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

Table of Contents

Appendices

List of Tables

List of Figures

List of Acronyms and Abbreviations

+/−	plus or minus
°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
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

[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

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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)

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

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.

[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

[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

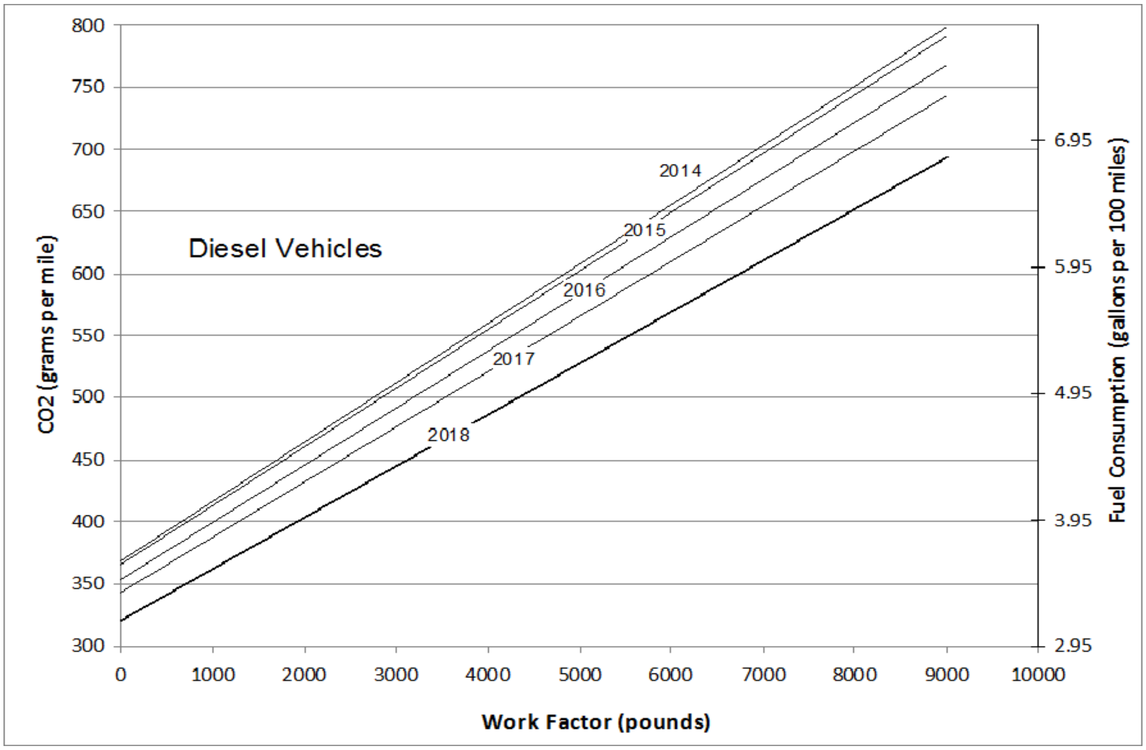
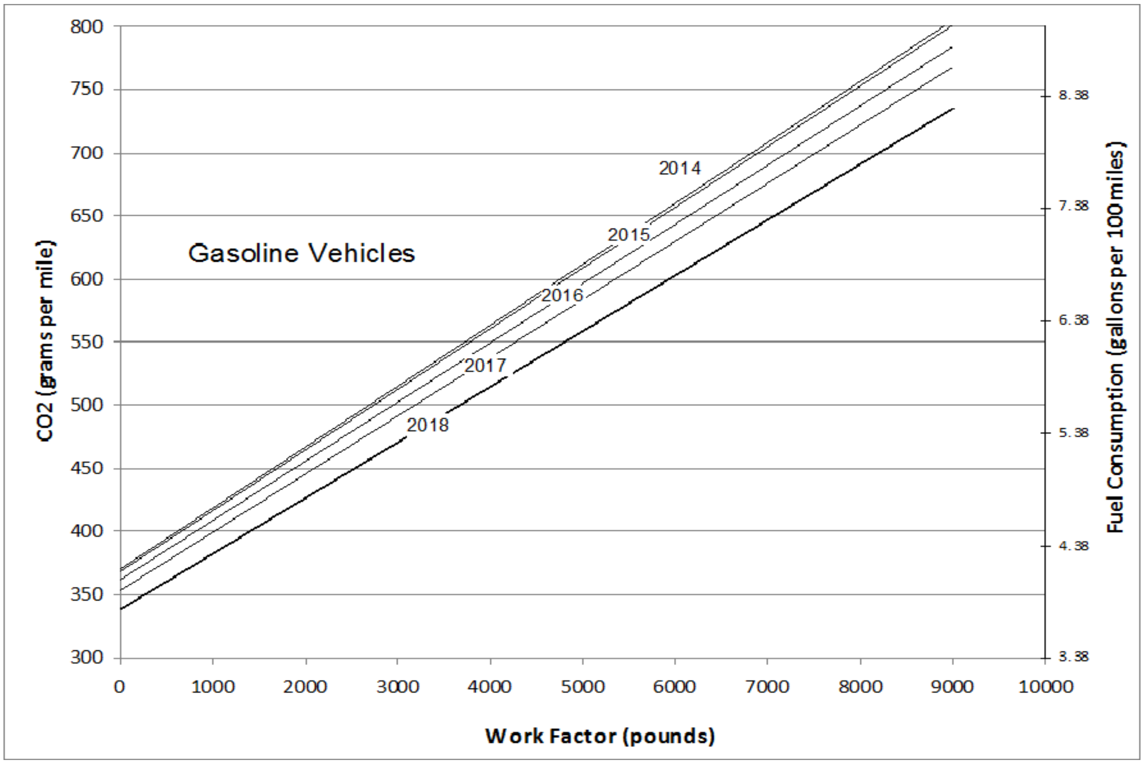


Figure 2.2-2. Proposed NHTSA Fuel Consumption Target and EPA CO_2 Target Standards for Gasoline HD Pickups and Vans



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
	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.
	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
	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
	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

[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."

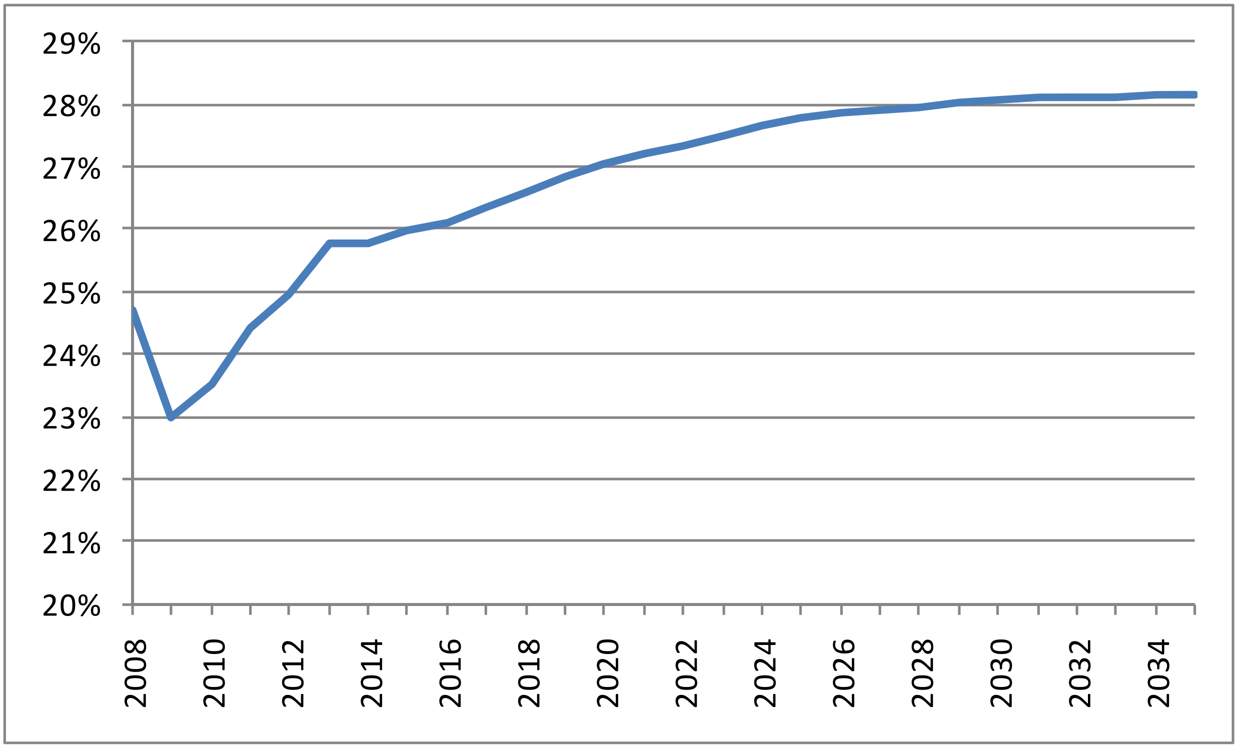
[20] EIA 2011. Table A2. "Energy Consumption by Sector and Source, United States, AEO 2011 Reference Case (quadrillion Btu, unless otherwise noted)."

[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 µg/m^3	Rolling 3-month average	Same as Primary	
Nitrogen dioxide	0.053 ppm (100 µg/m^3)	Annual (arithmetic mean)	Same as Primary	
	0.100 ppm (200 µg/m^3)	1 hour c/	None	
Particulate matter (PM_{10})	150 µg/m^3	24 hours d/	Same as Primary	
Particulate matter ($PM_{2.5}$)	15.0 µg/m^3	Annual (arithmetic mean) e/	Same as Primary	
	35 µg/m^3	24 hours f/	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8 hours g/ h/	Same as Primary	
	0.08 ppm (1997 std.)	8 hours h/ i/ j/	Same as Primary	
Sulfur dioxide	0.075 ppm (200 µg/m^3)	1 hour k/	0.5 ppm (1,300 µg/m^3)	3 hours b/

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

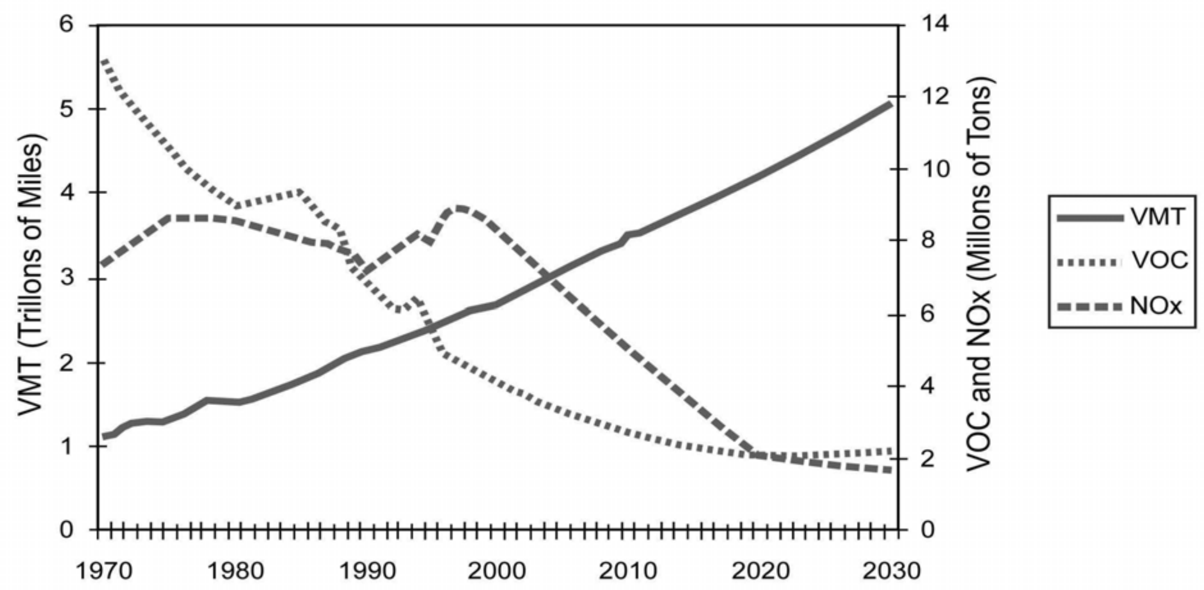
3.3.1.4 Clean Air Act and Conformity Regulations

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.

[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 (s*ee* 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/ SO₂	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/		Stationary (Non-EGU c/) Sources		Mobile Sources	
	SO_2	VOC	NO_x	Direct $PM_{2.5}$	NO_x	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

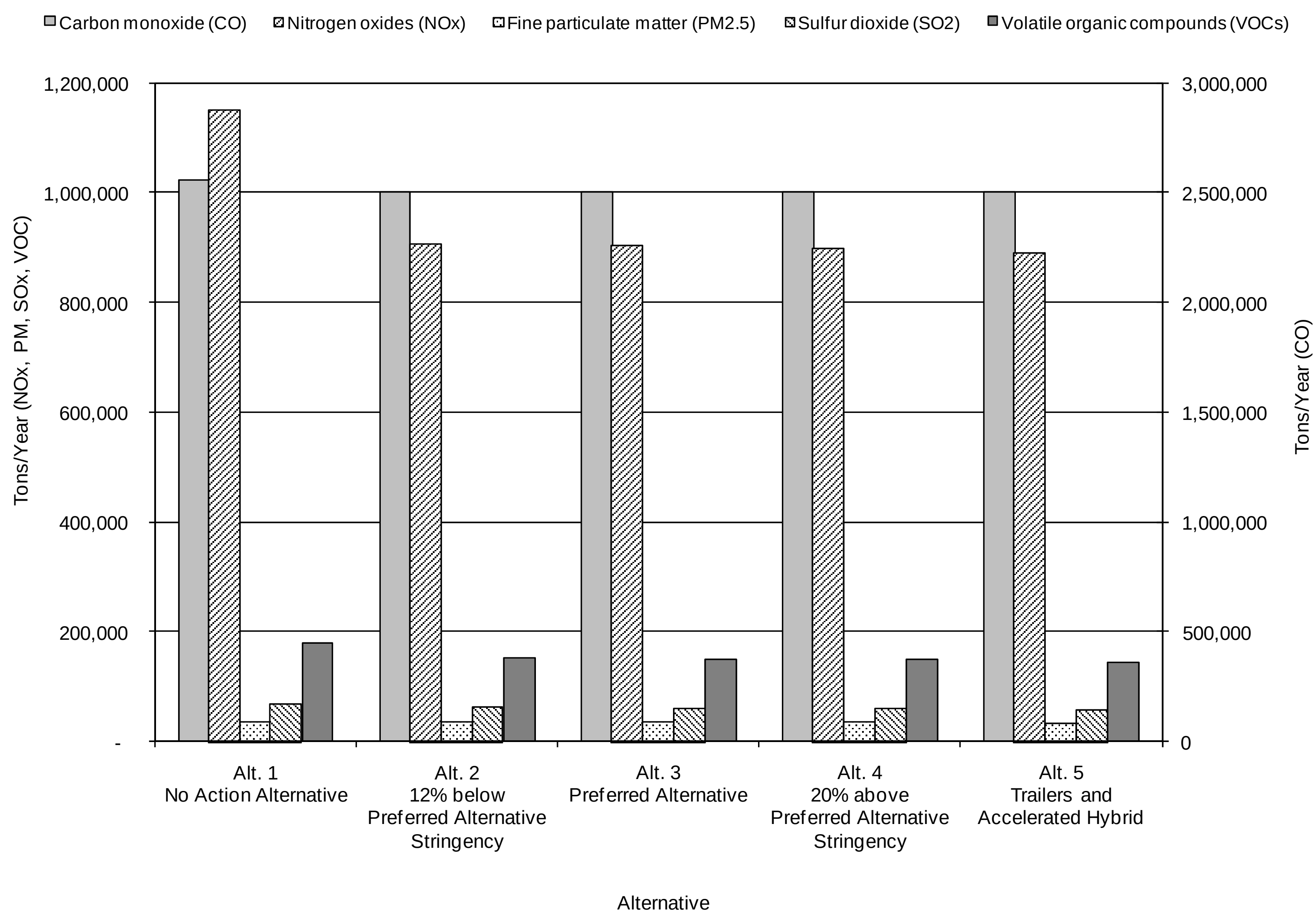


Figure 3.3.3-2. Nationwide Criteria Pollutant Emissions (tons per year) from HD Vehicles for the Preferred Alternative

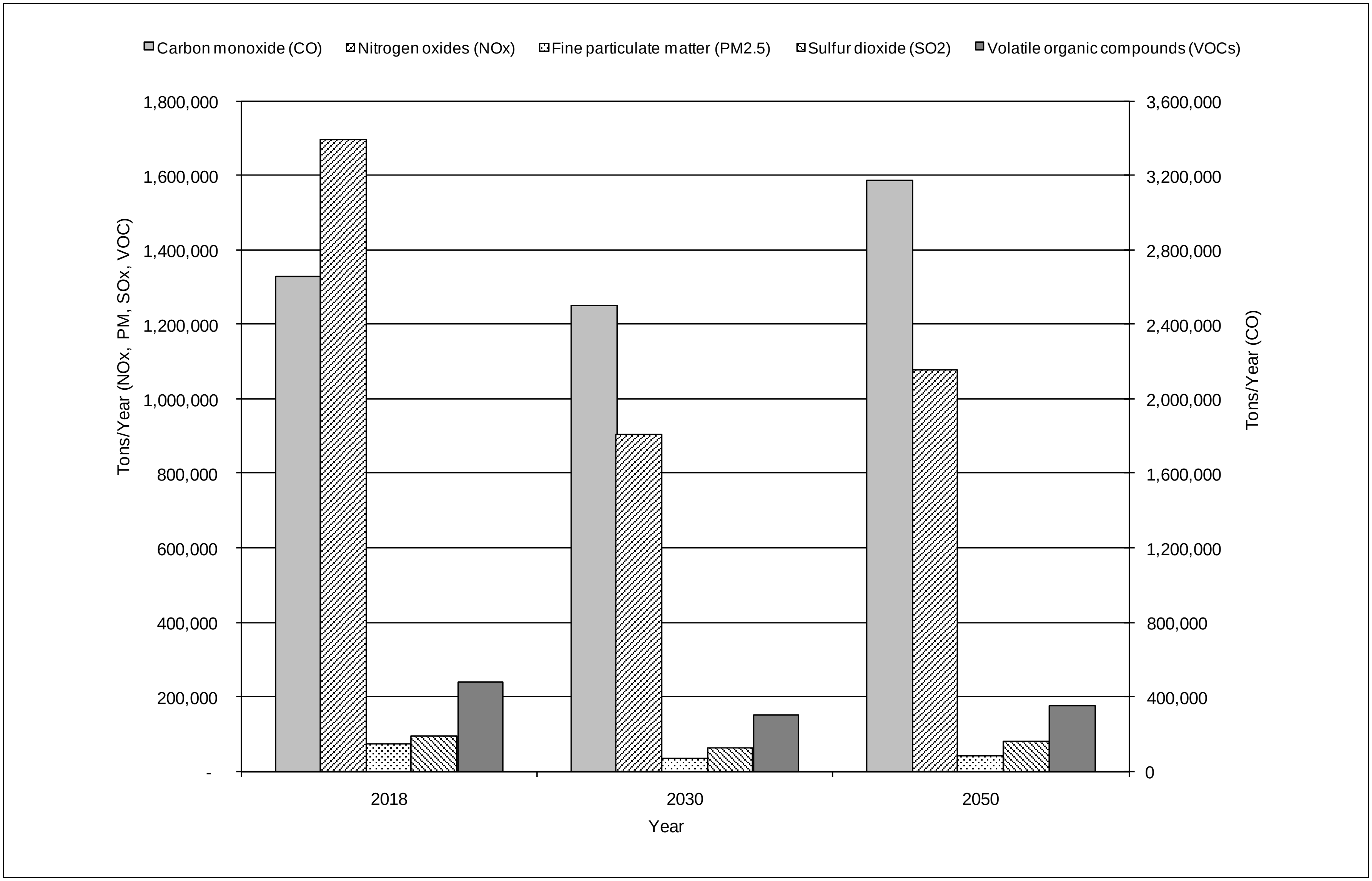


Table 3.3.3-2

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/

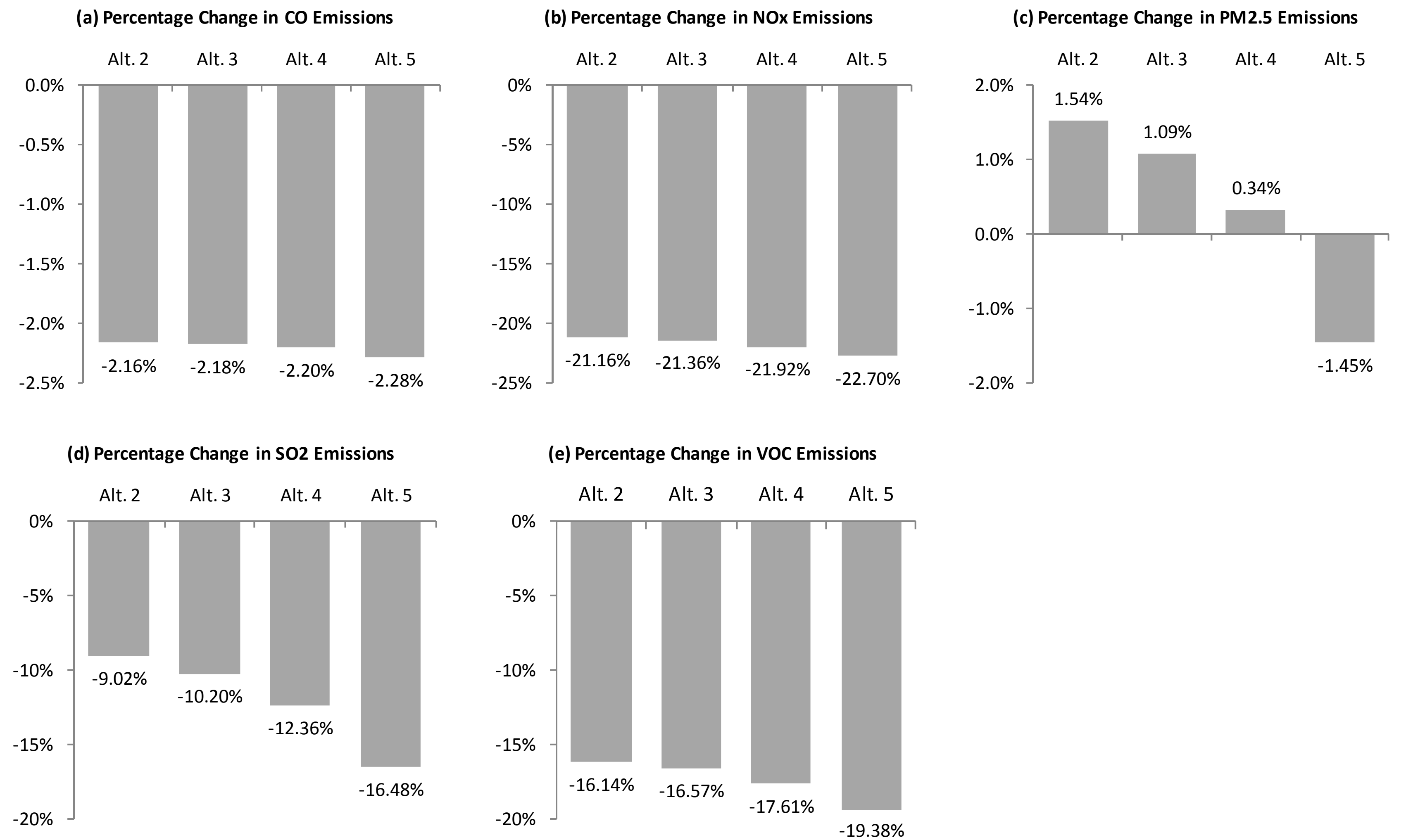
Poll. and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Carbon monoxide (CO)					
2018	0	-27,671	-27,861	-28,425	-29,237
2030	0	-55,343	-55,673	-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
Note: percentage scales differ for each pollutant.

Alternative 4: 20% above Preferred Alternative Stringency
Alternative 5: Trailers and Accelerated Hybrid

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

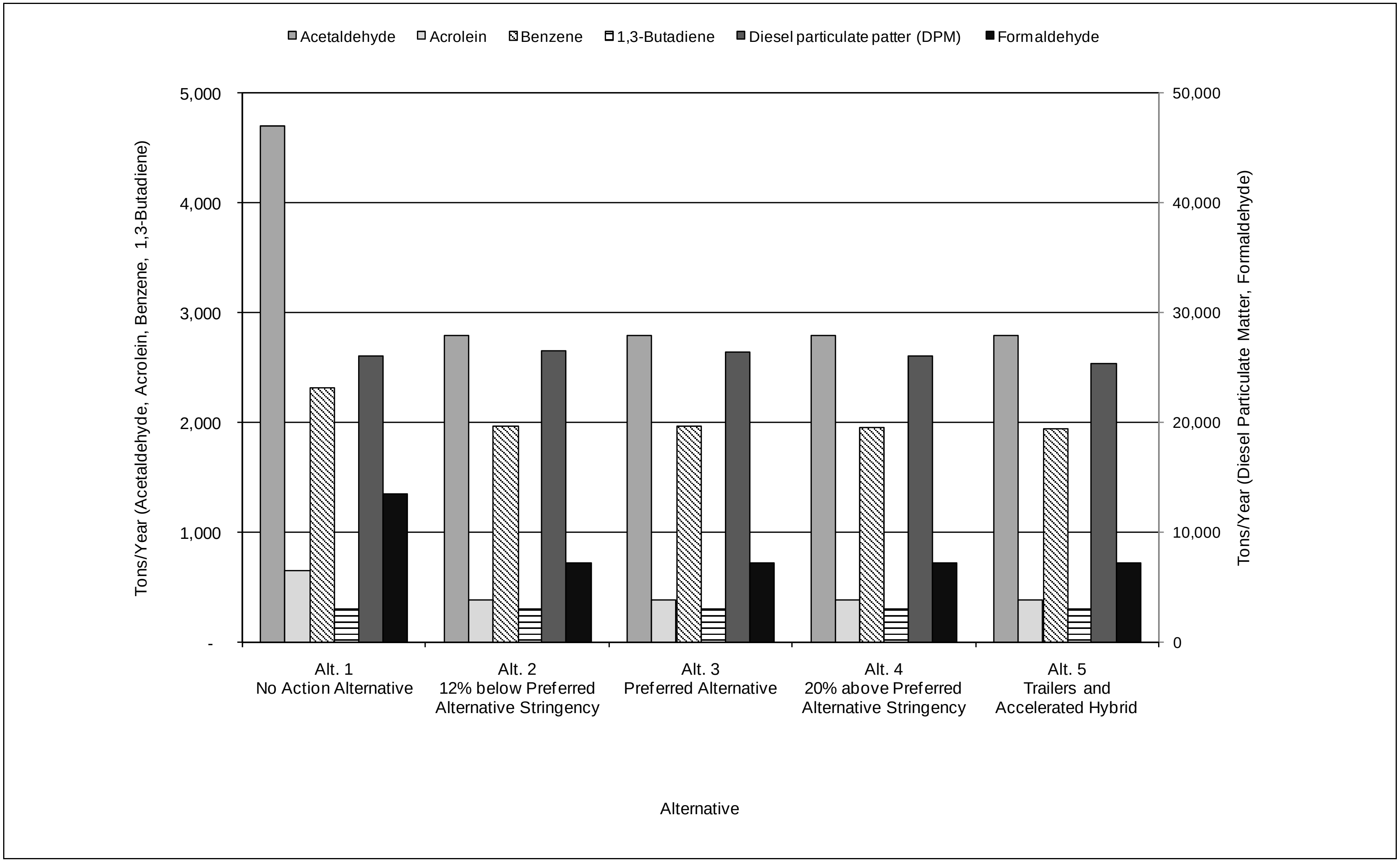


Figure 3.3.3-5 summarizes the changes over time in total national emissions of toxic air pollutants from HD vehicles for the Preferred Alternative. Figure 3.3.3-5 indicates a consistent trend among the toxic air pollutants. Emissions decline from 2018 to 2030 due to increasingly stringent EPA regulation 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

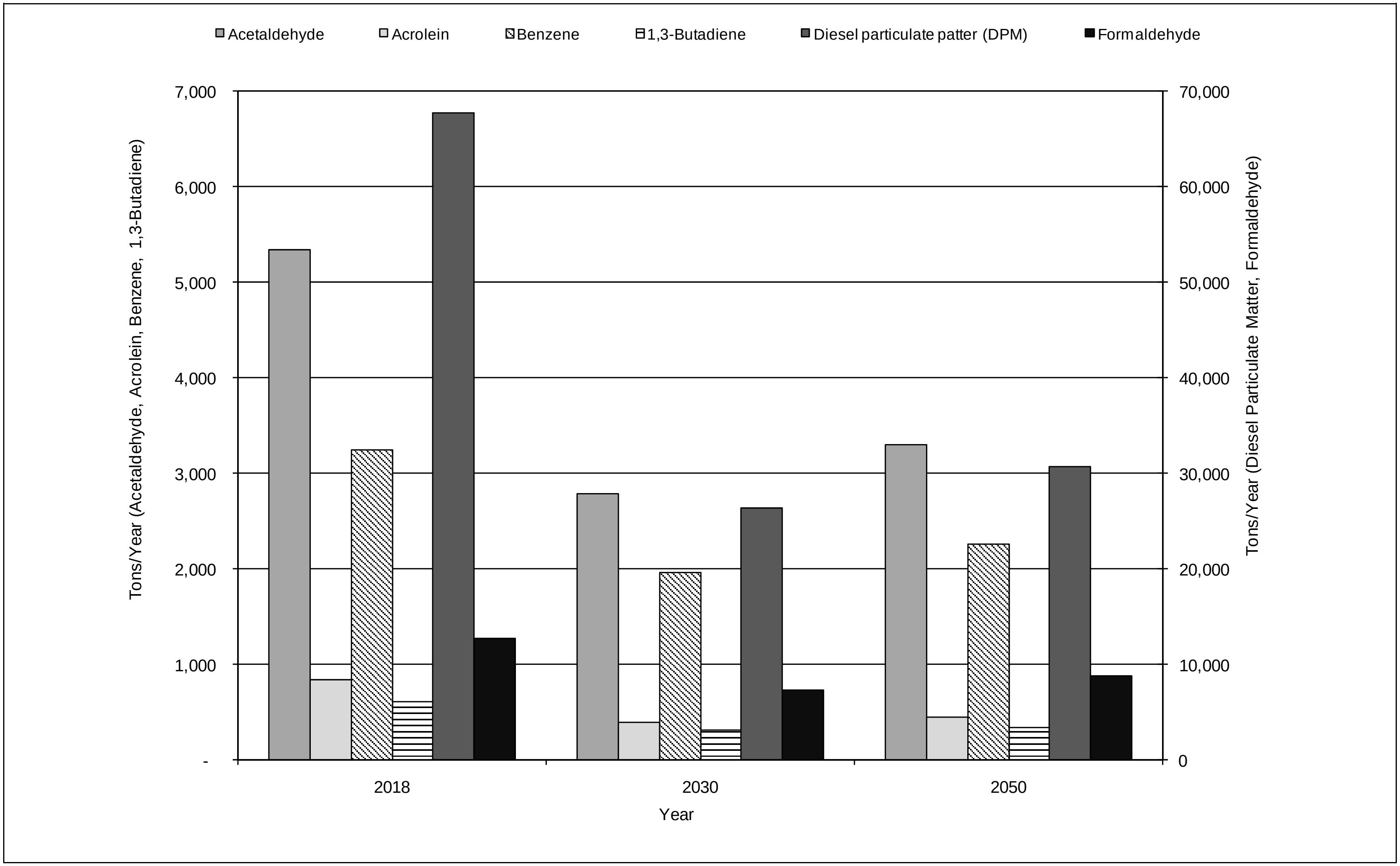


Table 3.3.3-6

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/

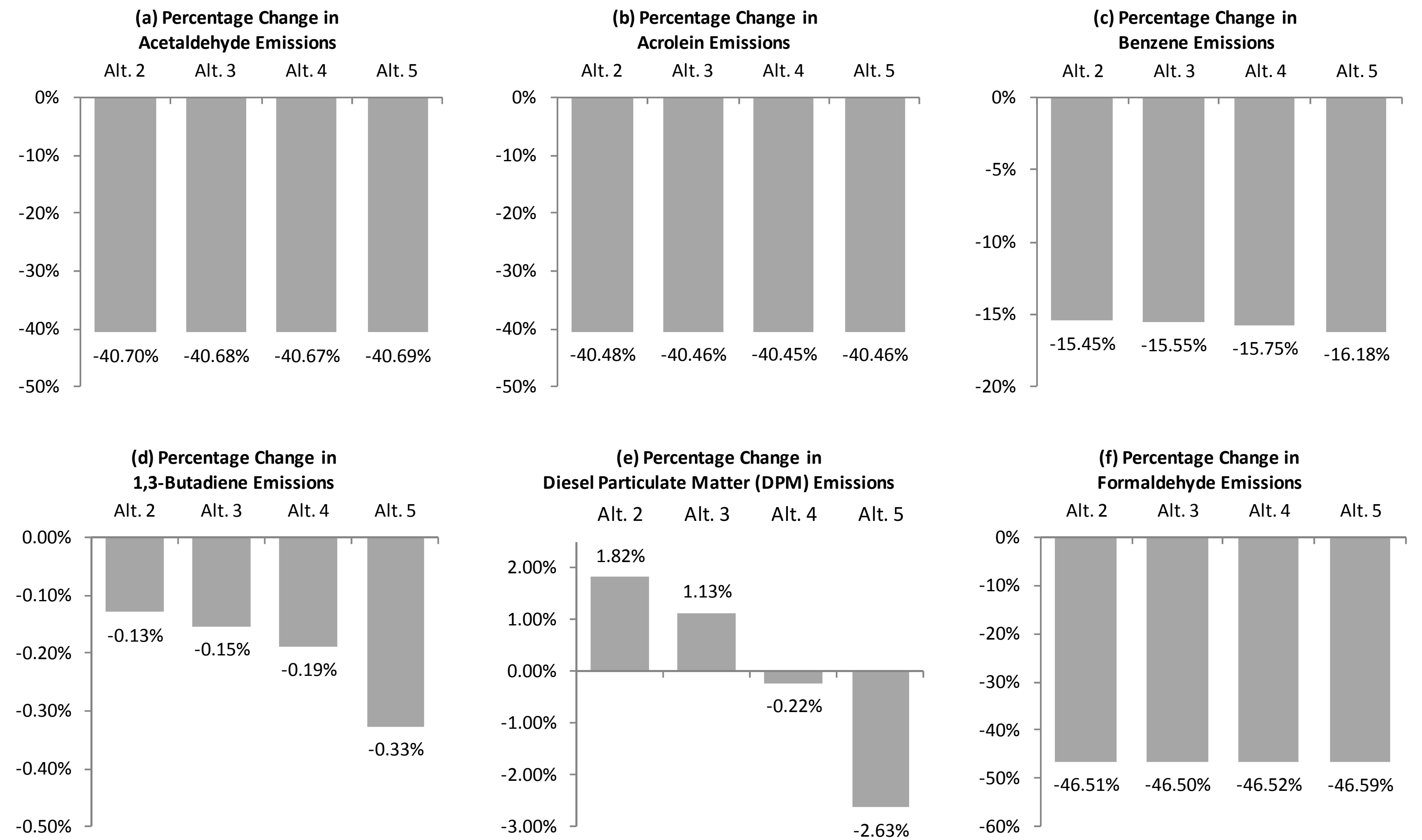
Pollutant and Year	Alt. 1 b/ No Action Alternative	Alt. 2 12% below Preferred Alternative Stringency	Alt. 3 Preferred Alternative	Alt. 4 20% above Preferred Alternative Stringency	Alt. 5 Trailers and Accelerated Hybrid
Acetaldehyde					
2018	0	-873	-873	-873	-873
2030	0	-1,913	-1,912	-1,911	-1,912
2050	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.

[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)

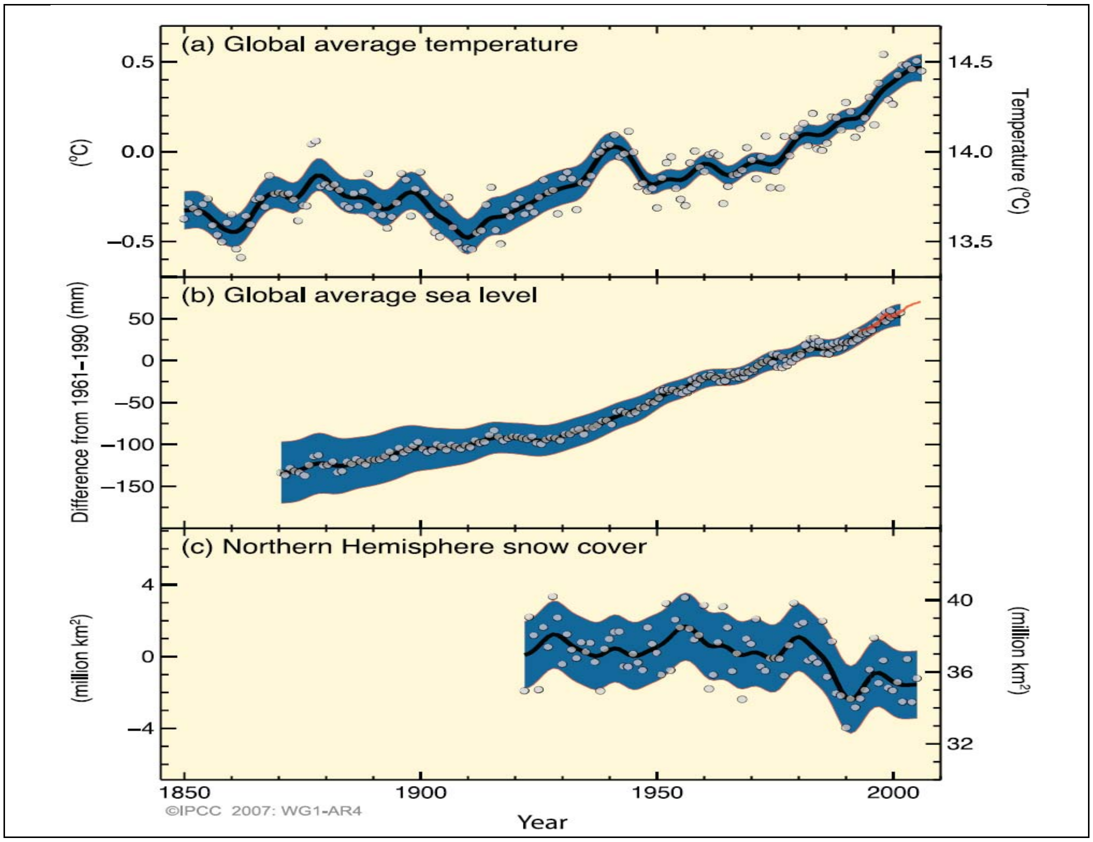
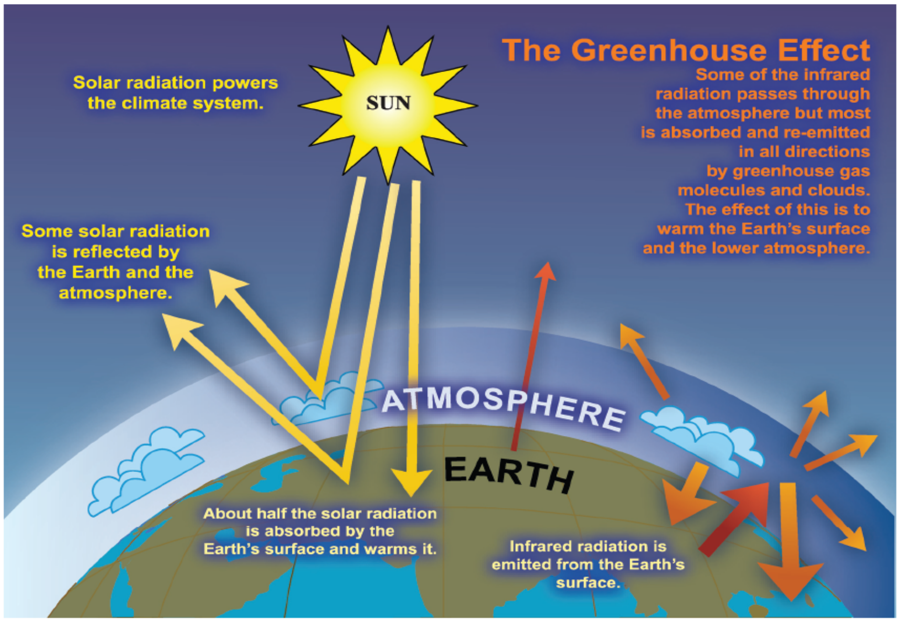


Figure 3.4.1-2. The Greenhouse Effect (Source: Le Treut *et al.* 2007)



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.

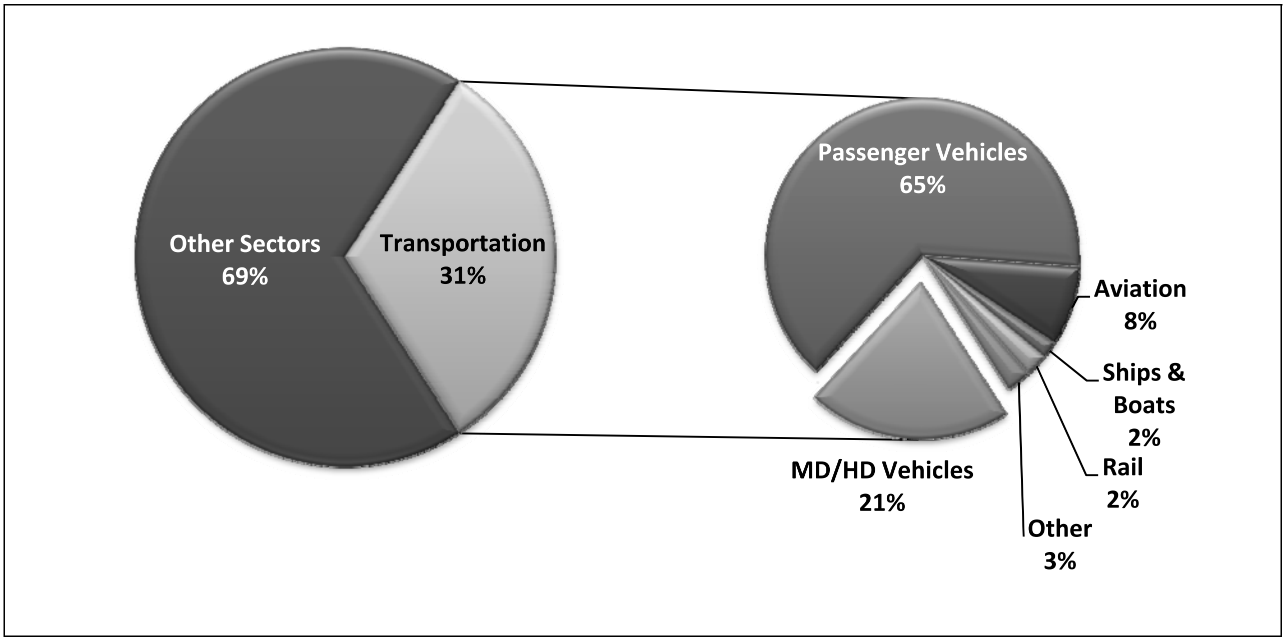
3.4.1.5 Evidence of Climate Change

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:

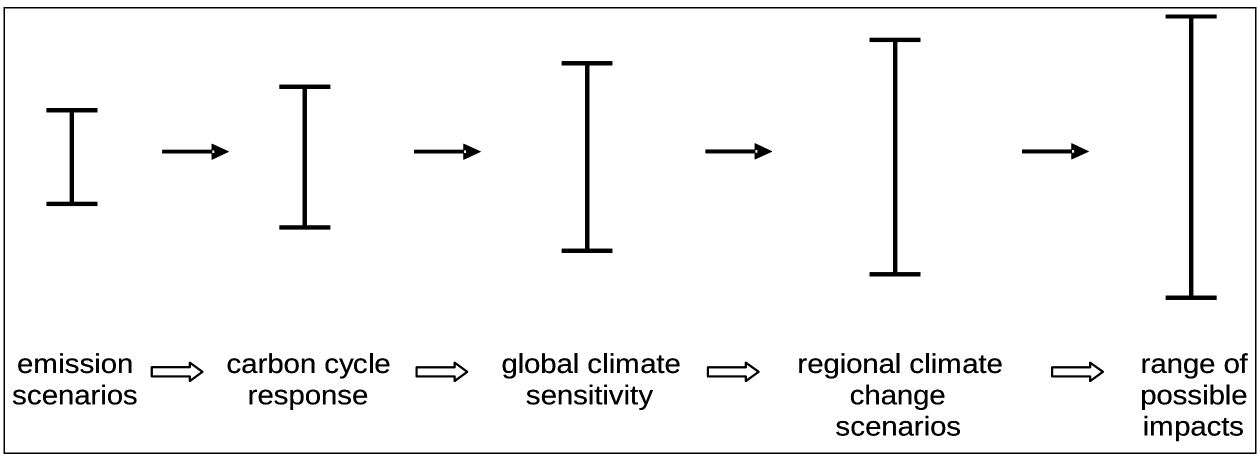
1. Analyzing the effects of the proposed action and alternatives on GHG emissions;
2. Estimating the monetized damages associated with CO_2 emissions and reductions attributable to each regulatory alternative; and
3. Analyzing how GHG emissions and reductions under each action alternative affect the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

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

[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.

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[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).

[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.

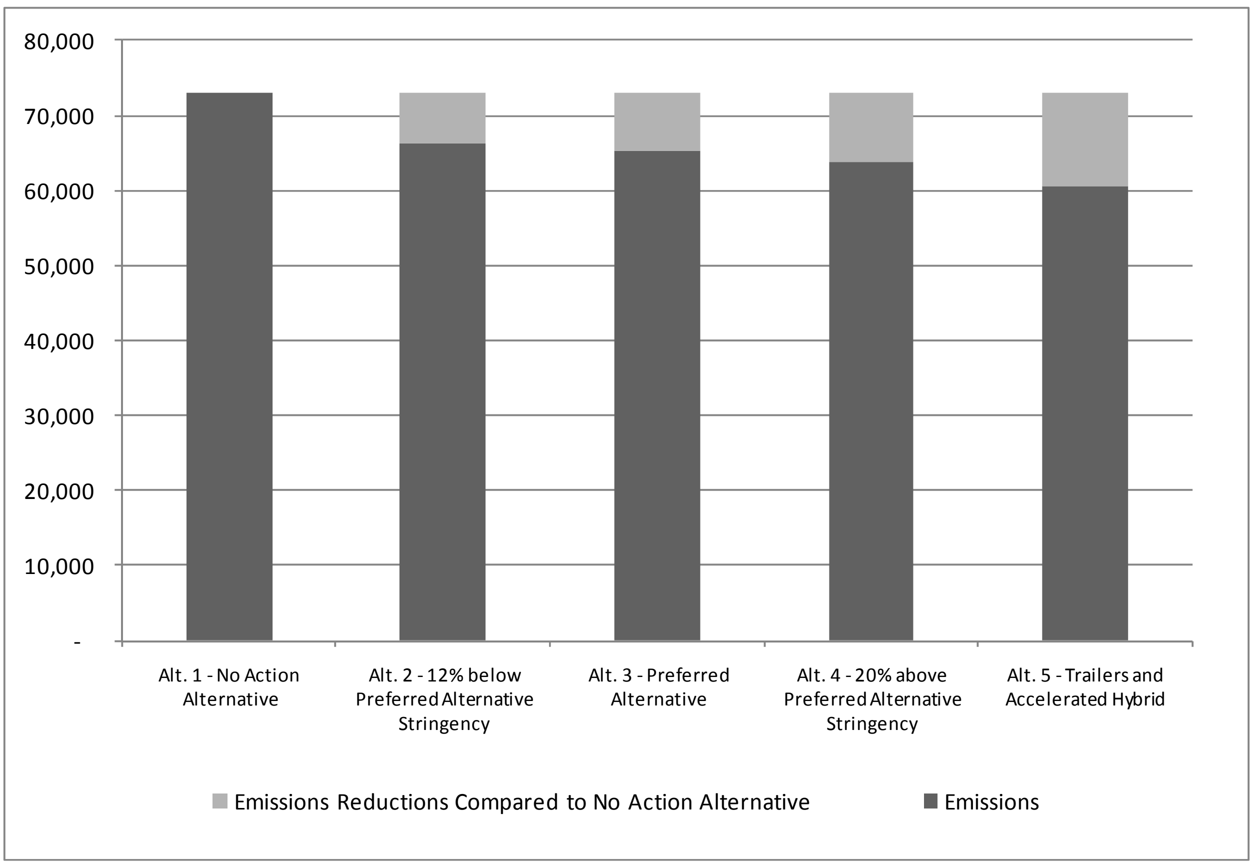
Table 3.4.4-1

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.

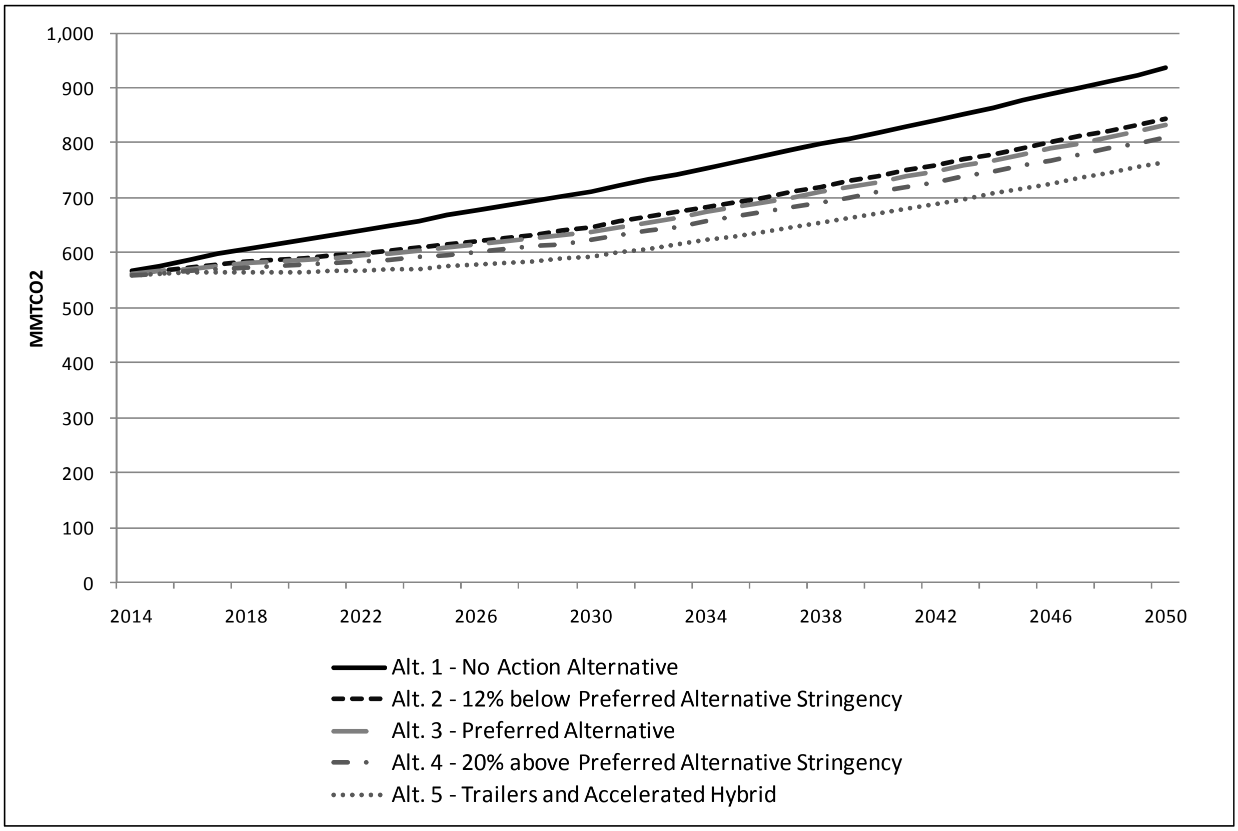
Figure 3.4.4-1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. HD Vehicles 2014 to 2100 by Alternative



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

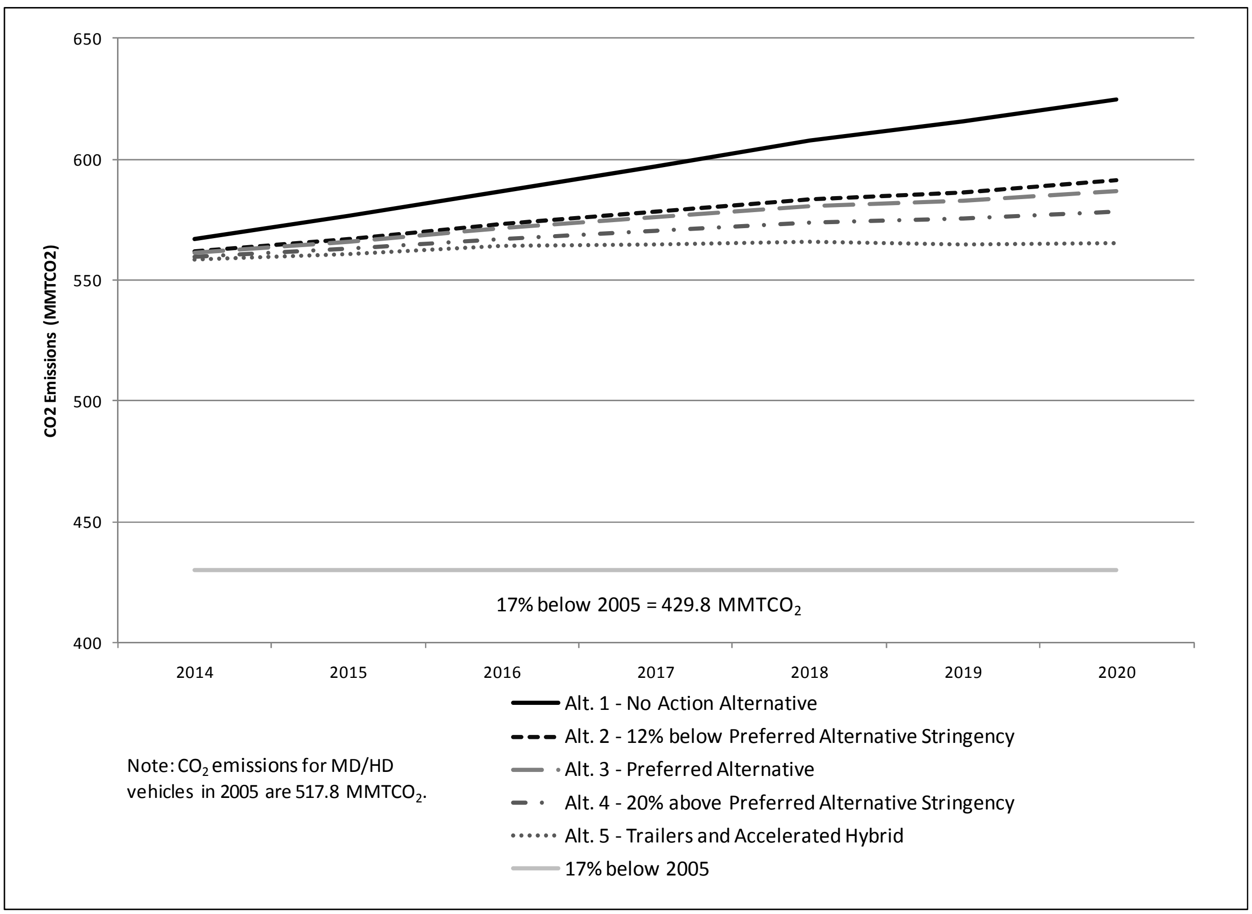
[75] On January 28, 2010, the United States submitted this target to the United Nations Framework Convention on Climate Change as part of a January 31 deadline negotiated in Copenhagen in December 2009, "in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target 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

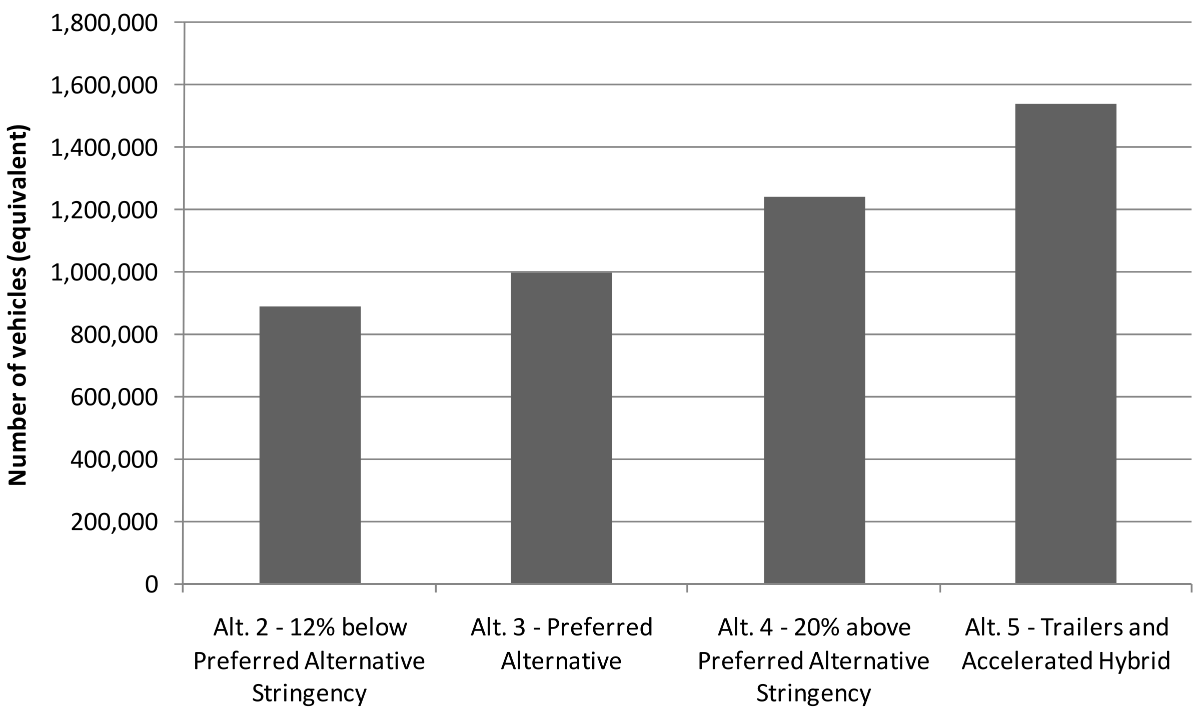
Figure 3.4.4-3. Projected Annual CO_2 Emissions from U.S. HD Vehicles by Alternative, Compared to 2005 Levels



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.