or to determine to what extent the different alternatives would affect tipping points.

As noted by the commenter, even under the most stringent alternative analyzed, this action alone is not likely to produce enough reductions in CO_2 emissions to avert CO_2 levels that some have identified as corresponding to abrupt and severe climate change. CO_2 emissions of HD vehicles account for roughly 1.2 percent of global annual CO_2 emissions. Even if NHTSA were to set standards that reduced emissions from this sector to 17% below 2005 levels (or to more stringent levels), thresholds for abrupt and severe climate change would not likely be avoided without other significant global actions. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions growth, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds, though it is not possible to quantify these effects given the state of the science. Moreover, while NHTSA's action alone does not produce sufficient CO_2 emissions reductions to avert abrupt and severe climate change, the proposed action taken together with other actions to reduce GHG emissions could make substantial contributions in averting levels of abrupt and severe climate change.

Addressing abrupt climate-change requires a global effort, including CO_2-reduction initiatives beyond the scope of the current rulemaking. Due to the largely incomplete and unavailable state of information surrounding this issue, the only conclusion NHTSA can reach at this time is that the reduction in CO_2 emissions expected under this rulemaking to a limited degree will lower the risk of abrupt climate change. However, NHTSA recognizes the potential severity of the consequences and the desire for unified action to avert the possible impacts associated with abrupt climate change. The EIS discussions of tipping points and abrupt climate change include discussions of potential impacts and the possible severity of those impacts. ***See*** **FEIS Section 4.5.9.2.**

Comments

Docket Number: 0025; 0081
Commenter: Vera Pardee, Center for Biological Diversity

Damages Inflicted by Crossing Tipping Points Are Not Monetized. As stated by the Agencies, in the context of climate change and its consequences, the phrase "tipping point" is used "to describe situations in which the climate system . . . 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 . . . could result in abrupt changes in the climate or any part of the system. Abrupt climate changes could occur so quickly and unexpectedly that human systems would have difficulty adapting to them." In response to the Center's July 2010 Comment Letter requesting the Agencies to analyze and monetize the effect of crossing climate change tipping points, however, the Agencies stated:

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.*

This response misses the point. Under the analysis presented in the DEIS, global CO_2 concentration levels are forecasted to reach 678 ppm. At those levels, climate tipping points will very likely have been exceeded, a probability level well within the Agencies' obligations to analyze and examine. The Agencies acknowledge this point themselves, as they state that "[s]everal . . . 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 forests) . . . could reach a tipping threshold within this century."

There can be no dispute that it is reasonably foreseeable that, at 687 ppm, tipping points will have been crossed. A recent study has conducted a comprehensive review of nine tipping elements in the Earth's climate system considered vulnerable to passing a tipping point in this century. Tipping points for two tipping elements – the Arctic summer sea ice and the Greenland ice sheet – were considered vulnerable to being triggered at mean global temperature increase of less than 2°C above 1980-1999 levels. Since a 678 ppm level would lead to 2.56°C mean global temperature rise by 2100 according to the DEIS relative to 1980-1999 levels, it is extremely likely that these tipping points will have been crossed at 678 ppm. In the case of the Greenland ice sheet, the triggering of irreversible melting by 1-2°C temperature rise above 1980-1999 levels would lead to an eventual seven-meter sea-level rise with catastrophic impacts. Another study reviewing the expert judgments of 43 scientists found that they allocated significant probabilities to triggering tipping points for five systems at mean global temperature change of 2–4 °C above year 2000 levels, including the dieback of the Amazon rainforest, the shutdown of the Atlantic Ocean thermohaline circulation, the disintegration of the West Antarctic ice sheet, and a shift to a more persistent El Niño regime. This study indicates that there is a significant probability of surpassing tipping points for these systems by or before reaching 678 ppm.

Finally, many ecosystems also have a high probability of exceeding tipping points well before 678 ppm, leading to ecosystem collapse and mass species extinction. The IPCC concluded that approximately 20 to 30% of species assessed will likely be at increased risk of extinction if global average temperature rise exceeds 1.5 to 2.5°C (relative to 1980-1999). Due to the synergistic impacts of ocean acidification and mass bleaching from ocean temperature rise, coral reefs are projected to experience "rapid and terminal" declines worldwide at atmospheric CO_2 concentrations of 450 ppm. Another study determined that ocean acidification would have detrimental effects on plankton at the base of the food web in the Southern Ocean at CO_2 levels of 450 ppm, and proposed a tipping point of 450 ppm for this ecosystem. Other scientists have found that CO_2 levels below 350 ppm are needed to protect coral reef ecosystems from collapse.

In any event, uncertainty about quantification of the effect of one specific action – here, the adoption of the HD Vehicle Rule – is no obstacle: under the cumulative impacts analysis, the Agencies need not quantify how increasing U.S. mileage standards alone would affect tipping points (indeed, no individual action by itself can halt GHG emissions sufficiently to avoid tipping points), when they can quantify the damages likely to arise from crossing them as a result of cumulative impacts. At present, the Agencies have in effect assigned a value of zero to the cost of crossing tipping points, a conclusion that is certain to be false. Instead, the DEIS, as part of its cumulative analysis, must describe and quantify the impact of the climate's having crossed tipping points in 2100, even if the Agencies believe they cannot quantify the crossing of these thresholds as the direct or indirect result of the HD Vehicle rulemaking alone. As discussed above, however, we note that in the Agencies need to analyze whether the proposed action contributes its proportional share to a solution that avoids tipping points. One can infer that it does not do so from the fact that emissions from the HD sector will actually increase under the proposed action, but the DEIS needs to squarely confront this issue. [Footnotes omitted].

* * * * *

As we pointed out in our Comment Letter, although the LD Vehicle FEIS devoted considerable space to the discussion of tipping points, it provided no quantitative analysis of their effects even on a cumulative basis, despite conceding that tipping points cannot be avoided. The result was that the costs of exceeding these points were left entirely out of the equation. In particular, NHTSA stated that it had not quantified these risks under either its direct-indirect or its cumulative analysis, claiming that "the present state of the art does not allow for quantification of how emission reductions *from a specific policy or action* might affect the probability and timing of abrupt climate change." LD Vehicle FEIS at 3-84, 4-49 (emphasis added). This justification cannot withstand scrutiny: under the cumulative impacts analysis, NHTSA need not quantify how increasing U.S. mileage standards alone would affect tipping points (indeed, no individual action by itself can halt GHG emissions sufficiently to avoid tipping points), when it can quantify the damages likely to arise from crossing them as a result of cumulative impacts. Instead, NHTSA assigned them a value of zero, a conclusion that is certain to be false. This zero value was also reflected in the crucial but incorrect assumption contained in the underlying LD Vehicle Rule that the social cost of carbon increases by a linear and non-variable 3% per year over the next century. As the LD Vehicle FEIS' discussion made perfectly clear, there is no linearity in the effects of climate change.

NHTSA possesses ample information to begin quantification of the tipping point risk, including the scientific literature cited here. The LD Vehicle FEIS discussed continental, subcontinental, regional and local effects of crossing tipping points, including dramatic alteration of the Asian monsoon; overturning of the circulation system in the Atlantic Ocean; the collapse of the West Antarctic ice sheet; the loss of the Greenland ice sheet; drying in the southwestern United States leading to drought and increases in fire frequencies; and loss of the Sierra Nevada snow pack. The LD Vehicle FEIS noted that such tipping points are characterized by rates of change sharply greater than what has prevailed over previous decades and change acceleration at a pace that exceeds the resources and ability of nations to respond to it. LD Vehicle FEIS, 4-155. It further pointed out that tipping points can occur at levels "exceeding 450 ppm" and that, while "future abrupt changes cannot be predicted with confidence, . . . climate surprises are to be expected." *Id*. at 4-156-157. The LD Vehicle FEIS also notes that, based on "'growing evidence that even modest increases in [global mean temperature] could commit the climate system to the risk of very large impacts on multiple-century time scales,' the risks of large-scale discontinuities were expertly judged to begin being a source of substantial risk around 1 °C (around 2 °F). Smith et al. (2008) projected 2.5 °C (4.5 °F) . . . to be the 'possible trigger for commitment to large-scale global impacts over multiple-century time scales.'" *Id*. at 4-157.

In other words, the best outcome the LD Vehicle FEIS described as resulting from its most stringent alternative and the "reasonably foreseeable" actions of other parties virtually commits the environment to massive, large-scale trigger points that cause changes to which we can no longer adapt. But, repeating the argument the Supreme Court rejected in *Massachusetts v. EPA*, the LD Vehicle FEIS concluded both that quantification of the effects of these developments is impossible and that nothing can be done:

This action [setting mileage standards] alone, even as analyzed for the most stringent alternative, is very unlikely to produce sufficient CO_2 emissions reductions to avert emission levels corresponding to abrupt and severe climate change. Under EPCA, as amended by EISA, NHTSA has the authority to set fuel economy standards for U.S. passenger cars and light trucks, which account for roughly 3.3 percent of global annual CO_2 emissions. Even if NHTSA could set standards that reduced emissions from this sector to zero, tipping-point thresholds (whether they occur at 550 ppm or any other level of that general order of magnitude) would not likely be avoided without other significant global actions.

LD Vehicle FEIS at 4-165. While superficially correct, this statement cannot support the conclusion that NHTSA may avoid providing an analysis of how the rulemaking could proportionately reduce greenhouse gas emissions from MD/HD Vehicles, so as to contribute its proportionate share to an environmental outcome in which combined cumulative action results in sustainable CO_2 stabilization.

Response

NHTSA appreciates the discussion of tipping points and citations provided by the commenter. Section 4.5 of the FEIS includes findings from several of the studies on tipping points and ocean acidification suggested by the commenter and others. While IPCC (2007), McNeil and Matear (2008), Lenton *et al*. (2008), and Kriegler *et al* (2009) were previously addressed in the DEIS, and now in the FEIS, elements of the other studies on tipping points and ocean acidification suggested here by the commenter, such as Veron *et al*. (2009), have been incorporated into Section 4.7.2 of the FEIS. Hansen *et al*. (2008) was not included because this source did not appear to have been extensively peer- or panel- reviewed.

Many scientists assert that if thresholds relating to the climate system are exceeded, this may result in severe and abrupt climate changes and impacts. For this reason, this EIS discusses the impacts on climate systems of reaching or passing various climate tipping points. *See* Section 4.5.9.2. That section contains discussions of potential impacts resulting from tipping points being reached for glaciers and ice sheets, the likelihood and persistence of drought, potential impacts on Amazon rainforests, and potential impacts on other climate systems.

Regarding the quantification of the impact of crossing climate tipping points in 2100, while many scientists assert that if thresholds relating to the climate system are exceeded it may result in severe and abrupt climate changes and impacts, there remains substantial uncertainty surrounding the existence of a single tipping point, and, if there is a single level, whether it corresponds to a specific CO_2 concentration (e.g., 450 parts per million (ppm)) or increase in annual average temperature (e.g., 2 °C over pre-industrial levels). For example, there are indicators of multiple tipping points within various global systems, as noted in scientific observations, peer-reviewed scientific literature, and paleoclimatic data. *See* Section 4.5.9. These points might occur when CO_2 concentrations are lower or higher than 450 ppm and would have varying direct and indirect impacts.

In the context of this EIS, due to the uncertainty surrounding the precise global temperature change or CO_2 concentration level that would constitute a tipping point, it is not currently practicable to attempt to estimate how this action could delay or mitigate the triggering of tipping points in any quantitative manner. Thus, it would not be possible for NHTSA to relate the reductions in CO_2 emissions, sea-level rise, precipitation changes, and temperatures to tipping-point thresholds or to determine to what extent the different alternatives would affect tipping points. This FEIS notes that the GHG emission reductions associated with the action alternatives will have a slight reduction in the timing or magnitude of effects associated with tipping points, though it is not possible to quantify these effects given the state of the science.

While NHTSA's action alone does not produce sufficient CO_2 emissions reductions, it is one of several federal programs, that, together, could make substantial contributions in averting levels of abrupt and severe climate change. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions growth, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. Addressing abrupt and severe climate-change tipping points (whatever they may be) requires a global effort, including CO_2-reduction initiatives beyond the scope of the current rulemaking. NHTSA recognizes the potential severity of the consequences and the desire for unified action to avert the possible impacts associated with abrupt climate change. The EIS discussions of tipping points and abrupt climate change, thus, include discussions of potential impacts and possible severity of those impacts. *See* Section 4.5.9.2.

Regarding the comment that the FEIS should determine what the "proportionate share" of emission reductions should be from the U.S. HD vehicle sector, NHTSA is charged with developing a Fuel Efficiency Improvement Program for medium- and heavy-duty vehicles that achieves the "maximum feasible" improvement in fuel efficiency in consideration of three statutory factors. Specifically, the program must be "appropriate, cost-effective, and technologically feasible." 49 U.S.C. § 3209w(k)(2). In setting fuel economy standards, NHTSA also takes into account other relevant factors such as safety and environmental concerns. Consistent with EPCA's overall purpose – energy conservation – NHTSA sought to balance the statutory factors noted above in articulating the range of alternatives analyzed in this EIS. Environmental benefits are one consideration in the development of reasonable alternatives analyzed in this EIS. While each of the alternatives would avert significant GHG emissions in comparison to the No Action Alternative, NEPA does not require that NHTSA develop alternatives designed to achieve specific GHG reduction targets. *See* also Section 6.2.6 for NHTSA's response to comments requesting a "proportionate share" analysis in the EIS.

6.4 CUMULATIVE IMPACTS

6.4.1 Reasonably Foreseeable Future Actions

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

[R]egardless of the final decision taken, the EIS must present all reasonable alternatives and their environmental impacts. This is especially true with regard to the cumulative impact analysis, as it requires the Agencies to reflect reasonably foreseeable future actions. The fuel usage in years after the current rulemaking is assumed to follow the business-as-usual prediction contained in the EIA's Annual Energy Outlook until 2035, after which no improvements of any kind are assumed. This assumption neglects technologies such as those mentioned above that would provide significant fuel economy improvements in the near future. In other words, even if the Agencies do not select technologies that allow for significant emissions reductions within the regulatory timeframe, the Agencies should describe these available and foreseeable reductions as part of the cumulative impacts analysis under NEPA.

* * * * *

[T]he assumptions underlying the cumulative effects analysis contain a number of flaws. NEPA and 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." However, the DEIS uses the Energy Information Administration's Annual Energy Outlook 2010 ("EIA 2010") Reference Case forecast of increase in average fuel efficiency to project future cumulative fuel efficiency gains. This reference case measures improvements anticipated solely from voluntary actions taken by producers, purchasers, and operators of these vehicles, and thus anticipates no improvements through regulatory action through 2035 (including the instant proposed regulation). The EIA 2010 Reference Case, therefore, is a classic definition of "business as usual." Moreover, because the EIA 2010 Reference Case projections run only through 2035, "no further increases in fuel efficiency are assumed to occur after 2035 [through 2100] for each regulatory class." Such a scenario is entirely implausible, rather than foreseeable, and thus seriously flawed. While the Agencies must be cautious not to err in the other direction, with overly optimistic assumptions, the overly pessimistic assumptions of the EIA contribute to the (mis-)impression left by the DEIS that the climate problem is insolvable. [Footnotes omitted].

Response

NHTSA believes the cumulative impacts analysis presented in the EIS reflects reasonably foreseeable gains in fuel efficiency in the HD sector. The cumulative impacts analysis presented in the DEIS reflected ongoing fuel efficiency gains under each alternative after 2018, consistent with Annual Energy Outlook (AEO) 2010 forecast annual percentage gains through 2035 for the categories of trucks that are roughly comparable to those covered by the proposed rule. The FEIS has been updated to reflect the AEO 2011 Early Release Reference Case forecast, which was the most up-to-date AEO forecast available at the time that the FEIS analysis was performed.

The specific methodology applied in the cumulative impacts analysis (Chapter 4) reflects year-to-year percentage gains in vehicle stock mpg for each of the three broad HD vehicle categories (pickups and vans, vocational vehicles, and tractors), consistent with percentage gains after 2018 in

the AEO forecast. In response to the comment, the FEIS extrapolates the AEO forecast beyond 2035 to 2050 by assuming a compound annual percentage increase in mpg from 2035 to 2050, based on the average annual percent increase forecast by AEO from 2030 through 2035.

This methodology results in a cumulative impacts baseline that is roughly consistent with the AEO forecast for total HD stock vehicle miles travelled (annual VMT per year for all HD trucks in use), total HD stock fuel use, and total HD stock mpg (VMT/fuel for all trucks in use). For the action alternatives, the cumulative impacts methodology applies the same annual percentage gains in vehicle stock mpg (derived from absolute gains after 2018 in the AEO forecast), compounded on the higher 2018 mpg level achieved under each action alternative. Therefore, the Chapter 4 analysis reflects ongoing gains in vehicle mpg after 2018 under each of the action alternatives.

The cumulative impacts methodology shows an overall increase in fuel economy in the action alternatives over the analysis presented in Chapter 3 (direct and indirect impacts). For tractor trucks, the cumulative impacts methodology increases fuel efficiency (mpg) under the action alternatives by 0.85% in 2019, rising to a 12.75% increase in 2050, above the level of the standards that apply for MY 2018 to match the percentage increase in fuel efficiency of the No Action Alternative in those years. In the case of vocational vehicles, the cumulative impacts methodology has little substantive impact on the No Action Alternative or the action alternatives because the AEO forecast is for no increase (actually for a small decrease) in "medium freight" truck fuel efficiency from 2018 through 2035. For HD pickups and vans, the cumulative impacts methodology increases fuel efficiency under the action alternatives by 1.5% in 2019, rising to a 17.9% increase in 2050, above the level of the standards that apply for MY 2018 to match the percentage increase in fuel efficiency of the No Action Alternative in those years. This methodology does not attempt to forecast the specific requirements of any future rule increasing HD fuel efficiency requirements after 2018 or the new vehicle market penetration for specific technologies beyond 2018. However, the cumulative impacts analysis does implicitly assume that higher new vehicle penetration rates for some combination of new vehicle technologies would be needed in order to achieve the overall percentage gains in mpg forecast for 2018 through 2050, above the levels achieved under each action alternative based just on the requirements of this rule for vehicles built after 2018.

In addition to these forecast 2018-2050 mpg gains reflected in the Air Quality and fuel consumption results reported through 2050, the climate section of Chapter 4 also reflects the cumulative impacts of ongoing gains in truck fuel efficiency from 2050 to 2100 together with other global actions taken to reduce GHG emissions to levels below those that would be achieved under the current climate emission trajectory reflected in the Chapter 3 results.[3]

In response to the comment that the agency does not take into account regulatory actions, NHTSA has included an additional analysis in Section 4.2.4 of the overall benefits of NHTSA and EPA's Joint National Program. In particular, Section 4.2.4 estimates the total benefits of the agencies' past, present, and reasonably foreseeable future regulatory actions under the Program.

[3] As described in Section 4.4.3.1, NHTSA used a scaling methodology to project the impact of MY 2051-2100 HD vehicles using Global Change Assessment Model (GCAM) assumptions regarding the growth of U.S. transportation fuel consumption

6.4.2 Non-Climate Cumulative Impacts of Carbon Dioxide

Comments

Docket Number: TRANS-Cambridge
Commenter: L. Knife and Son, Inc.

The science on climate change over the past year has shown that we are experiencing destabilizing effects at a faster rate than the International Panel on Climate Change predicted in its Fourth Assessment Report in 2007. In July, 2010, Nature reported that global warming is responsible for a 40 percent decline in the ocean's phytoplankton. A Geoscience study reports that oceans are acidifying ten times faster today than 55 million years ago, when a mass extinction of marine species occurred. In March, 2010, Science reported that the East Siberian Arctic Shelf methane stores are destabilizing and venting, and that release of even a fraction of the methane could trigger abrupt climate warming.

Response

NHTSA agrees with the commenter. In Section 4.7.2.1 of the DEIS (and the FEIS), NHTSA notes the following, "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)."

Comments

Docket Number: 0081
Commenter: Vera Pardee, Center for Biological Diversity

Damages Caused by Ocean Acidification Are Not Considered or Monetized.
Several recent findings relevant to ocean acidification, including the additive effects of ocean acidification and other stressors, have apparently not been considered by the Agencies. A recent study examined the ecological stress of ocean acidification in areas of low oxygen (also known as "dead zones"), concluding that the additive effects of these stressors "may cross critical thresholds for organisms living near the edge of their physiological tolerances and may thus appear as abrupt and major changes in the health of an ecosystem." Ocean acidification also exacerbates coral bleaching as high-CO_2 waters act synergistically with increased temperature to lower the threshold for coral bleaching. It is crucial that the ecological consequences of ocean acidification be considered in the context of other stressors because pH changes that may not reach a dangerous threshold for calcification may nonetheless wreak havoc on an ecosystem already under duress from other factors.

The DEIS focuses largely on impacts to marine calcifiers and includes discussion of impacts on marine fish and mammals. These impacts, however, are likely to be broader than indicated in the DEIS. For instance, high partial pressures of CO_2 can detrimentally affect "acid-base regulation, calcification and growth [as well as] respiration, energy turnover and mode of metabolism." Another recent study suggests that although a single organism may be able to nominally survive in elevated CO_2 conditions, populations may not. In fact, the authors suggest that elevated marine CO_2 may have resulted in mass extinctions in the past. Other reviews and studies have further elucidated the negative impacts of high levels of CO_2 in seawater with regard to cardiac mortality in fish and growth and reproduction in marine organisms. Finally, it should be noted that the threshold for detrimental physiological impacts on many marine organisms is relatively low. The DEIS fails to consider or analyze these greenhouse gas pollution damages.

In sum, as stated in *Center for Biological Diversity v. NHTSA*, "[e]ven if NHTSA may use a cost-benefit analysis to determine the 'maximum feasible' fuel economy standard, it cannot put a thumb on the scale by undervaluing the benefits and overvaluing the costs of more stringent standards." [Footnotes omitted].

Response

NHTSA appreciates the citations provided by the commenter. These sources generally support the material in Section 4.7.2 of this EIS, which documents the many adverse effects of ocean acidification. In response to this comment, NHTSA has incorporated into the FEIS all of the peer-reviewed studies cited by the commenter. NHTSA also notes that many of the citations provided by the commenter were already included in Section 4.7.2 (Feely *et al*. 2010, McNeil and Matear 2008) or were included in literature reviews discussed in that section (e.g., Ishimatsu *et al*. 2004). NHTSA has added information from peer-reviewed literature that is not already in Section 4.7.2: Anthony *et al*. (2008), Pörtner *et al*. (2004), and Pörtner *et al*. (2005).

Regarding threshold effects, NHTSA's DEIS referenced a recent analysis by Hoegh-Guldberg *et al*. (2007). NHTSA included this paper on thresholds because it refers to present-day observations and it is widely-cited by scientists in the field. NHTSA agrees with the commenter that it is not reasonable to infer that effects on a single individual imply population-level effects. Regarding the study about mass extinctions in the past, NHTSA has focused on the many peer-reviewed studies reporting current observations because they are more relevant and provide stronger evidence of the effects of ocean acidification on marine organisms.

6.5 NATIONAL SECURITY IMPACTS

Comments

Docket Number: 0142
Commenter: Janice Nolan, Hilary Sinnamon, Peter Zalzal, Katie Patterson, and Britt Groosman - American Lung Association and Environmental Defense Fund

Our nation's dependence on oil is also a threat to national security. The U.S. consumes nearly 25 percent of the world's oil production, but controls less than 2 percent of the supply. . . . And over half of the oil we use each day is imported from foreign countries, many of which do not like us. In 2008, we sent over $1 billion a day overseas to pay for oil, the majority of it going to nations deemed "dangerous or unstable."

The rate at which we consume oil helps our enemies by paying to finance and sustain their unfriendly regimes. And the longer the U.S. remains dependent on petroleum, the more the U.S. will have to engage in tough fights just to protect our energy supplies.

More than 70 percent of the oil we consume is for transportation. If we want to reduce our dependence on oil, we must address fuel consumption from our transportation sector. Former CIA director Jim Woosley has said, "Except for our own Civil War, this is the only war that we have fought where we are paying for both sides. We pay Saudi Arabia $160 billion for its oil, and $3 or $4 billion of that goes to the Wahhabis, who teach children to hate. We are paying for these terrorists with our SUVs." . . . And retired General and 28th Commandant of the Marine Corps P.X. Kelley and Frederick W. Smith, Chairman, President, and CEO of FedEx Corporation said together in a letter to President Obama, "Simply put, energy security cannot be improved without addressing oil dependence, and oil dependence cannot be meaningfully reduced without addressing transportation." . . .

The U.S. Environmental Protection Agency (EPA) estimates that by 2030, this program will save nearly 5.8 billion gallons of oil annually. . . . By 2030, this rule alone would reduce daily oil use by enough to offset all of the oil we imported this year from Iraq, based on current vehicle miles traveled. And together with policies underway to address fuel consumption and greenhouse gases from passenger vehicles, our nation could save enough oil to offset more than all of the oil we import from the entire Middle East by 2025. [Footnotes omitted].

* * * * *

As clearly outlined in the proposal, GHG emissions threaten our health and the environment by contributing to climate change. And like oil consumption, climate change is a real threat to our national security at home and abroad. These threats have been clearly laid out in a number of reports by federal agencies, military experts and independent organizations. For example, the National Intelligence Council issued two reports detailing the threat of climate change. And the Pentagon, in its 2010 Quadrennial Defense Review, acknowledges that climate change is already being observed in every region of the world and outlines the dramatic threats climate change will have on our military and national security. . . . The Center for American Progress also released a report, "Securing America's Future," that shows the inextricable link between global warming pollution and our national security.

This proposed rule would result in significant and necessary greenhouse gas emissions reductions for the nation as a whole. EPA estimates that the program could reduce annual GHG emissions by 72 million metric tons in 2030, or a total of 250 million tons over the lifetime of MY2014-2017 vehicles, mitigating the impacts on our environment and improving national security. [Footnotes omitted].

Docket Number: TRANS-Chicago
Commenter: Christopher Miller, Operation Free

I'm sorry to say that the United States is currently a great source of income for the Iranian government and the insurgency. The money we spend on oil is being used to hurt and kill our soldiers, sailors, airmen, and marines in large number and fund terrorism and Islamic extremism. Every time the price of oil goes up by one dollar, Iran gets another $1.5 billion to use against us. The connection between our oil addiction and the enemy couldn't be clearer. We need to break that connection by breaking our addiction. The scope of our addiction is extensive. The U.S. consumes nearly 19 million barrels of oil a day, which is nearly a quarter of the oil consumed in the entire world and more than all E.U. nations combined. Over half of the oil we use each day is imported from foreign countries, many of which do not like us. And more than 70 percent of the oil we consume is used for transportation. The rate at which we consume oil helps our enemies at the same time it is threatening us. Just ask former CIA Director Jim Woolsey who says: "Except for our own Civil War, this is the only war that we have fought where we are paying for both sides. We pay Saudi Arabia $160 billion for its oil, and $3 or $4 billion of that goes to the Wahhabis who teach their children to hate. We are paying for these terrorists with our SUVs." And we're not just addicted to oil at home. I can attest firsthand that our military is also addicted to oil. It takes billions of gallons to run the military on the ground abroad, and that oil comes from foreign nation that don't like us. If one of these unfriendly leaders ends oil exports to us, our military would be unable to function effectively. So how do we break our addiction to oil? Well, we start at home. We ask Americans to create technologies that can take our trucks farther on one gallon of gasoline. We look to industry leaders like FedEx, who have already put hundreds of efficient hybrid trucks on the roads. And we ask our government to implement programs that require deployment of these cleaner and more efficient vehicles on a nationwide scale. Will the policy being considered here today alone break our addition to oil? No. But reducing our oil consumption by 500 million barrels together with similar policies underway to address fuel consumption and greenhouse gases from passenger vehicles, our nation could save enough oil to offset more than all of the oil we import from the entire Middle East by 2025.

Docket Number: PAPER-Chicago
Commenter: Richard Stuckey

Our dependence on imports of foreign oil will be reduced. We will have less need to support a massive military that costs 50 percent of the entire world's defense budget, largely to defend our access to foreign oil. Defense Department studies have shown that global warming is one of the largest threats to national security. If we can reduce the effects of global warming our needs for a massive military will be further reduced, thereby reducing our government deficit.

Docket Number: TRANS-Cambridge
Commenter: Wade Barnes

The Strait of Hormuz accounts for 20 percent of the world's traded oil with over 17 million barrels per day transiting the 21-mile wide chokepoint, according to the (Energy Information Administration) EIA. The rate at which we consume this oil helps our enemies, and at the same time it is threatening us. Just ask former U.S. Secretary of State, George Shultz, "The flow of funds from oil producers in many cases goes to states that are antithetical to us and are trying to do us damage. And some of the money leaks out into terrorists' hands." Though U.S. law prevents the purchase of oil from Iran for domestic use, our tireless consumption drives up revenues for all oil-producing nations by spurring demand in the global market. In 2008, we sent over $1 billion a day overseas to pay for oil. Some of this money falls into the hands of our enemies, who use it to buy cutting-edge weapons, like explosively formed projectiles specially designed to pierce American armored vehicles and kill U.S. combat troops. Every time the price of oil goes up by one dollar, Iran gets another $1.5 billion to use against us. The connection between our oil addiction and the enemy is crystal clear. We need to break that connection by breaking our addiction. And the scope of our addiction is extensive. The U.S. consumes nearly 19 million barrels of oil a day, which is nearly a quarter of the oil consumed in the entire world. Nineteen million barrels per day is a consumption rate greater than all EU nations combined. Over half of the oil we use each day is imported from foreign countries, many of which do not like us. More than 70 percent of that oil is used for transportation. Today, the nation's fleet of trucks and buses consumes nearly 100 million gallons per day. To put this in perspective, the BP oil spill is estimated to have leaked 200 million gallons of crude into the Gulf of Mexico. So our commercial trucks use the same amount of oil in two days that was leaked in the entire Deepwater Horizon rig disaster. We are not just consuming oil at home. I can attest firsthand that our military is also addicted to oil. My last tour of duty was as the Auxiliaries Engineering Officer on USS Peleliu, a large amphibious ship designed to deliver Marines into conflict zones, or humanitarian crises, around the world. As a naval engineer, my duties included supervising the ship's propulsion plant as we refueled with one million gallons of diesel fuel on a weekly basis. So how do we break our addiction to oil? We start at home. We leverage the ingenuity of the American private sector to create technologies that take our trucks farther on one gallon of gasoline. We look for economic success stories in demand reduction, like the hundreds of efficient hybrid trucks FedEx operates on American roads. And we ask our government to implement programs that require deployment of these cleaner and more efficient vehicles on a nationwide scale. Will the policy considered here today break our addiction to oil by itself? No, but the 500 million barrel demand reduction it is estimated to achieve is a vitally important step. By 2030, these proposed fuel efficiency standards would reduce daily oil use by more than the amount of oil we imported this entire year from Iraq. And together with similar policies designed to address passenger vehicle fuel consumption, Americans could save enough oil to offset all of our Middle Eastern oil imports by 2025.

Response

NHTSA agrees with these comments that dependence on foreign sources of oil is a threat to U.S. national security. Sections 4.5.7.1 and 4.5.7.2 of the FEIS contain a discussion of the potential national security impacts of climate change. The latter Section draws largely from the U.S. DOD's Quadrennial Defense Review, which is cited in these comments. The agency has also added additional information to the FEIS from the references cited by the commenters.

NHTSA recognizes that potential national and energy security risks exist due to the possibility of tension over oil supplies. Much of the world's oil and gas supplies are located in countries facing social, economic, and demographic challenges making them even more vulnerable to the potential local instability associated with the impacts of climate change. Because of U.S. dependence on oil, the military could be called on to protect energy resources through such measures as securing shipping lanes from foreign oil fields. To maintain such military effectiveness and flexibility, the Department of Defense identified in the Quadrennial Defense Review that it is "increasing its use of renewable energy supplies and reducing energy demand to improve operational effectiveness, reduce greenhouse gas emissions in support of U.S. climate change initiatives, and protect the Department from energy price fluctuations" (DOD 2010). The Department of the Navy has also stated that the Navy and Marine Corps rely far too much on petroleum, which "degrades the strategic position of our country and the tactical performance of our forces. The global supply of oil is finite, it is becoming increasingly difficult to find and exploit, and over time cost continues to rise" (U.S. Department of the Navy 2011).

In remarks given to the White House Energy Security Summit on April 26, 2011, Deputy Security of Defense William J. Lynn, III noted the direct impact of energy security on military readiness and flexibility. According to Deputy Security Lynn, "Today, energy technology remains a critical

element of our military superiority. Addressing energy needs must be a fundamental part of our military planning" (DOD 2011).

Thus, to the degree to which the proposed rule reduces reliance upon imported energy supplies or promotes the development of technologies that can be deployed by either consumers or the nation's defense forces, the United States could expect benefits related to national security, reduced energy costs, and increased energy supply. These benefits are why President Obama has identified this rule as a key component for improving energy security and putting America on a path to reducing oil imports in the Blueprint for a Secure Energy Future (White House 2011).

Comments

Docket Number: TRANS-Cambridge
Commenter: Jonathan Gensler
[Portions of this comment that are substantively similar to other comments have been omitted.]

Abroad, we face food and water shortages that exacerbate conflict; these conflicts will require action by U.S. forces. Rising sea levels are already causing mass migration in places like Bangladesh, which result in huge refugee populations that provide terrorists with a growing pool of recruits, and not to mention, a pretty handy place to hide. And natural disasters, like the tsunami that hit Indonesia in 2004, also required action by U.S. forces. Not to say that the tsunami is related to climate changes, but it is easy to understand how other massive weather events can cause these types of events. After the tsunami, the United States Military spent $5 million every single day responding with logistical aid, ships, planes and helicopters to Indonesia. No other military in the world has the capacity to respond so quickly to a disaster of such magnitude. Climate change is also already impacting the military directly. In 2008, the National Intelligence Council judged that more than 30 of the United States Military installations were already facing elevated risks from rising sea levels.

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The longer the U.S. remains dependent on fossil fuels, the more the U.S. will have to engage in tough wars, just to protect our energy supplies, putting American lives at risk; I have been there. . . . A Military Advisory Board, comprised of eleven retired three-star and four-star generals and admirals stated, "Our dependency on foreign oil reduces our international leverage, places our troops in dangerous global regions, funds nations and individuals who wish us harm, and weakens our economy; our dependency and inefficient use of oil also puts our troops at risk." . . .

Docket Number: TRANS-Chicago
Commenter: Ashkan Bayatpour

The connection between oil addiction, climate change, and national security is real. The U.S. consumes 25 percent of the world's oil production but controls less than 3 percent of the supply. The longer the U.S. remains dependent on fossil fuels, the more the U.S. will have to engage in tough fights just to protect our energy supplies, putting American lives at risk. The global warming pollution we create burning this fuel further threatens our troops and our security. While some policymakers aren't taking the threat of climate change seriously, the consensus among security experts is that climate change is real and the threat is real. The National Intelligence Council has issued two reports detailing the threat of climate change, and in the 2010 Quadrennial Defense Review, the Pentagon acknowledges that climate change is already being observed in every region of the world and outlines the dramatic threat climate change will have on our military and our national security.

* * * * *

Rising sea levels are already causing mass migration in places like Bangladesh, which result in huge refugee populations which provide terrorists a growing pool of recruits and a place to hide. Natural disasters like the tsunami that hit Indonesia in 2004 require action by U.S. forces. The U.S. military spent $5 million per day responding with logistical aid, ships, planes, helicopters to Indonesia. No other military force in the world had the capacity to respond so quickly to this disaster. These are just a few examples of why we need to act now both to reduce our dependency on oil and to address greenhouse gas pollution.

Docket Number: TRANS-Chicago
Commenter: Rich Stuckney

Reducing the dependence on foreign oil has much to do with our massive military efforts. The entire nation's dependence on it largely depends on our access to foreign oil. Various studies have shown that global warming is one of the greatest threats to national security. If we can reduce the effects of global warming, our needs for a massive military will further reduce.

Response

NHTSA agrees with the commenters that global climate change could have profound implications for America's national security both domestically and abroad. Although peer-reviewed studies are largely unavailable, several national security reports address this issue. These reports represent a collection of security assessments based on congressional testimony as well as assessments from military advisory boards and councils on foreign relations.

In its recently released Quadrennial Defense Review, the U.S. Department of Defense (DOD) noted that climate change "will shape the operating environment, roles, and missions that we undertake" (DOD 2010). In particular, DOD notes that climate change could have significant geopolitical impacts around the world, such as increased poverty, food and water scarcity, environmental degradation, mass migration, and weakening of already fragile governments. Although climate change alone does not cause conflict, it may accelerate instability or conflict, thereby placing burdens to respond on civilian institutions and militaries around the world. For example, the U.S. military may be required for humanitarian assistance or disaster response both within the United States and overseas (DOD 2010).

Other sources agree. Sea-level rise, storm surges, extreme weather events, and changes in temperature and precipitation patterns all pose serious threats to global stability. Regions in Asia, Africa, and the Middle East with marginal living standards will be particularly vulnerable as economic and environmental conditions worsen (NIC 2008; CNA 2007). Further, climate change acts as a threat multiplier[4] for instability in volatile regions of the world (NIC 2008; CNA 2007).

Areas of conflict driven by climate change that might impact U.S. and international security (Pew 2009; NIC 2008; ECEC 2008; Busby 2007; CNA 2007) include the following:

- ***Conflict over resources.*** **Climate change is projected to reduce freshwater resources and agricultural production in regions of the Middle East, Africa, China, and India.**

[4] "Threat multiplier" refers to an action that further intensifies the instability of a system that poses a security concern.

For example, 40% of the world's population obtains more than 50% of its drinking water from the summer melt of mountain glaciers, which are projected to disappear within the next few decades. International tensions over freshwater rights will escalate (Brown and Crawford 2009; CNA 2007; ECEC 2008). Globally, competition between herders and farmers for water and land will increase (CNA 2007). A reduction in agricultural production is projected worldwide, which could lead to food insecurity, impacts on human health, and volatile global food prices (Pew 2009; Brown and Crawford 2009; CNA 2007). Within the United States, as Dr. Thomas Finger, Deputy Director of National Intelligence for Analysis, testified in June 2008, climate change could impact the stability of some states possibly leading to interstate conflict, particularly over water resources (EPA 2009).

- ***Economic damage and risk to coastal cities and critical infrastructure*. Coastal zones are home to port facilities, oil refineries, and roughly one-fifth of the world's population. These locations are particularly vulnerable to sea-level rise and an increase in natural disasters. The Caribbean, Central America, and the eastern coasts of China and India are projected to be particularly affected (ECEC 2008). Sea-level rise and storm surges are projected to impact several critical U.S. military bases located on coastlines and low-lying Pacific islands (CNA 2007; Pew 2009; Busby 2007). These risks are expected to increase over time (CNA 2007).**
- ***Loss of territory and border disputes*. Several countries could lose land as coastlines or entire small islands are submerged. International legal disputes might occur in response to the changing landscape. These could include disputes over the opening of coldwater waterways as sea ice melts in response to warming temperatures and the ownership of resources underlying historically ice-laden areas (Busby 2007; CNA 2007; ECEC 2008; EPA 2009).**
- ***Environmentally induced migration*. Loss of coastal land, desertification, and a decreased availability of resources due to climate change can all lead to population migration. For example, there are already documented cases of India receiving many environmental refugees from Bangladesh, a particularly vulnerable, highly populated coastal nation with 46% of its population living at low elevations (Busby 2007). Countries afflicted by poor health conditions, high unemployment, or social exclusion[5] could find that these conditions amplify with climate change, and the increases in these conditions may lead to increased migration from those countries (ECEC 2008). For countries that accept populations displaced by climate change, migration could lead to increased economic burdens and possible internal conflicts due to the introduction of new social and religious ideologies (Pew 2009). By 2020, the United Nations estimates that environmental migrants might number in the millions (ECEC 2008).**
- ***Situations of fragility and radicalization.* Climate change could significantly weaken fragile, unstable governments (CNA 2007). It could also intensify ongoing conflicts, leading to the spread of extremism, authoritarianism, and radical ideologies (ECEC 2008; CNA 2007; Brown and Crawford 2009). For example, unstable regions of Africa including Somalia, Ethiopia, and the Darfur region of Sudan are projected to be**

[5] According to DFID (2005), "Social exclusion describes a process by which certain groups are systematically disadvantaged because they are discriminated against on the basis of their ethnicity, race, religion, sexual orientation, caste, descent, gender, age, disability, HIV status, migrant status, or where they live. Discrimination occurs in public institutions, such as the legal system or education and health services, as well as in social institutions like the household."

particularly susceptible to humanitarian disasters as governments fail to meet the needs of their populations (Busby 2007; CNA 2007).

- ***Tension over energy supply*. Much of the world's oil and gas supplies are located in countries facing social, economic, and demographic challenges making them even more vulnerable to the potential local instability associated with the impacts of climate change. This local instability may impact global energy security, increasing competition for these resources and thereby hindering economic growth (CNA 2007; ECEC 2008). The United States depends on oil, and the military could be called on to protect energy resources through such measures as securing shipping lanes from foreign oil fields. Within U.S. borders, extreme weather events are projected to increase in frequency and duration. These events could cause blackouts of the national electricity grid, directly impacting the critical operations of the Department of Defense (CNA 2007). Hence, these blackouts could create an urgent need of military assistance to civilians while simultaneously weakening the ability of the Department of Defense to respond to this need (CNA 2007).**
- ***Pressure on international governance.* Many countries already suffering adverse impacts linked to climate change are calling for the international community to mitigate greenhouse gases (Pew 2009; Brown and Crawford 2009; ECEC 2008). Over time, international governance could be stressed by the resentment of those impacted by climate change towards those considered responsible for climate change, increasing friction in foreign relations (ECEC 2008).**

These areas of conflict could add political and social tension, as well as an economic burden, to the United States and other stable countries, for example, if such countries were to accept large immigrant and refugee populations (CNA 2007; ECEC 2008; Busby 2007). The U.S. military could become overextended as it responds to extreme weather events and natural disasters, and to potential threats from existing and/or new radical populations (CNA 2007; Pew 2009; Busby 2007). As a result of the risks described above, the National Intelligence Council (2008) has expressed increasing concern regarding the geopolitical and national security consequences of climate change.

Although the proposed rule alone would not be sufficient to prevent the above from occurring, it is a valuable part of a global effort to reduce GHG emissions and slow the effects of climate change. Because the proposed rule and its alternatives all reduce GHG emissions compared to the No Action Alternative, NHTSA expects that threats posed by climate change will be reduced to some degree by this action.

Comments

Docket Number: 0116
Commenter: Dale Tyson, HayDay Farms Inc.

There are only two ways to meet EISA's goal of reducing U.S. dependence on foreign oil: either burn less petroleum or switch to a domestically produced fuel. However, the HD Rule largely ignores the real and immediate energy security benefits available from natural gas vehicles ("NGVs") in favor of incremental improvements to petroleum fuel consumption, a distant second-best means of reducing U.S. petroleum imports. Fuel switching is the only realistic energy-security alternative, and the most abundant, efficient and secure replacement is natural gas. The U.S. and Canada supply 99% of U.S. natural gas demand, and unlike U.S. oil reserves, U.S. gas reserves are growing. Estimates from the Potential Gas Committee and the Energy Information Administration indicate domestic supplies are sufficient to meet demand for more than 100 years; as recently as several years ago, this estimate was 65 years. Our company is moving aggressively to purchase and deploy NGVs as part of our fleet and we look forward to the positive contribution we can make in our nation's fight for greater energy independence. Relying on foreign oil undermines more than U.S. energy security - it undermines our economy as well. The U.S. current account deficit for the most recent quarter was $123 billion, during which time we imported $90 billion of petroleum. In contrast, producing and distributing natural gas as a transportation fuel means creating jobs here in America, which the May 21,2010 Presidential Memo described as one of the central goals of this rulemaking. In 2008, U.S. production of 20 Tcf of natural gas created more than 1.3 million jobs; even a modest increase in demand for natural gas as a transportation fuel could create tens of thousands of jobs associated with producing natural gas. A significant push to increase the number of NGVs in the U.S. also would create hundreds of thousands of additional jobs related to manufacturing natural gas vehicles and building the relevant infrastructure. Moreover, natural gas vehicles are as available as natural gas. Worldwide, there are more than 12 million natural gas vehicles on the road today. In the last seven years, the market for NGVs has more than tripled, thanks to a compound growth rate of over 17 percent per year. Demand for U.S. NGVs would thus give domestic manufacturers a base upon which to build an export market. And another economic opportunity exists in converting existing petroleum vehicles to run on natural gas, yet another well-established technology that can further job creation here at home. In sum, the most effective way to meet the goal of reducing U.S. petroleum consumption is by encouraging further growth in the U.S. medium- and heavy-duty natural gas vehicle fleet, a policy which will also significantly assist the U.S. economy. Fortunately, as described below, NHTSA's failure to recognize the energy security advantages of natural gas in this rulemaking can be fixed by nothing more than incorporating into the final HD Rule the same provision for natural gas vehicles that Congress specified in the light-duty fuel economy statute.

Docket Number: TRANS-Cambridge
Commenter: Jeffrey Clarke, Natural Gas Vehicles America

Now, on energy security. Increasing the use of natural gas as a transportation fuel is one of the best ways the U.S. can address the issue of energy security. In the past several years, a wealth of new data has been developed demonstrating that the U.S. has an abundant supply of readily available, economically priced, natural gas. Domestic natural gas currently supplies about 87 percent of natural gas demand here in the U.S. Most of the remaining natural gas is supplied by Canada, or North American sources. Only about three percent is imported. In the past decade, natural gas reserves in the U.S. have actually increased, not declined, as new resources come on-line. Estimates from the Colorado School of Mines' Potential Gas Committee, the EIA, MIT and numerous other respected organizations, indicate that domestic supplies are sufficient to meet demand for more than 100 years-plus. As recently as several years ago, this estimate was only a 65-year supply. Because natural gas is an abundant domestic fuel, we can increase its use without increasing dependence on foreign sources of energy, without increasing imports of oil, and without sending billions of much needed capital overseas.

Response

The agencies received numerous comments relating to the proposed rule; those comments will be addressed in the forthcoming rulemaking documents. The commenters request that the proposed rule reflect the energy security and economic benefits that they state exist for natural gas vehicles. NHTSA recognizes that risks to national security exist in regard to the nation's reliance on foreign sources of oil. That said, the fundamental purpose of this EIS is to evaluate the environmental impacts of the alternatives to inform the decisionmaker, so that these impacts can be taken into account. The agency has analyzed what it believes to be the range of environmental impacts for the alternatives under consideration. For more information regarding the agency's approach to natural gas and other alternative fuel vehicles for purposes of this rulemaking, please consult the NPRM or the forthcoming rulemaking documents.

6.6 COST-BENEFIT ANALYSIS

Comments

Docket Number: 0025; 0081; 0112
Commenter: Vera Pardee, Center for Biological Diversity

NHTSA should conduct a cost-benefit analysis that properly accounts for all of the damages caused by climate change and that recognizes that mitigation costs will sharply increase over time.

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In the Comment letter as well as in its comments to the proposed LD Vehicle Rule, the Center demonstrated that NHTSA's assumptions concerning costs and benefits were skewed against reaching the truly maximum feasible fuel efficiency standards that are mandated by law. In general, NHTSA systematically undercounted the enormous benefits resulting from increased fuel efficiency and overestimated the costs. Moreover, NHTSA's rulemaking did not result even in a situation where these undercounted benefits equaled the overestimated costs; rather, achievable benefits were left on the table. Discount rates were too high, payback periods too short, and NHTSA failed to assess the cost of, and much require, shorter vehicle redesign cycles.

NHTSA also failed to assess the economic benefits of increased job creation resulting from speeding up the technology adaptation cycle. … In addition, the scientific studies cited above lend additional support to the argument that the economic, environmental, social and other benefits of avoiding the effects of climate change have been severely understated in light of the fact that climate change effects have occurred sooner than anticipated, that tipping points are likely to occur within decades and not centuries and some may have occurred already, that climate commitment already exposes the Earth to irreversible effects, and that mitigation costs increase the longer they are delayed. [Footnotes omitted.]

* * * * *

The Agencies must fully account for the benefits arising from the greenhouse gas emission reductions and fuel efficiency improvements proposed in the alternatives, properly value the social cost of carbon, and account for tipping points. Although the costs of all of the alternatives presently discussed are already dwarfed by the benefits they achieve even under the limited accounting accomplished so far, the actual discrepancy is far greater. The Agencies cannot put their thumb on the cost-benefit analysis, and should not design rules that create profits for polluters while leaving a host of feasible, appropriate and cost-effective fuel efficiency programs crucial to mitigating climate change damages on the cutting room floor.

* * * * *

We appreciate the Agencies' efforts to improve the DEIS' description of the environmental impacts of climate change in its direct, indirect, and cumulative analyses of the HD Vehicle Rule. Nonetheless, the DEIS continues to understate the benefits to be derived from reducing greenhouse gas pollution from these vehicles in drastic ways. Although it is clear that the costs of any of the alternatives discussed are lower than their stated benefits by orders of magnitude, the actual discrepancy is even more dramatic. The failure to correctly portray the cost-benefit calculation involved in demanding higher fuel efficiency standards prevents decision-makers and the public from fully comprehending the consequences of the actions at issue, and thus violates NEPA. [Footnote omitted]

* * * * *

As outlined above, the DEIS drastically undervalues the benefits of greater fuel economy reductions. We request that the Agencies perform a full benefits analysis in the FEIS.

On the other side of the coin, the initial outlays required to implement the fuel efficiency improvements recommended by the Agencies are minimal, and in fact, "overall cost per ton of the rule, considering fuel savings, is negative - fuel savings associated with the rule more than offset projected costs by a wide margin." In fact, "the application of fuel-saving technologies in response to the proposed standards would, on average, yield private returns to truck owners of 140% to 420%." In other words, the proposed rulemaking will actually increase the profits of the regulated entities. This result belies the Agencies' conclusion that further improvements in fuel economy are not feasible. The Agencies have yet to describe and analyze an alternative that combines all feasible technological improvements, including all feasible technology-forcing measures; to calculate the costs of that alternative; and to correctly state its benefits. Thus, it remains impossible to assess the true cost-effectiveness of such an alternative, though continuing increases in fuel efficiency could still more than pay for the slightly increased costs. However, the vast gap between the cost outlays and the tremendous benefits to be reaped leaves no doubt that much greater regulatory stringency can be achieved without beginning to affect cost-effectiveness. [Footnotes omitted.]

* * * * *

We have provided extensive comments on the shortcomings of the Agencies' cost-benefit analysis in our prior comment letters, including the understatement of the social cost of carbon and the failure to monetize the damages attendant to crossing tipping points and ocean acidification, among other things. We have urged the Agencies to abandon an approach that removes the use of technologies presently available or that can be implemented during the rulemaking years based on cost concerns even though the proposed rulemaking results in net profits to the regulated industry (without ever taking the social cost of carbon into consideration at all). We have also described the Agencies' failure to provide the public and decision-makers with truly relevant comparisons that put the consequences of the proposed alternatives into sharp focus. We add here that the Agencies themselves acknowledge defects in their analysis when they state that the "monetized benefits of CO_2 reductions . . . represent only a partial accounting of total benefits due to omitted climate change impacts and other factors that are not readily monetized" and omit "other impacts such as benefits related to non-GHG emission reductions." For example, one such benefit is the reduction of costs required to maintain a U.S. military presence to help secure stable oil supplies. In addition, the Agencies have simply failed to analyze the costs and benefits of the most technologically advanced alternatives, Nos. 6b and 8. [Footnotes omitted.]

Docket Number: 0087
Commenter: Environmental Defense Fund

We encourage NHTSA to prepare a final EIS that thoroughly considers the host of societal costs and benefits in order to develop "a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program designed to achieve the maximum feasible improvement," as mandated by the Energy Policy and Conservation Act (EPCA) as amended by the Energy Independence and Security Act of 2007 (EISA). See 42 U.S.C. § 32902(k)(2). In analyzing the proposed alternatives, EDF requests that NHTSA conduct a thorough and transparent analyses that estimates the full suite of benefits, both monetized and non-monetized, associated with the fuel consumption reduction of each alternative.

Docket Number: 0145
Commenter: Stanley Gee, Recreation Vehicle Industry Association

Per the Jan. 18, 2011, Executive Order [Executive Order 13563, Improving Regulation and Regulatory Review], EPA and NHTSA must assess the implications of price increases *not in isolation* but rather in conjunction with other environmental and safety regulatory requirements that are planned to take effect in the 2014 to 2018 timeframe. EPA and NHTSA must compile a joint list of emissions, fuel economy and safety regulatory requirements that will go into effect in the 2014-2018 timeframe and submit this list along with the accompanying aggregate cost implications to the docket for public review and consideration.

Response

In preparing this EIS, NHTSA has analyzed and disclosed the environmental impacts of a reasonable range of alternatives, including direct, indirect, and cumulative impacts. The EIS focuses on environmental impacts; however the agency has monetized some of the environmental impacts presented in this EIS in order to aid the discussion and comparison of the alternatives. A more fulsome cost-benefit analysis will be included with the forthcoming final rulemaking documents.

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7.3 AFFECTED ENVIRONMENT – DIRECT AND INDIRECT IMPACTS (CHAPTER 3)

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	5 years of experience in energy market analysis, petroleum transportation and infrastructure, and renewable energy policy
Anne Choate, Climate Change Advisor	
	M.S., Environmental Science, Johns Hopkins University; B.A., Environmental Science and Policy, Duke University
	17 years of experience analyzing greenhouse gas emissions, mitigation strategies, and climate impacts; one year at EPA OAQPS, followed by 16 years at ICF. Leader of ICF's Climate Change Impacts and Adaptation team, with 8 years experience analyzing climate risks and adaptation strategies in the built and natural environments

Name/Role	Qualifications/Experience
Sharon G. Douglas, Photochemical Modeling Analysis Lead	
	M.S., Meteorology, Pennsylvania State University, University Park, PA, 1986; B.A., Earth and Planetary Science, Johns Hopkins University, Baltimore, MD, 1983
	25 years of experience in meteorological and air quality modeling, and health impact assessment
David Ernst, Air Quality Lead	
	M.C.R.P., Environmental Policy, Harvard University; B.S., Urban Systems Engineering; B.A., Ethics and Politics, Brown University
	31 years of experience preparing air quality analysis for NEPA documents
Lizelle Espinosa, Reference Manager	
	B.S., Government Administration, Christopher Newport University
	8 years of experience in environmental consulting in the areas of environmental impact assessment, policy analysis, and regulatory compliance
Mark Flugge, Climate Change Analyst	
	D.Phil., Atmospheric Chemistry, University of Oxford – United Kingdom; M.Chem., Chemistry, University of Oxford – United Kingdom
	12 years of experience analyzing atmospheric chemistry, greenhouse gas, and climate change issues
Randall Freed, Senior Climate Change Advisor	
	M.S., Water Resource Management, University of Maryland; B.S., Zoology, University of Maryland
	37 years of experience in assessing and managing environmental risk; 16 years of experience assessing climate change issues
Frank Gallivan, Air Quality Analyst	
	M.C.P., City Planning, University of California – Berkeley; B.A., Economics and Classical Archaeology, Dartmouth College
	5 years of experience in transportation planning and policy
Jay L. Haney, Photochemical Modeling Analysis Specialist	
	M.S., Meteorology, Saint Louis University, St. Louis, Missouri, 1980; B.S., Meteorology, Saint Louis University, St. Louis, Missouri, 1978
	32 years of experience in meteorological and air quality modeling, and emission inventory assessment
John Hansel, Senior NEPA Advisor	
	J.D., American University Washington College of Law; B.A., Economics, University of Wisconsin – Madison
	38 years of experience developing and managing environmental protection and policies
Melinda Harris, Climate Change Analyst	
	Ph.D. (Candidate), Economics, University of Maryland; M.A., Economics, University of Maryland; B.A., Economics, University of Maryland
	21 years of experience in environmental and economic policy issues
Gregory Haskins, Air Quality Analyst	
	B.S., Mathematics, Economics, University of Michigan – Ann Arbor
	2 year of experience in air quality analysis
W. Seth Hartley, Air Quality Analyst	
	M.S., Atmospheric Sciences, University of Washington – Seattle; B.S., Physics, North Carolina State University
	12 years of experience in air pollution and air quality analysis

Name/Role	Qualifications/Experience
Belle Hudischewskyj Guelden, Photochemical Modeling Analysis Specialist	
	B.S., Meteorology, California State University, San Jose, 1980; A.S., Mathematics, Sierra Junior College, 1977
	31 years of experience in meteorological and air quality data analysis and modeling
Joseph Herr, Climate Change Analyst	
	B.S., Natural Resources, University of Vermont; B.S. Business Administration, University of Vermont
	7 years experience calculating greenhouse gas emissions and physical impacts of climate change
Christopher Holder, Air Quality Analyst	
	M.S., Meteorology, North Carolina State University; B.A., Meteorology, North Carolina State University
	6 years of experience in hazardous air pollutant risk assessment, climate change impacts, greenhouse gas emission estimation, and renewable energy technologies and policy
Joe Keithley, NEPA Analyst	
	J.D., Indiana University; M.P.A., Environmental Policy and Natural Resource Management, Indiana University; B.S., Environmental Science, DePaul University
	8 years of environmental experience in regulatory development and policy analysis
Penelope Kellar, Technical Editor	
	M.S., Ecology, University of California – Davis; B.S., Conservation of Natural Resources, University of California – Berkeley
	27 years of experience in working with Federal and State agencies on environmental quality issues
Charlotte Mack, Climate Change Researcher	
	M.S., Natural Resources and Environment, University of Michigan; M.P.P., Public Policy, University of Michigan; B.S., Environmental Science, University of Delaware
	5 years of experience working on climate change issues
Kristen Marin, Air Quality Analyst	
	M.E.M., Environmental Health and Security, Duke University; B.S., Atmospheric Science, Cornell University
	4 years of experience in air quality analysis
Rawlings Miller, Climate Change Analyst	
	Ph.D., Atmospheric Sciences, University of Arizona; M.S., Aerospace Engineering, Boston University; B.S., Physics, Union College
	13 years of experience with climate change modeling, air quality research, and impacts analysis; 7 years of consulting experience on environmental issues; 3 years of experience in preparing NEPA documents
Thomas C. Myers, Photochemical Modeling Analysis Specialist	
	M.A., Physics, University of California at Davis, 1976; B.S., Physics, University of the Pacific, 1971
	35 years of experience in air quality model development and application
Rick Nevin, Energy Lead and Data Manager	
	M.B.A., Finance, Managerial Economics, and Strategy, Northwestern University; M.A., Economics, Boston University; B.A., Economics and Mathematics, Boston University
	29 years of experience managing and preparing environmental, energy, and economic analyses

Name/Role	Qualifications/Experience
Jamie O'Malley, NEPA Researcher	
	B.A., Global Change and Sociology, University of Michigan
	2 years of experience with NEPA documentation preparation
Andrew Papson, Air Quality Analyst	
	M. Eng., Transportation Engineering, University of California – Berkeley; B.S., Materials Science, Stanford University
	4 years of experience analyzing vehicle emissions and fuel efficiency
William Pepper, Climate Change Modeling Lead	
	M.A., Mathematics, Temple University; B.S., Mathematics, University of Maryland
	38 years of experience in computer modeling; 31 years of experience in information systems, modeling, and analyzing transportation and environmental issues
Annah Peterson, NEPA Analyst	
	M.E.M., Environmental Economics and Policy, Duke University; B.S. Biology, Reed College.
	4 years environmental consulting experience; 3 years experience with NEPA document preparation.
Gretchen Pinkham, NEPA Researcher	
	B.S., Environmental Studies, Keene State College
	2 years of experience with NEPA documentation preparation
Marybeth Riley-Gilbert, Climate Change Analyst and Comment Response Lead	
	M.S., Atmospheric Science, Cornell University; B.S., Earth and Planetary Sciences, University of New Mexico
	7 years of experience in analysis of climate change impacts to water resources, terrestrial and marine ecosystems, transportation infrastructure, and human health
Zeta Rosenberg, Senior Energy Advisor	
	Ph.D. (less dissertation), History; M.A., Economics, George Washington University; M.A., History, University of Toronto – Canada; B.A., History, University of New Brunswick – Canada
	34 years of experience in energy analysis
Emily Rowan, Climate Change Analyst	
	B.A., Science in Society, Wesleyan University
	4 years experience in climate change impacts and adaptation
Jonathan Schmeltz, Geographic Information Systems Analyst	
	B.S., Geographic Science, James Madison University
	4 years of experience in geographic information systems
Peter Schultz, Senior Climate Change Analyst	
	Ph.D., Geosciences, Pennsylvania State University; M.S., Geosciences, Pennsylvania State University; B.S., Geology, Virginia Polytechnic Institute and State University
	21 years of experience in climate and global change research, management, decision support, and communication
Courtney Skuce, Document Production Support	
	B.A., Biology, Boston University
	2 years of experience with NEPA documentation preparation
Cassandra Snow, Climate Change Researcher	
	B.A., Environmental Science and Public Policy, Harvard University
	2 years of experience in climate change impacts and adaptation

Name/Role	Qualifications/Experience
Aaron Sobel, Climate Change Researcher	
	M.E.S.M., Environmental Science and Management, University of California – Santa Barbara; B.S., Geographic Science, James Madison University
	2 years of experience in climate change and sustainability
Elizabeth Strange, Senior Climate Change Analyst	
	Ph.D., Ecology, University of California – Davis; M.S., Ecology, University of California – Davis; B.A., Biology, San Francisco State University
	Expert in climate change impacts and adaptation, with 16 years of experience analyzing impacts on ecosystems and water resources.
John Venezia, Climate Change Lead	
	M.S., Environmental Science and Policy, Johns Hopkins University; B.S., Biology and Environmental Science & Policy, Duke University
	13 years of experience analyzing climate change, green house gas (GHG) emission sources, and options for reducing emissions, focusing on the energy sector
Satish Vutukuru, Air Quality Analyst	
	Ph.D., Mechanical and Aerospace Engineering, M.S., Chemical Engineering, University of California – Irvine; B. Tech., Chemical Engineering, Indian Institute of Technology – India
	6 years of experience in air quality modeling, health risk assessment, and environmental impact analysis
Jennifer Wallis, NEPA Researcher	
	M.E.M., Environmental Management, Duke University; B.S., Environmental Conservation Studies, University of New Hampshire
	2 years of experience with NEPA documentation preparation
Isaac Warren, NEPA Researcher	
	B.A, Biology, Duke University
	2 years of experience with NEPA documentation preparation
Yihua Wei, Photochemical Modeling Analysis Specialist	
	M.S., Atmospheric Science, State University of New York at Albany, 1988; M.S., Physics, Indiana State University, 1986; B.S., Physics, Nanjing University, China, 1982
	21 years of experience in emissions processing and emission inventory development

Chapter 9 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.

9.1 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 Health 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

9.2 STATE AND LOCAL GOVERNMENT ORGANIZATIONS

- American Samoa Office of Grants Policy/Office of the Governor, Department of Commerce, American Samoa Government
- American Samoa, Office of the Governor
- Arkansas State Clearinghouse, Department of Finance and Administration
- California Air Resources Board
- California Attorney General's Office
- Commonwealth of Puerto Rico, Office of the Governor Planning Board
- 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
- Illinois Department of Transportation, Office of the Secretary
- Iowa Department of Management
- Maine State Planning Office
- Maryland Department of Planning
- Maryland State Clearinghouse for Intergovernmental Assistance
- Massachusetts Office of the Attorney General
- National Association of Attorneys General
- National Governors Association, Environment, Energy & Transportation Division
- National League of Cities
- New Hampshire Office of Energy and Planning, Intergovernmental Review Process
- North Dakota Department of Commerce
- North Mariana Islands Office of Management and Budget, Office of the Governor
- NYS Department of Environmental Conservation
- 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 Missouri, Department of Natural Resources
- State of New York, 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

9.3 ELECTED OFFICIALS

- The Honorable Robert Bentley, Governor of Alabama
- The Honorable Sean Parnell, Governor of Alaska
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa
- The Honorable Jan Brewer, Governor of Arizona
- The Honorable Mike Beebe, Governor of Arkansas
- The Honorable Jerry Brown, Governor of California
- The Honorable John Hickenlooper, Governor of Colorado
- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable Dan Malloy, Governor of Connecticut

- The Honorable Jack Markell, Governor of Delaware
- The Honorable Rick Scott, Governor of Florida
- The Honorable Nathan Deal, Governor of Georgia
- The Honorable Eddie Calvo, Governor of Guam
- The Honorable Neil Abercrombie, Governor of Hawaii
- The Honorable C.L. "Butch" Otter, Governor of Idaho
- The Honorable Pat Quinn, Governor of Illinois
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Terry Branstad, Governor of Iowa
- The Honorable Sam Brownback, Governor of Kansas
- The Honorable Steve Beshear, Governor of Kentucky
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable Paul LePage, Governor of Maine
- The Honorable Martin O'Malley, Governor of Maryland
- The Honorable Deval Patrick, Governor of Massachusetts
- The Honorable Rick Snyder, Governor of Michigan
- The Honorable Mark Dayton, Governor of Minnesota
- The Honorable Haley Barbour, Governor of Mississippi
- The Honorable Jay Nixon, Governor of Missouri
- The Honorable Brian Schweitzer, Governor of Montana
- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable Brian Sandoval, Governor of Nevada
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable Chris Christie, Governor of New Jersey
- The Honorable Susana Martinez, Governor of New Mexico

- The Honorable Andrew Cuomo, Governor of New York
- The Honorable Beverly Perdue, Governor of North Carolina
- The Honorable Jack Dalrymple, Governor of North Dakota
- The Honorable John Kasich, Governor of Ohio
- The Honorable Mary Fallin, Governor of Oklahoma
- The Honorable John Kitzhaber, Governor of Oregon
- The Honorable Tom Corbett, Governor of Pennsylvania
- The Honorable Luis G. Fortuño, Governor of Puerto Rico
- The Honorable Lincoln Chafee, Governor of Rhode Island
- The Honorable Nikki R. Haley, Governor of South Carolina
- The Honorable Dennis Daugaard, Governor of South Dakota
- The Honorable Bill Haslam, Governor of Tennessee
- The Honorable Rick Perry, Governor of Texas
- The Honorable John P. deJongh, Jr., Governor of the United States Virgin Islands
- The Honorable Gary Herbert, Governor of Utah
- The Honorable Peter Shumlin, Governor of Vermont
- The Honorable Bob McDonnell, Governor of Virginia
- The Honorable Chris Gregoire, Governor of Washington
- The Honorable Earl Ray Tomblin, Governor of West Virginia
- The Honorable Scott Walker, Governor of Wisconsin
- The Honorable Matthew Mead, Governor of Wyoming
- The Honorable Vincent C. Gray, Mayor of the District of Columbia

9.4 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

- Tetlin Village Council

9.5 STAKEHOLDERS

- AirFlow Truck Company
- Allison Transmission, Inc.
- Aluminum Association's Automotive Transportation Group
- American Automotive Policy Council
- American Bus Association
- American Chemistry Council, Plastics
- American Council for an Energy-Efficient Economy
- American Jewish Committee
- American Lung Association
- American Natural Gas Alliance
- American Powersports Mfg. Co. Inc.
- American Road & Transportation Builders Association (ARTBA)
- American Trucking Association
- Andrenika Erin Randle
- Appalachian Mountain Club
- Argonne National Laboratory
- Ashkan Bayatpour
- Auto Research Center LLC
- BAE Systems Platform Solutions, Power & Energy Management
- BlueGreen Alliance
- Border Valley Trading LTD
- Bridgestone Americas Tire Operations Product Development Group, Techincal Standards and Regulations
- CALSTART

- Carol Oldham
- Center for Biological Diversity
- Ceres and the Investor Network on Climate Risk (INCR)
- Chelsea Board of Health
- Chris Freda
- Clare Robins
- Clean Air Task Force
- Clean Energy
- Con-way Inc
- Cory Jones
- Counteract Balancing Beads
- Cummins, Inc.
- Cummins, Inc., Product Environmental Management
- Cynthia Linton
- DAF Trucks
- Daimler Trucks North America
- Daimler Vans USA LLC
- Dale Eugene Ballard
- Dan Proctor
- Dana Holding Corporation
- Dean Lemon
- Detriot Diesel Corporation
- Dominic A. Cardella
- Donna Ray Mitchell

- Eaton Corporation, Eaton Vehicle Group
- Engine Manufacturers Association
- Environment Illinois
- Environmental Defense Fund
- Eva H. Gurria
- Florida Power & Light Co.
- Ford Motor Company
- Ford Motor Company, Vehicle Environmental Regulatory Strategy & Planning
- George Quilty
- Georgia Yelton
- Green Truck Association (GTA)
- HayDay Farms, Inc
- HINO, Technical Management Division
- Illinois Trucking Association
- International Boundary and Water Commission, U.S. Section, Engineering Department
- James Proctor
- Jessica Feldish
- Jonathan Gensler
- Jonathan Rosenthal
- Jonathan Glassman
- Joshua Zuckerman
- Kenworth Truck Company
- Lauren Nowak
- Mack and Volvo Trucks
- Mairead Kennelly

- Margaret E. Sheehan
- Marine Mammal Commission
- Mark Kraemer
- Martin Suhrke
- Mathew Todaro
- Michelin North America, Inc.
- Michigan Tech University, ME-EM Department
- Mihir Chaudhary
- National Automobile Dealers Association, Legal & Regulatory Group
- National Groundwater Association
- National Ready Mixed Concrete Association (NRMCA)
- National Science Foundation, Office of the General Counsel
- National Truck Equipment Association
- National Wildlife Federation, Great Lakes Office
- National Wildlife Federation, National Advocacy Center
- Natural Gas Vehicles (NGV) America
- Natural Resources Defense Council, Transportation Program
- Navistar, Inc.
- Northeast States for Coordinated Air Use Management
- Nose Cone Manufacturing Company
- Oak Ridge National Laboratory
- Odyne Systems
- Oshkosh Corporation
- Owner-Operator Independent Drivers Association, Inc.
- PACCAR Inc.

- PACCAR Technical Center
- Peter Gorr
- Peterbilt Motors Company
- Pew Environment Group, Climate and Energy Programs
- Presidio Trust, NEPA Compliance
- Recreation Vehicle Industry Association
- Richard J. Stuckey
- Rinda West
- Rita Billon
- Road Safe America
- Rocky Mountain Institute
- Roger Shamel
- Rubber Manufacturers Association
- Ryder System, Inc, Government Relations & Environmental Services
- SaviCorp, Inc.
- School Bus Manufacturers Technical Council
- Securing America's Future Energy
- Sentech, Inc.
- Sierra Club
- Sierra Club, Massachusetts Chapter
- Small Business Administration, Office of General Counsel, Department of Litigation and Claims
- Small Business Administration, Office of Management & Administration, Office of the Associate Administrator
- Socially Responsible Investing, General Board of Pension and Health Benefits of The United Methodist Church
- Susan Shamel

- Teamsters Joint Council 25
- Teressa Bryant
- The Aluminum Association
- The Aluminum Association, Inc., Aluminum Transportation Group
- The Heavy-Duty Fuel Efficiency Leadership Group
- The National RV Dealers Association (RVDA)
- Thor Motor Coach
- TIAX LLC
- ToChi Technologies Inc
- Trillium Asset Management Corporation
- Truck Trailer Manufacturers Association
- Trucking and Renting and Leasing Association
- Truman Project
- Tufts University, The Fletcher School of Law and Diplomacy
- U.S. Chamber of Commerce
- Union of Concerned Scientists, Clean Vehicles Program
- United Automobile, Aerospace and Agricultural Workers of America (UAW)
- University of Michigan, Transportation Research Institute
- Valles Caldera Trust
- Volvo Group, Volvo Powertrain
- Volvo Powertrain
- Wabash National Corporation
- Walter S. Pozgzuio
- Waste Management, Federal Public Affairs
- West Virginia University

- West Virginia University, College of Engineering & Mineral Resources, Center for Alternative Fuels, Engines & Emissions

Chapter 10 Index