Corporate Average Fuel Economy Standards

Passenger Cars and Light Trucks

Model Years 2017-2025

Final Environmental Impact Statement

July 2012

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Final Environmental Impact Statement
Corporate Average Fuel Economy Standards
Passenger Cars and Light Trucks
Model Years 2017–2025

RESPONSIBLE AGENCY:

National Highway Traffic Safety Administration (NHTSA)

COOPERATING AGENCY:

U.S. Environmental Protection Agency (EPA)

TITLE:

Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2017–2025, Final Environmental Impact Statement

ABSTRACT:

This Final Environmental Impact Statement (Final EIS) analyzes the environmental impacts of a range of alternative fuel economy standards, including a Preferred Alternative, for passenger cars and light trucks ("light-duty vehicles") that NHTSA has proposed under the Energy Policy and Conservation Act, as amended. Environmental impacts analyzed in this Final EIS include those related to fuel and energy use, air quality, and climate change. In developing the proposed Corporate Average Fuel Economy (CAFE) standards, NHTSA considered "technological feasibility, economic practicability, the effect of other vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy," as required by 49 U.S.C. § 32902(f). The proposal is consistent with President Obama's directive to improve the fuel economy of and reduce greenhouse gas emissions from model year 2017–2025 light-duty vehicles through coordinated federal standards.

TIMING OF AGENCY ACTION:

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

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FINAL ENVIRONMENTAL IMPACT STATEMENT

CORPORATE AVERAGE FUEL ECONOMY STANDARDS
PASSENGER CARS AND LIGHT TRUCKS
MODEL YEARS 2017–2025

JULY 2012

LEAD AGENCY:
NATIONAL HIGHWAY TRAFFIC SAFETY
ADMINISTRATION

COOPERATING AGENCY:
U.S. ENVIRONMENTAL PROTECTION AGENCY

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ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the National Highway Traffic Safety Administration has endeavored to limit the use of acronyms and abbreviations in this Environmental Impact Statement. However, this is a complex document, and the use of acronyms and abbreviations is unavoidable, particularly in tables and figures. This list of acronyms and abbreviations defines those used in the text of the main document. Table footnotes define acronyms and abbreviations used therein. Acronyms and abbreviations in figures are defined somewhere in the figures or just below them.

°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
AEO	Annual Energy Outlook
AER	Annual Energy Review
AMO	Atlantic Multidecadal Oscillation
AMOC	Atlantic Meridional Overturning Circulation
AOGCM	atmospheric-ocean general circulation model
BACT	Best Available Control Technology
BiW	Body in White
BTU	British thermal unit
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CBD	Center for Biological Diversity
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	methane
CMAQ	Congestion Mitigation and Air Quality Improvement
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COI	cost of illness
CRC	Consulting Resources Corporation
DICE	Dynamic Integrated Climate and Economy model
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPM	diesel particulate matter
EDF	Environmental Defense Fund
EEI	Edison Electric Institute
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act

EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
EV	electric vehicle
FHWA	Federal Highway Administration
FR	Federal Register
FTA	Federal Transit Administration
FUND	Climate Framework for Uncertainty, Negotiation, and Distribution model
GCAM	Global Change Assessment Model
GCM	general circulation model
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
gpm	gallons per mile
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GWP	global warming potential
HD	heavy-duty; medium- and heavy-duty
HEV	hybrid electric vehicle
HFC	hydrofluorocarbon
HHS	U.S. Department of Health and Human Services
IARC	International Agency for Research on Cancer
ICCT	International Council on Clean Transportation
ICV	internal combustion vehicle
IEO	International Energy Outlook
IGSM	Integrated Global System Model
IPCC	Intergovernmental Panel on Climate Change
IRIS	Integrated Risk Information System
ISO	International Organization for Standardization
LCA	life-cycle assessment
Li-ion	lithium-ion
MAGICC	Model for Assessment of Greenhouse Gas-induced Climate Change
MECA	Manufacturers of Emission Controls Association
MERGE	Model for Evaluating Regional and Global Effects
MDOT	Michigan Department of Transportation
$MMTCO_2$	million metric tons of carbon dioxide
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
MOC	Meridional Overturning Circulation
MOVES	Motor Vehicle Emission Simulator (EPA)
MOVES2010a	2010 Motor Vehicle Emission Simulator (EPA)
mpg	miles per gallon
mph	miles per hour
MSAT	mobile source air toxic
MY	model year

N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NEI	National Emissions Inventory
NEMS	Natinal Energy Modeling System
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHTSA	National Highway Traffic Safety Administration
NiMH	nickel-metal hydride
NO	nitric oxide
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NPRM	Notice of Proposed Rulemaking
NRC	National Research Council
NRDC	Natural Resources Defense Council
NVH	noise, vibration, and harshness
PAGE	Policy Analysis for the Greenhouse Effect model
PAH	polycyclic aromatic hydrocarbon
PEF	petroleum equivalence factor
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
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
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
TSD	Technical Support Document

UCS	Union of Concerned Scientists
U.S.C.	United States Code
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VMT	vehicle miles traveled
VOC	volatile organic compound
VSL	value of statistical life
WCI	Western Climate Initiative
WGI	Work Group I, IPCC
WMO	World Meteorological Organization
WTP	willingness to pay

Glossary

To help readers more fully understand this EIS, this Glossary includes definitions for technical and scientific terms, and plain English terms used differently in the context of the EIS. Italicized terms in definitions indicate terms also included in this Glossary.

Term	Definition
Adaptation	As used in this EIS, initiatives and measures to reduce the vulnerability of natural and human systems from actual or expected effects of climate change effects. There are various types of adaptation, 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 humans.
Attainment area	Region where concentrations of *criteria pollutants* do not exceed limits established under National Ambient Air Quality Standards.
Battery electric vehicle (BEV)	Type of *electric vehicle* that is completely electrically powered and does not incorporate an internal combustion engine.
Benthic	Describing habitat or organisms occurring at the bottom of a body of water.
Biofuel	Liquid fuels and blending components produced from biomass feedstocks, used primarily for transportation.
Biomass	Organic non-fossil material of biological origin (material from living, or recently living organisms) constituting a renewable energy source. As an energy source, biomass can either be used directly, or converted into other energy products such as *biofuel*. Direct biomass fuel can be used to generate electricity with steam turbines and gasifiers or produce heat, usually by direct combustion. Examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips, and even municipal solid waste. Converted biomass includes plant or animal matter converted into fibers or other industrial chemicals, including biofuels. Biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).
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).
Black carbon	Operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability; consists of soot, charcoal, and/or possible light-absorbing refractory organic matter.

Term	Definition
Carbon fixation	This is the process by which inorganic carbon (typically CO_2) is used in an organic compound. An example is the uptake of CO_2 by plants during the process of photosynthesis.
Carbon sequestration	The act or process of increasing carbon storage of a reservoir (other than the atmosphere).
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.
Climate feedback	An interaction mechanism between processes in the climate system is called a climate feedback, when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it.
Criteria pollutants	Air pollutants for which EPA has established National Ambient Air Quality Standards. Under the Clean Air Act, as amended, EPA has established National Ambient Air Quality Standards for six relatively commonplace pollutants (carbon monoxide, airborne lead, nitrogen dioxide, ozone, sulfur dioxide, and fine particulate matter; these are the *criteria pollutants*) that can accumulate in the atmosphere as a result of normal levels of human activity.
Cryosphere	The portion of Earth's surface frozen water, such as snow, *permafrost*, floating ice, and glaciers.
Cumulative impacts	"…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 CFR § 1508.7
Direct impacts	Effects "caused by the action and occur at the same time and place." 40 CFR § 1508.8.
Downstream emissions	Emissions released from a vehicle while it is in operation, parked, or being refueled, and consisting of tailpipe exhaust, evaporative emissions of volatile organic compounds from the vehicle's fuel storage and delivery system, and particulates generated by brake and tire wear.
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. Therefore, the extent of an ecosystem can range from very small spatial scales to, ultimately, all of Earth.
Electric vehicle (EV)	A vehicle that uses battery technologies to provide power, therefore reducing or even eliminating liquid fuel consumption during vehicle operation. The term "electric vehicle" covers a range of different vehicle types, including *battery electric vehicles* (BEVs), *hybrid electric vehicles* (HEVs), and *plug-in hybrid electric vehicles* (PHEVs).

Term	Definition
El Niño-Southern Oscillation (ENSO)	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 basin-wide 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 2 to approximately 7 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 rate	Rate at which contaminants are discharged from a particular source, usually in weight unit per time period.
Energy intensity	The sum of all energy supplied to an economy divided by its real (inflation-adjusted) *Gross Domestic Product* (GDP). Energy intensity measures the efficiency at which energy is converted to GDP; a high value indicates an inefficient conversion of energy to GDP and a lower value indicates a more efficient conversion.
Eutrophication	The process by which a body of water (often shallow) becomes rich in dissolved nutrients, like phosphorus and nitrogen. Sources for these nutrients typically include agricultural fertilizers and sewage.
Evapotranspiration	The combined process of water evaporation from Earth's surface and *transpiration* from vegetation.
Fossil fuel	Fuels formed by natural processes such as anaerobic (in the absence of oxygen) decomposition of buried dead organisms. The age of the organisms resulting in fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels, which contain carbon, include coal, petroleum, and natural gas.
Global warming potential (GWP)	A relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of CO_2. GWP is calculated over a specific time interval, commonly 20, 100, or 500 years. GWP is expressed as a factor of CO_2 (whose GWP is standardized to 1). For example, the 100-year GWP of methane according to IPCC's Second Assessment Report is 21, which means that if the same mass of methane and CO_2 were introduced into the atmosphere, that methane would trap 21 times more heat than the CO_2 over the next 100 years.

Term	Definition
Greenhouse gas (GHG)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), CO_2, nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary GHGs in Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances.
GREET model	Model developed by Argonne National Laboratory that provides estimates of energy use and emissions associated with vehicle and fuel systems. GREET calculates consumption of total energy, fossil fuels, petroleum, coal and natural gas, emissions of CO_2-equivalent greenhouse gases, and emissions of criteria pollutants. GREET is used in this EIS analysis to model *upstream emissions*.
Gross Domestic Product (GDP)	The total market value of all the goods and services produced in an economy at a given time.
Hybrid electric vehicle (HEV)	Type of *electric vehicle* that incorporates a battery and electric motor system coupled with an internal combustion engine.
Hydrosphere	The component of the climate system comprising liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, and underground water.
Indirect impacts	Effects that "are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable." 40 CFR § 1508.8
Life-cycle assessment (LCA)	An analytical method based on a systems perspective used to evaluate the environmental impacts of materials, products, processes, or systems throughout their life cycles.
Mass reduction	Mass reduction reduces fuel consumption by decreasing vehicle mass while maintaining the same vehicle size.
MOVES model	The Motor Vehicle Emission Simulator (MOVES), developed by EPA's Office of Transportation and Air Quality, is a modeling system that estimates emissions of *criteria pollutants* and *toxic air pollutants* for on-road mobile sources. MOVES currently estimates emissions from cars, trucks, and motorcycles, and is used in this EIS analysis to model *downstream emissions*.
NEPA scoping process	An early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.
Nonattainment area	Region where concentrations of *criteria pollutants* exceed federal limits National Ambient Air Quality Standards. Nonattainment areas are required to develop and implement plans to comply with the National Ambient Air Quality Standards within specified periods.

Term	Definition
Ocean acidification	A decrease in the pH of sea water due to the uptake of *anthropogenic* carbon dioxide.
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).
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below zero degrees Celsius for at least 2 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.
Plug-in hybrid electric vehicle (PHEV)	A hybrid vehicle with a large capacity rechargeable battery that can be recharged by plugging into the electrical grid as well as using the on-board charging capabilities of normal hybrids (e.g., regenerative braking). Just like a normal hybrid vehicle, a plug-in hybrid also utilizes an internal combustion engine as a backup when battery life is depleted.
Photosynthetic nitrogen efficiency	The amount of carbon in the plant that is converted to usable sugars during photosynthesis. With greater atmospheric CO_2, the amount of carbon converted to sugars is greater even when the amount of nitrogen available to the plant does not change.
Phototoxicity	An abnormal adverse reaction of a plant to ultraviolet radiation during which a toxic compound in a plant can be produced or enhanced. This can be exacerbated by environmental pollutants or increasing UV radiation.
Primary fuels	Energy sources consumed in the initial production of energy. Primary fuels used in the United States include nuclear power, hydropower, coal, natural gas, and crude oil (converted to petroleum and other liquid fuels for consumption).
Radiative forcing	Measure of how a climatic factor such as a GHG affects the energy balance of the Earth-atmosphere system. A positive forcing tends to warm the Earth's surface while a negative forcing tends to cool it.
Rebound effect	A effect whereby improved fuel economy reduces the fuel cost of driving and leads to additional use of passenger cars and light trucks.
Quads	In this EIS, quadrillion British thermal units.
Social cost of carbon (SCC)	An estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions; the estimated price of the damages caused by each ton of CO_2 released into the atmosphere.
Survival rate	In the context of this EIS, the proportion of vehicles originally produced during a model year expected to remain in service at the age they will have reached during each subsequent year.
Stratification	The layering of warmer, less dense water over colder, denser water.
Technologies	In the context of this EIS, engine technologies, transmission, vehicle, electrification/accessory, and hybrid technologies that affect fuel economy.

Term	Definition
Tipping point	A point in the climate system 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.
Toxic air pollutants	Toxic air pollutants, also known as hazardous air pollutants, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. EPA has identified 188 substances as toxic air pollutants.
Track width	The lateral distance between the centerlines of the base tires at ground.
Transpiration	Water loss from plant leaves.
Upstream emissions	Emissions associated with crude-petroleum extraction and transportation, and with the refining, storage, and distribution of transportation fuels.
Urban Heat island effect	Phenomenon of consistently higher ambient temperatures in metropolitan regions compared to the surrounding rural areas. Metropolitan regions have modified the land surfaces with materials (e.g., pavement) that absorb solar energy, thereby retaining heat within the localized area.
Vehicle footprint	A vehicle's wheelbase multiplied by the vehicle's average track width.
Vehicle miles traveled (VMT)	Total number of miles driven.
Volpe model	CAFE compliance and effects model developed by the DOT Volpe Center that, for any given year, applies technologies to the manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration.
Wheelbase	The longitudinal distance between front and rear wheel centerlines.

SUMMARY

FOREWORD

The National Highway Traffic Safety Administration (NHTSA) prepared this Environmental Impact Statement (EIS) to analyze and disclose the potential environmental impacts of the proposed Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks for model years (MYs) 2017 and beyond (the Proposed Action). NHTSA prepared this document pursuant to Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) implementing regulations, U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations.

This EIS compares the potential environmental impacts of four alternative approaches to regulating light-duty vehicle fuel economy for MYs 2017–2025, including a Preferred Alternative and a No Action Alternative. This EIS analyzes direct, indirect, and cumulative impacts in proportion to their potential significance. The alternatives NHTSA selected for evaluation encompass a reasonable range of alternatives to evaluate the potential environmental impacts of the Proposed Action and alternatives under NEPA. EIS chapters and appendices provide or reference all relevant supporting information.

BACKGROUND

The Energy Policy and Conservation Act of 1975 (EPCA) established the CAFE program to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States. The Secretary has delegated responsibility for implementing the CAFE program to NHTSA.

In December 2007, Congress enacted the Energy Independence and Security Act of 2007 (EISA), amending the EPCA CAFE program requirements by providing DOT additional rulemaking authority and responsibilities. Pursuant to EISA, NHTSA has issued final CAFE standards for MY 2011 passenger cars and light trucks, and standards for MY 2012–2016 passenger cars and light trucks and MY 2014–2018 medium- and heavy-duty vehicles in joint rulemakings with the Environmental Protection Agency (EPA).

On May 21, 2010, President Obama issued a Presidential Memorandum entitled "Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks." This memorandum builds on the President's previous memorandum from January 26, 2009, which established a Joint National Program and led to the NHTSA and EPA joint final rulemaking establishing fuel economy and greenhouse gas (GHG) standards for MY 2012–2016 passenger cars and light trucks. The President's 2010 memorandum requested that NHTSA and EPA continue the joint National Program by developing federal standards to improve fuel efficiency and reduce the GHG emissions of U.S. passenger cars and light trucks manufactured in MYs 2017–2025. The President requested that the agencies develop a Notice of Intent announcing plans for setting those standards by September 30, 2010, which would include "potential standards that could be practicably implemented nationally for the 2017–2025 model years and a schedule for setting those standards as expeditiously as possible, consistent with providing sufficient lead time to vehicle manufacturers."

On September 30, 2010, NHTSA and EPA issued a Notice of Intent that announced plans to develop a rulemaking setting stringent fuel economy and GHG emissions standards for U.S. passenger cars and light trucks for MY 2017 and beyond. The notice was accompanied by an Interim Joint Technical Assessment Report, intended to inform the rulemaking process, which NHTSA, EPA, and the California Air Resources Board (CARB) developed in coordination with the U.S. Department of Energy (DOE). On December 8, 2010, the agencies published a Supplemental Notice of Intent highlighting many of the key comments received in response to the September Notice of Intent and the Interim Joint Technical Assessment Report. Over the next several months, the agencies, working with California, engaged in discussions with individual automobile manufacturers, automotive suppliers, states, environmental groups, consumer groups, and the United Auto Workers, who all expressed support for continuation of the National Program. These discussions and efforts focused on developing information that supported the underlying technical assessments that informed the proposed standards. On May 10, 2011, NHTSA published a Notice of Intent to prepare an EIS for new CAFE standards. On July 29, 2011, NHTSA and EPA issued a final Supplemental Notice of Intent generally describing the agencies' expectations for the Notice of Proposed Rulemaking (NPRM), including the intended levels of standards to be proposed and key program elements, such as compliance flexibilities and the mid-term evaluation. The NPRM was issued together with the Draft EIS on November 16, 2011.

NHTSA developed this EIS pursuant to NEPA, which directs that federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must, "to the fullest extent possible," prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action). To inform its development of the final CAFE standards, NHTSA prepared this EIS, which analyzes, discloses, and compares the potential environmental impacts of a reasonable range of alternatives, including a Preferred Alternative, and discusses impacts in proportion to their significance.

PURPOSE AND NEED FOR THE PROPOSED ACTION

NEPA requires that proposed alternatives be developed based on the action's purpose and need. The purpose and need statement explains why the action is needed, describes the action's intended purpose, and serves as the basis for developing a reasonable range of alternatives to be considered in the NEPA analysis. In accordance with EPCA/EISA, one purpose of the Joint Rulemaking is to establish CAFE standards for MYs 2017 and beyond at "the maximum feasible average fuel economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year." When determining the maximum feasible levels that manufacturers can achieve in each model year, EPCA requires that the Secretary of Transportation consider the four statutory factors of technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy. In addition, the agency has the authority to – and traditionally does – consider other relevant factors, such as the effect of the CAFE standards on motor vehicle safety.

Under EISA, NHTSA must establish separate standards for passenger cars and light trucks for each model year, subject to two principal requirements. First, in certain years, the standards are subject to a minimum requirement regarding stringency – they must be set at levels high enough to ensure that the combined U.S. passenger car and light-truck fleet achieves an average fuel economy level of not less than 35 miles per gallon (mpg) not later than MY 2020. Second, the agency must establish separate average fuel economy standards for all new passenger cars and light trucks at the maximum feasible average fuel economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year.

Finally, NHTSA also is acting pursuant to President Obama's memorandum to DOT on May 21, 2010, as described in Section 1.1 of this EIS. This memorandum further outlines the purpose of and need for the Proposed Action.

PROPOSED ACTION AND ALTERNATIVES AND ANALYSIS METHODOLOGIES

NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives. NHTSA's Proposed Action is to set fuel economy standards for passenger cars and light trucks in accordance with EPCA/EISA. In developing the Proposed Action and alternatives, NHTSA considered the four EPCA factors that guide the agency's determination of "maximum feasible" standards. NHTSA's decisionmaking process balances the four statutory EPCA factors, along with considerations such as environmental impacts and safety.

In any single rulemaking under EPCA, fuel economy standards may be established for not more than 5 model years. For this reason, NHTSA's proposal is limited to setting standards for MYs 2017–2021. In the NPRM, NHTSA also set forth values for MYs 2022–2025 that reflected the agency's estimate of the standards we would have proposed and adopted had we the authority to do so. The CAFE standards for MYs 2022–2025 will be determined in a subsequent, de novo notice and comment rulemaking. However, because NHTSA's effort is part of a joint NHTSA/EPA rulemaking for a coordinated and harmonized National Program covering MYs 2017–2025, this EIS addresses the potential impacts of the proposed standards for MY 2017–2021 and the values set forth for MYs 2022–2025 for each of the alternatives, thus covering the full MY 2017–2025 period. When NHTSA refers to the standards in this EIS as "required," it recognizes that fuel economy standards for MY 2022–2025 will not, in fact, be required in this rulemaking. Rather, it is assumed for purposes of the analysis in this EIS that the values set forth for MYs 2022–2025 will be made required in the future. Similarly, when NHTSA refers to the "Proposed Action" or to the "proposed standards," these terms are intended to identify the full time period covered by the coordinated National Program (MYs 2017–2025) for purposes of analysis, but subject to the specific caveats noted above.

NHTSA has selected a reasonable range of alternatives to evaluate the potential environmental impacts of the Proposed Action under NEPA. The specific alternatives NHTSA selected, described below and listed in Table S-1 and Sections 2.2.4 and 2.2.5 of this EIS, encompass a reasonable range within which to set CAFE standards and to evaluate the potential environmental impacts under NEPA, in view of EPCA requirements. Pursuant to CEQ regulations, the agency has included a No Action Alternative (Alternative 1), which assumes no action would occur under the National Program. The No Action Alternative assumes that NHTSA would not issue a rule regarding CAFE standards for MY 2017–2025 2025 passenger cars and light trucks; rather, consistent with previous EISs, the agency assumes that NHTSA's MY 2016 fuel economy standards and EPA's MY 2016 GHG standards would continue indefinitely. This alternative provides an analytical baseline against which to compare the environmental impacts of the three action alternatives.

Uncertainty over Market-Driven Improvements in Fuel Economy

In recognition of the uncertainty inherent in forecasting the fuel economy of the future light-duty vehicle fleet in the absence of agency action, this EIS provides two sets of analyses regarding the No Action Alternative against which the corresponding impacts of the action alternatives were measured. Analyses A1 and A2 reflect a No Action Alternative that assumes that, in the absence of the Proposed Action, the baseline light-duty vehicle fleet in MY 2017 and beyond would attain an average fleetwide fuel economy no higher than the minimum levels necessary to comply with NHTSA and EPA's MY 2016 standards established by final rule in April 2010. Analyses A1 and A2 also assume that the average annual fleetwide fuel economy under the action alternatives would be no higher than the minimum necessary to comply with the level of the agency's CAFE standard for a particular year during the rulemaking period. Finally, after MY 2025, NHTSA assumes that average fleetwide fuel economy under the action alternatives will never exceed the level set forth for the MY 2025 standards. Tables and figures in this summary that depict results for Analysis A have "A1" or "A2" after the table or figure number.

Analyses B1 and B2 reflect a No Action Alternative that assumes that, in the absence of the Proposed Action, the average fleetwide fuel economy level of passenger cars and light trucks would continue to increase beyond the level necessary to meet the MY 2016 standards. These analyses also reflect action alternatives that assume that once manufacturers comply with the CAFE standard for a particular year during the MY 2017–2025 period, they would consider making further improvements in fuel economy if it is cost-effective to do so. NHTSA forecast the fleets assumed in Analyses B1 and B2 using the "voluntary over-compliance" simulation capability of the Volpe model, described in Section 2.2.1 of this EIS and in Section IV.C.4.c of the NPRM. For this simulation, the agency used all the same inputs as for Analysis A, but applied a payback period of 1 year for purposes of simulating whether a manufacturer would apply additional technology to an already CAFE-compliant fleet through MY 2025. In other words, NHTSA assumed manufacturers would continue to add fuel economy technologies that pay for themselves through fuel savings within 1 year. More discussion of this methodology is available in Section IV.G of the NPRM. In Analyses B1 and B2, the agency has also assumed that average fleetwide fuel economy will continue to increase after MY 2025 at rates consistent with historical changes in the fuel economy of new passenger cars and light trucks during periods when CAFE standards remained fixed and did not require manufacturers to offer vehicles with higher fuel economy than in the immediately preceding model years. Tables and figures in this summary that depict results for Analyses B1 and B2 have "B1" or "B2" after the table or figure number.

Uncertainty in New Vehicle Fleet Forecast

To evaluate the environmental impacts of the proposed alternatives, NHTSA must project what vehicles and technologies will exist in future model years and then evaluate what technologies can feasibly be applied to those vehicles to raise their fuel economy. To project the future fleet, NHTSA must develop a baseline vehicle fleet. For this Final EIS, NHTSA has analyzed the potential environmental impacts of the Proposed Action and alternatives using two different forecasts of the light-duty vehicle fleet through MY 2025.

In the NPRM, NHTSA and EPA used 2008 MY CAFE certification data to establish the "2008-based fleet projection." In addition to the MY 2008 CAFE certification data, NHTSA based the forecast of the light-duty vehicle fleet through 2025 on the Annual Energy Outlook (AEO) 2011 interim projection of future fleet sales volumes and on the CSM Worldwide future new vehicle fleet forecast from 2009. In this Final EIS, one new vehicle fleet forecast (referred to as the MY 2008 baseline and assumed in Analyses A1 and B1) is similar to the one used in the NPRM. In response to comments, this Final EIS also includes another new vehicle fleet forecast (generally referred to as the MY 2010 baseline and assumed in Analyses A2 and B2) using a baseline fleet constructed from MY 2010 CAFE certification data, AEO 2012 Early Release fleet sales projections to MY 2025 published in 2012, and a purchased LMC Automotive-based new vehicle fleet projection (by vehicle type and manufacturer) out to MY 2025. The significant uncertainty associated with forecasting sales volumes, vehicle technologies, fuel prices, consumer demand, and other variables out to MY 2025 makes it reasonable and appropriate to evaluate the impacts of the Proposed Action and alternatives using two baselines.

The two new vehicle fleet forecasts have certain differences. For example, the MY 2008 vehicle data (reflected in Analyses A1 and B1) represent the most recent model year for which the industry had sales data that were not affected by the subsequent economic recession. However, the CSM forecast used for the MY 2008 baseline, appears to have been particularly influenced by the recession, showing major declines in market share for some manufacturers (e.g., Chrysler), which NHTSA does not believe is reasonably reflective of future trends. On the other hand, the MY 2010 baseline (reflected in Analyses A2 and B2) employs a future new vehicle fleet that is more current.

In addition, although MY 2010 CAFE certification data have become available since the publication of the NPRM, it continues to show the effects of the recession. For example, industry-wide sales were skewed down 20 percent compared to pre-recession MY 2008 levels. Using the MY 2008 vehicle data avoids using these sudden and perhaps temporary baseline market shifts when projecting the future new vehicle fleet. On the other hand, the MY 2010 CAFE certification data accounts for the phase-out of some brands and the introduction of some technologies, which might be more reflective of the future new vehicle fleet.

Designation of Analyses in this EIS Based on Uncertainties

In light of the uncertainties discussed above, this Final EIS presents the potential environmental impacts for each of the alternatives using two different assumptions regarding market-driven fuel economy improvements and two different sets of fleet characteristic assumptions. By retaining the assumptions used in Analysis A and Analysis B from the Draft EIS, this approach produces four sets of results for direct and indirect impacts – Analyses A1 and A2 and Analyses B1 and B2 – for each alternative as described below. The two sets of fleet-characteristic assumptions also produce two sets of results for cumulative impacts – Analyses C1 and C2 – for each of the alternatives as described below.

- In Analyses A1 and A2, the agency assumes that the average fleetwide fuel economy for light-duty vehicles would not exceed the minimum level necessary to comply with CAFE standards. Therefore, Analyses A1 and A2 measure the impacts of the action alternatives under which average fleetwide fuel economy in each model year does not exceed the level of the CAFE standards for that model year, compared to a No Action Alternative under which average fleetwide fuel economy after MY 2016 will never exceed the level of the agencies' MY 2016 standards established by final rule in April 2010. Tables and figures in this Final EIS that depict results for Analysis A1 (these have "A1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis A2 (these have "A2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.
- In Analyses B1 and B2, the agency assumes continued improvements in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Therefore, Analyses B1 and B2 measure the impacts of the action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing improvements in new vehicle fuel economy after MY 2025, compared to a No Action Alternative that assumes the average fleetwide fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards, even in the absence of agency action. Tables and figures in this Final EIS

that depict results for Analysis B1 (these have "B1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis B2 (these have "B2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.

- CEQ NEPA implementing regulations require agencies to consider the cumulative impacts of major federal actions. NHTSA refers to the cumulative impacts analysis as Analysis C throughout this EIS. In Analyses C1 and C2, the agency compares action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing fuel economy improvements after MY 2025 with a No Action Alternative under which there are no continued improvements in fuel economy after MY 2016 (i.e., the average fleetwide fuel economy for light-duty vehicles would not exceed the latest existing standard). In this way, the cumulative impacts analysis combines the No Action Alternative from Analyses A1 and A2 with the action alternatives from Analyses B1 and B2. Tables and figures in this Final EIS that depict results for Analysis C1 (these have "C1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis C2 (these have "C2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection. For more explanation of NHTSA's methodology regarding the cumulative impacts analysis, *see* Section 2.5.

Analysis A1 is generally comparable to Analysis A in the Draft EIS, and Analysis B1 is generally comparable to Analysis B in the Draft EIS. Analysis A2 and Analysis B2 make the same assumptions about growth during and after the years of the Proposed Action as Analysis A1 and Analysis B1, respectively, except these analyses reflect a MY 2010 baseline fleet (as described above).

NHTSA has provided separate tables illustrating the environmental impacts projected in each analysis. In discussing these impacts, NHTSA often presents the results of Analyses A1 and A2 together and Analyses B1 and B2 together in what appears to be a range (e.g., "light-duty vehicle 2017–2060 fuel consumption is projected to range from 4,987 to 5,372 billion gallons under the Preferred Alternative in Analyses A1 and A2"). This form of presenting the results is not intended to bound all the possible, or even likely, potential impacts that may occur under a given alternative in a given year. In other words, the values should not be interpreted as a true minimum or maximum potential impact. Rather, this format presents results using the same methodology but under different assumptions, as described above.

Alternatives

NHTSA has analyzed a reasonable range of action alternatives with stringencies that increase annually, on average, 2 percent to 7 percent from the MY 2016 standards for passenger cars and for light trucks. As the agency stated in the Notice of Intent to issue an EIS and in the Draft EIS, NHTSA believes that, based on the different ways it could weigh EPCA's four statutory factors, the maximum feasible level of CAFE stringency falls within this range. Throughout this EIS, estimated impacts are shown for three action alternatives that illustrate this range of average annual percentage increases in fleetwide fuel economy. The regulatory alternatives analyzed here are the same as those presented in the Draft EIS and the NPRM. Table S-1 shows the estimated average required and achieved fleetwide fuel economy forecasts by model year under the alternatives. The action alternatives are as follows:

- Alternative 2 – Alternative 2 would require a 2 percent average annual fleetwide increase in fuel economy for both passenger cars and light trucks for MYs 2017–2025. Alternative 2 represents the lower bound of the range of annual stringency increases NHTSA believes includes the maximum feasible stringency.
- Alternative 3 (Preferred) – Under the Preferred Alternative, manufacturers would be required to meet an estimated average fleetwide fuel economy level of 40.3 to 41.0 mpg in MY 2021 and 48.7 to 49.7 mpg in MY 2025. These averages are uncertain, because, as discussed in Section 1.3.2.1 of this EIS, the actual average required fuel economy levels in the future will depend upon the actual composition of the future fleet, which can only be estimated – with considerable uncertainty – at this time. The proposed stringency increases to the attribute-based standards (i.e. the target functions as expressed on a gallons per mile [gpm] basis) for MYs 2017–2021 average 3.6 percent for passenger cars. In recognition of manufacturers' unique challenges in improving the fuel economy and GHG emissions of full-size pickup trucks (a subset of light trucks) as we transition from the MY 2016 standards to MY 2017 and later, while preserving the utility (e.g., towing and payload capabilities) of those vehicles, NHTSA's proposal includes a slower annual rate of improvement for light trucks in the first phase of the program. The proposed stringency increases to the attribute-based standards for MYs 2017–2025 average 2.3 percent (on a gpm basis) for light trucks. For MYs 2022–2025, the annual stringency increases set forth average 4.4 percent (also on a gpm basis) for both passenger cars and light trucks. The target curves identified as the Preferred Alternative and analyzed in this Final EIS are the same as those that defined the Preferred Alternative in the Draft EIS and outlined as the proposal in the NPRM. In other words, the rate of increase in stringency of the Preferred Alternative analyzed in the Final EIS has not changed.
- Alternative 4 – Alternative 4 would require a 7 percent average annual fleetwide increase in fuel economy for both passenger cars and light trucks for MYs 2017–2025. Alternative 4 represents the upper bound of the range of annual stringency increases NHTSA believes includes the maximum feasible stringency.

Table S-1. Estimated Average Required[a] and Achieved[b] Fleetwide Fuel Economy (mpg) for Combined U.S. Passenger Cars and Light Trucks by Model Year and Alternative under each Analysis

Alternative	Analysis	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Required										
1 – No Action	A1 & B1	34.6	34.7	34.8	34.8	34.8	34.9	34.9	35.0	35.1
	A2 & B2	34.3	34.3	34.3	34.3	34.3	34.4	34.4	34.5	34.5
2 – 2%/Year Cars and Trucks	A1 & B1	35.5	36.3	37.2	37.9	38.8	39.6	40.5	41.5	42.5
	A2 & B2	35.1	35.8	36.6	37.4	38.2	39.0	39.8	40.8	41.6
3 – Preferred	A1 & B1	35.4	36.5	37.7	38.9	41.0	43.0	45.1	47.4	49.7
	A2 & B2	35.1	36.1	37.1	38.3	40.3	42.3	44.3	46.5	48.7
4 – 7%/Year Cars and Trucks	A1 & B1	37.3	40.3	43.6	47.0	50.8	54.8	59.2	64.0	69.2
	A2 & B2	36.9	39.8	42.9	46.3	49.9	53.9	58.2	62.8	67.8

Table S-1. Estimated Average Required[a] and Achieved[b] Fleetwide Fuel Economy (mpg) for Combined U.S. Passenger Cars and Light Trucks by Model Year and Alternative under each Analysis (continued)

Alternative	Analysis	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Achieved										
1 – No Action	A1	33.7	34.1	34.4	34.6	34.9	34.9	35.0	35.1	35.2
	A2	33.3	33.7	33.9	34.3	34.4	34.5	34.5	34.6	34.6
	B1	34.5	35.3	36.1	36.4	36.7	37.0	37.2	37.3	37.5
	B2	34.1	34.5	35.2	35.7	36.2	36.4	36.6	36.8	36.9
2 – 2%/Year Cars and Trucks	A1	35.0	36.1	37.5	38.6	39.6	40.2	40.8	41.6	41.9
	A2	34.7	35.6	36.7	37.9	38.8	39.2	39.9	40.7	40.9
	B1	35.2	36.4	37.7	38.8	39.4	40.2	40.7	41.5	42.2
	B2	34.8	35.6	36.8	38.0	38.9	39.4	40.1	40.9	41.5
3 – Preferred	A1	35.0	36.6	38.7	40.8	42.6	43.8	44.6	46.0	47.4
	A2	34.8	36.0	38.2	39.9	42.0	42.9	44.2	45.6	46.2
	B1	35.6	37.1	39.1	40.8	42.3	43.6	44.6	46.1	48.1
	B2	34.9	36.1	38.4	40.3	42.1	43.2	44.5	45.7	47.1
4 – 7%/Year Cars and Trucks	A1	37.8	40.3	43.4	46.7	49.7	52.3	53.8	56.4	58.4
	A2	37.2	39.0	42.1	45.1	47.7	49.7	51.9	54.5	57.1
	B1	37.9	40.5	43.9	46.7	49.6	51.6	53.8	56.1	58.3
	B2	37.0	38.8	42.2	45.5	48.3	50.2	52.0	54.8	56.9

a. Estimated average *required* fuel economy levels are based on application of the mathematical function defining the alternative to the market forecast defining the estimated future fleets of new passenger cars and light trucks.

b. For the No Action Alternative, estimated average *achieved* fuel economy levels reflect the agency's estimates of manufacturers' potential responses to these requirements, taking into account available technology, available adjustments to fuel economy levels based on reduction of air conditioner energy consumption, fuel economy calculations specific to electric vehicles, and EISA/EPCA provisions allowing manufacturers to earn CAFE credits by producing flexible-fuel vehicles, to pay civil penalties in lieu of achieving compliance with CAFE standards, to carry CAFE credits forward between model years (up to 5 years), and to transfer CAFE credits between the passenger car and light-truck fleets. In addition, for the action alternatives, estimated achieved levels take into account available adjustments to fuel economy levels based on application of technologies (other than those that improve air conditioner efficiency) that reduce off-cycle energy consumption.

The range being considered under the action alternatives encompasses a spectrum of possible standards the agency could select, based on the different ways NHTSA could weigh EPCA's four statutory factors. By providing environmental analyses of these points and the Preferred Alternative, the decisionmaker and the public can determine the environmental effects of points that fall between Alternatives 2 and 4. The action alternatives evaluated in this EIS therefore provide decisionmakers with the ability to select from a wide variety of other potential alternatives with stringencies that increase annually at average percentage rates between 2 and 7 percent. This includes, for example, alternatives with stringencies that increase at different rates for passenger cars and for light trucks, and stringencies that increase by different rates in different years.

These alternatives reflect differences in the degree of technology adoption across the fleet, in costs to manufacturers and consumers, and in conservation of oil and related reductions in GHGs. For example, the most stringent alternative NHTSA is evaluating (Alternative 4) would require greater adoption of technology across the fleet, including more advanced technology, than the least stringent action alternative (Alternative 2) NHTSA is evaluating. As a result, Alternative 4 would impose greater costs and achieve greater energy conservation and related reductions in GHGs than other action alternatives, compared to the No Action Alternative. The agency's Preferred Alternative (Alternative 3) represents the required fuel economy level NHTSA has tentatively determined to be the maximum feasible level under EPCA, based on balancing the four statutory factors and other relevant considerations. For a detailed description of the alternatives, *see* Section 2.2 of this Final EIS.

POTENTIAL ENVIRONMENTAL CONSEQUENCES

This section describes how the Proposed Action and alternatives could affect energy use, air quality, and climate, as reported in Chapters 3, 4, and 5 of the EIS, respectively. Air quality and climate impacts are reported for the entire light-duty vehicle fleet (passenger cars and light trucks combined), while Appendix A to the EIS provides the air quality and climate impacts of the Proposed Action and alternatives for passenger cars and light trucks separately. The EIS also qualitatively describes potential additional impacts on water resources, biological resources, hazardous materials and regulated wastes, noise, and environmental justice.

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

The analysis of the direct and indirect impacts compares the action alternatives in a particular analysis (A1, A2, B1, or B2) with the No Action Alternative in that analysis, applying their respective assumptions as described above. The cumulative impacts analysis accounts for other past, present, and reasonably foreseeable future actions, consistent with NEPA requirements. The cumulative impacts analysis presents the environmental impacts (including impacts to energy, air quality, and climate) due to the fuel economy improvements that result directly or indirectly from the action alternatives in addition to reasonably foreseeable improvements in fuel economy caused by other actions – that is, fuel economy improvements that would result from actions taken by manufacturers without the agency's action and in response to market demands. The cumulative impacts analysis also compares the action alternatives in a particular analysis (C1 or C2) with the No Action Alternative in that analysis, applying their respective assumptions as described above.

Energy

NHTSA's Proposed Action would regulate fuel economy and therefore impact fuel consumption in the U.S. transportation sector. Transportation fuel comprises a large portion of total U.S. energy consumption and energy imports, and has a significant impact on the functioning of the energy sector as a whole. Because automotive fuel consumption is expected to account for most U.S. net energy imports through 2035, the United States has the potential to achieve large reductions in imported oil use and, consequently, reductions in the country's net energy imports during this time by increasing the fuel economy of its fleet of passenger cars and light trucks.

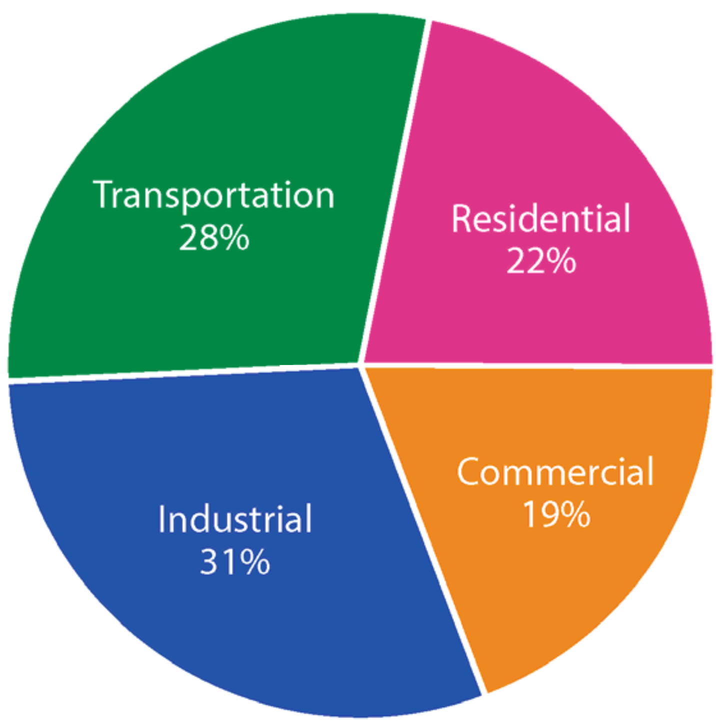
Increasing the fuel economy of the light-duty vehicle fleet is likely to have far-reaching impacts related to reducing U.S. dependence on foreign oil. Reducing dependence on energy imports is a key component of the President's March 30, 2011, *Blueprint for a Secure Energy Future*, which indicates that increasing transportation efficiency is an essential step toward that goal. The 1-year progress report to the President's *Blueprint* reaffirms the major role increased fuel efficiency in transportation has already played in reducing U.S. dependence on foreign oil. Similarly, DOE has stated that vehicle efficiency has the greatest short- to mid-term impact on oil consumption.

Energy intensity measures the efficiency at which energy is converted to Gross Domestic Product (GDP), with a high value indicating an inefficient conversion of energy to GDP and a lower value indicating a more efficient conversion. The energy intensity of the U.S. economy has decreased by 54 percent over 4 decades (from 15,890 British thermal units [Btu] per real dollar of GDP in 1970 to 7,400 Btu per real dollar of GDP in 2010), indicating an overall increase in the efficiency with which the U.S. uses energy. Although U.S. energy efficiency has been increasing and the U.S. share of global energy consumption has been declining in recent decades, total U.S. energy consumption has been increasing over that same period.

Most of the increase in U.S. energy consumption over the past decades has not come from increased domestic energy production, but instead from the increase in imports largely for use in the transportation sector. Transportation fuel consumption has grown steadily on an annual basis. Transportation is now the largest consumer of petroleum in the U.S. economy and a major contributor to U.S. net imports. The United States is poised to reverse the trend of the last 4 decades and achieve large reductions in net energy imports through 2035 due to continuing increases in U.S. energy efficiency and recent developments in U.S. energy production. Stronger fuel economy standards for light-duty vehicles have the potential to further increase U.S. energy efficiency in the transportation sector and reduce U.S. dependence on petroleum.

The transportation sector is the second-largest consumer of energy in the United States (after the industrial sector), representing 28 percent of total U.S. energy use, as shown in Figure S-1.

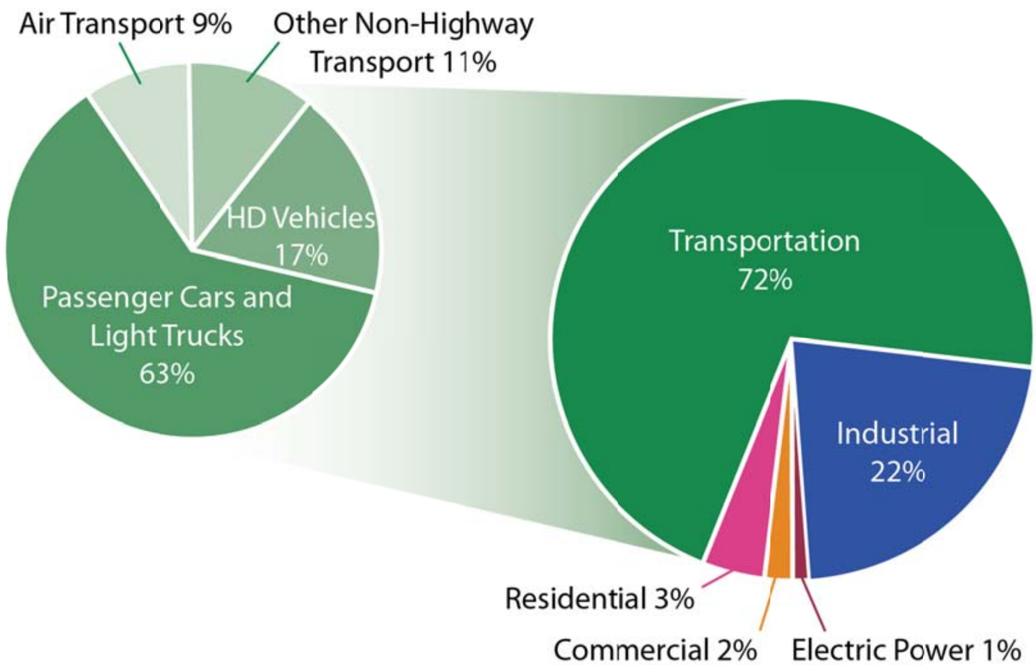
Figure S-1. U.S. Energy Consumption by Sector, 2010



Source: EIA (Energy Information Administration). Annual Energy Outlook 2012. Early Release Overview. DOE/EIA-0383ER. U.S. Department of Energy: Washington, DC. *Available at*: <http://www.eia.gov/forecasts/aeo/er/>. (Accessed: May 31, 2012).

Petroleum is by far the largest source of energy used in the transportation sector, accounting for almost 95 percent of this sector's energy consumption. Consequently, transportation accounts for the largest share of total U.S. petroleum consumption. As shown in Figure S-2, the transportation sector consumes 72 percent of the petroleum used in the United States.

Figure S-2. U.S. Petroleum Consumption by Sector, 2010



HD = heavy-duty

Left Pie Chart Data Source: EIA. 2012. Annual Energy Outlook 2012. Early Release Overview. Table 7—Transportation Sector key Indicators and Delivered Energy Consumption. DOE/EIA-0383ER. U.S. Department of Energy: Washington, D.C. Available at: <http://www.eia.gov/oiaf/aeo/tablebrowser/>. (Accessed: May 31, 2012).

Right Pie Chart Data Source: EIA. 2011. Annual Energy Review 2010. Table 5.13a-d—Petroleum Consumption Estimates, 1949–2010. DOE/EIA-0384 (2010). U.S. Department of Energy: Washington, D.C. Available at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>. (Accessed: April 20, 2012).

More than half of transportation-sector energy use can be attributed to petroleum (gasoline and diesel fuel) consumption by passenger cars and light trucks. In the future, the transportation sector will continue to be the largest petroleum consumer and the second largest component of total U.S. energy consumption after the industrial sector. NHTSA's analysis of fuel consumption in this EIS assumes that fuel consumed by passenger cars and light trucks will consist predominantly of gasoline and diesel fuel derived from petroleum for the foreseeable future.

Key Findings for Energy Use

To calculate fuel savings for each action alternative, NHTSA subtracted projected fuel consumption under each action alternative from the level under the No Action Alternative. The fuel consumption and savings figures presented below are for 2017–2060 (2060 being the year by which nearly the entire U.S. light-duty vehicle fleet will likely be composed of MY 2017–2025 and later vehicles).

Direct and Indirect Impacts

As the alternatives increase in stringency, total fuel consumption decreases in all of the analyses. In Analyses A1 and A2, light-duty vehicle fuel consumption from 2017–2060 under the No Action Alternative is projected to range from 6,052 to 6,562 billion gallons. Light-duty vehicle fuel consumption from 2017–2060 is projected to range from 5,400 to 5,812 billion gallons under Alternative 2, 4,987 to 5,372 billion gallons under the Preferred Alternative, and 4,456 to 4,795 billion gallons under Alternative 4. In Analyses B1 and B2, light-duty vehicle fuel consumption from 2017–2060 under the No Action Alternative is projected to range from 5,280 to 5,694 billion gallons. Light-duty vehicle fuel consumption from 2017–2060 is projected to range from 5,080 to 5,476 billion gallons under Alternative 2, 4,694 to 5,054 under the Preferred Alternative, and 4,261 to 4,559 billion gallons under Alternative 4.

Fuel savings is the reduction in fuel consumption over a specific period. In contrast to fuel consumption, fuel savings under each action alternative compared to the No Action Alternative increases with stringency. Figures S-3-A1, A2, B1, and B2 demonstrate fuel savings for Analyses A1, A2, B1 and B2, respectively, from 2017–2060 under each action alternative compared to the No Action Alternative. In Analyses A1 and A2, light-duty vehicle 2017–2060 fuel savings would range from 652 to 751 billion gallons under Alternative 2, 1,066 to 1,190 billion gallons under the Preferred Alternative, and 1,597 to 1,767 billion gallons under Alternative 4. In Analyses B1 and B2, light-duty vehicle 2017–2060 fuel savings would range from 200 to 219 billion gallons under Alternative 2, 585 to 640 billion gallons under the Preferred Alternative, and 1,019 to 1,135 billion gallons under Alternative 4.

Figure S-3-A1. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A1

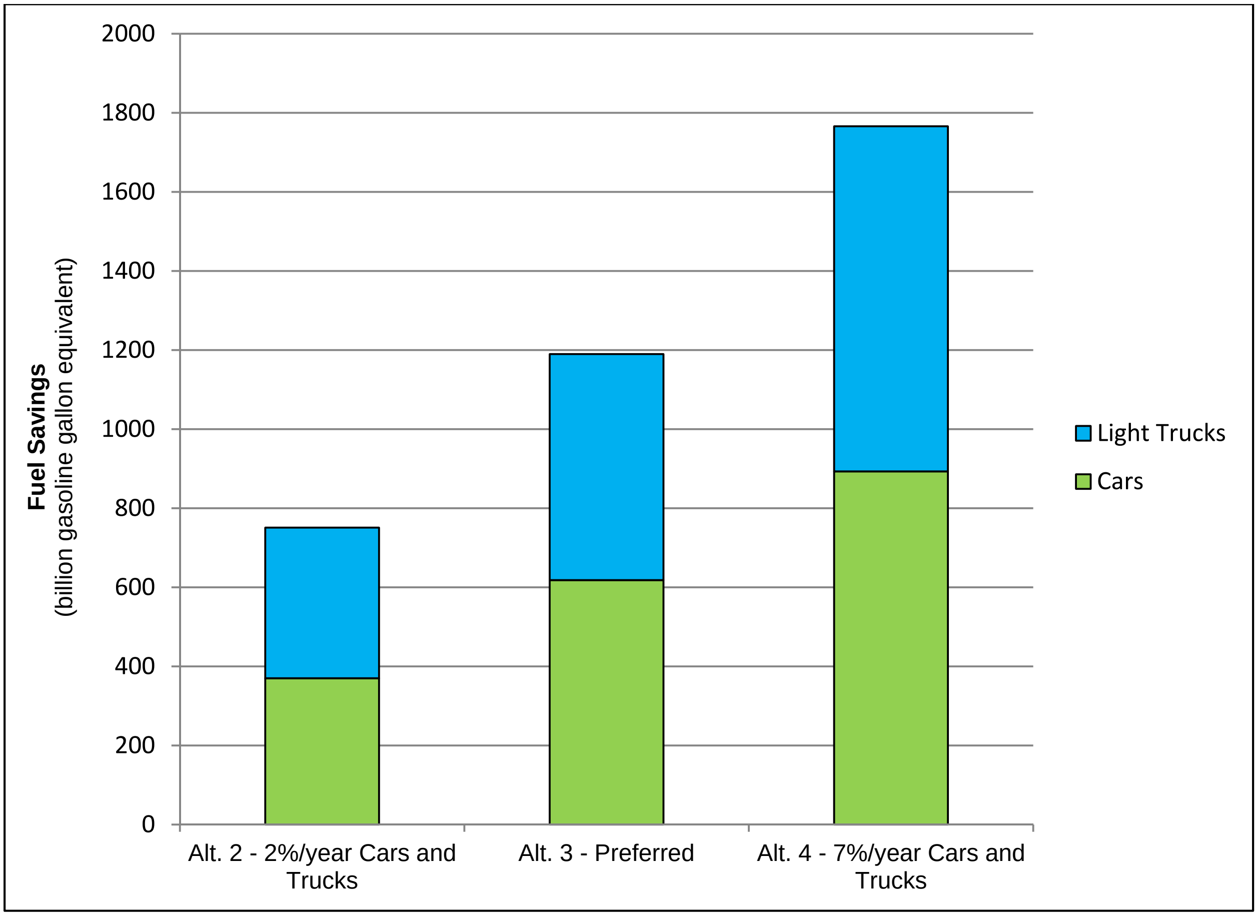


Figure S-3-A2. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A2

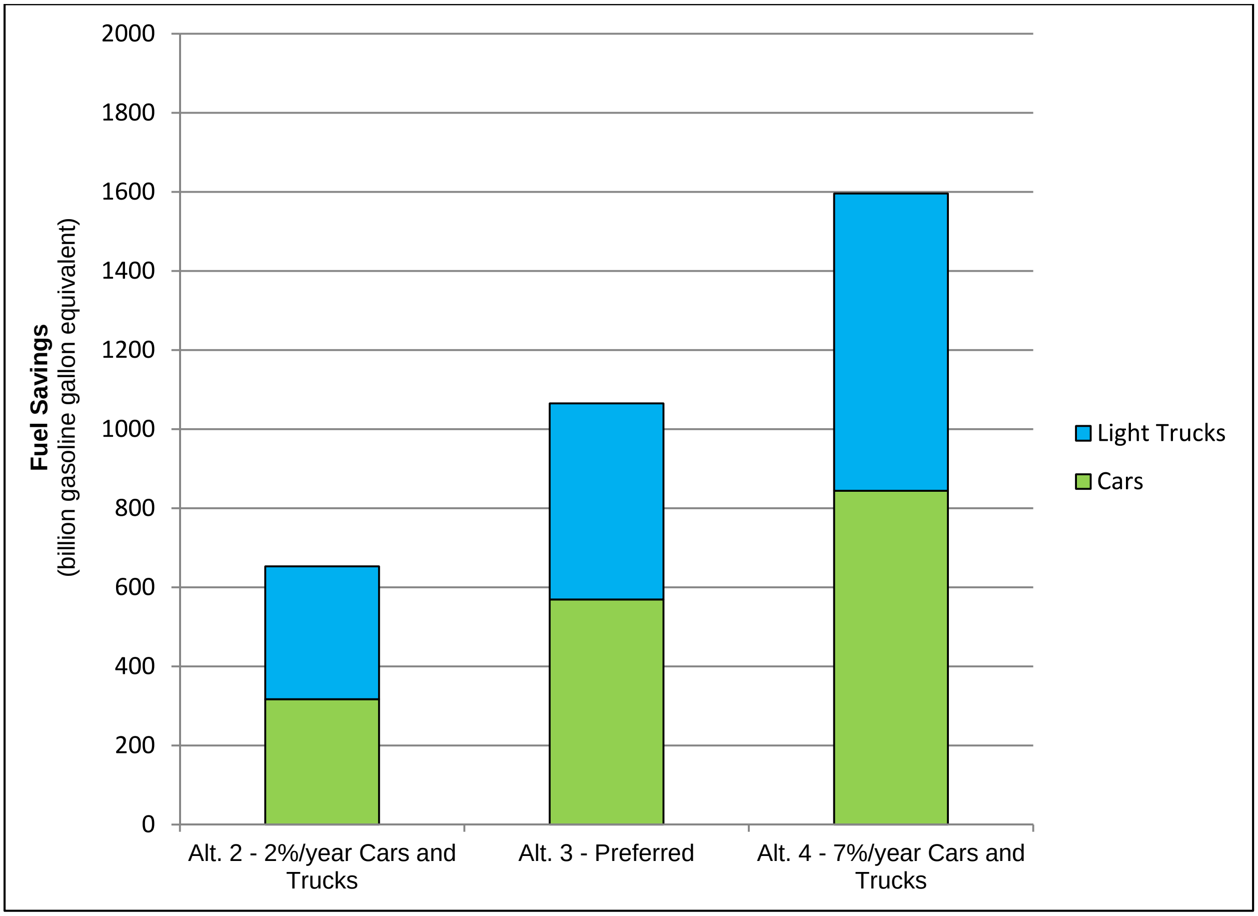


Figure S-3-B1. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B1

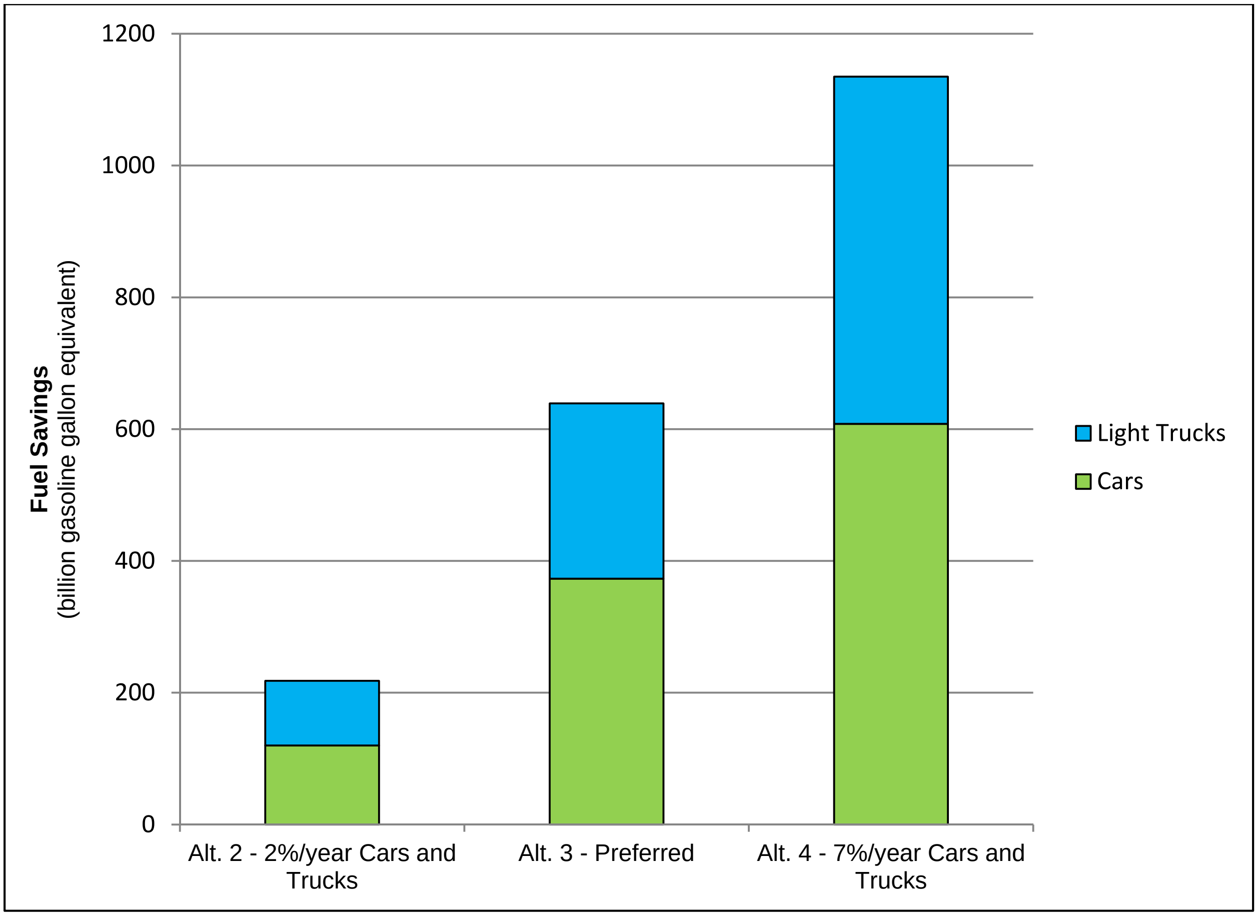
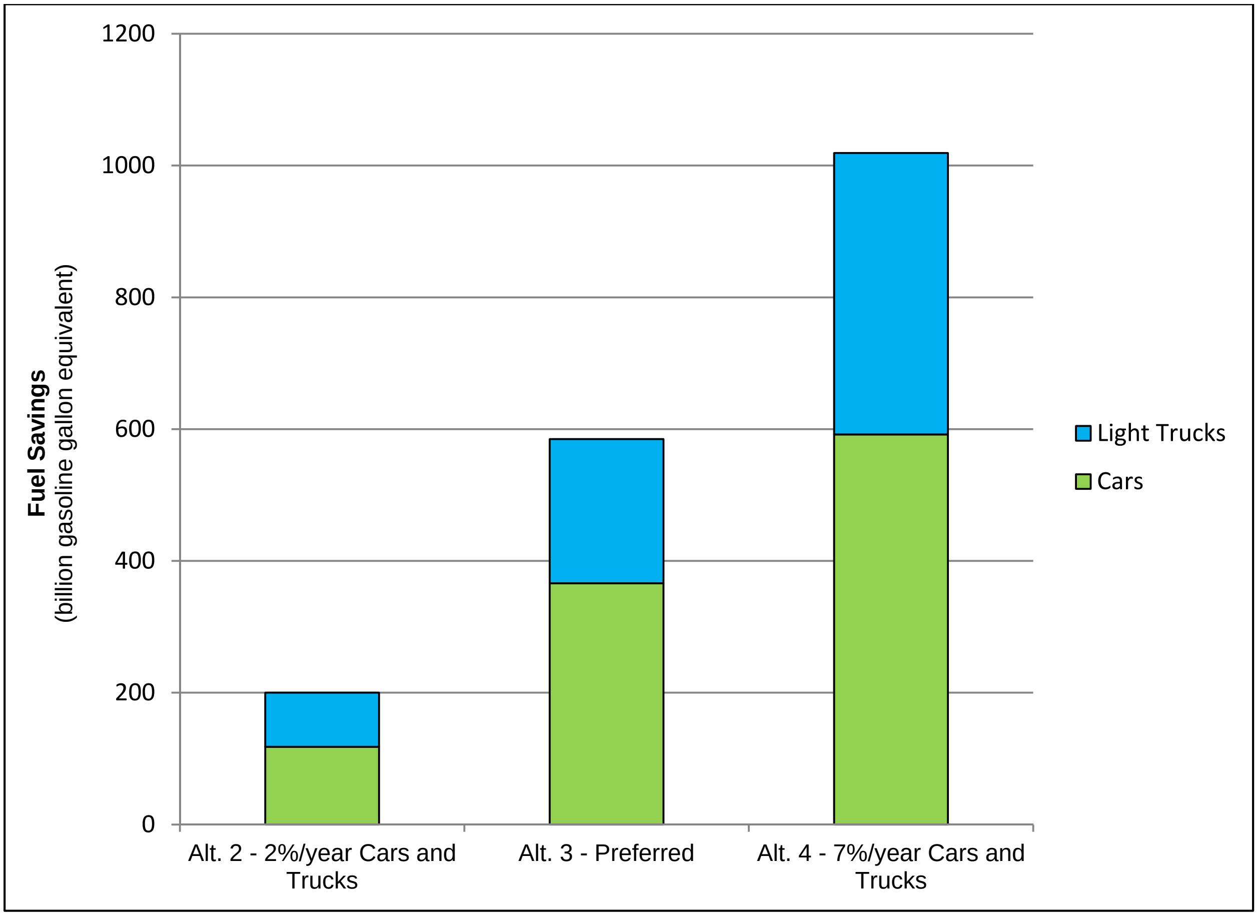


Figure S-3-B2. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B2



Cumulative Impacts

As with direct and indirect impacts, fuel consumption under each action alternative will decrease with increasing stringency under the cumulative impacts analysis, which incorporates other past, present, and reasonably foreseeable future actions that would lead to improvements in fuel economy. Under the No Action Alternative, total combined gas and diesel fuel consumption during the period 2017–2060 is projected to be 6,562 billion gallons in Analysis C1 and 6,052 billion gallons in Analysis C2. In Analysis C1, total fuel consumption for the same period under the action alternatives ranges from a low of 4,559 billion gallons under Alternative 4 to a high of 5,476 billion gallons under Alternative 2. Total fuel consumption under the Preferred Alternative falls between these levels, amounting to 5,054 billion gallons. In Analysis C2, total fuel consumption under the action alternatives ranges from a low of 4,261 billion gallons under Alternative 4 to a high of 5,080 billion gallons under Alternative 2. Total fuel consumption under the Preferred Alternative falls between these levels, amounting to 4,694 billion gallons.

Similarly, under the cumulative impacts analysis, fuel savings from passenger cars and light trucks increase with increased fuel economy stringency. Figures S-3-C1 and C2 show fuel savings for the period 2017–2060 under each alternative compared to the No Action Alternative. In Analysis C1, fuel savings during this period range from a low of 1,087 billion gallons under Alternative 2 to a high of 2,003 billion gallons under Alternative 4. Fuel savings under the Preferred Alternative in Analysis C1 falls between these levels, amounting to 1,508 billion gallons. In Analysis C2, fuel savings range from a low of 973 billion gallons under Alternative 2 to a high of 1,792 billion gallons under Alternative 4. Fuel savings under the Preferred Alternative in Analysis C2 falls between these levels, amounting to 1,358 billion gallons.

Figure S-3-C1. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C1

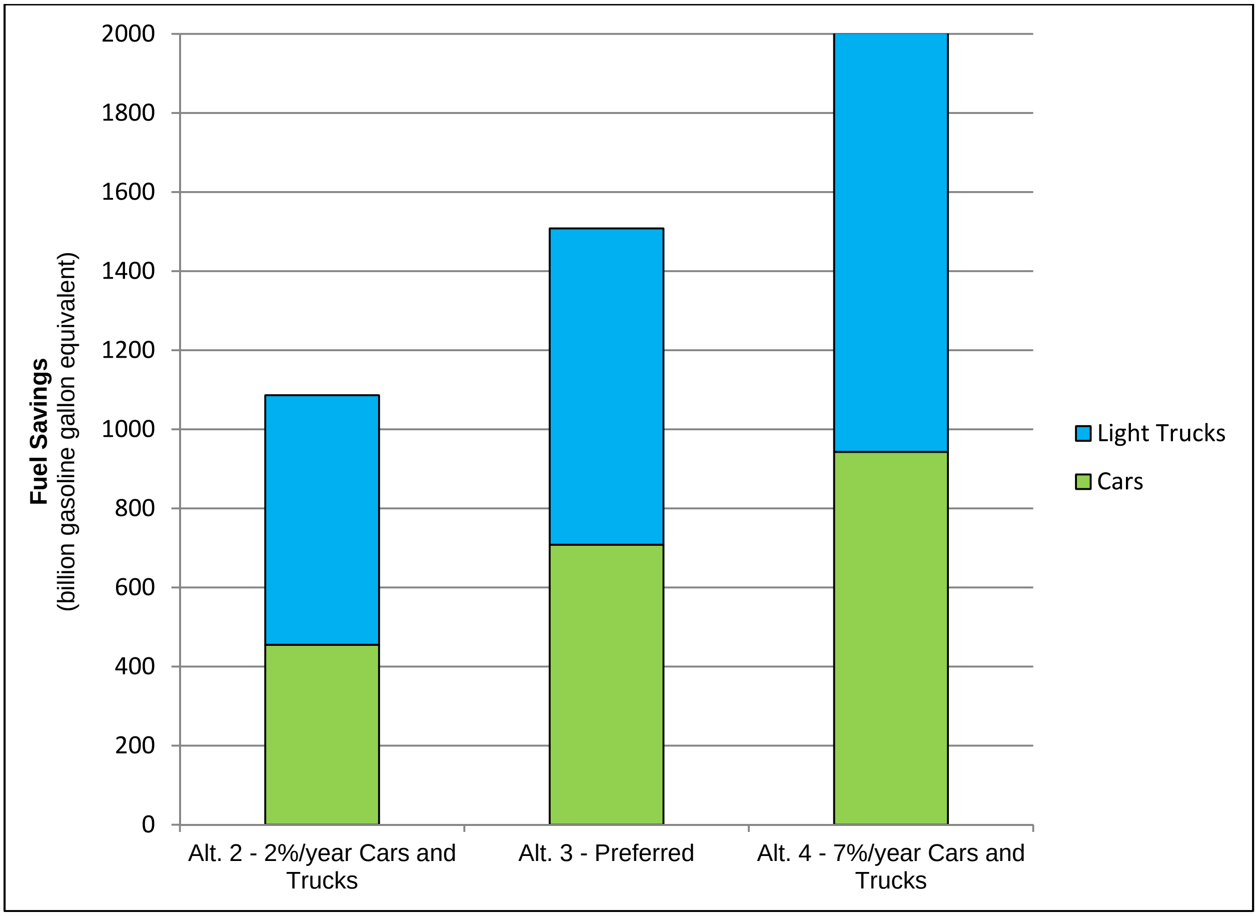
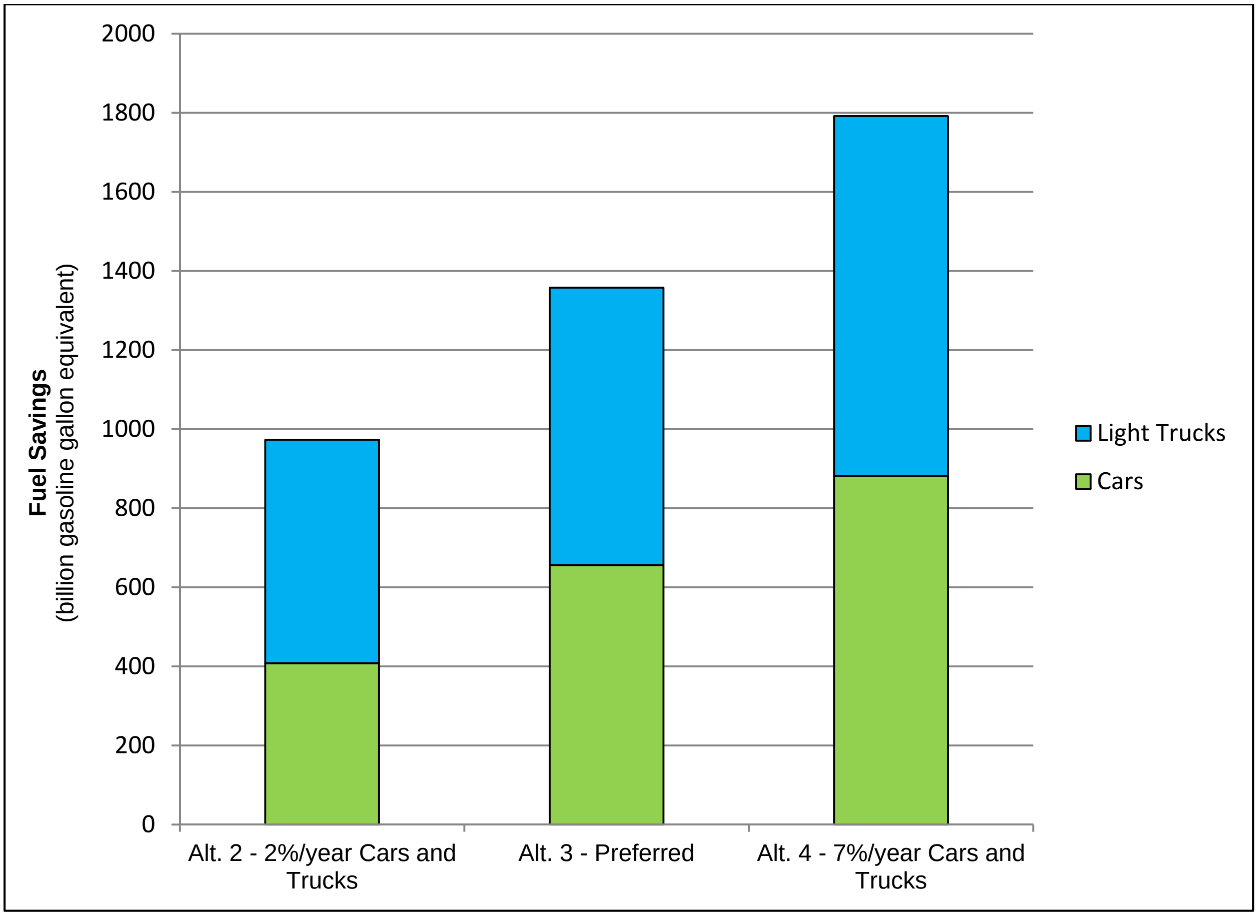


Figure S-3-C2. U.S. Passenger Car and Light Truck Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C2



Air Quality

Air pollution and air quality can affect public health, public welfare, and the environment. The Proposed Action and alternatives under consideration would affect air pollutant emissions and air quality. The EIS air quality analysis assesses the impacts of the alternatives in relation to emissions of pollutants of concern from mobile sources, the resulting impacts to human health, and the monetized health benefits of emissions reductions. Although air pollutant emissions generally decline under the action alternatives compared to the No Action Alternative, the magnitudes of the declines are not consistent across all pollutants (and some air pollutant emissions might increase), reflecting the complex interactions between tailpipe emission rates of the various vehicle types, the technologies NHTSA assumes manufacturers will incorporate to comply with the standards, upstream emission rates, the relative proportions of gasoline and diesel in total fuel consumption reductions, and increases in vehicle miles traveled (VMT).

Under the authority of the Clean Air Act (CAA) and its amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six relatively common air pollutants – known as “criteria” pollutants because EPA regulates them by developing human health-based or environmentally based criteria for setting permissible levels. The criteria pollutants are carbon monoxide (CO), nitrogen dioxide

(NO_2), ozone, sulfur dioxide (SO_2), lead, and particulate matter (PM) with an aerodynamic diameter equal to or less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$, or fine particles). Ozone is not emitted directly from vehicles, but is formed from emissions of ozone precursor pollutants such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs).

In addition to criteria pollutants, motor vehicles emit some substances defined by the 1990 CAA Amendments as hazardous air pollutants. Hazardous air pollutants include certain VOCs, compounds in PM, pesticides, herbicides, and radionuclides that present tangible hazards based on scientific studies of human (and other mammal) exposure. Hazardous air pollutants from vehicles are known as mobile source air toxics (MSATs). The MSATs included in this analysis are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde. EPA and the Federal Highway Administration have identified these air toxics as the MSATs that typically are of greatest concern when analyzing impacts of highway vehicles. DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class.

Health Effects of the Pollutants

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

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

MSATs are also associated with adverse health effects. For example, EPA classifies acetaldehyde, benzene, 1,3-butadiene, formaldehyde, and certain components of DPM as either known or probable human carcinogens. Many MSATs are also associated with non-cancer health effects, such as respiratory irritation.

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

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

Highway vehicles (including vehicles covered by the proposed rule) are responsible for approximately 53 percent of total U.S. emissions of CO, 1.7 percent of $PM_{2.5}$ emissions, and 1.2 percent of PM_{10} emissions. Highway vehicles also contribute approximately 24 percent of total nationwide emissions of VOCs and 31 percent of NO_x, both of which are chemical precursors of ozone. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors. Highway vehicles contribute less than 0.4 percent of SO_2, but SO_2

and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere. With the elimination of lead in automotive gasoline, it is no longer emitted from motor vehicles in more than negligible quantities and therefore is not assessed in this analysis.

Methodology

The air quality results presented in this EIS, including impacts to human health, are based on a number of assumptions about the types and rates of emissions from the combustion of fossil fuels. In addition to tailpipe emissions, the analysis accounts for upstream emissions from the production and distribution of fuels, including contributions from the power plants that generate the electricity used to recharge electric vehicles (EVs) and from the production of the fuel burned in those power plants. Emissions and other environmental impacts from electricity production depend on the efficiency of the power plant and the mix of fuel sources used, sometimes referred to as the "grid mix." To estimate upstream emissions, the analysis uses the GREET model (1 2011 version developed by DOE Argonne National Laboratory), which contains data on emissions intensities (amount of pollutant emitted per unit of electrical energy generated) that extend to 2020. To project the U.S. average electricity generating fuel mix for the reference year 2020, the analysis uses the National Energy Modeling System (NEMS) AEO 2012 Early Release version, an energy-economy modeling system from DOE.

Assumptions in the modeling tools result in a temporally static and geographically homogeneous grid that overstates air quality impacts under alternatives that predict a high level of EV deployment. Therefore, NHTSA has added an alternate analysis to illustrate the effects of a cleaner future grid on air quality. This analysis is based on an assumption of steady improvements to the grid during the course of the next several decades — the period during which any EV deployment associated with increases in the CAFE standards would occur — and, if the current early trends continue, a higher concentration of EVs in areas served by cleaner electrical grids. This alternate analysis was performed using the same methodology used throughout the document, and it generated the inputs necessary to allow modeling of air quality impacts and their resulting health outcomes and monetized health effects. The results of the health outcomes and monetized health effects of these two cases are reported alongside each other for comparison in Chapter 4 of the EIS, and summarized below. In the discussion below, the "Base Grid Mix" is the analysis presented throughout this document and is based on NEMS AEO 2012 Early Release version fuel mix and emissions projections for the year 2020. The "Alternate Grid Mix" is based on the fuel mix and emissions projections of the cleaner "GHG Price Economy-Wide" emissions side case in the final AEO 2011 for the year 2035. Supporting calculations for the Alternate Grid Mix appear in the charts in Appendix H.

Key Findings for Air Quality

The findings for air quality effects are shown for the year 2040 in this Summary, a mid-term forecast year by which time a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet the proposed standards. The results reported in this section apply to Analyses A1, A2, B1, B2, C1, and C2 for 2040, unless otherwise noted. The EIS provides findings for air quality effects for 2021, 2025, 2040, and 2060. In general, emissions of criteria air pollutants decrease with increased stringency across alternatives, with several exceptions. The increases and decreases in emissions reflect the complex interactions among 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.

To estimate reduced incidence of $PM_{2.5}$-related adverse health effects and the associated monetized health benefits from the emission reductions, NHTSA multiplied direct $PM_{2.5}$ and $PM_{2.5}$ precursor (NO_x, SO_2, and VOCs) emission reductions by EPA-provided pollutant-specific benefit-per-ton estimates. Reductions in adverse health outcomes include reduced incidences of premature mortality, chronic bronchitis, respiratory emergency room visits, and work-loss days.

Direct and Indirect Impacts

Criteria Pollutants

- Emissions of criteria pollutants are highest under the No Action Alternative and generally decline as fuel consumption decreases from the least stringent alternative (No Action) to the most stringent (Alternative 4), as shown in Figures S-4-A1, A2, B1, and B2. CO is a partial exception to this general trend, with CO emissions increasing under Alternatives 2 and 3, and decreasing under Alternative 4. These increases under Alternatives 2 and 3 occur because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. Under Alternative 4, the reverse is true. NO_x and SO_2 are also partial exceptions, with emissions generally decreasing under Alternatives 2 and 3, and increasing under Alternative 4. Many of the emissions changes are relatively small, especially under Alternatives 2 and 3 in the years before 2060.
- Emissions of CO, $PM_{2.5}$, and VOCs generally are lowest under Alternative 4, while emissions of SO_2 and NO_x are highest under Alternative 4.
- Under the Preferred Alternative, emissions of all criteria pollutants are reduced compared to the No Action Alternative for most analyses, except CO emissions, which increase slightly from the No Action Alternative in all analyses. Excluding CO, emissions under the Preferred Alternative generally are lower than emissions under Alternative 2 for all pollutants. Emissions of $PM_{2.5}$ and VOCs under the Preferred Alternative are generally higher than emissions under Alternative 4, while emissions of NO_x and SO_2 under the Preferred Alternative are generally lower than emissions under Alternative 4.
- As discussed above, these results depend upon assumptions regarding the future electrical grid mix. NHTSA has also conducted an alternate analysis which examines the impacts of the action alternatives assuming a cleaner grid mix.

Figure S-4-A1. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis A1

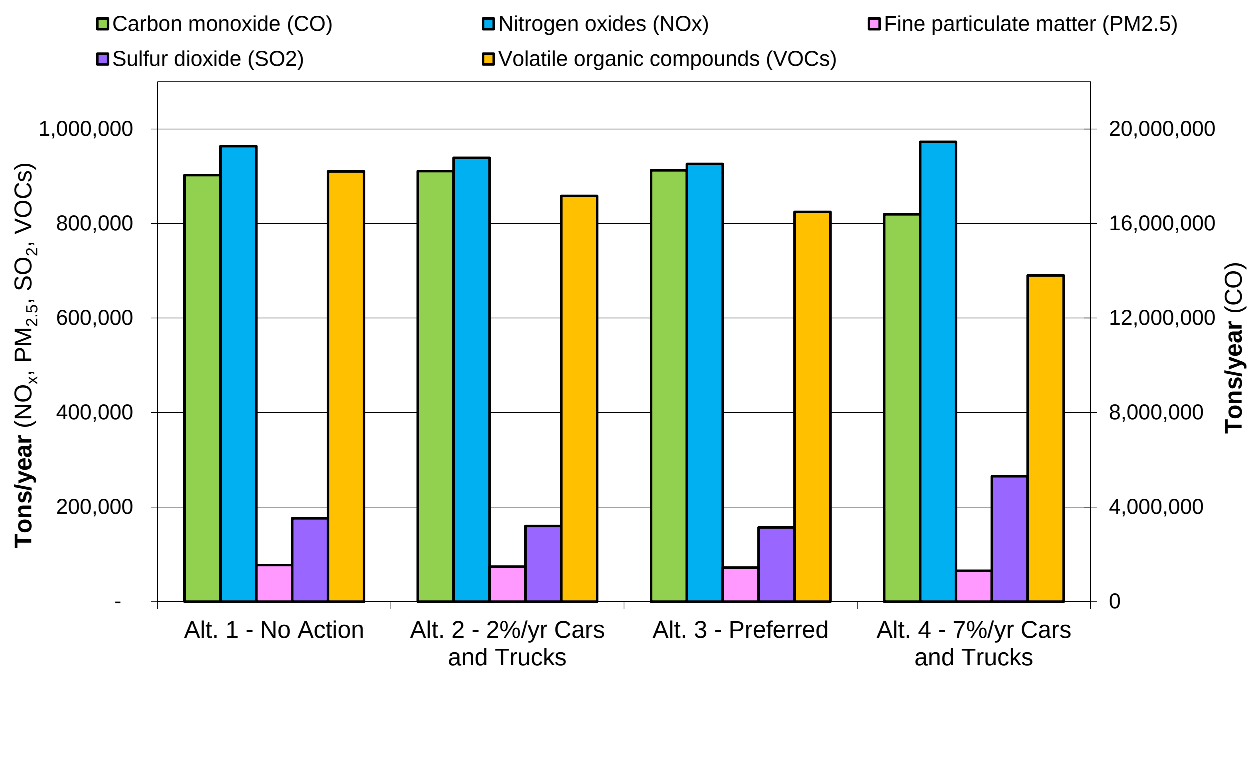


Figure S-4-A2. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis A2

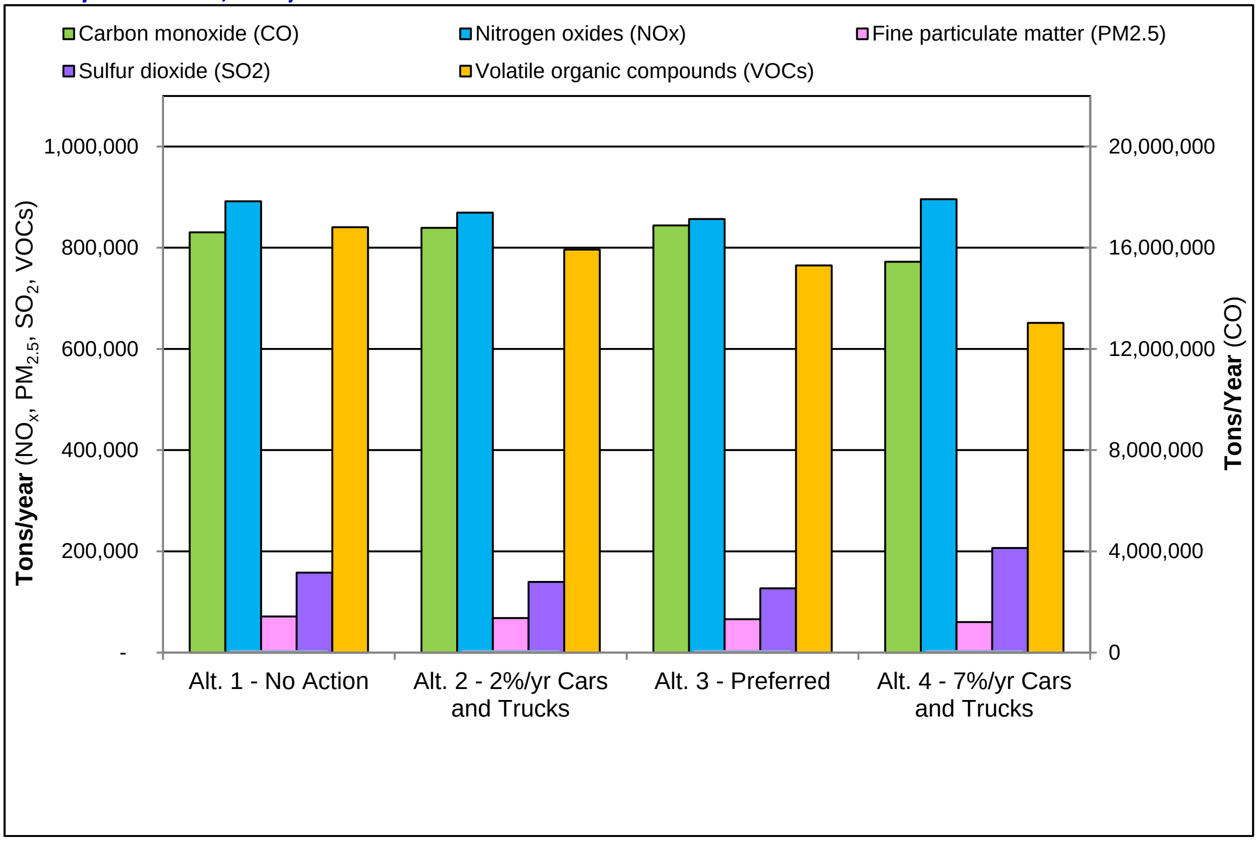


Figure S-4-B1. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis B1

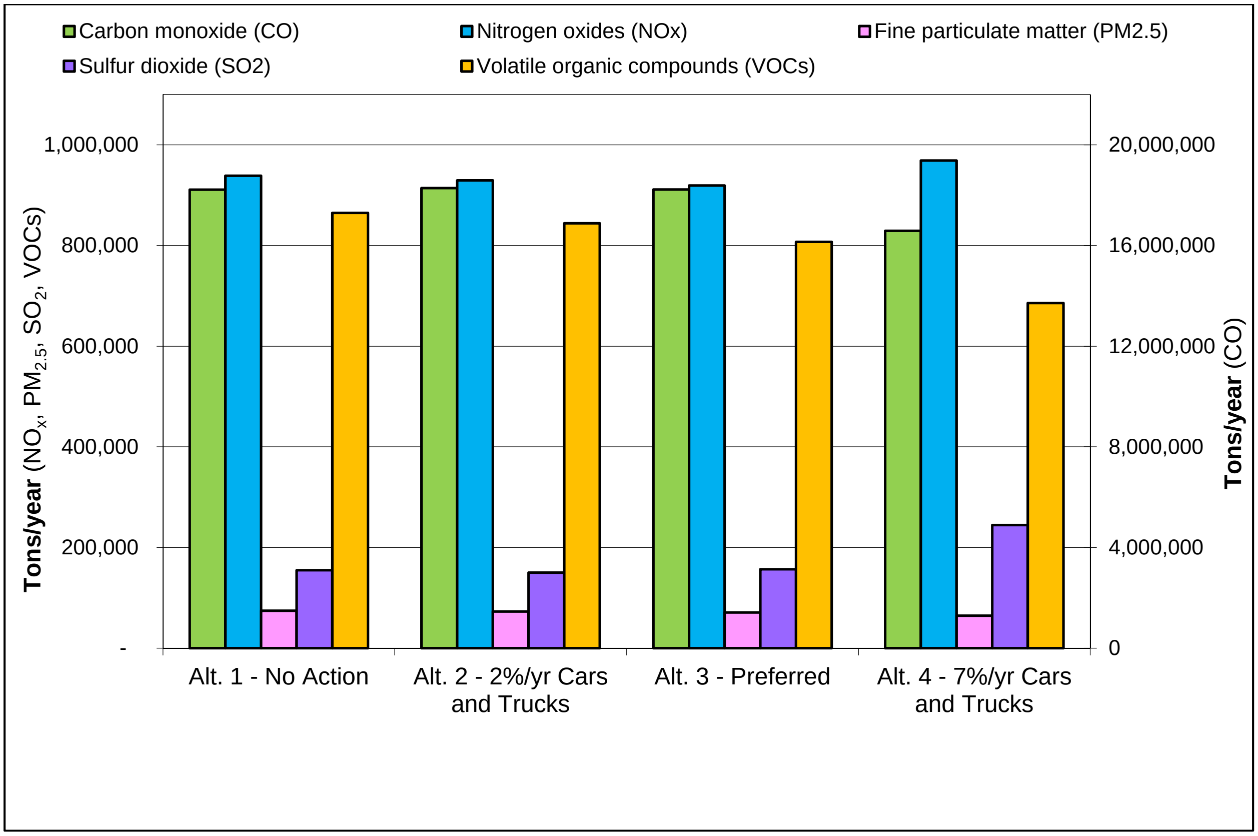
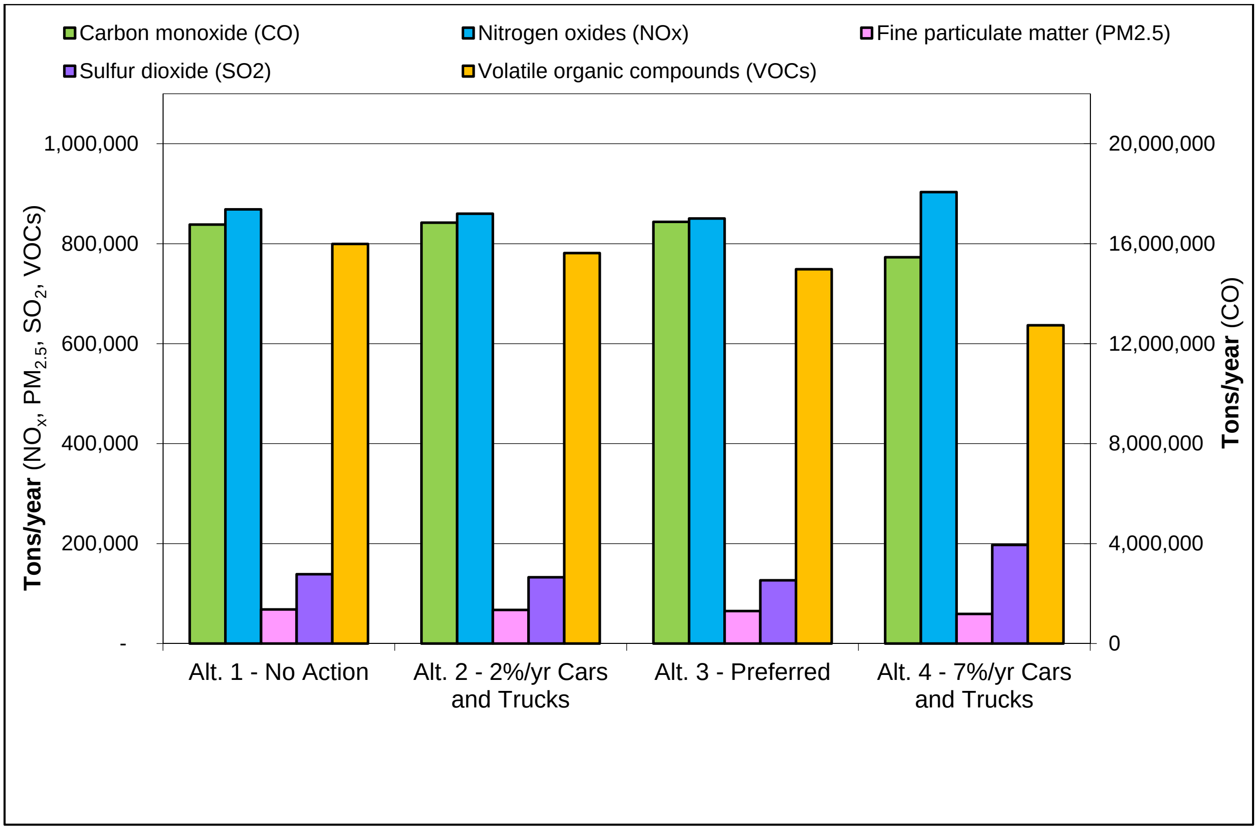


Figure S-4-B2. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis B2



Hazardous Air Pollutants

- Emissions of acetaldehyde, acrolein, and formaldehyde generally increase from Alternative 1 to Alternative 4, as shown in Figures S-5-A1, A2, B1, and B2. These increases occur because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. This trend is least pronounced for formaldehyde, for which emissions decrease under Alternatives 2 and 3 for several combinations of analyses and years. Acetaldehyde emissions also decrease under Alternative 4 for certain analyses and years. Many of the emissions changes are relatively small, especially under Alternatives 2 and 3 in the years before 2060.
- Emissions of 1,3-butadiene are approximately equivalent for each alternative and year (except for decreases under Alternative 4 in 2040 and 2060). Benzene emissions generally decrease from Alternative 1 to Alternative 4. DPM emissions generally decrease from Alternative 1 to Alternative 3 for all analysis years. Under Alternative 4, DPM emissions decrease until 2025 by an amount that is smaller than under the other action alternatives, and increase to just below or above the No Action Alternative levels (except in Analysis A1). 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 economy requirements.
- Under the Preferred Alternative, emissions of benzene and DPM are generally reduced compared to the No Action Alternative. In contrast, emissions of acetaldehyde, acrolein, and 1,3-butadiene generally increase under the Preferred Alternative compared to the No Action Alternative.

Emissions of formaldehyde under the Preferred Alternative either increase or decrease compared to the No Action Alternative, depending on the analysis. Emissions of benzene and DPM under the Preferred Alternative are lower than under Alternative 2, and higher than under Alternative 4 (except for DPM in Analyses A1 and A2). Emissions of acetaldehyde, acrolein and 1,3-butadiene under the Preferred Alternative are generally higher than under Alternative 2 and either higher or lower than under Alternative 4, depending on the year and analysis. Emissions of formaldehyde under the Preferred Alternative are either lower or higher than under Alternative 2 depending on the analysis, but lower than under Alternative 4 across all analyses.

Figure S-5-A1. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis A1

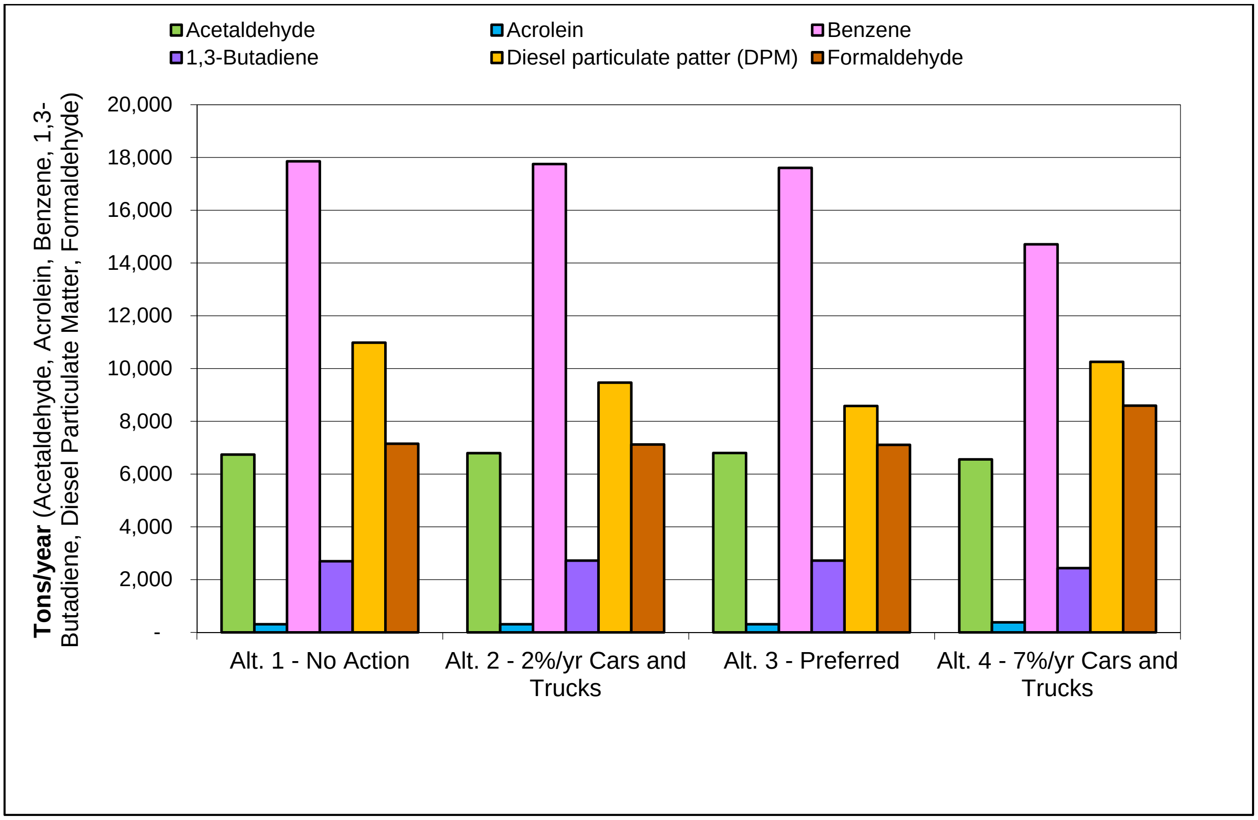


Figure S-5-A2. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis A2

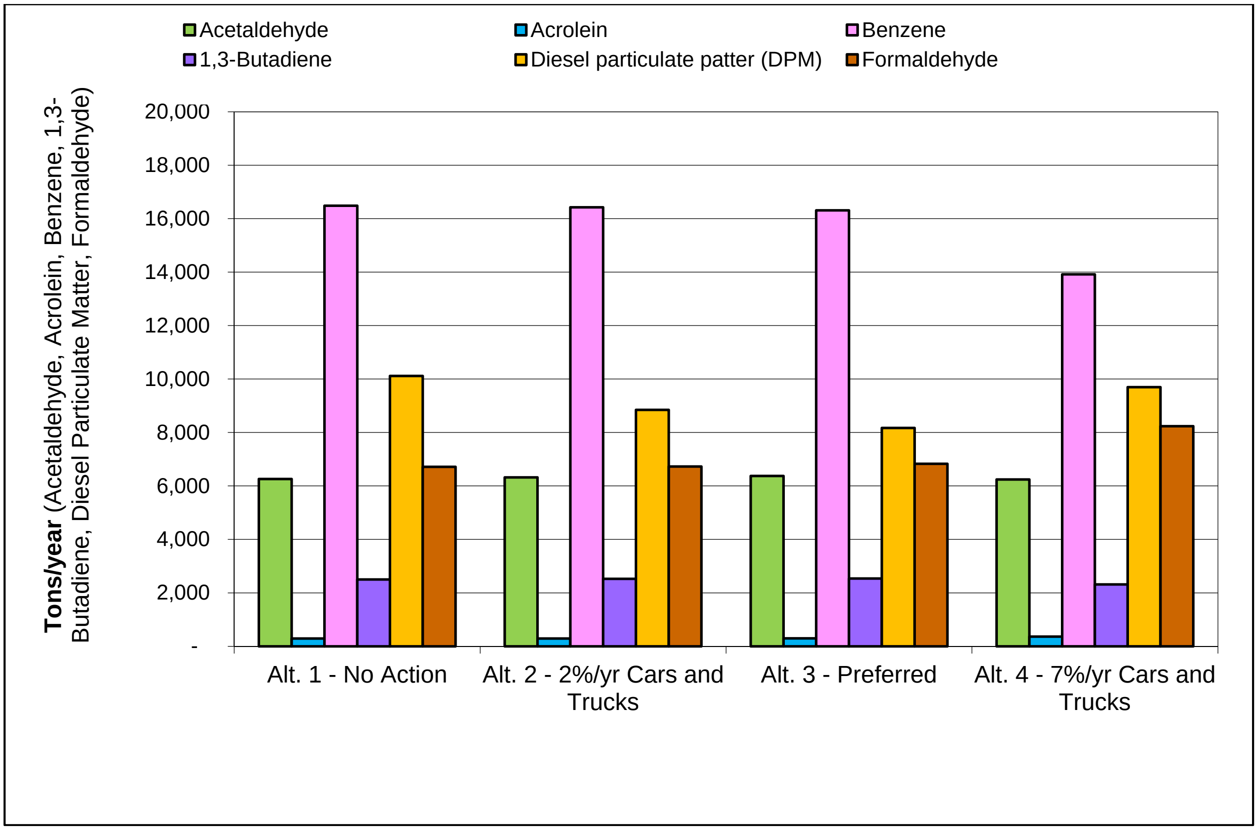


Figure S-5-B1. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis B1

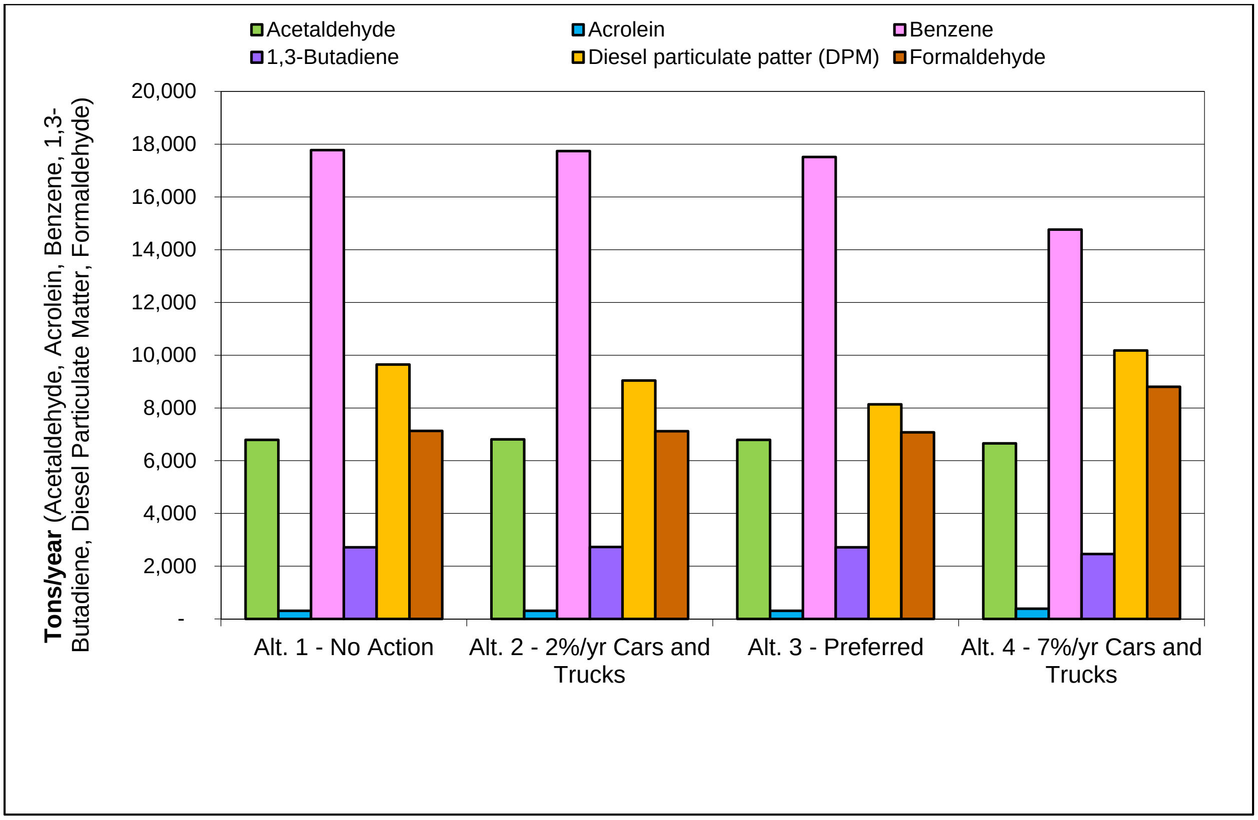
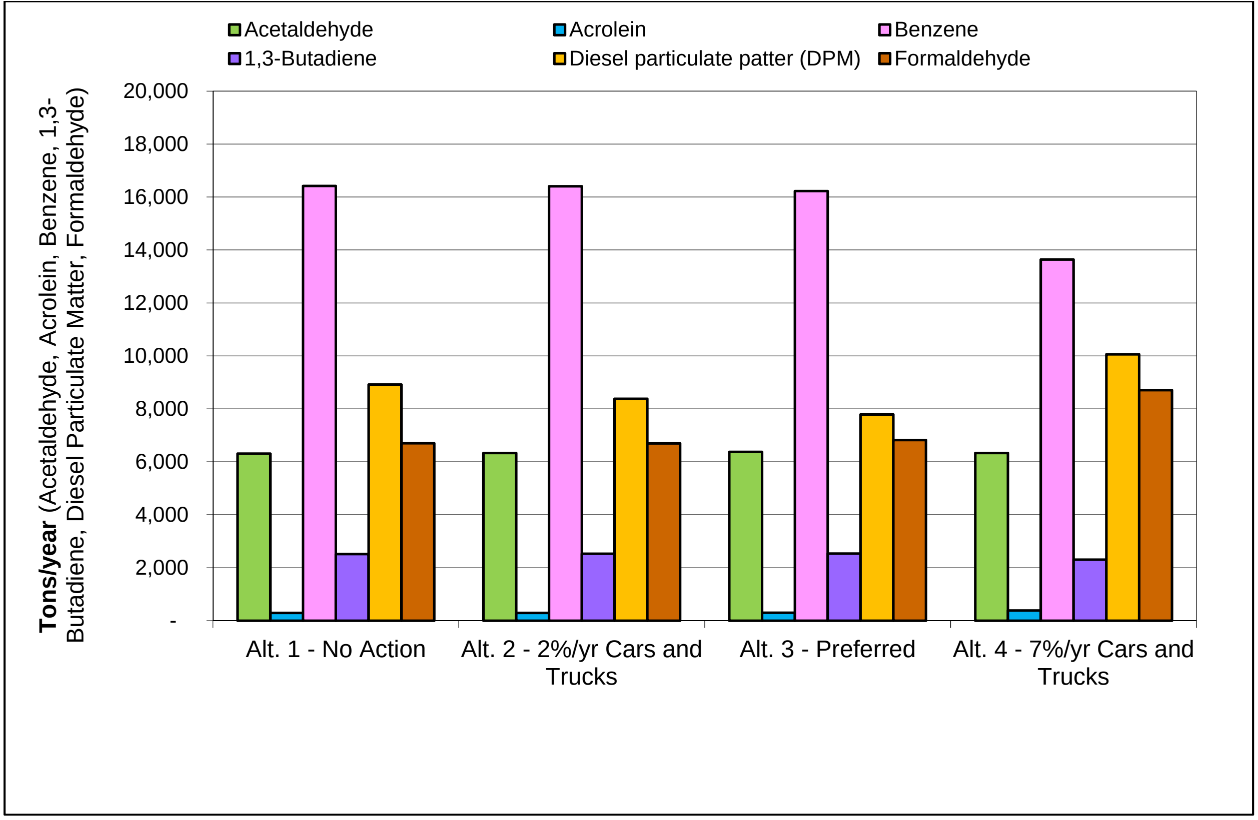


Figure S-5-B2. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis B2



Health and Monetized Health Benefits

- All action alternatives would generally result in reduced adverse health effects (mortality, chronic bronchitis, emergency room visits for asthma, and work-loss days) nationwide compared to the No Action Alternative. Exceptions to this trend in the Base Grid Mix case are Alternative 2 in 2060 and Alternative 4 in 2040 and 2060, under which adverse health outcomes increase in Analyses B1 and B2 compared to the No Action Alternative. Assuming the Alternate Grid Mix, all action alternatives would generally result in reduced adverse health effects nationwide compared to the No Action Alternative.
- Because monetized health benefits increase with reductions in adverse health effects, monetized benefits would generally increase across alternatives along with increasing fuel economy standards. When estimating quantified and monetized health impacts, EPA relies on results from two $PM_{2.5}$-related premature mortality studies it considers equivalent: Pope et al. (2002) and Laden et al. (2006). EPA recommends that monetized benefits be shown using incidence estimates derived from each of these studies and valued using a 3 percent and a 7 percent discount rate to account for an assumed lag in the occurrence of mortality after exposure, for a total of four separate calculations of monetized health benefits in each grid mix. Assuming the Base Grid Mix, estimated monetized health benefits in 2040 range from \$750 million to \$6.7 billion (\$2.3 billion to \$6.7 billion under the Preferred Alternative) in Analyses A1 and A2. In Analyses B1 and B2, monetized health impacts in 2040 range from a negative impact of \$48 million to a benefit of \$3.7 billion (\$1.0 billion to \$3.7 billion under the Preferred Alternative). With the Alternate Grid Mix, estimated monetized health

benefits in 2040 range from $1.5 billion to $9.1 billion in Analyses A1 and A2. In Analyses B1 and B2, monetized health benefits in 2040 range from $590 million to $6.3 billion.

- Under the Preferred Alternative in the Base Grid Mix case, reductions in adverse health outcomes are greater and monetized health benefits are higher than under the No Action Alternative, Alternative 2, and Alternative 4 (except in 2021). Under the Preferred Alternative in the Alternate Grid Mix case, reductions in adverse health outcomes are greater and monetized health benefits are higher than under the No Action Alternative and Alternative 2, but lower than under Alternative 4 in all years.

See Section 4.2.1 of this EIS for data on the direct effects of criteria and hazardous air pollutant emissions, and monetized health benefits for the alternatives.

Cumulative Impacts

Criteria Pollutants

- Cumulative emissions of criteria pollutants are highest under the No Action Alternative and generally decline as fuel consumption decreases across the action alternatives, as shown in Figures S-4-C1 and C2. CO is a partial exception to this general trend, with CO emissions increasing under Alternative 2, increasing or decreasing under the Preferred Alternative (depending on analysis), and decreasing further under Alternative 4 to below the level of the No Action Alternative. Increases that are projected to occur under Alternatives 2 and 3 do so because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. NO_x and SO_2 are also partial exceptions, with emissions decreasing under Alternative 2 and the Preferred Alternative but increasing under Alternative 4.
- Emissions of CO, $PM_{2.5}$, and VOCs are lowest under Alternative 4, while emissions of NO_x and SO_2 are lowest under the Preferred Alternative (except in 2021) or Alternative 4 (in 2021).
- Under the Preferred Alternative, emissions of all criteria pollutants are reduced compared to the No Action Alternative, except for CO emissions, which are slightly higher under the Preferred Alternative than under the No Action Alternative. Emissions of all criteria pollutants under the Preferred Alternative are lower than emissions under Alternative 2 (except CO emissions for some years). Emissions of $PM_{2.5}$ and VOCs under the Preferred Alternative are higher than emissions under Alternative 4, while emissions of NO_x and SO_2 under the Preferred Alternative are generally lower than emissions under Alternative 4.
- As discussed above, these results depend upon assumptions regarding the future electrical grid mix. NHTSA has also conducted an alternate analysis which examines the impacts of the action alternatives assuming a cleaner grid mix.

Figure S-4-C1. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis C1

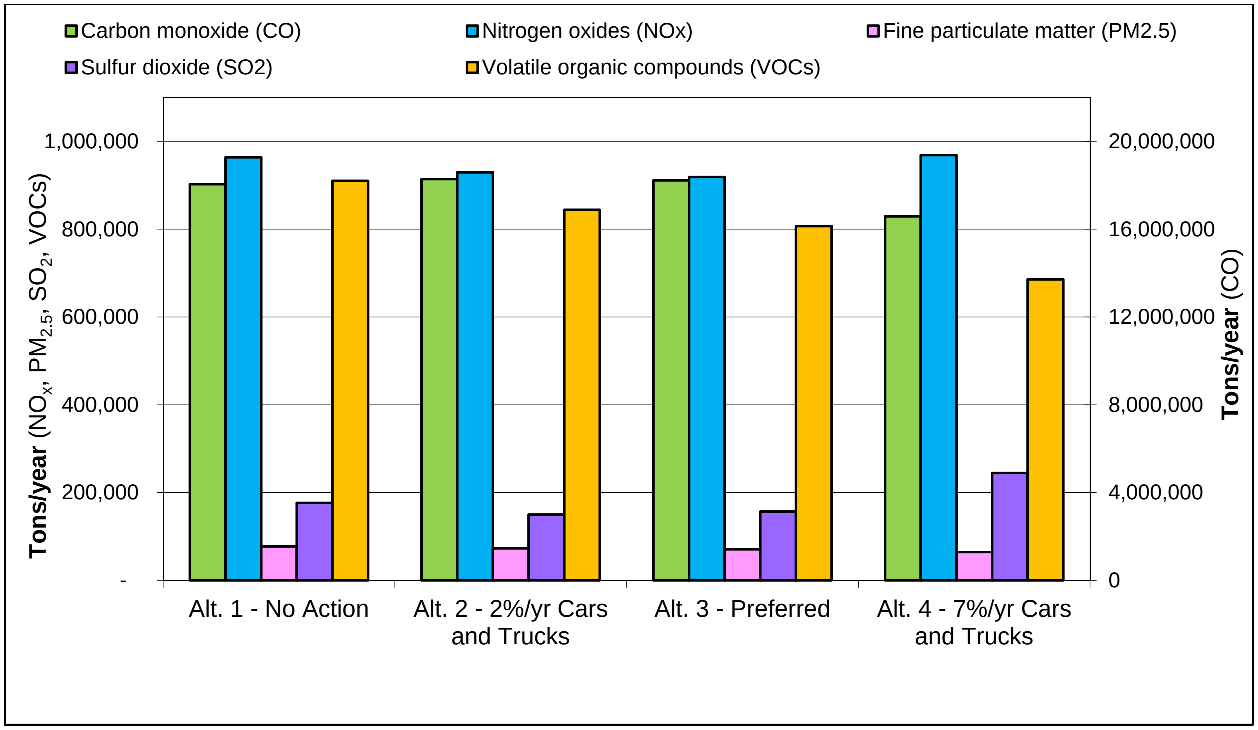
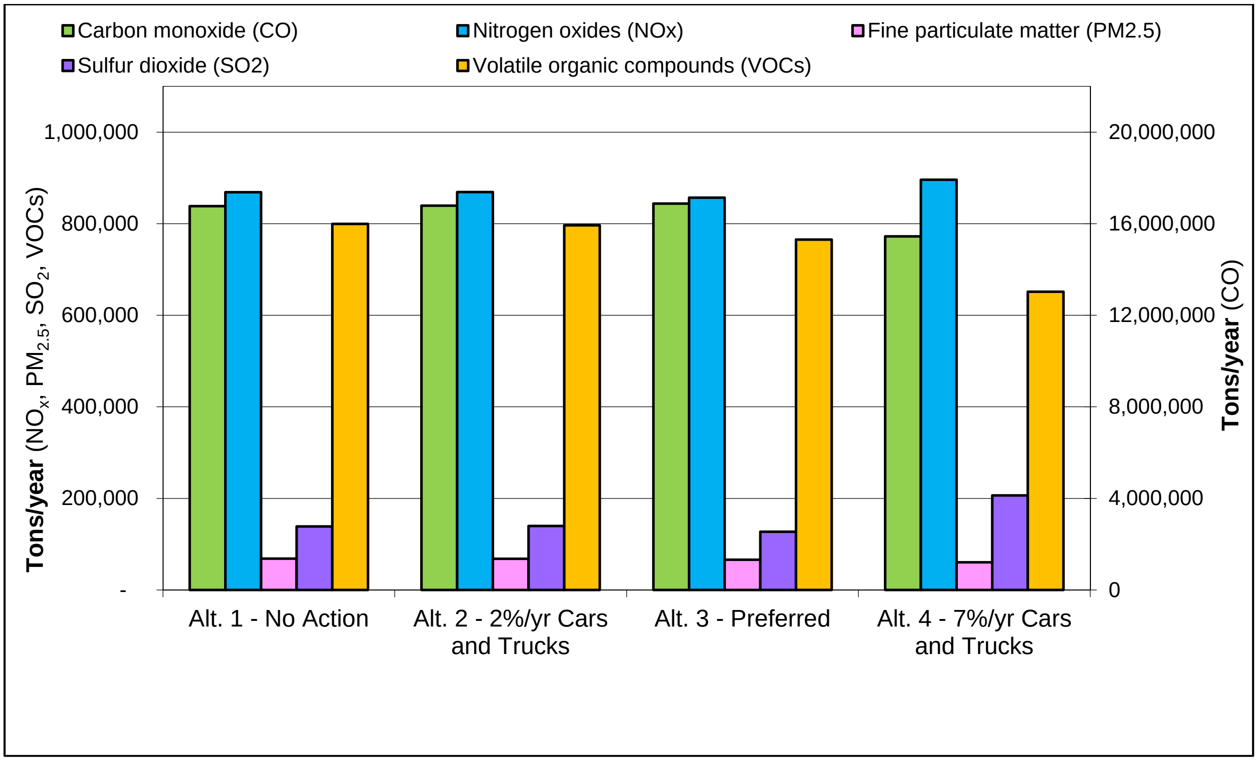


Figure S-4-C2. Nationwide Criteria Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis C2



Hazardous Air Pollutants

- Emissions of benzene generally are highest under the No Action Alternative and decline as fuel consumption decreases across the action alternatives, as shown in Figures S-5-C1 and C2. Emissions of acetaldehyde and 1,3-butadiene increase under Alternative 2 and the Preferred Alternative and generally decrease under Alternative 4. Emissions of DPM are highest under the No Action Alternative, decrease under Alternative 2 and the Preferred Alternative, and decrease by a lesser amount under Alternative 4. Emissions of acrolein and formaldehyde generally increase with decreasing fuel consumption across all the action alternatives because of increased driving due to the rebound effect.
- Emissions of benzene and 1,3-butadiene generally are lowest under Alternative 4, while emissions of acrolein, are lowest under the No Action Alternative. Emissions of DPM are lowest under the Preferred Alternative or Alternative 4, depending on the analysis. Emissions of acetaldehyde are the lowest under the No Action Alternative or Alternative 4, depending on the analysis, and emissions of formaldehyde are lowest under the Alternative 2 or the Preferred Alternative, depending on the analysis.
- Under the Preferred Alternative, emissions of acetaldehyde and acrolein generally increase compared to the No Action Alternative. Emissions of benzene under the Preferred Alternative generally are lower than under Alternative 2 and higher than under Alternative 4. Emissions of 1,3-butadiene under the Preferred Alternative are slightly higher than under Alternative 2 and generally higher than under Alternative 4. Under the Preferred Alternative, emissions of DPM are reduced compared to the No Action Alternative, but are higher or lower than under Alternative 4, depending on the analysis. Formaldehyde emissions under the Preferred Alternative are either higher or lower compared to the No Action Alternative, depending on the analysis, but lower than under Alternative 4.

Figure S-5-C1. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis C1

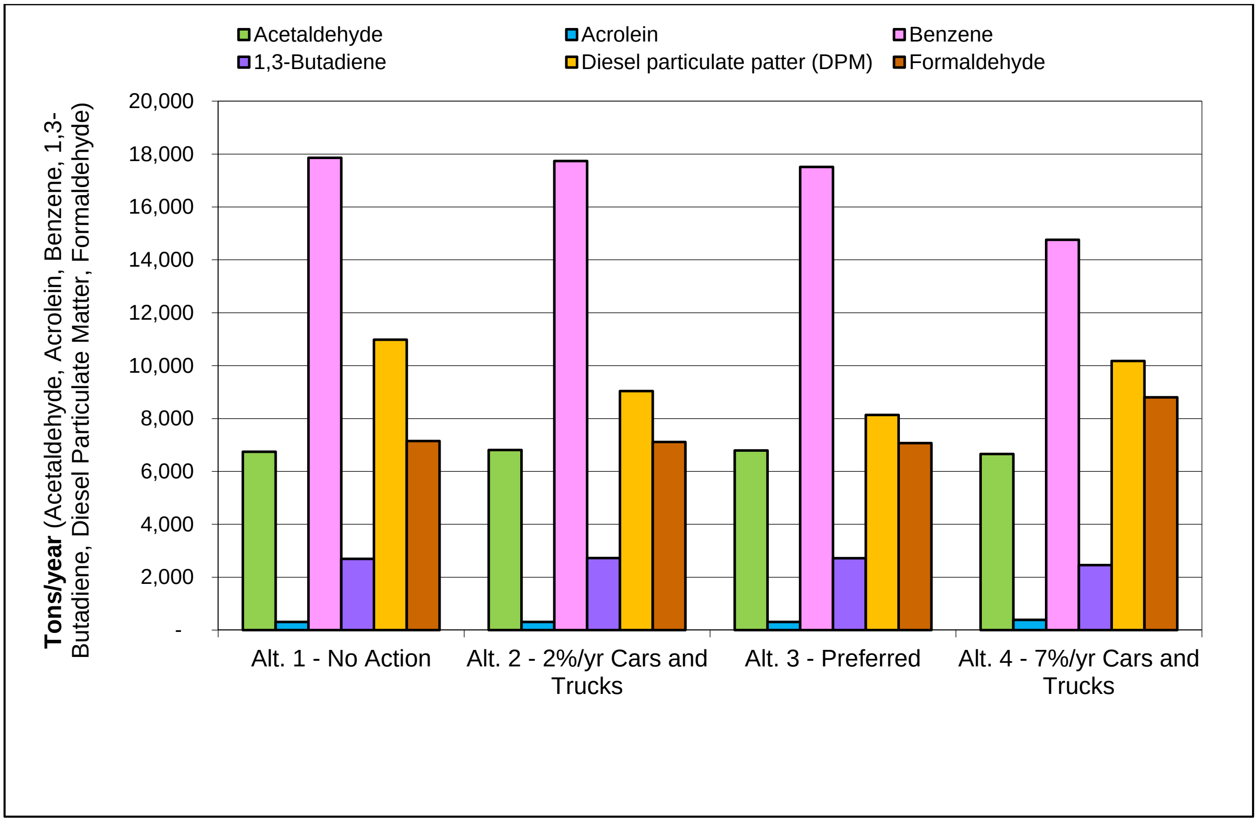
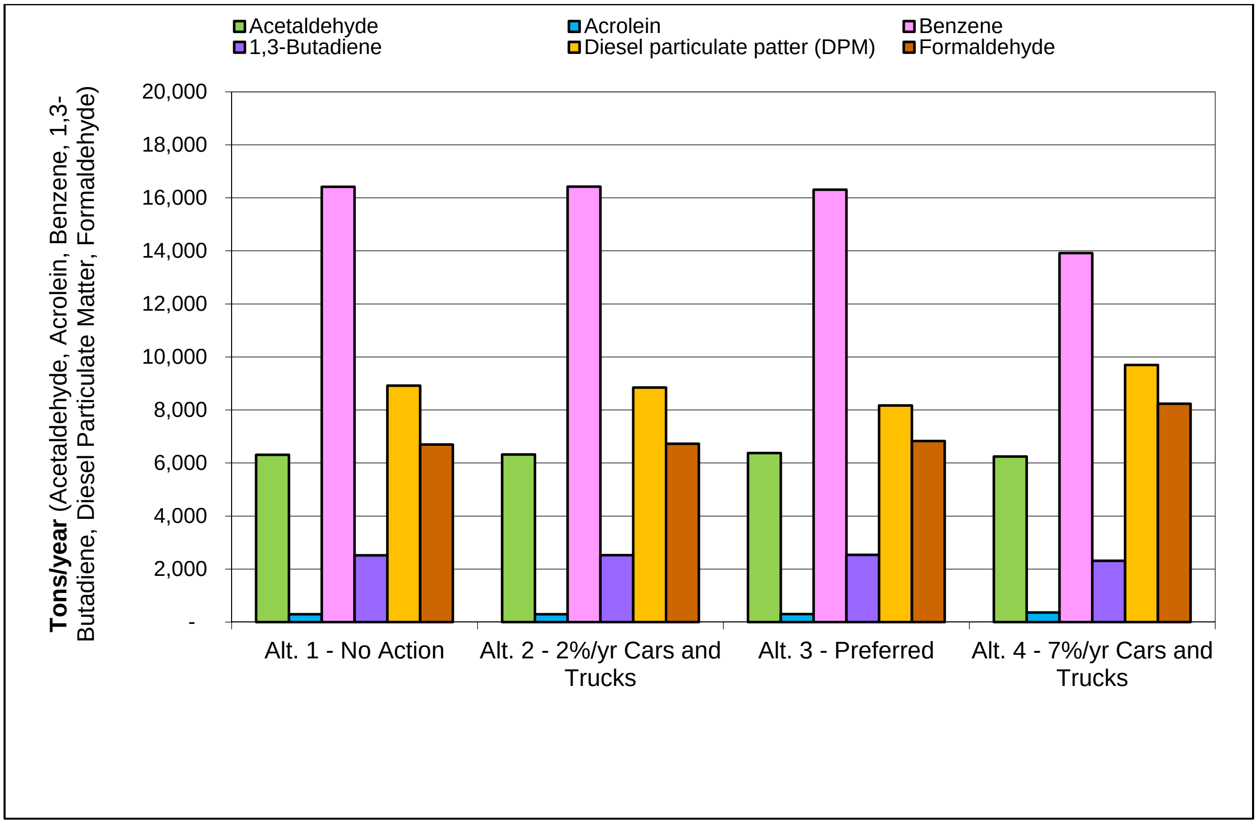


Figure S-5-C2. Nationwide Toxic Air Pollutant Emissions (tons/year) from U.S. Passenger Cars and Light Trucks for 2040 by Alternative, Analysis C2



Health and Monetized Health Benefits

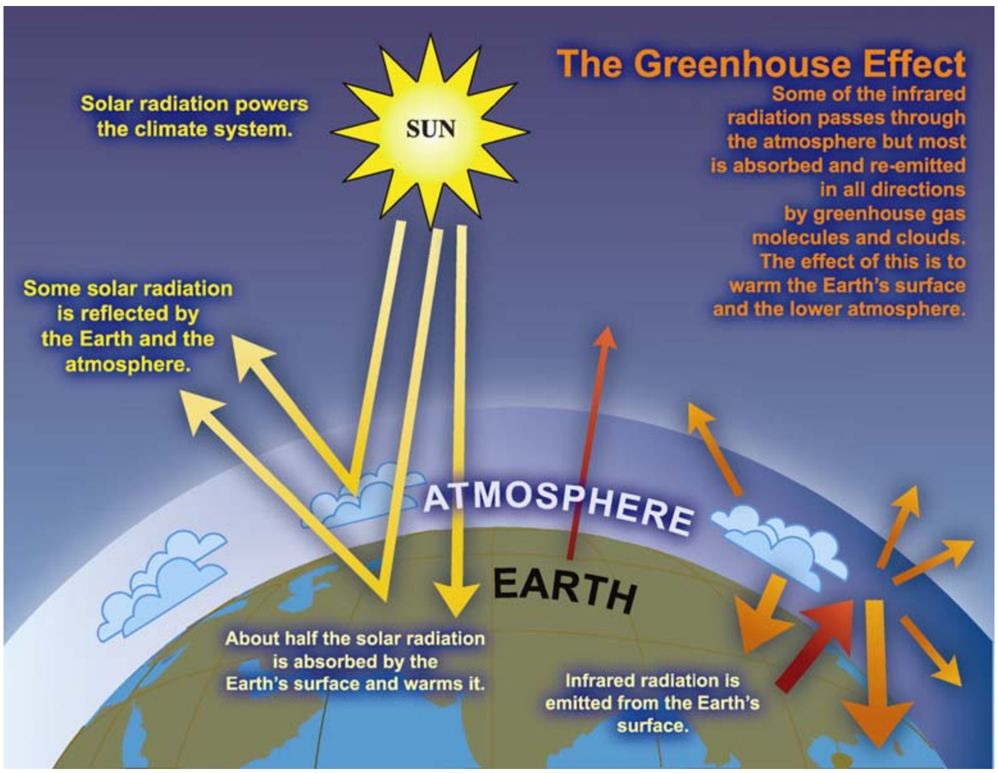
- Alternatives 2 through 4 would result in reduced adverse health effects nationwide compared to the No Action Alternative. Reductions generally increase as fuel consumption decreases across alternatives.
- The monetized health benefits follow the same patterns as the reductions in adverse health effects. In the Base Grid Mix case, estimated annual monetized health benefits in 2040 range from a low of \$1.6 billion to a high of \$7.6 billion (\$2.6 billion to \$7.6 billion under the Preferred Alternative). In the Alternate Grid Mix case, estimated monetized health benefits in 2040 range from \$2.0 billion to \$10.0 billion (\$2.2 billion to \$6.7 billion under the Preferred Alternative).
- Under the Preferred Alternative with the Base Grid Mix, cumulative reductions in adverse health outcomes are greater and monetized health benefits are higher than under the No Action Alternative, Alternative 2, and Alternative 4. Under the Preferred Alternative with the Alternate Grid Mix, reductions in adverse health outcomes are greater and monetized health benefits are higher than under the No Action Alternative and Alternative 2, but lower than under Alternative 4.

See Section 4.2.2 of this EIS for cumulative effects data on criteria and hazardous air pollutant emissions*,* monetized health benefits for the alternatives.

Climate

Earth's natural greenhouse effect is responsible for maintaining surface temperatures warm enough to sustain life (*see* Figure S-6). Human activities emit greenhouse gases (GHGs) to the atmosphere through the combustion of fossil fuels, industrial processes, solvent use, land-use change, forest management, agricultural production, and waste management. Carbon Dioxide (CO_2) and other GHGs trap heat in the troposphere (the layer of the atmosphere that extends from Earth's surface up to approximately 8 miles), absorb heat energy emitted by Earth's surface and its lower atmosphere, and radiate much of it back to the surface. Without GHGs in the atmosphere, most of this heat energy would escape back to space.

Figure S-6. The Greenhouse Effect



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

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

Since the industrial revolution, when fossil fuels began to be burned in increasing quantities, concentrations of GHGs in the atmosphere have increased. CO_2 has increased by more than 38 percent since pre-industrial times, while the concentration of CH_4 is now 149 percent above pre-industrial levels.

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

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

A recent National Research Council (NRC) report stated that there is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that the changes are largely caused by human activities. These activities – such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees – contribute to increased concentrations of GHGs in the atmosphere, which in turn trap increasing amounts of heat, altering Earth's energy balance.

Throughout this EIS, NHTSA has relied extensively on findings of the United Nations Intergovernmental Panel on Climate Change (IPCC), the U.S. Climate Change Science Program (CCSP), the NRC, the Arctic Council, the U.S. Global Change Research Program (GCRP), and EPA. This discussion focuses heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and U.S. climate change. *See* Section 5.1 of this EIS for more detail.

Impacts of Climate Change

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

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

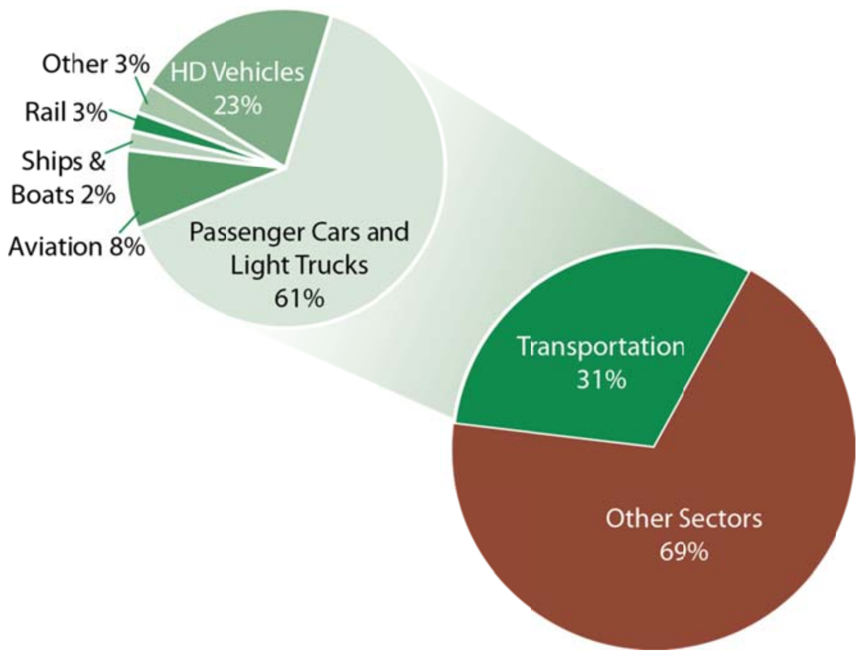
In addition to its role as a GHG in the atmosphere, CO_2 is transferred from the atmosphere to water, plants, and soil. In water, CO_2 combines with water molecules to form carbonic acid. When CO_2 dissolves in seawater, a series of well-known chemical reactions begins that increases the concentration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

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

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

Contributions to the buildup of GHGs in the atmosphere vary greatly from country to country and depend heavily on the level of industrial and economic activity. Emissions from the United States account for approximately 17.4 percent of total global CO_2 emissions (based on comprehensive global CO_2 emissions data available for 2005). As shown in Figure S-7, the U.S. transportation sector contributed 31 percent of total U.S. CO_2 emissions in 2010, with passenger cars and light trucks accounting for 61 percent of total U.S. CO_2 emissions from transportation. Therefore, 18.8 percent of total U.S. CO_2 emissions come from passenger cars and light trucks. From a global perspective, U.S. passenger cars and light trucks account for roughly 3.3 percent of total global CO_2 emissions.

Figure S-7. Contribution of Transportation to U.S. CO2 Emissions and Proportion Attributable by Mode, 2010



HD = heavy-duty

Source: EPA (U.S. Environmental Protection Agency). 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010. Tables 2-14 and 2-15. Washington, D.C. EPA 430-R-12-001. Available at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>. (Accessed: April 20, 2012).

Key Findings for Climate

The action alternatives would decrease the growth in global GHG emissions when compared to the No Action Alternative, resulting in reductions in the anticipated increases that are otherwise projected to occur in CO_2 concentrations, temperature, precipitation, and sea level. They would also, to a small degree, reduce the impacts and risks of climate change.

Note that under the No Action Alternative, total CO_2, CH_4, and N_2O emissions from passenger cars and light trucks in the United States are projected to substantially increase between 2017 and 2100 in Analyses A1 and A2, while undergoing little to moderate growth in Analyses B1 and B2. Growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in a growth in VMT. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

NHTSA estimates that the action alternatives would reduce fuel consumption and CO_2 emissions from what they would be in the absence of the standards (i.e., fuel consumption and CO_2 emissions under the No Action Alternative) (*see* Figures S-8-A1, A2, B1, and B2).

The global emissions scenario used in the cumulative effects analysis (and described in Chapter 5 of this EIS) differs from the global emissions scenario used for climate change modeling of direct and indirect effects. In the cumulative effects analysis, the Reference Case global emissions scenario used in the climate modeling analysis reflects reasonably foreseeable actions in global climate change policy; in contrast, the global emissions scenario used for the analysis of direct and indirect effects assumes that no significant global controls on GHG emissions are adopted. *See* Section 5.3.3.2.2 of the EIS for more explanation of the cumulative effects methodology.

Estimates of GHG emissions and reductions (direct and indirect impacts and cumulative impacts) are presented below for each of the four alternatives. Key climate effects, such as mean global increase in surface temperature and sea-level rise, which result from changes in GHG emissions, are also presented for each of the four alternatives. These effects are typically modeled to 2100 or longer due to the amount of time required for the climate system to show the effects of the GHG (or in this case, emission) reductions. This inertia primarily reflects the amount of time required for the ocean to warm in response to increased radiative forcing.

The impacts of the action alternatives on global mean surface temperature, precipitation, or sea-level rise are small in relation to the expected changes associated with the emissions trajectories that assume that no significant global controls on GHG emissions are adopted. This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lasting; therefore, in aggregate they can have large consequences for health and welfare and would be an important contribution to reducing the risks associated with climate change.

Direct and Indirect Impacts

Greenhouse Gas Emissions

- In Analyses A1 and A2, U.S. passenger cars and light trucks are projected to emit between 138,800 and 155,400 million metric tons of carbon dioxide ($MMTCO_2$) in the period 2017–2100. In Analyses B1 and B2, these vehicles are projected to emit between 111,400 and 124,100 $MMTCO_2$. The action alternatives would reduce these emissions by 12 to 28 percent in Analyses A1 and A2 and by 2 to 18 percent in Analyses B1 and B2 by 2100. Figures S-8-A1, A2, B1, and B2 show projected annual CO_2 emissions from passenger cars and light trucks under each alternative. As shown in the figures, emissions are highest under the No Action Alternative, while Alternatives 2 through 4 show increasing reductions in emissions compared to the No Action Alternative.

- Compared to total projected U.S. emissions of 7,193 $MMTCO_2$ under the No Action Alternative in 2100, the action alternatives are expected to reduce U.S. CO_2 emissions in 2100 by between 3.2 and 8.3 percent in Analysis A and between 0.1 and 3.6 percent in Analysis B.
- Compared to total global CO_2 emissions from all sources of 5,099,256 $MMTCO_2$ under the No Action Alternative from 2017 through 2100, the action alternatives are expected to reduce global CO_2 emissions by between 0.33 and 0.84 percent in Analysis A and between 0.05 and 0.43 percent in Analysis B by 2100.
- The emission reductions under the alternatives are equivalent to the annual emissions from between 14.8 and 36.9 million passenger cars and light trucks in 2025 in Analysis A and between 9.2 and 30.6 million passenger cars and light trucks in Analysis B, compared to the No Action Alternative. Emission reductions in 2025 under the Preferred Alternative fall within this range, and are projected to be equivalent to a reduction of between 22.9 to 23.3 million passenger cars and light trucks in Analysis A and 17.5 million passenger cars and light trucks in Analysis B.

Figure S-8-A1. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A1

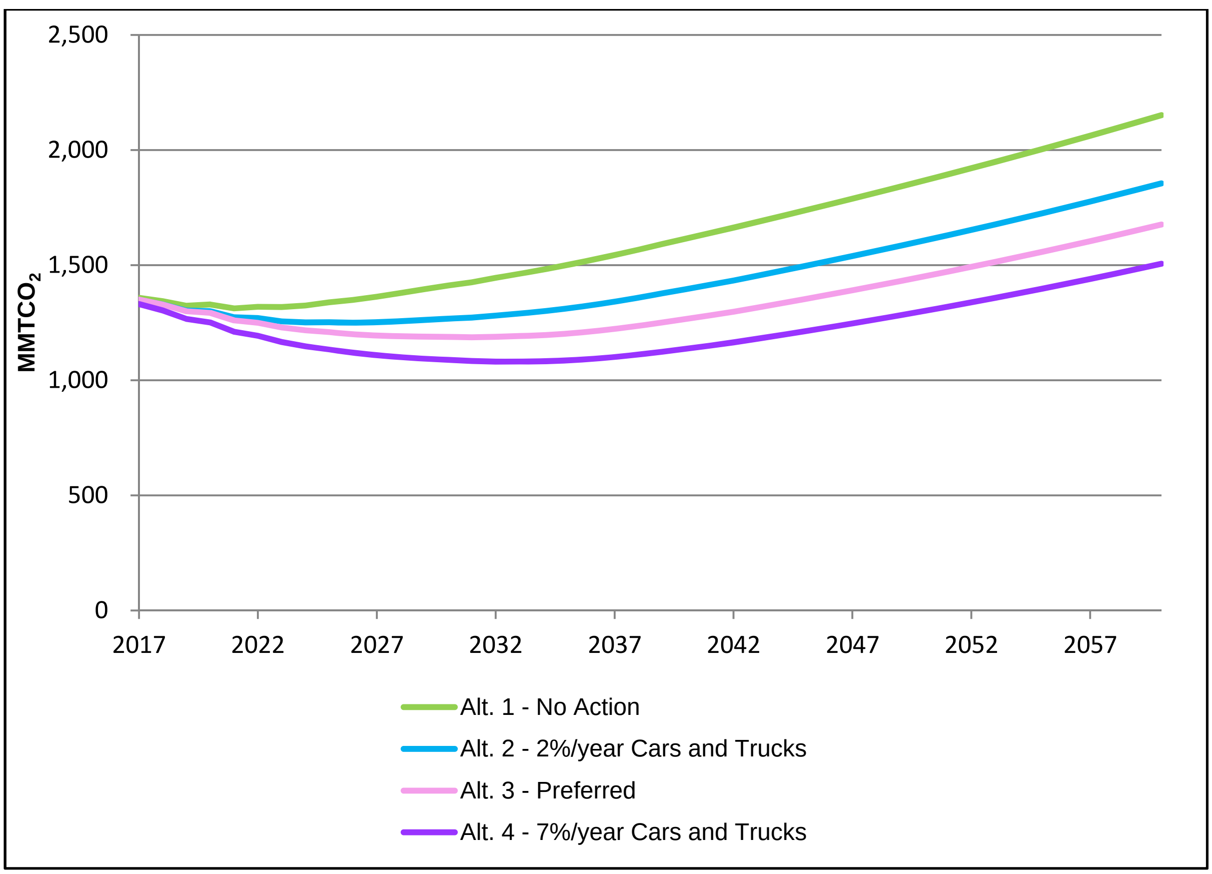


Figure S-8-A2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A2

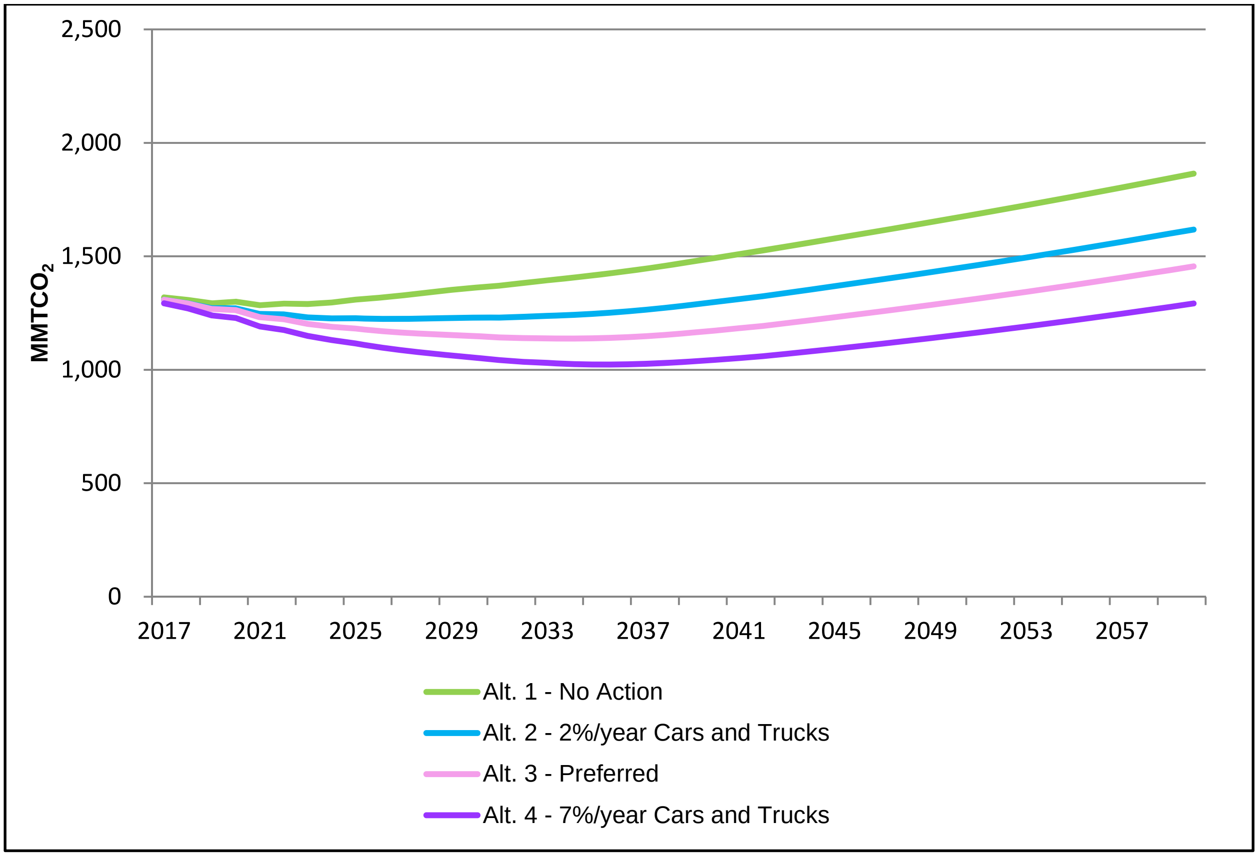


Figure S-8-B1. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B1

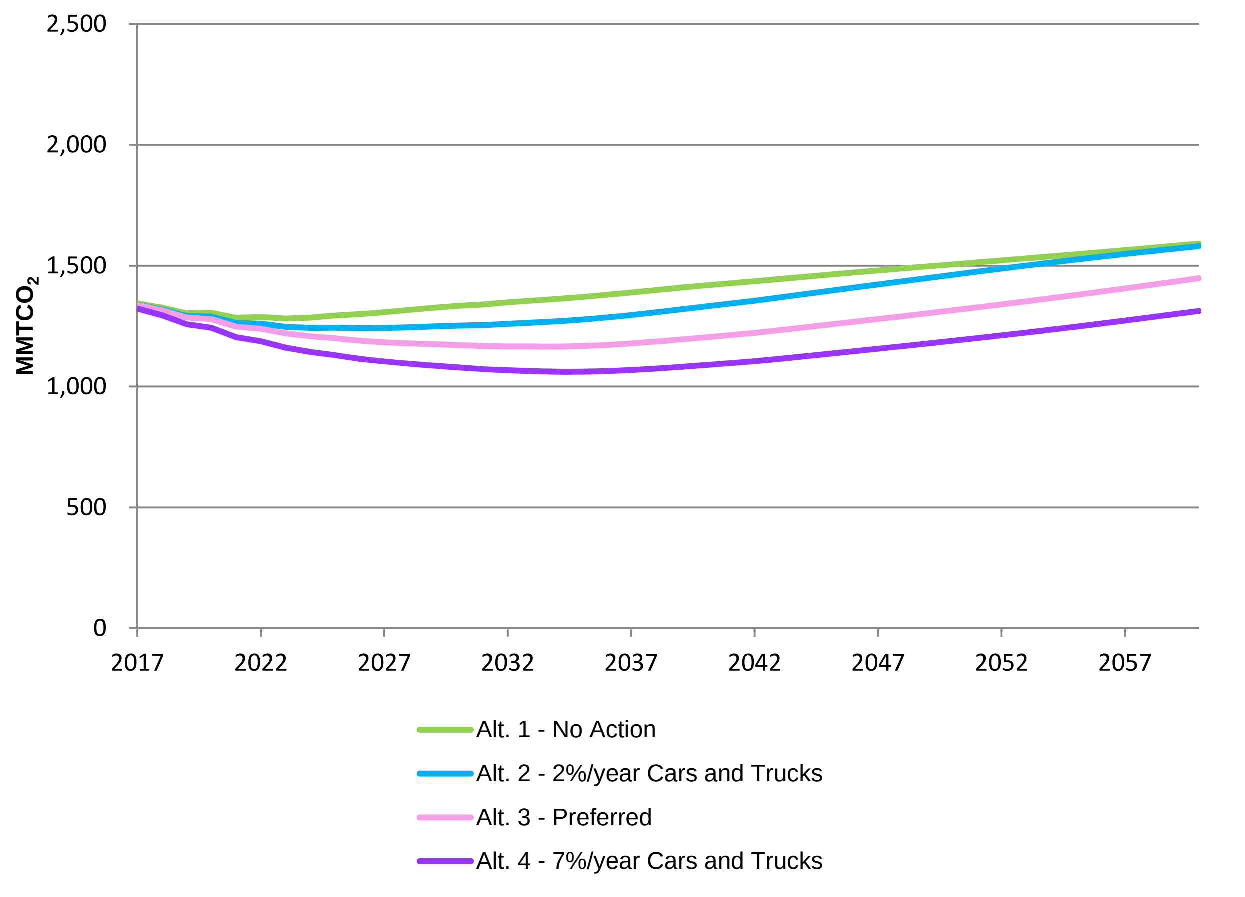
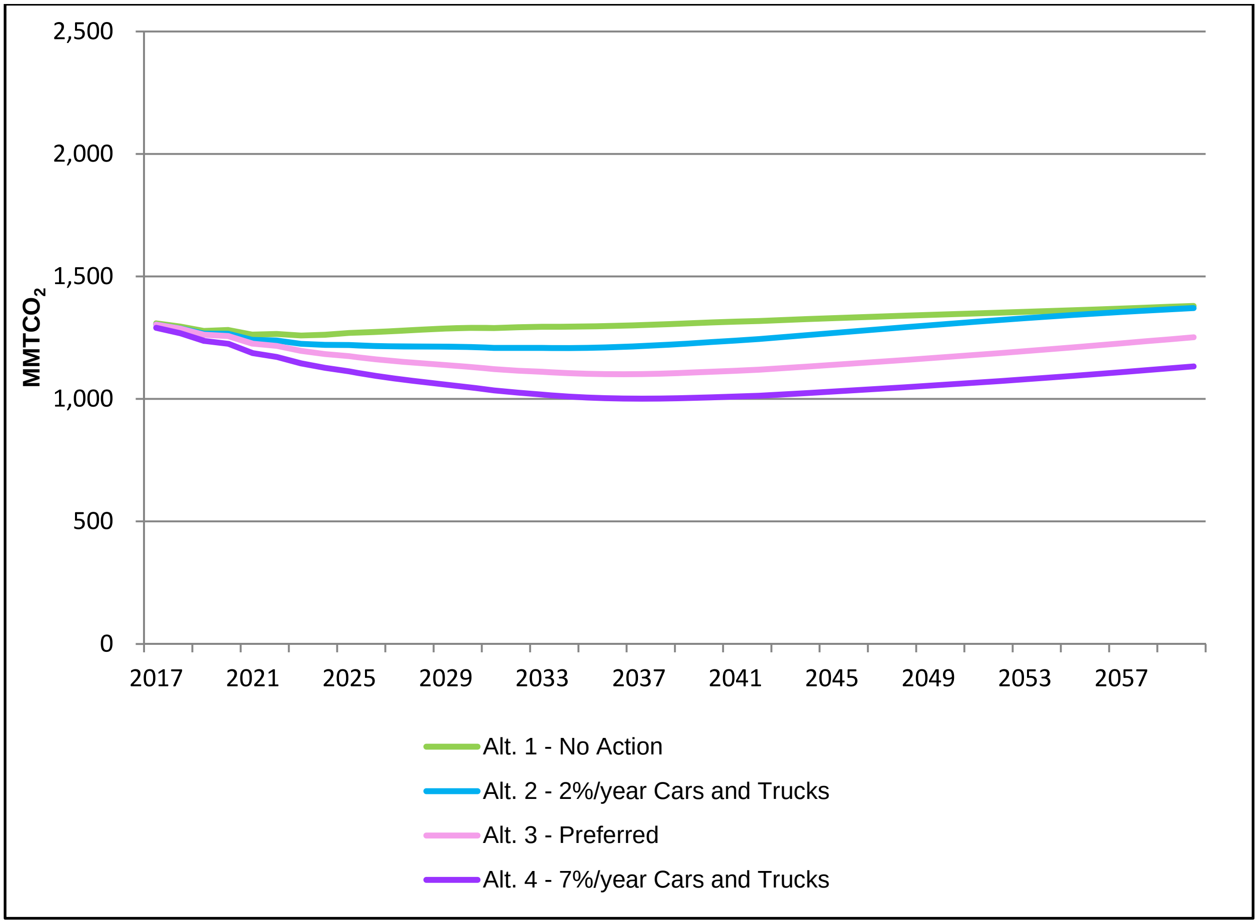


Figure S-8-B2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B2



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

CO_2 emissions affect the concentration of CO_2 in the atmosphere, which in turn affects global temperature, sea level, and precipitation patterns. For the analysis of direct and indirect effects, NHTSA used the GCAMReference scenario to represent the Reference Case emissions scenario; that is, future global emissions assuming no additional climate policy. The impacts of the Proposed Action and alternatives on temperature, precipitation, or sea-level rise are small in absolute terms because the action alternatives result in a small proportional change to the emissions trajectories in the Reference Case scenario to which the alternatives were compared. Although these effects are small, they occur on a global scale and are long-lasting, and would be an important contribution to reducing the risks associated with climate change.

- Estimated CO_2 concentrations in the atmosphere for 2100 would range from approximately 781 parts per million (ppm) in Analysis A and 783 ppm in Analysis B under Alternative 4 to approximately 785 ppm under the No Action Alternative, indicating a maximum atmospheric CO_2 reduction of approximately 4 ppm from the No Action Alternative in Analysis A and 2 ppm in Analysis B. The Preferred Alternative would reduce global CO_2 concentrations by approximately 3.0 ppm in Analysis A and 1.1 ppm in Analysis B from CO_2 concentrations under the No Action Alternative.

- Global mean surface temperature is anticipated to increase by approximately 3.06 °C (5.51 °F) under the No Action Alternative by 2100. Implementing the most stringent alternative (Alternative 4) would reduce this projected temperature increase by between 0.014 and 0.015 °C (0.025 and 0.027 °F) in Analysis A and between 0.007 and 0.008 °C (0.013 and 0.014 °F) in Analysis B, while implementing Alternative 2 would reduce projected temperature increase by up to 0.006 °C (0.011 °F) in Analysis A and 0.001 °C (0.002 °F) in Analysis B. Falling between these two levels, the Preferred Alternative would decrease projected temperature increase under the No Action Alternative by between 0.009 and 0.010 °C (0.016 and 0.018 °F) in Analysis A and 0.004 °C (0.007 °F) in Analysis B. Figures S-9-A1, A2, B1, and B2 demonstrate show in the growth of projected global mean temperature under each action alternative compared to the No Action Alternative.
- Projected sea-level rise in 2100 ranges from a high of 37.40 centimeters (14.72 inches) under the No Action Alternative to a low of 37.26 centimeters (14.67 inches) in Analysis A and 37.32 centimeters (14.69 inches) in Analysis B under Alternative 4. Therefore, the action alternatives would result in a maximum reduction of sea-level rise equal to 0.14 centimeter (0.06 inch) in Analysis A and 0.08 centimeter (0.03 inch) in Analysis B by 2100 from the level projected under the No Action Alternative. Sea-level rise under the Preferred Alternative would be reduced by between 0.09 centimeter and 0.10 centimeter (0.035 and 0.039 inch) in Analysis A to between 0.04 centimeter and 0.05 centimeter (0.016 and 0.020 inch) in Analysis B from the No Action Alternative.
- Global mean precipitation is anticipated to increase by 4.50 percent by 2090 under the No Action Alternative. Under the action alternatives, this increase would be reduced by approximately 0.02 percent under Alternative 4 to between 0.00 percent and 0.01 percent under Alternative 2. The Preferred Alternative would result in a reduction of between 0.01 percent and 0.02 percent in Analysis A (0.01 percent in Analysis B) in global mean precipitation increase, indicating a total increase of 4.49 percent in Analysis A (4.50 percent in Analysis B).

Figure S-9-A1. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis A1

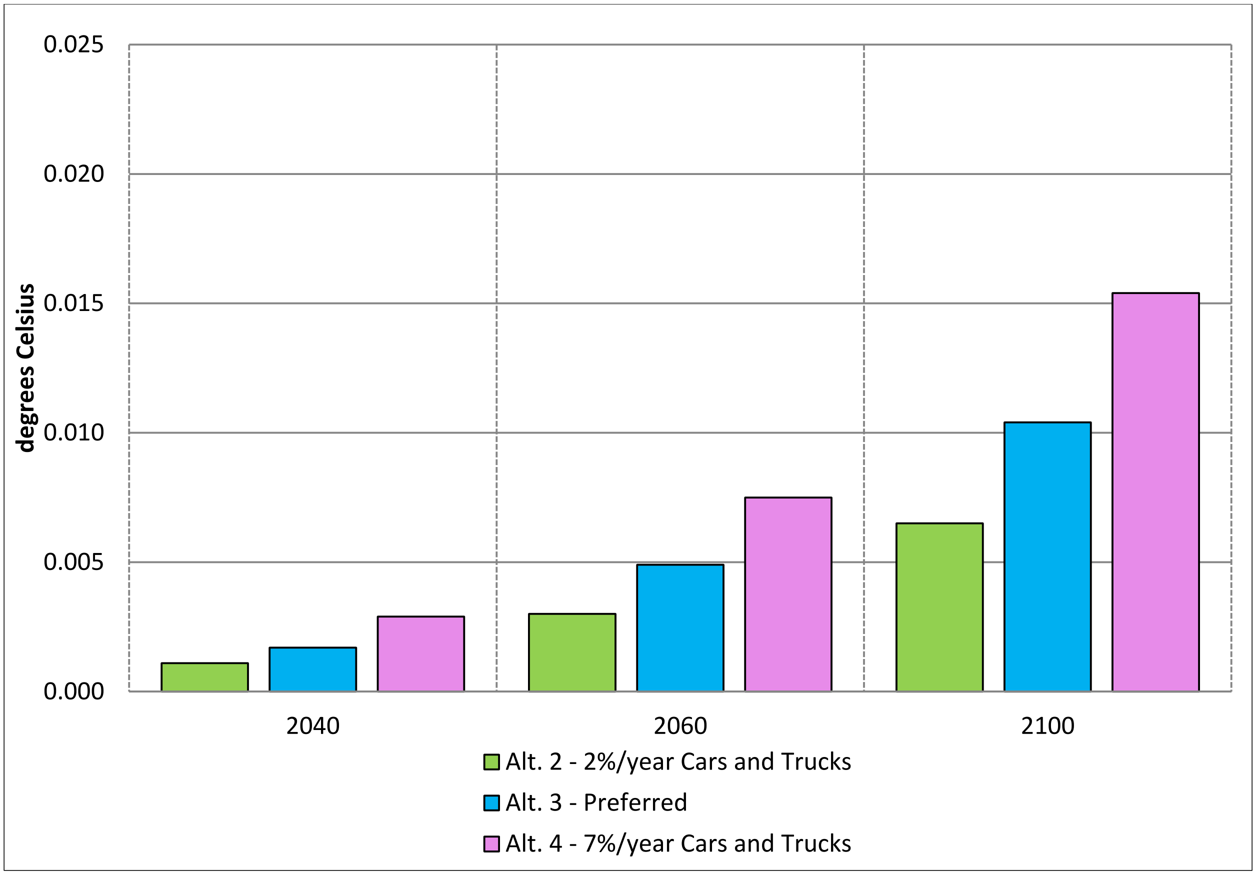


Figure S-9-A2. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis A2

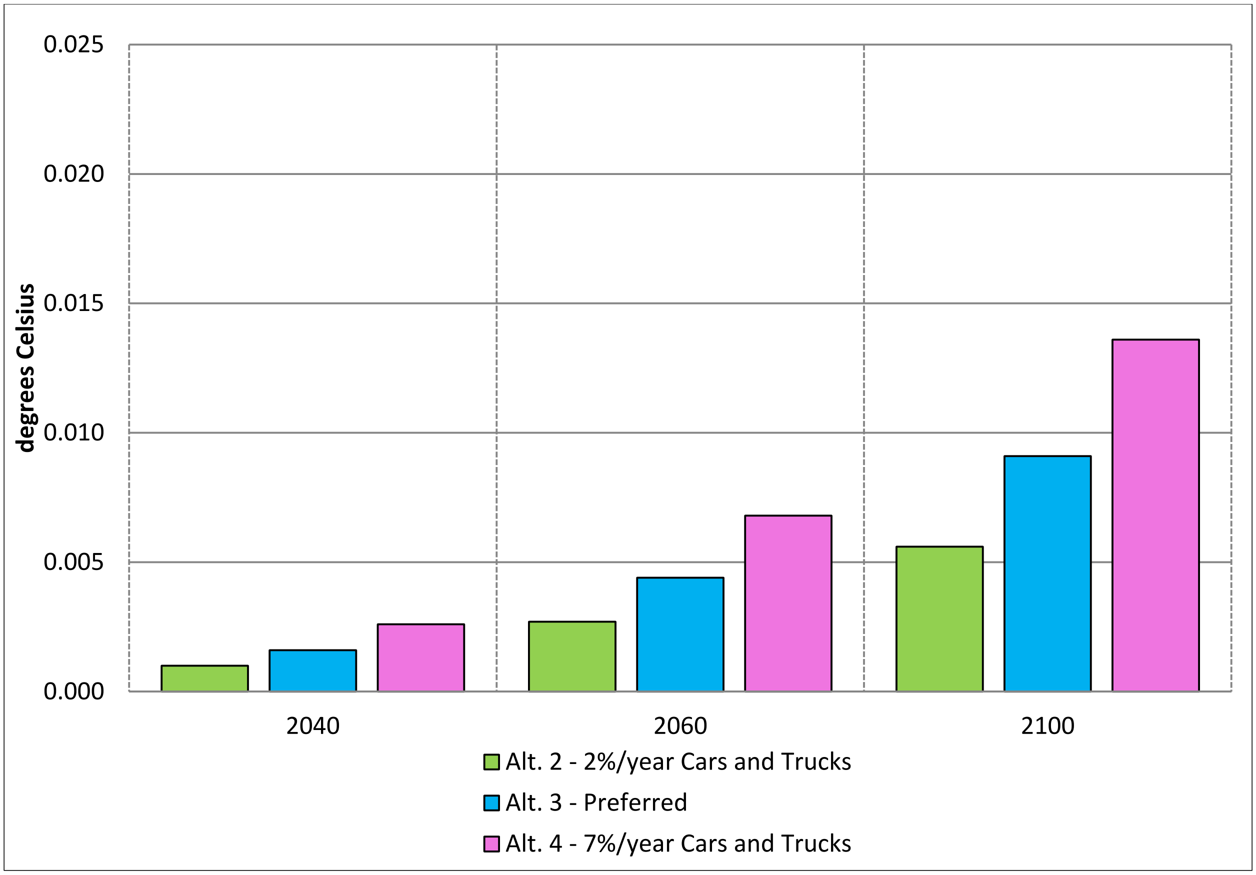


Figure S-9-B1. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis B1

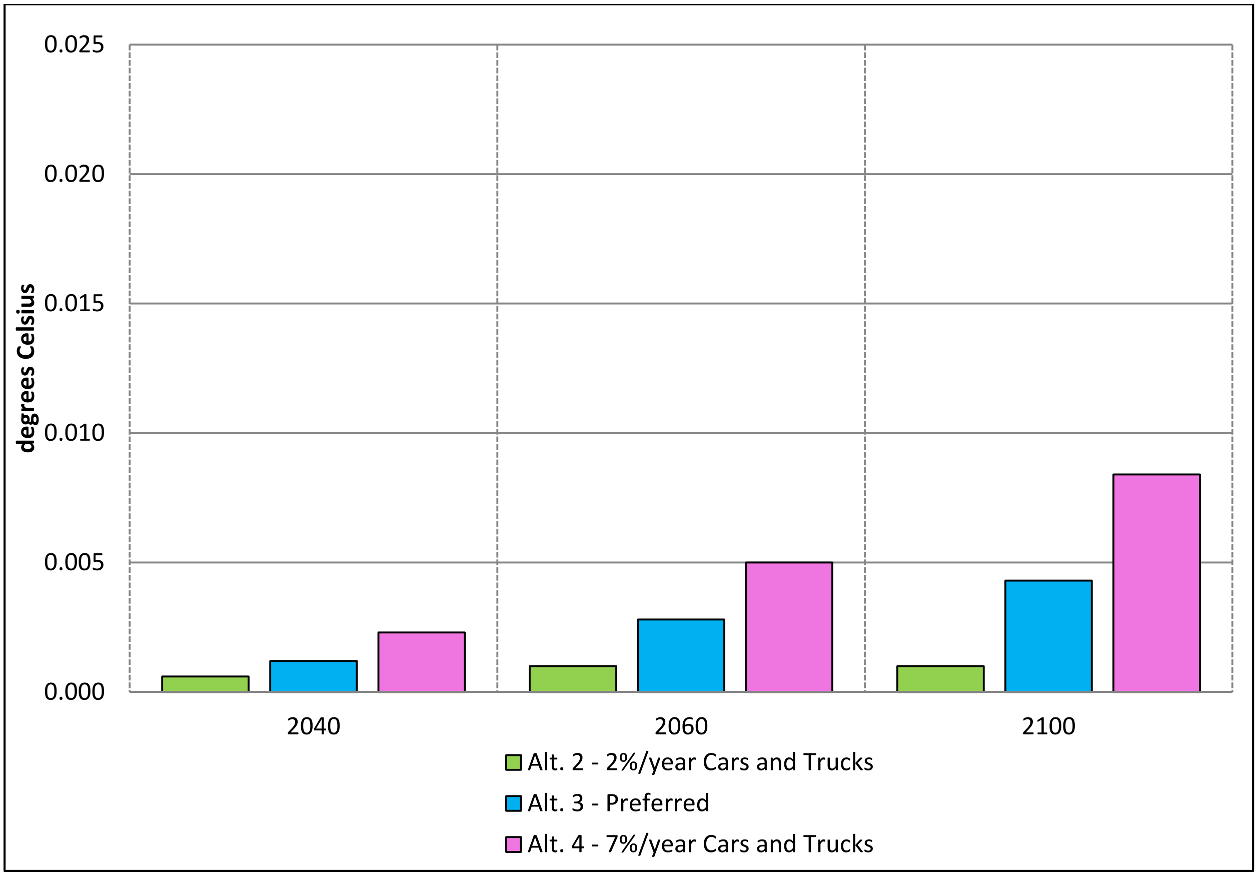
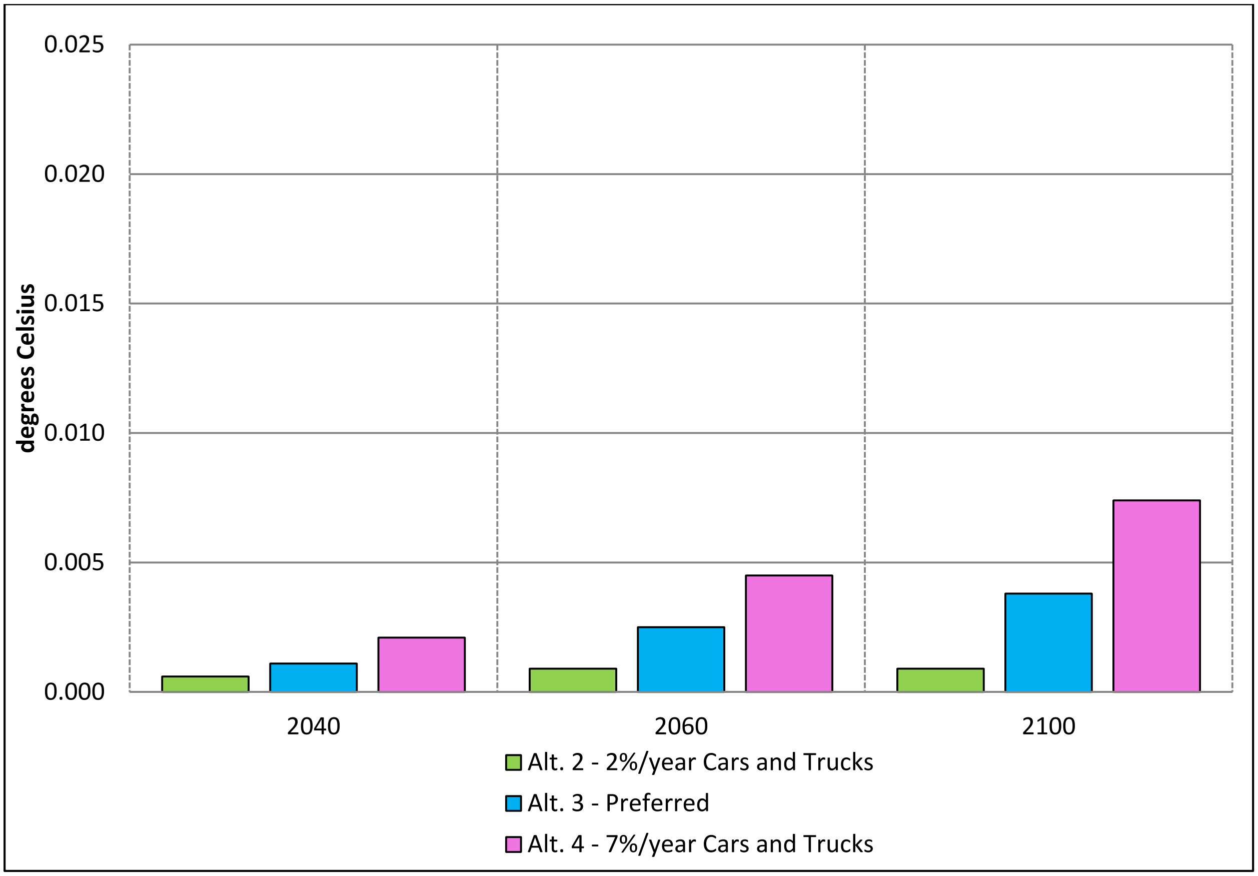


Figure S-9-B2. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis B2



Cumulative Impacts

Greenhouse Gas Emissions

- Projections of total emission reductions over the 2017–2100 period under the action alternatives and other reasonably foreseeable future actions (i.e., forecasted fuel-efficiency increases resulting from market-driven demand) range from 29,800 to 53,300 $MMTCO_2$ compared to the No Action Alternative. The action alternatives would reduce total U.S. passenger car and light-truck emissions by between 22 and 34 percent by 2100. Figures S-8-C1 and C2 show projected annual CO_2 emissions from U.S. passenger cars and light trucks by alternative compared to the No Action Alternative.
- Compared to projected total global CO_2 emissions from all sources of 4,190,614 $MMTCO_2$ from 2017 through 2100, the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.7 to 1.3 percent across all action alternatives from their projected levels under the No Action Alternative.

Figure S-8-C1. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis C1

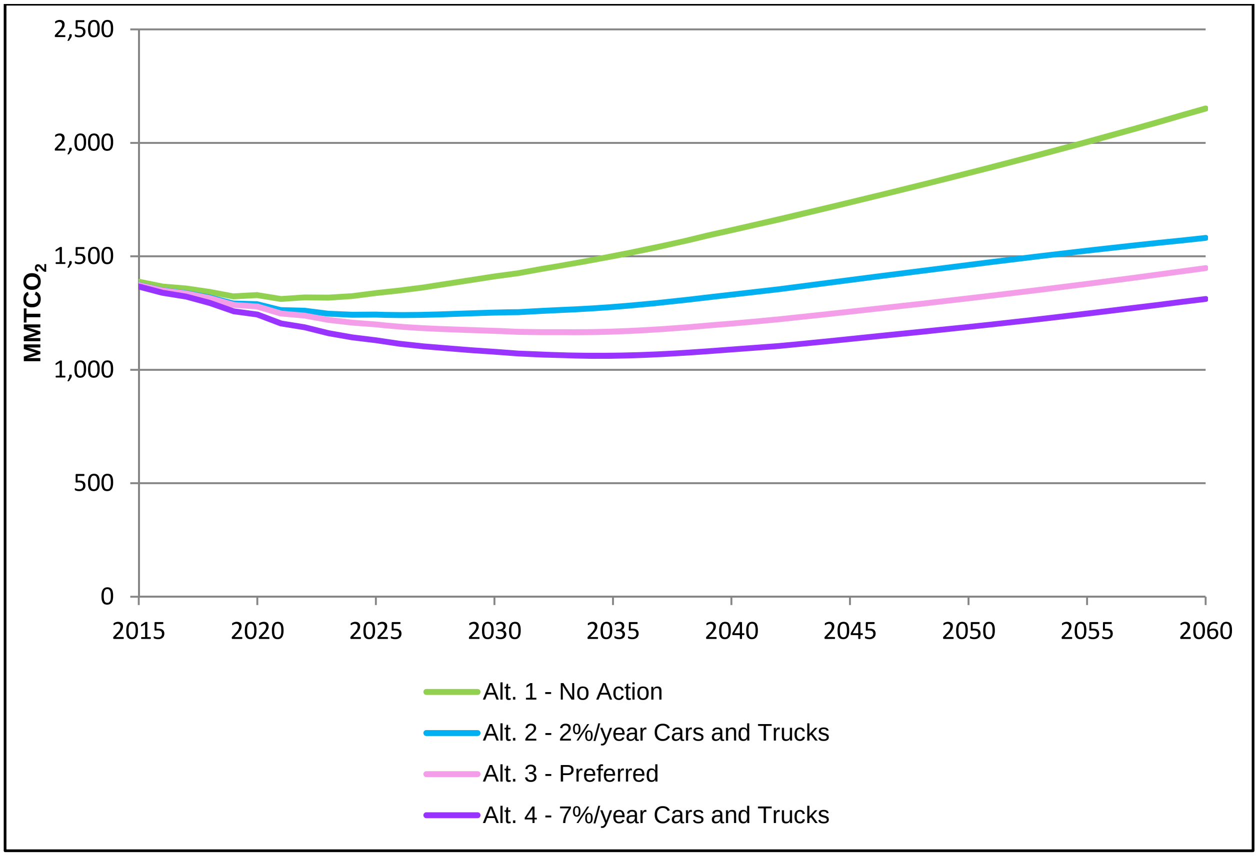
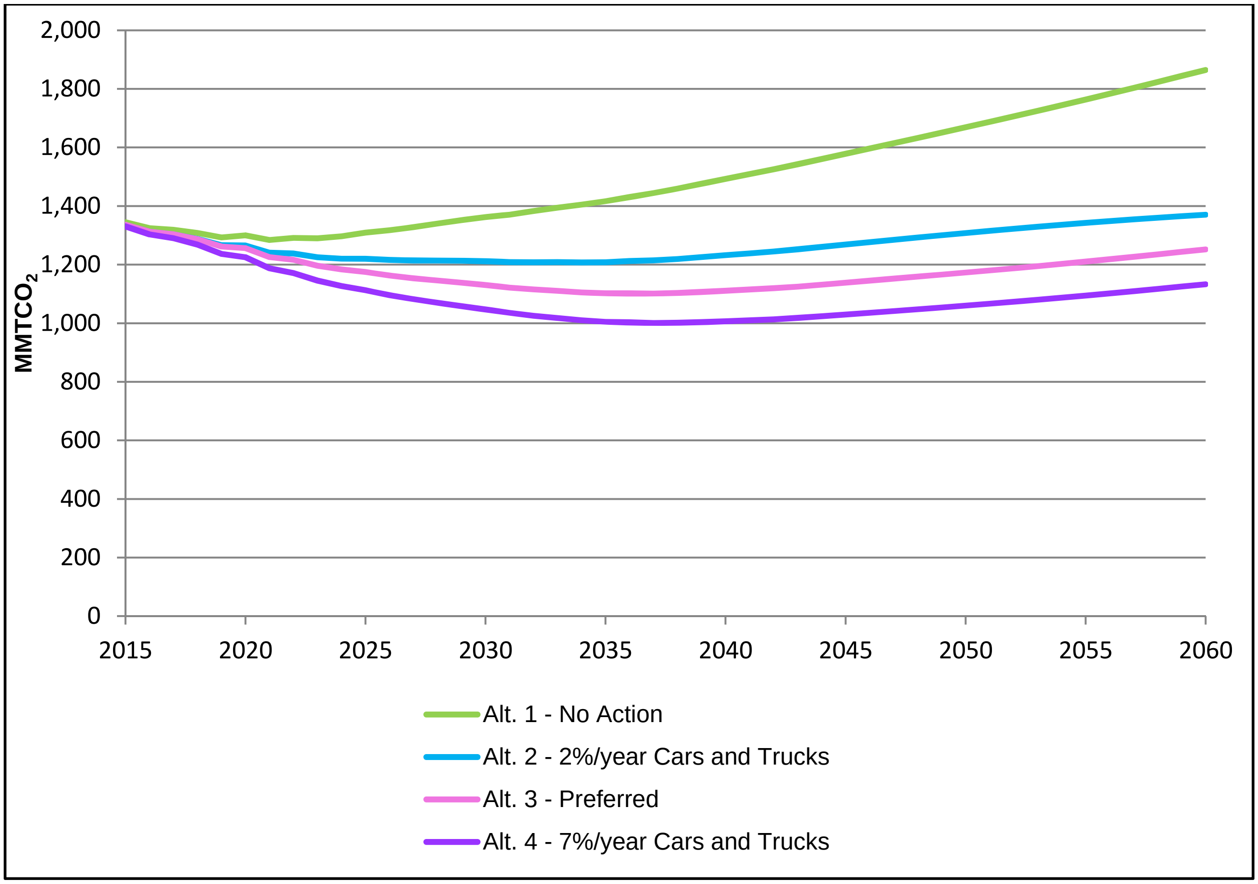


Figure S-8-C2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis C2



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

- Estimated atmospheric CO_2 concentrations for 2100 range from a low of 672.9 ppm under Alternative 4 to a high of 677.8 ppm under the No Action Alternative. The Preferred Alternative would result in CO_2 concentrations of between 673.8 ppm and 674.3 ppm, a reduction of between 3.5 and 4.0 ppm from the No Action Alternative.
- The reduction in global mean temperature increase for the action alternatives in relation to the No Action Alternative in 2100 ranges from a low of 0.011 °C (0.020 °F) to a high of 0.020 °C (0.036 °F). The Preferred Alternative would result in a reduction of between 0.014 and 0.016 °C (0.25 and 0.029 °F) from the projected temperature increase of 2.564 °C (4.615 °F) under the No Action Alternative. Figures S-9-C1 and C2 illustrate reductions in the increase of global mean temperature under each action alternative compared to the No Action Alternative.
- Projected sea-level rise in 2100 ranges from a high of 33.42 centimeters (13.16 inches) under the No Action Alternative to a low of 33.25 centimeters (13.09 inches) under Alternative 4, indicating a maximum reduction of sea-level rise equal to 0.17 centimeter (0.07 inch) by 2100 from the level that could occur under the No Action Alternative. Sea-level rise under the Preferred Alternative would be between 33.29 and 33.30 centimeters (13.106 to 13.110 inches), a 0.13- to 0.12-centimeter (0.051- to 0.047-inch) reduction from the No Action Alternative.

See Section 5.4 of this EIS for more details about the direct, indirect, and cumulative impacts on climate.

Figure S-9-C1. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis C1

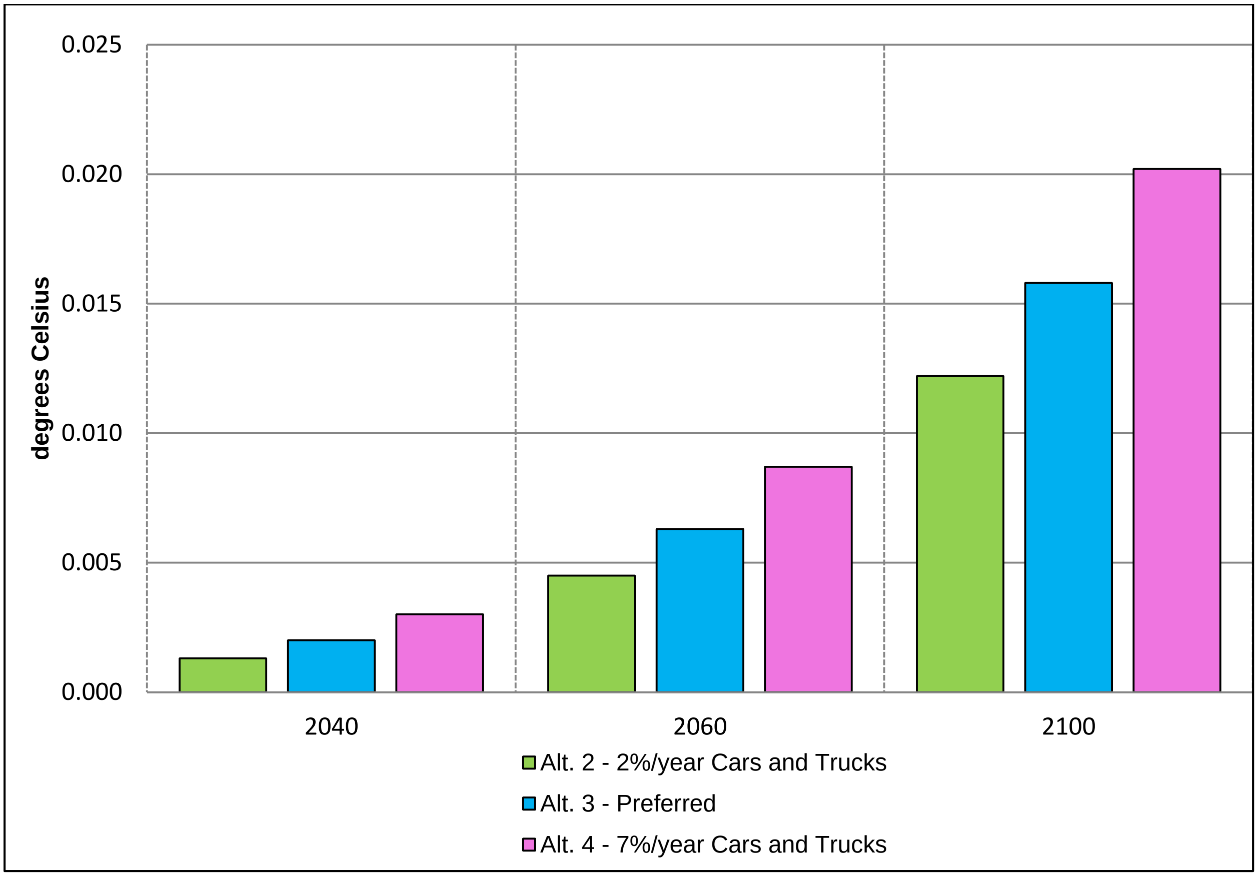
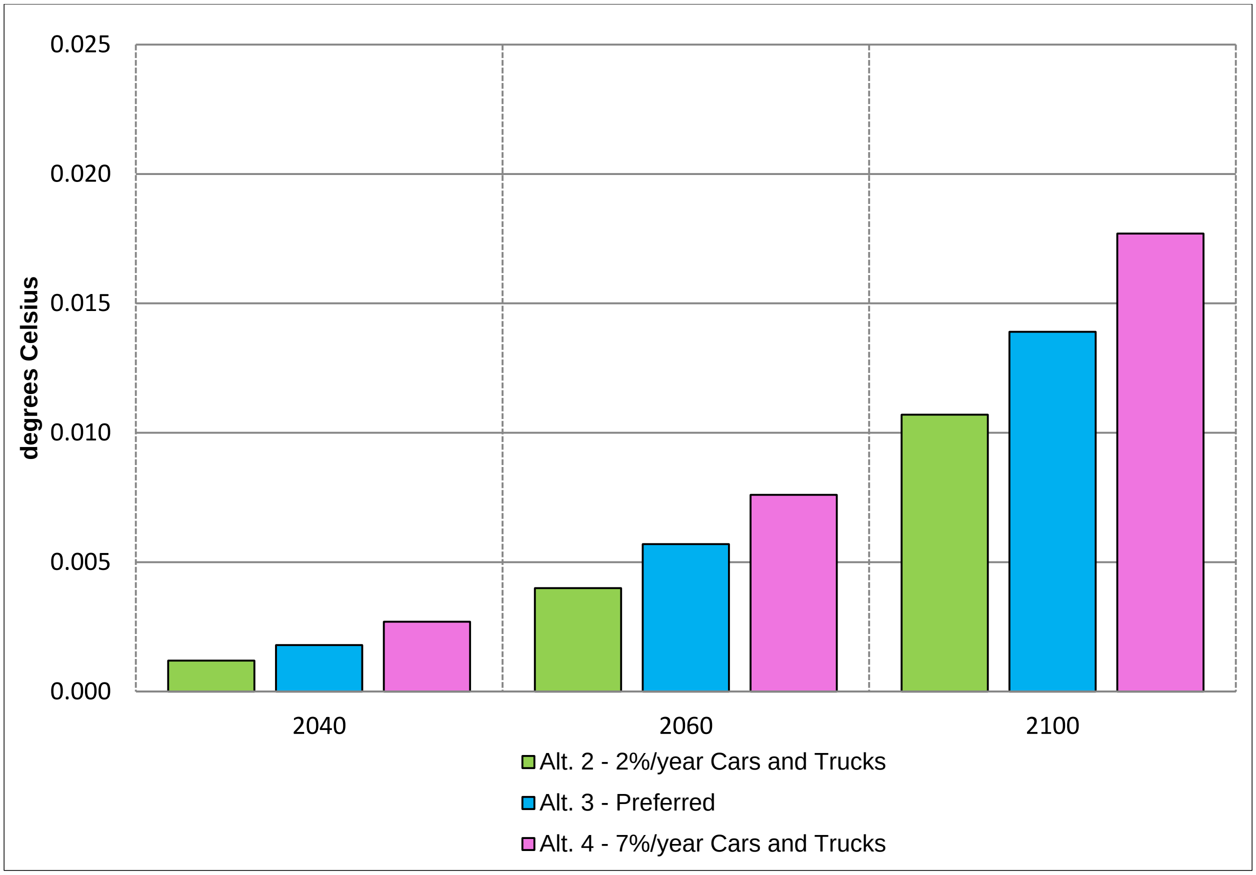


Figure S-9-C2. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis C2



Health, Societal, and Environmental Impacts of Climate Change

The action alternatives would reduce the impacts of climate change that would otherwise occur under the No Action Alternative. The magnitude of the changes in climate effects that would be produced by the most stringent action alternative is roughly 2 to 4 ppm less of CO_2, a few hundredths of a degree difference in temperature increase, a small percentage change in the rate of precipitation increase, and 1 to 2 millimeters (0.04 to 0.08 inch) of sea-level rise. Although the projected reductions in CO_2 and climate effects are small compared to total projected future climate change, they are quantifiable, directionally consistent, and would be an important contribution to reducing the risks associated with climate change. While NHTSA does quantify the reductions in monetized damages attributable to each action alternative (in the social cost of carbon analysis), many specific impacts on health, society, and the environment cannot be estimated quantitatively. Therefore, NHTSA provides a detailed discussion of the impacts of climate change on various resource sectors in Section 5.5 of the EIS. Section 5.6 discusses the changes in non-climate impacts (such as ocean acidification by CO_2) associated with the alternatives.

CHAPTER 1 PURPOSE AND NEED FOR THE PROPOSED ACTION

1.1 Introduction

The Energy Policy and Conservation Act of 1975 (EPCA)[1] established the Corporate Average Fuel Economy (CAFE) Program to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States.[2] The Secretary has delegated the responsibility for implementing the EPCA fuel economy program to the National Highway Traffic Safety Administration (NHTSA).[3]

In December 2007, Congress enacted the Energy Independence and Security Act of 2007 (EISA),[4] amending the EPCA CAFE program requirements by providing the U.S. Department of Transportation (DOT) additional rulemaking authority and responsibilities. Pursuant to EISA, NHTSA has issued final CAFE standards for model year (MY) 2011 passenger cars and light trucks,[5] and standards for MY 2012–2016 passenger cars and light trucks[6] and MY 2014–2018 medium- and heavy-duty vehicles in joint rulemakings with the U.S. Environmental Protection Agency (EPA).[7]

On May 21, 2010, President Obama issued a Presidential Memorandum entitled "Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks."[8] This memorandum builds on the President's previous memorandum[9] from January 26, 2009, which established the Joint National Program and led to the NHTSA and EPA joint final rulemaking establishing fuel economy and greenhouse gas (GHG) standards for MY 2012–2016 passenger cars and light trucks. The President's 2010 memorandum requested that NHTSA and EPA continue the Joint National Program by developing joint federal standards to improve fuel economy and reduce the GHG emissions of light-duty vehicles manufactured in MYs 2017–2025. The President requested that the agencies develop a Notice of Intent (NOI) announcing plans for setting those standards by September 30, 2010, which would include "potential standards that could be practicably implemented nationally for the 2017–2025 model years and a schedule for setting those standards as expeditiously as possible, consistent with providing sufficient lead time to vehicle manufacturers."

[1] EPCA was enacted for the purpose of serving the Nation's energy demands and promoting conservation methods when feasibly obtainable. EPCA is codified at 49 United States Code (U.S.C.) § 32901 et seq.
[2] 49 Code of Federal Regulations (CFR) § 1.50. In addition, EPA calculates the average fuel economy for each automobile manufacturer that sells vehicles in the United States. 49 U.S.C. § 32904.
[3] Accordingly, the Secretary of Transportation, DOT, and NHTSA are used interchangeably in this section of the Final EIS.
[4] EISA amends and builds on EPCA by setting forth a comprehensive energy strategy for the twenty-first century, addressing renewable fuels and CAFE standards. Pub. L. No. 110-140, 121 Stat. 1492 (Dec. 19, 2007).
[5] NHTSA initially proposed standards for MY 2011–2015 passenger cars and light trucks (*see* Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011–2015. Notice of Proposed Rulemaking, 73 *Federal Register* [FR] 24352 [May 2, 2008]); however, on January 7, 2009, DOT announced that the Bush Administration would not issue the final rule for this rulemaking (*see* DOT 2009). Instead, NHTSA issued a Final Rule only for MY 2011 passenger cars and light trucks (*see* Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011. Final Rule; Record of Decision, 74 FR 14196 [Mar. 30, 2009]).
[6] *See* Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 FR 25324 (May 7, 2010).
[7] *See* Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles**,** 76 FR 57106 (Sept. 15, 2011).
[8] *See* White House (2010b).
[9] *See* White House (2009).

On September 30, 2010, NHTSA and EPA issued an NOI that announced plans to develop a rulemaking setting stringent fuel economy and GHG emissions standards for light-duty vehicles for MY 2017 and beyond.[10] The notice was accompanied by an Interim Joint Technical Assessment Report, intended to inform the rulemaking process, which was developed by NHTSA, EPA, and the California Air Resources Board (CARB), in coordination with the U.S. Department of Energy (DOE). On December 8, 2010, the agencies published a Supplemental NOI highlighting many of the key comments received in response to the September NOI and the Interim Technical Assessment Report.[11] Over the next several months, the agencies, working with California, engaged in discussions with individual auto manufacturers, automotive suppliers, states, environmental groups, consumer groups, and the United Auto Workers, who all expressed support for a continuation of the National Program. These discussions and efforts focused on developing information that supported the underlying technical assessments that informed the proposed standards.[12] On May 10, 2011, NHTSA published an NOI to prepare an Environmental Impact Statement (EIS) for new CAFE standards.[13] On July 29, 2011, NHTSA and EPA issued a final Supplemental NOI generally describing the agencies' expectations for the Notice of Proposed Rulemaking (NPRM), including the intended levels of standards to be proposed and key program elements like compliance flexibilities and the mid-term evaluation.[14] The NPRM[15] was issued together with the Draft EIS on November 16, 2011.[16]

This EIS has been developed pursuant to the National Environmental Policy Act (NEPA).[17] NEPA directs that federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must, "to the fullest extent possible," prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action).[18] To inform its development of the final CAFE standards, NHTSA prepared this EIS, which analyzes, discloses, and compares the potential environmental impacts of a reasonable range of action alternatives, including a Preferred Alternative,[19] pursuant to Council on Environmental Quality (CEQ) NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations.[20] This EIS analyzes direct, indirect, and cumulative impacts, and discusses impacts in proportion to their significance.

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[10] *See* 2017 and Later Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Notice of Intent, 75 FR 62739 (Oct. 13, 2010).

[11] *See* 2017 and Later Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Supplemental Notice of Intent, 75 FR 76337 (Dec. 8, 2010).

[12] *See* 2017–2025 Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Supplemental Notice of Intent, 76 FR 48758 (Aug. 9, 2011).

[13] Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 76 FR 26996 (May 10, 2011).

[14] *See* 2017–2025 Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Supplemental Notice of Intent, 76 FR 48758 (Aug. 9, 2011).

[15] *See* Notice of Proposed Rulemaking (NPRM) for 2017 and Later Model Year Light-Duty Vehicle Corporate Average Fuel Economy and Greenhouse Gas Emissions Standards, 76 FR 74854 (Dec. 1, 2011).

[16] NHTSA posted both the NPRM and the Draft EIS on its fuel economy website (www.nhtsa.gov/fuel-economy). On November 25, 2011, NHTSA published the Notice of Availability of the Draft EIS in the Federal Register. *See* Notice of Availability of the Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards Model Years 2017–2025, 76 FR 72703 (Nov. 25, 2011).

[17] 42 U.S.C. §§ 4321–4347.

[18] 42 U.S.C. § 4332.

[19] On July 29, 2011, President Obama announced aspects of the agency's proposed Preferred Alternative (White House 2011a). On that day, a number of stakeholders signed "Letters of Commitment" in support of the program but recognizing that the National Program will be subject to full notice-and-comment rulemaking, which provides all interested parties "the right to participate fully, comment, and submit information, the results of which are not pre-determined but depend upon processes set by law" (NHTSA 2011a). Preparation of this Final EIS is part of this process and will inform NHTSA's final decision.

[20] NEPA is codified at 42 U.S.C. §§ 4321–4347. CEQ NEPA implementing regulations are codified at 40 CFR Parts 1500–1508, and NHTSA's NEPA implementing regulations are codified at 49 CFR Part 520.

1.2 Purpose and Need

NEPA requires that agencies develop alternatives to a proposed action based on the action's purpose and need. The purpose and need statement explains why the action is needed, describes the action's intended purpose, and serves as the basis for developing the range of alternatives to be considered in the NEPA analysis.[21] In accordance with EPCA/EISA, one purpose of the joint rulemaking is to establish CAFE standards for MY 2017 and beyond at "the maximum feasible average fuel economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year."[22] When determining the maximum feasible levels that manufacturers can achieve in each model year, EPCA requires that the Secretary of Transportation consider the four statutory factors of "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[23] In addition, the agency has the authority to – and traditionally does – consider other relevant factors, such as the effect of the CAFE standards on motor vehicle safety.[24]

NHTSA has defined these considerations as follows:[25]

- "Technological feasibility" refers to whether a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established.
- "Economic practicability" refers to whether a standard is one within the financial capability of the industry, but not so stringent as to lead to adverse economic consequences, such as significant job losses or unreasonable elimination of consumer choice.
- "The effect of other motor vehicle standards of the Government on fuel economy" involves an analysis of the effects of compliance with emission,[26] safety, noise, or damageability standards on fuel economy capability and therefore on average fuel economy.
- "The need of the United States to conserve energy" means the consumer cost, national balance of payments, environmental, and foreign policy implications of the Nation's need for large quantities of petroleum, especially imported petroleum.

Under EISA, NHTSA must establish separate standards for passenger cars and light trucks for each model year, subject to two principal requirements. First, the standards are subject to a minimum requirement regarding stringency – they must be set at levels high enough to ensure that the combined U.S. passenger car and light-truck fleet achieves an average fuel economy level of not less than 35 miles per gallon (mpg) not later than MY 2020.[27] Second, the agency must establish separate average fuel economy standards for all new passenger cars and light trucks at the maximum feasible average fuel

[21] 40 CFR § 1502.13.
[22] 49 U.S.C. § 32902(a).
[23] 49 U.S.C. §§ 32902(a), 32902(f).
[24] *See*, *e.g.*, *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)); Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011–2015, Notice of Proposed Rulemaking, 73 FR 24352 (May 2, 2008).
[25] Final Rule, Record of Decision, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 FR 14196 (Mar. 30, 2009).
[26] In the case of emission standards, this includes standards adopted by the Federal Government and can include standards adopted by the states, because in certain circumstances, the Clean Air Act (CAA) allows states to adopt and enforce state standards different from the federal standards.
[27] 49 U.S.C. § 32902(b)(2)(A).

economy level that the Secretary of Transportation decides the manufacturers can achieve in that model year.[28]

Standards must also be "based on one or more vehicle attributes related to fuel economy" and "expressed in the form of a mathematical function."[29] In addition, EISA requires that the CAFE standards for passenger cars and light trucks increase ratably in each model year between MY 2011 and MY 2020.[30] Finally, NHTSA is also guided by President Obama's memorandum to DOT on May 21, 2010, as described in Section 1.1. This memorandum further outlines the purpose of and need for the Proposed Action.

1.3 National Environmental Policy Act and Joint Rulemaking Process

Together with the Draft EIS, NHTSA and EPA issued proposed rules to establish CAFE standards and GHG emission standards for light-duty vehicles for MY 2017 and beyond. The proposed rules address the urgent and closely intertwined challenges of energy independence and security and climate change by proposing a strong and coordinated federal fuel economy and GHG program for passenger cars, light-duty trucks, and medium-duty passenger vehicles (hereinafter, "passenger cars and light trucks" or "light-duty vehicles"), referred to as the National Program. The proposed rules can achieve substantial improvements in fuel economy and reductions of GHG emissions from the light-duty vehicle sector. The proposal built on the first phase of the National Program, established by a joint final rulemaking issued by NHTSA and EPA in April 2010, in which NHTSA set CAFE standards and EPA set GHG emission standards for MY 2012–2016 passenger cars and light trucks.[31]

The National Program holds the promise of delivering additional environmental and energy benefits, cost savings, and administrative efficiencies nationwide that might not be available under a less coordinated approach. The National Program also offers the prospect of regulatory convergence by making it possible for the standards of two federal agencies and the standards of California and other states to act in a unified way to provide these benefits. This would allow automakers to produce and sell a single light-duty fleet nationally. Therefore, the approach mitigates the additional costs manufacturers would otherwise potentially face in having to comply with multiple sets of federal and state standards.

1.3.1 Building Blocks of the National Program

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

[28] 49 U.S.C. § 32902(a).
[29] 49 U.S.C. § 32902(b)(3)(A).
[30] 49 U.S.C. § 32902(b)(2)(C). NHTSA interprets this requirement, in combination with the requirement to set the standards for each model year at the level determined to be the maximum feasible level for that model year, to mean that the annual increases should not be disproportionately large or small in relation to each other.
[31] Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 FR 25324 (May 7, 2010).

emissions of CO_2. Therefore, the same technologies address these twin problems (those that reduce fuel consumption and thereby reduce CO_2 emissions).

1.3.1.1 DOT's Corporate Average Fuel Economy Program

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

To verify compliance with the CAFE standards, EPA determines fuel economy by measuring the amount of CO_2 and other carbon compounds emitted from the tailpipe. The carbon content of the test fuel is then used to calculate the amount of fuel that had to be consumed per mile to produce that amount of CO_2. Finally, that fuel consumption figure is converted into an mpg figure. CAFE standards do not address the 5 to 8 percent of GHG emissions that are not CO_2 (i.e., nitrous oxide, methane, and hydrofluorocarbons [HFCs]).

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

Under the Clean Air Act (CAA), EPA is responsible for addressing air pollutants from motor vehicles. In 2007, the U.S. Supreme Court issued a decision on *Massachusetts v. Environmental Protection Agency*,[32] a case involving a 2003 EPA order denying a petition for rulemaking to regulate GHG emissions from motor vehicles under CAA Section 202(a).[33] The Court held that GHGs were air pollutants for purposes of the CAA and further held that the EPA Administrator must determine whether emissions from new motor vehicles cause or contribute to air pollution that might reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. The Court further ruled that, in making these decisions, the EPA Administrator is required to follow the language of CAA Section 202(a). The Court rejected the argument that EPA cannot regulate CO_2 from motor vehicles because to do so would de facto tighten fuel economy standards, authority over which Congress has assigned to DOT. The Court held that the fact "that DOT sets mileage standards in no way licenses EPA to shirk its environmental responsibilities. EPA has been charged with protecting the public's 'health' and 'welfare', a statutory obligation wholly independent of DOT's mandate to promote energy efficiency." The Court concluded that "[t]he two obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[34]

EPA has since found that emissions of GHGs from new motor vehicles and motor vehicle engines do cause or contribute to air pollution that can reasonably be anticipated to endanger public health and

[32] 549 U.S. 497 (2007).
[33] *See* Notice of Denial of Petition for Rulemaking, Control of Emissions From New Highway Vehicles and Engines, 68 FR 52922 (Sept. 8, 2003).
[34] 549 U.S. at 531-32. For more information on *Massachusetts v. Environmental Protection Agency, see* the July 30, 2008, Advance Notice of Proposed Rulemaking, Regulating Greenhouse Gas Emissions under the Clean Air Act, 73 FR 44354 at 44397. This includes a comprehensive discussion of the litigation history, the U.S. Supreme Court findings, and subsequent actions undertaken by the Bush Administration and EPA from 2007 through 2008 in response to the Supreme Court remand.

welfare.[35] The NHTSA and EPA joint final rulemaking for MY 2012–2016 passenger cars and light trucks issued in 2010 and the current proposal are part of EPA's response to the U.S. Supreme Court decision.[36]

1.3.1.3 California Air Resources Board Greenhouse Gas Program

CARB sets emissions standards for motor vehicles for the State of California. In 2004, CARB approved standards regulating the emission of CO_2 and other GHGs for MY 2009–2016 light-duty vehicles. The California standards apply to each model year from 2009 through 2016 and require maximum emissions for passenger cars and some light trucks of 323 grams per mile CO_2-equivalent (CO_2e) in 2009, increasing in stringency to 205 grams per mile in 2016, and 439 grams per mile for light trucks in 2009, increasing in stringency to 332 grams per mile in 2016.[37]

On June 30, 2009, EPA granted California's request for a waiver of preemption under the CAA.[38] The waiver allowed California, and the 13 other states (as well as the District of Columbia) that had adopted the California standards, to implement the standards beginning with MY 2009. In February 2010, CARB revised its program so that for MYs 2012–2016 manufacturers may elect to comply with the California standards by demonstrating compliance with the EPA GHG standards.[39] On June 14, 2011, EPA confirmed that CARB's amendments to its motor vehicle emissions standards are within the scope of the existing waiver for California's GHG emissions standards for 2009 and later, thereby allowing continued implementation of the California emission standards in applicable states.[40]

As requested by the President and in the interest of maximizing regulatory harmonization, NHTSA and EPA worked closely with CARB throughout the development of the proposed rules. In a letter to Secretary of Transportation Ray LaHood and EPA Administrator Lisa Jackson dated July 28, 2011, CARB wrote that "California welcomes the opportunity to be a partner in helping to advance a continued, harmonized National Program" for model years 2017 and beyond.[41] On December 9, 2011, CARB released its proposal for MY 2017–2025 GHG emissions standards consistent with the standards EPA proposed, and CARB adopted these standards on January 26, 2012.[42] In adopting their GHG standards, CARB directed the Executive Officer to continue collaborating with EPA and NHTSA as the federal GHG standards were finalized, and in the mid-term review process to minimize potential lost benefits from federal treatment of upstream emissions of electricity and hydrogen fueled vehicles.[43] CARB also reconfirmed its commitment to propose to revise its GHG emissions standards for MYs 2017–2025 such that compliance with EPA GHG emissions standards shall be deemed compliance with the California GHG emissions standards, "as long as EPA's final GHG standards, at a minimum, preserve the

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[35] Final Rule, Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 FR 66496 (Dec. 15, 2009).
[36] *See* Light-Duty Vehicles Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 FR 25324 (May 7, 2010).
[37] California Code of Regulations, Title 13 § 1961.1(a)(1).
[38] *See* California State Motor Vehicle Pollution Control Standards, Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles, 74 FR 32744 (July 8, 2009).
[39] *See* California Code of Regulations, Title 13 § 1961.1(a)(1)(A)(ii).
[40] California State Motor Vehicle Pollution Control Standards; Within-the-Scope Determination for Amendments to California's Motor Vehicle Greenhouse Gas Regulations; Notice of Decision, 76 FR 34693 (June 14, 2011).
[41] *See* CARB (2011).
[42] *See* California Low-Emission Vehicles (LEV) & GHG 2012 regulations approved by State of California Air Resources Board, Resolution 12-11. *Available at:* <http://www.arb.ca.gov/regact/2012/cfo2012/res12-11.pdf>. (Accessed: June 11, 2012).
[43] *Id*.

greenhouse reduction benefits set forth in U.S. EPA's December 1, 2011 Notice of Proposed Rulemaking for 2017 through 2025 model year passenger vehicles."[44]

1.3.2 Proposed Action

For this EIS, NHTSA's Proposed Action is to set fuel economy standards for passenger cars and light trucks, in accordance with EPCA/EISA. In any single rulemaking under EPCA, fuel economy standards may be established for not more than 5 model years.[45] For this reason, NHTSA's proposal is limited to setting standards for MYs 2017–2021. In the NPRM, NHTSA also set forth values for MYs 2022–2025 that reflected the agency's estimate of the standards we would have proposed and adopted had we the authority to do so. The CAFE standards for MYs 2022–2025 will be determined in a subsequent, de novo notice and comment rulemaking. However, because NHTSA's effort is part of a joint NHTSA and EPA rulemaking for a coordinated and harmonized National Program covering MYs 2017–2025, this EIS addresses the potential impacts of the proposed standards for MYs 2017–2021 and the values set forth for MYs 2022–2025 for each of the alternatives, therefore covering the full MY 2017–2025 period. When NHTSA refers to the standards in this EIS as "required," it recognizes that fuel economy standards for MY 2022–2025 will not, in fact, be required in this rulemaking. Rather, it is assumed for purposes of the analysis in this EIS that the values set forth for MYs 2022–2025 will be made required in the future. Similarly, when NHTSA refers to the "Proposed Action" or to the "proposed standards," these terms are intended to identify the full period covered by the coordinated National Program (MYs 2017–2025) for purposes of analysis, but subject to the specific caveats noted above.

1.3.2.1 Level of the Standards

In the NPRM, NHTSA and EPA proposed separate but harmonized sets of standards for passenger cars and light trucks under each agency's respective statutory authority. The proposed standards for both agencies begin with MY 2017, with standards increasing in stringency through MY 2025. Under NHTSA's Proposed Action, the agency currently estimates that the combined average of manufacturers' required fuel economy levels would be 40.3 to 41.0 mpg in MY 2021 and 48.7 to 49.7 mpg in MY 2025 (as compared to estimated average required fuel economy levels of 34.3 to 34.8 mpg and 34.5 to 35.1 mpg in MY 2021 and MY 2025, respectively, under the No Action Alternative). Under EPA's proposal, issued concurrently with NHTSA's proposal, EPA estimated that manufacturers would, on average, be required to meet an estimated combined average emissions level of approximately 163 grams per mile of CO_2 in MY 2025.

The averages for NHTSA's Proposed Action differ slightly from those presented in the Draft EIS and NRPM. The differences reflect corrections to the MY 2008-based new vehicle fleet forecast underlying the analysis presented in the Draft EIS and NPRM, and development of the MY 2010-based new vehicle fleet forecast to support the analysis for this Final EIS.[46] However, the standards defining the No Action Alternative, the Preferred Alternative, and the other regulatory alternatives are the same as those presented in the Draft EIS and NPRM. Because the standards are attribute based and apply separately to each manufacturer and separately to passenger cars and light trucks, actual average required fuel economy levels will depend on the future composition of the fleet. NHTSA has estimated the future composition of the fleet nearly 15 years into the future, and such estimates are subject to considerable uncertainty. Therefore, the average future required fuel economy under each regulatory alternative is also subject to considerable uncertainty.

[44] *See* CARB (2011).
[45] 49 U.S.C. § 32902(b)(3)(B).
[46] *See* Section 2.2.2 for more information about the new vehicle fleet forecasts used in this Final EIS.

Under EPCA, EPA has the authority to measure and calculate manufacturers' average fuel economy for the CAFE program. For the first time, EPA's proposed rule would allow manufacturers to account for improvements to air conditioner efficiency that have a measurable impact on real-world fuel economy in the calculation of fuel economy for CAFE compliance. Because such improvements are available for compliance, NHTSA's proposed standards (like EPA's GHG standards) assume manufacturers will improve air conditioner efficiency to meet those standards. This aspect of the agencies' proposal is discussed in more detail in the NPRM.

The standards are "harmonized," even though they are not identical and reflect different rates of increase in stringency for the different programs. The difference is rooted in differences in NHTSA's and EPA's respective statutory authorities. For example, whereas NHTSA is regulating vehicle fuel economy, EPA is regulating GHGs, which include HFC-based refrigerants used in air conditioner systems that can leak from vehicles during normal vehicle operation or at end-of-life. Under the proposed GHG standards, EPA expects manufacturers to take advantage of the option to generate CO_2-e credits by reducing HFC leakage from vehicle air conditioner systems. Accordingly, the level of EPA's proposed standards reflects the expected amounts of HFC leakage improvement. Air-conditioner refrigerant *leakage* improvements, unlike the air conditioner *efficiency* improvements described above, have no impact on fuel economy. Therefore, NHTSA does not consider improvements in air conditioner systems related to refrigerant leakage for purposes of CAFE compliance, and NHTSA's Proposed Action does not include such improvements or their mpg equivalents. The agencies' joint proposals are still harmonized because they allow industry to build a single national fleet that will satisfy both CAFE requirements under EPCA/EISA, and GHG emissions requirements under the CAA.

1.3.2.2 Form of the Standards

In this rulemaking, NHTSA and EPA again proposed attribute-based standards for passenger cars and light trucks. NHTSA adopted an attribute standard based on vehicle footprint in its Reformed CAFE program for light trucks for MYs 2008–2011,[47] and extended this approach to passenger cars in the CAFE rule for MY 2011, as required by EISA.[48] NHTSA and EPA also used an attribute standard for the joint rule establishing standards for MY 2012–2016 passenger cars and light trucks.[49]

Under an attribute-based standard, each vehicle model has a performance target (fuel economy for the CAFE standards; CO_2 grams per mile for the GHG emissions standards), the level of which depends on the vehicle's attribute. For this rulemaking, along with the rulemakings for previous model years, NHTSA and EPA proposed vehicle footprint as the attribute for CAFE and GHG standards. Vehicle footprint is one measure of vehicle size and is defined as a vehicle's wheelbase multiplied by the vehicle's track width. The agencies believe that the footprint attribute is the most appropriate attribute on which to base the standards under consideration, as discussed in the NPRM. As required by EPCA and amended by EISA, each manufacturer would have separate standards for cars and for trucks, based on the footprint target curves promulgated by the agency and the mix of vehicles that each manufacturer produces for sale in a given model year. Generally, larger vehicles (i.e., vehicles with larger footprints) would be subject to less stringent standards (i.e., higher CO_2 gram-per-mile standards and lower CAFE standards) than smaller vehicles. This is because, typically, smaller vehicles are more capable of achieving more stringent standards than larger vehicles.

[47] Final Rule, Average Fuel Economy Standards for Light Trucks Model Years 2008–2011, 71 FR 17566 (Apr. 6, 2006).
[48] Final Rule, Record of Decision, Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 FR 14196 (Mar. 30, 2009).
[49] *See* Chapter 2 of NHTSA (2010a).

After using vehicle footprint as the attribute to determine each specific vehicle model performance target, the manufacturers' fleet average performance is then determined by the production-weighted[50] average (for CAFE, harmonic average) of those targets. The manufacturer's ultimate compliance obligation is based on that average; no particular vehicle is required to meet or exceed its particular performance target level, but the fleet on average must meet or exceed the average required level to comply.

Therefore, although a manufacturer's fleet average standard could be estimated throughout the model year based on the projected production volume of its vehicle fleet, the standard with which the manufacturer must comply would be based on its final model year production figures. A manufacturer's calculation of fleet average emissions at the end of the model year would therefore be based on the production-weighted average (for CAFE, harmonic average) emissions of each model in its fleet.

In the NPRM, NHTSA and EPA included a full discussion of the equations and coefficients that define the passenger car and light-truck curves proposed for each model year by each agency.

1.3.2.3 Program Flexibilities for Achieving Compliance

As with previous model-year rules, NHTSA and EPA proposed standards intended to provide manufacturers compliance flexibility, especially in the early years of the program. The flexibility provisions the agencies proposed for this rulemaking, and that are discussed in the NPRM, fall under the following categories: CO_2/CAFE Credits Generated Based on Fleet Average Over-Compliance; Air Conditioning Improvement Credits/Fuel Economy Value Increases; Off-Cycle Credits/Fuel Economy Value Increases; Incentives for Electric Vehicles, Plug-in Hybrid Electric Vehicles, and Fuel Cell Vehicles; and Incentives for "Game Changing" Technologies Performance for Full-Size Pickup Trucks including Hybridization. Under the proposal, some of these flexibilities would be available to manufacturers in aiding compliance under both sets of standards, but some flexibilities, such as air conditioning credits related to refrigerant leakage and incentives for electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles, would only be available under the EPA standard due to differences between the CAFE and CAA legal authorities — the CAA provides EPA broad discretion to create incentives for certain technologies, but NHTSA's authority under EPCA/EISA is more constrained.

1.3.2.4 Compliance

The MY 2012–2016 final rules established detailed and comprehensive regulatory provisions for compliance and enforcement under the CAFE and GHG emissions standards programs. These provisions remain in place for model years beyond MY 2016 without additional action by the agencies, and the agencies did not propose any significant modifications to them in the NPRM for the MY 2017–2025 program. EPA already oversees testing, collects and processes test data, and performs calculations to determine compliance with both CAFE and CAA standards, and EPA developed certification, testing, reporting, and associated compliance activities for the GHG program that closely track those in previously existing CAFE and CAA Tier 2 vehicle emission standards programs. Under this coordinated approach, the compliance mechanisms for both programs are consistent and not duplicative. EPA also applies the CAA authorities applicable to its separate in-use requirements in this program.

The compliance approach allows manufacturers to satisfy the GHG program requirements in the same general way they comply with previously existing applicable CAA and CAFE requirements. Manufacturers will demonstrate compliance on a fleet-average basis at the end of each model year,

[50] Production for sale in the United States.

allowing model-level testing to continue throughout the year, as is the current practice for CAFE determinations. The compliance program design includes a single set of manufacturer reporting requirements and relies on a single set of underlying data. This approach still allows each agency to assess compliance with its respective program under its respective statutory authority.

1.4 Cooperating Agency

Section 1501.6 of the CEQ NEPA implementing regulations emphasizes agency cooperation early in the NEPA process and authorizes a lead agency (in this case, NHTSA) to request the assistance of other agencies that either have jurisdiction by law or have special expertise regarding issues considered in an EIS.[51] On September 26, 2011, NHTSA invited EPA to be a cooperating agency pursuant to CEQ regulations because of its special expertise in the areas of climate change and air quality. In its invitation letter, NHTSA suggested that EPA's role in the development of the EIS could include the following:

- Providing input on determining the significant issues to be analyzed in the EIS from climate change and air quality perspectives.
- Helping NHTSA "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 § 501.7(a)(3).
- Participating in coordination meetings, as appropriate.
- Reviewing and commenting on the Draft EIS and the Final EIS before publication.

On October 7, 2011, EPA accepted NHTSA's invitation and agreed to become a cooperating agency.[52] EPA personnel have participated in technical discussions regarding analyses for the proposal and were asked to review and comment on draft sections and the draft final versions of the Draft and Final EISs.

1.5 Public Review and Comment

NHTSA submitted to EPA a Draft EIS to disclose and analyze the potential environmental impacts of the agency's Proposed Action and reasonable alternative standards pursuant to CEQ NEPA implementing regulations, DOT Order 5610.1C, and NHTSA regulations. On November 25, 2011, EPA published a Notice of Availability of the Draft EIS for the new CAFE standards for MY 2017–2025 passenger cars and light trucks.[53] The Draft EIS requested public input on the agency's environmental analysis by January 31, 2012; publication of the Notice of Availability triggered the Draft EIS public comment period. On December 1, 2011, EPA and NHTSA published the joint NPRM,[54] and opened a 60-day comment period. The agencies invited the public to submit comments on the NPRM on or before January 30, 2012, by

[51] 40 CFR § 1501.6.

[52] While NEPA requires NHTSA to complete an EIS for this rulemaking, EPA does not have the same statutory obligation. EPA actions under the CAA, including EPA's proposed vehicle GHG emission standards for light-duty vehicles under the joint rulemaking, are not subject to NEPA requirements. *See* Section 7(c) of the Energy Supply and Environmental Coordination Act of 1974 (15 U.S.C. § 793(c)(1)). EPA is completing its own environmental review of the proposed rule as part of a separate Regulatory Impact Analysis for this rulemaking.

[53] Notice of Availability of the Draft Environmental Impact Statement for New Corporate Average Fuel Economy Standards Model Year 2017–2025, 76 FR 72703 (Nov. 25, 2011).

[54] Proposed Rulemaking To Establish 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emission and Corporate Average Fuel Economy Standards, 76 FR 74854 (Dec. 1, 2011).

posting to either the NHTSA or EPA docket (NHTSA-2010-0131 or EPA-HQ-OAR-2010-0799). The comment period for the NPRM was subsequently extended to February 15, 2012.[55]

Consistent with NEPA and its implementing regulations, NHTSA mailed a copy of the Draft EIS to:

- Contacts at federal agencies with jurisdiction by law or special expertise regarding 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 tribes and tribal organizations
- Individuals and contacts at other stakeholder organizations that NHTSA reasonably expects to be interested in the NEPA analysis for the new CAFE standards, including advocacy, industry, and other organizations

NHTSA and EPA held joint public hearings on the Draft EIS and NPRM on January 17, 2012, in Detroit, Michigan; on January 19, 2012, in Philadelphia, Pennsylvania; and on January 24, 2012, in San Francisco, California.

NHTSA received 18 responses to its May 10, 2011[56] NOI. In addition to these comments, NHTSA received more than 10,000 comments from supporters of the National Wildlife Federation Action Fund, mostly as form letters, and a comment letter from the Union of Concerned Scientists enclosing more than 600 individual comments from its supporters. Chapter 1 of the Draft EIS summarizes comments on the NOI.

NHTSA also received several thousand comments in the dockets for the Draft EIS and the NPRM, including numerous comments in form letters. The agency also received 402 oral comments and 118 written comments during the 3 public hearings. NHTSA reviewed the oral and written submissions for comments relevant to the EIS. Several commenters referenced or submitted studies, research, and other information supporting or in addition to their comments. NHTSA carefully reviewed these submissions to determine if they were appropriate for inclusion in this EIS.

As described in Chapter 9 of this EIS, comments that raised issues central to the rule or the rulemaking process will be addressed by the forthcoming final rule and the associated documents.

1.6 Next Steps in the National Environmental Policy Act and Joint Rulemaking Process

No sooner than 30 days after EPA announces the availability of the Final EIS in the *Federal Register*, NHTSA will publish a final rule and Record of Decision. The Record of Decision will state and explain NHTSA's decision.

[55] 77 FR 2028 (Jan. 13, 2012).
[56] Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 76 FR 26996 (May 10, 2011).

CHAPTER 2 PROPOSED ACTION AND ALTERNATIVES AND ANALYSIS METHODOLOGIES

2.1 Introduction

NEPA requires that, in the case of a major federal action, an agency must evaluate the environmental impacts of its proposed action and alternatives to that action.[1] An agency must rigorously explore and objectively evaluate all reasonable alternatives, including the alternative of taking no action. 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]

This chapter describes the Proposed Action and the alternatives examined in this EIS; explains the methodologies and assumptions applied in the analysis of environmental impacts; and summarizes environmental impacts reported in subsequent EIS chapters, as follows:

Section 2.2, Proposed Action and Alternatives
Section 2.3, Standards-setting and EIS Methodologies and Assumptions
Section 2.4, Resource Areas Affected and Types of Emissions
Section 2.5, Direct and Indirect versus Cumulative Impacts
Section 2.6, Comparison of Alternatives

2.2 Proposed Action and Alternatives

NHTSA's Proposed Action is to set fuel economy standards for MY 2017 and beyond passenger cars and light trucks (also referred to as the light-duty vehicle fleet) in accordance with EPCA, as amended by EISA. In developing the Proposed Action and alternatives, NHTSA considered the four EPCA factors that guide the agency's determination of "maximum feasible" standards: technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy.[4] In addition, NHTSA considered relevant environmental and safety factors.[5] During the process of developing standards, NHTSA consulted with EPA and the U.S. Department of Energy (DOE) regarding a variety of matters, as required by EPCA.[6] Consistent with CEQ NEPA implementing regulations, this EIS compares the Proposed Action and a reasonable range of alternatives to the No Action Alternative (Alternative 1), which assumes that NHTSA and EPA would not issue a new rule regarding CAFE or greenhouse gas (GHG) emission standards.[7]

[1] 42 U.S.C. § 4332(2)(C).
[2] 40 CFR §§ 1502.14(a), (d).
[3] 40 CFR § 1502.13. *See Vermont Yankee Nuclear Power Corp. v. Natural Res. Def. Council*, 435 U.S. 519, 551 (1978); *City of Alexandria v. Slater*, 198 F.3d 862, 867-69 (D.C. Cir. 1999), *cert. denied sub nom.*, 531 U.S. 820 (2000).
[4] 49 U.S.C. § 32902(f).
[5] As noted in Chapter 1, NHTSA interprets the statutory factors as including environmental issues and permitting the consideration of other relevant societal issues, such as safety. *See*, e.g., *Competitive Enterprise Inst. v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing *Competitive Enterprise Inst. v. NHTSA*, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)); and Average Fuel Economy Standards, Passenger Cars and Light Trucks; MYs 2011–2015, 73 FR 24352 (May 2, 2008).
[6] 49 U.S.C. § 32902(i).
[7] 40 CFR § 1502.14(d).

Under EPCA, as amended by EISA, NHTSA is required to set separate average fuel economy standards for passenger cars and light trucks. Because NHTSA intends to set standards both for cars and for trucks, and because evaluating the environmental impacts of this proposal requires consideration of the impacts of the standards for both vehicle classes, the main analyses presented in this EIS reflect the combined environmental impacts associated with the proposed standards for passenger cars and light trucks. In addition, Appendix A shows separate results for passenger cars and light trucks under each alternative.

2.2.1 Uncertainty Over Market-Driven Improvements in Fuel Economy (Analyses A and B)

If NHTSA were not to adopt new fuel economy standards, it is possible that manufacturers would attain an average fleetwide fuel economy no better than that required under the existing NHTSA and EPA standards for MY 2016. An assumption that fleetwide fuel economy would generally remain unchanged in the absence of additional action under the National Program, described more fully in the Notice of Proposed Rulemaking (NPRM), is based on projections of relatively stable fuel prices, certain historical evidence of manufacturer CAFE compliance, and market observations wherein consumers appear not to purchase products that are in their economic self-interest (the "energy paradox"). In the context of vehicle fuel economy, selecting an appropriate baseline against which to compare this proposal and the alternatives is complex and challenging. As NHTSA recently stated regarding the agencies' new standards for heavy-duty (HD) vehicles, it is not possible to know with certainty the future fleetwide fuel efficiency and GHG emissions performance of a vehicle fleet in the absence of more stringent standards, because manufacturer behavior, consumer sales, and vehicle use depend on many factors beyond the agencies' control.

NHTSA understands that market forces can independently result in changes to the future light-duty vehicle fleet even in the absence of agency action, and that, to the extent they can be estimated, those changes should be incorporated into the baseline. In response to the MY 2014–2018 HD Draft EIS, NHTSA received several comments comparing the action alternatives to the HD vehicle annual energy consumption forecast produced by the U.S. Energy Information Administration (EIA) and describing that forecast, known as the Annual Energy Outlook (AEO), as "business as usual." In response to these comments, in the MY 2014–2018 HD Final EIS, NHTSA added a market forecast analysis" comparing the environmental impacts of the action alternatives to those of a baseline derived from the AEO forecast available at the time the EIS modeling was performed. That baseline assumed that market forces would independently result in increases in fuel efficiency in the future HD fleet even in the absence of the proposed HD vehicle rule.

NHTSA believes that similar considerations are appropriate and relevant to this analysis. From a market-driven perspective, there is considerable evidence that many customers now care more about fuel economy than in past decades due to, among other things, uncertainty over future fuel prices and growing concern for energy security and the environmental impacts of petroleum use. A number of manufacturers have announced plans to introduce technology that would allow them to reach fuel economy levels well beyond levels required by the MY 2016 standards, and some historical evidence indicates that manufacturers might overcomply with standards under certain economic and regulatory conditions.[8] Although fuel price projections reported in the AEO appear relatively stable, there is inherent uncertainty in such projections, and actual fuel prices could fluctuate, perhaps significantly,

[8] In its latest report on the fuel economy, carbon dioxide (CO_2) emissions, and technology trends of new light-duty vehicles, EPA notes that the fuel economy of the combined car and light-truck fleet has increased since 2005, with the largest increase in 2009. In fact, MY 2010 had the highest fuel economy since the tracking database began in 1975 (EPA 2012b).

from the AEO forecasts. As a result of these considerations and comments received during the scoping process for this EIS, NHTSA believes it is appropriate to account for market forces and technology advances that would result in fuel economy gains even in the absence of regulatory action.

In recognition of the uncertainty inherent in forecasting the fuel economy of the future light-duty vehicle fleet in the absence of agency action, the Draft EIS provided two analyses regarding the No Action Alternative against which the corresponding impacts of the action alternatives were measured. Analysis A reflected a No Action Alternative that assumed that, in the absence of the Proposed Action, the baseline fleet in MY 2017 and beyond would attain an average fleetwide fuel economy no higher than the minimum necessary to comply with the agencies' MY 2016 standards established by final rule in April 2010. Analysis B reflected a No Action Alternative that assumed that, in the absence of the Proposed Action, the average fleetwide fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards.[9] NHTSA forecast the fleet for Analysis B using the "voluntary overcompliance" simulation capability of the Volpe model, described below and in Section IV.C.4.c of the NPRM. Specifically, the agency used all of the same inputs as for Analysis A, but applied a payback period of 1 year for purposes of calculating the value of future fuel savings when simulating whether a manufacturer would apply additional technology to an already CAFE-compliant fleet.[10] More discussion about this methodology is available in Section IV.G.4 of the NPRM. In addition, NHTSA provides more information about the use of payback periods in its analysis in Section 9.2.3.3.3 of this Final EIS.

Regarding the action alternatives, there is similar uncertainty about whether and to what degree manufacturers will overcomply with CAFE standards *during* the rulemaking period and about whether and to what degree fleetwide fuel economy will change in the absence of further agency action *after* the rulemaking period. For the action alternatives during and after the rulemaking period, assumptions should be generally consistent with those made for the No Action Alternative regarding manufacturers' incentive to increase fuel economy. For example, if the agency assumes that market forces would lead to an increase in fuel economy in the absence of the rule, it is reasonable also to assume manufacturer overcompliance during the rulemaking period and continued growth in fuel economy after the rulemaking period. On the other hand, if the agency assumes that manufacturers would achieve fuel economy levels no higher than the level of current standards in the absence of a new rule, it is reasonable also to assume manufacturers would not overcomply during or after the rulemaking period.

Therefore, for Analysis A in the Draft EIS NHTSA assumed that the average annual fleetwide fuel economy under the action alternatives would be no higher than the minimum necessary to comply with the level of the agency's CAFE standard for a particular year during the rulemaking period. For Analysis B NHTSA assumed that once manufacturers complied with the CAFE standard during the MY 2017–2025 period, they would consider making further improvements in fuel economy as if buyers were willing to pay for fuel savings that would be realized during the first year of vehicle ownership (as described above for the No Action Alternative). Therefore, Analysis B assumed manufacturers would overcomply if additional technology were sufficiently cost effective. In effect, this assumption assumed manufacturers

[9] The No Action Alternative used in Analysis B is referred to as the "market-driven baseline" in NHTSA's Preliminary Regulatory Impact Analysis (RIA) and as "voluntary overcompliance" in the NPRM.

[10] In other words, NHTSA assumes that manufacturers will act as if buyers value the resulting savings in fuel costs associated with additional fuel economy technology only during their first year of ownership. If a consumer will not recover the full cost of the additional technology within the first year of vehicle ownership, NHTSA assumes the manufacturer will not incorporate that technology.

would add an even greater degree of additional technologies in earlier years to cover compliance in later years of the rulemaking period.

After MY 2025, for Analysis A NHTSA assumed that average fleetwide fuel economy under the action alternatives would never exceed the level set forth for the MY 2025 standards. In contrast, for Analysis B the agency assumed that fleetwide fuel economy would continue to increase after MY 2025 beyond the levels set forth in the MY 2025 standards. Specifically, in the Draft EIS, in Analysis B the agency assumed that the fuel economy achieved by new passenger cars and light trucks would increase at rates of 0.2 percent and 0.4 percent, respectively, annually after MY 2025. These rates of increase were developed by examining historical changes in the fuel economy of new passenger cars and light trucks during periods when CAFE standards remained fixed, and therefore did not require manufacturers to offer vehicles with higher fuel economy than in the immediately preceding model years. While the actual fuel economy of new vehicles produced during such years was undoubtedly affected by many factors other than CAFE standards, the agency viewed these figures as reasonable estimates of the likely trend in fuel economy in model years following 2025.[11]

Although the agency received several comments in response to the Draft EIS that questioned whether manufacturers would continue to improve fuel economy absent increasingly stringent CAFE regulations, other commenters noted that manufacturers have consistently improved fuel economy over time. In addition, many commenters noted increasingly high demand among consumers for increased fuel economy. Based on this uncertainty, NHTSA believes it is valuable to continue to present both analyses to ensure that the decisionmaker and the public are fully informed. Therefore, this Final EIS continues to present results for Analyses A and B, using the same general assumptions, in recognition of the uncertainty inherent in forecasting the extent to which the fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet regulatory standards. However, in response to comments, NHTSA has reevaluated the assumed rates of growth in fuel economy after the rulemaking period for Analysis B by improving the way we account for fuel prices and technological development in the assumed rate of fuel economy improvement. For the analysis presented in this Final EIS, in Analysis B the agency assumed that the fuel economy achieved by new passenger cars and light trucks would increase at rates of 0.25 percent and 0.87 percent, respectively, annually after MY 2025.

2.2.2 Uncertainty in New Vehicle Fleet Forecast

To evaluate the environmental impacts of the proposed alternatives, NHTSA must project what vehicles and technologies will exist in future model years and then evaluate what technologies can feasibly be applied to those vehicles to raise their fuel economy (*see* Section 2.3.2.1). To project the future fleet, NHTSA must develop a baseline vehicle fleet. In the NPRM, the NHTSA and EPA used MY 2008 CAFE certification data to establish the "2008-based fleet projection."[12] The agencies noted that MY 2009 CAFE certification data was not likely to be representative because it was so dramatically influenced by the economic recession (Joint Draft Technical Support Document [TSD] Section 1.2.1). The agencies further noted that MY 2010 CAFE certification data might be available for use in the final rulemaking for purposes of creating a baseline fleet. The agencies also stated that a copy of the MY 2010 CAFE

[11] Market-driven improvements in fuel economy for MYs 2017–2025 are calculated by the Volpe model and are based on vehicle sales and the application of specific fuel-saving technologies by manufacturers. In contrast, for MY 2026 and later, market-driven improvements in fuel economy are not technology specific, but rather are extrapolated based on historical evidence. This methodology differs from that used in the AEO, which generally assumes technology-specific improvements in fuel economy through 2035.

[12] 2008-based fleet projection is a new term that is the same as the reference fleet. The term is added to clarify when we are using the 2008 baseline and reference fleet rather than the 2010 baseline and reference fleet described later in this section.

certification data would be put in the public docket if it became available during the comment period. The MY 2010 data were reported by the manufacturers throughout calendar year 2011 as the final sales figures were compiled and submitted to the EPA database. Because the CAFE data submissions were late,[13] it was not possible to submit the new 2010 data into the docket during the public comment period.

For analysis supporting the NPRM, the agencies developed a forecast of the new light-duty vehicle fleet through MY 2025 based on: (1) the vehicle models in the MY 2008 CAFE certification data, (2) the AEO 2011 interim projection of future fleet sales volumes, and (3) the future new vehicle fleet forecast by CSM Worldwide in 2009. In the proposal, the agencies stated that they planned to use MY 2010 CAFE certification data, if available, for analysis supporting the final rule (Joint Draft TSD, p. 1–2). The agencies also indicated their intention, for analysis supporting the final rule, to use a more recent version of EIA's AEO and an updated market forecast (Joint Draft TSD, p. 1–28).

For this Final EIS, NHTSA has analyzed the potential environmental impacts of the Proposed Action and alternatives using two different forecasts of the new light-duty vehicle fleet through MY 2025. These two fleet forecasts (Analyses 1 and 2, as defined below) were combined with the two fuel economy forecasts (Analyses A and B) described in Section 2.2.1 to create a total of four different analyses of the direct and indirect impacts of the alternatives (A1, A2, B1, and B2; *see* Section 2.2.3). The significant uncertainty associated with forecasting sales volumes, vehicle technologies, fuel prices, consumer demand, and other variables out to MY 2025 makes it reasonable and appropriate to evaluate the impacts of the Proposed Action and alternatives using two fleet baselines.[14] One new vehicle fleet forecast (generally referred to as the "MY 2008 baseline" and reflected in Analyses A1 and B1) is similar to the one used for the NPRM and uses corrected[15] MY 2008 CAFE certification data, AEO fleet sales projections published in 2011, and a purchased CSM-based new vehicle fleet projection (by vehicle type and manufacturer) out to MY 2025. The agencies received comments regarding the fleet forecast used in the NPRM suggesting that updates in several respects could be helpful to the agencies' analysis of final standards. Given those comments, and because the agencies were already planning to produce an updated new vehicle fleet forecast, this EIS also contains another fleet forecast (generally referred to as the "MY 2010 baseline" and reflected in Analyses A2 and B2) using a baseline fleet constructed from MY 2010 CAFE certification data, AEO fleet sales projections to MY 2025 published in 2012, and a purchased LMC Automotive-based new vehicle fleet projection (by vehicle type and manufacturer) out to MY 2025.

The two new vehicle fleet forecasts have certain differences. For example, the MY 2008 vehicle data (reflected in Analyses A1 and B1) represents the most recent model year for which the industry had sales data that was not affected by the subsequent economic recession. This information could help provide a reasonable forecast if one believes that future vehicle sales are more likely to be reflective of pre-recession sales than sales over the past several model years. Conversely, the MY 2010 baseline (reflected in Analyses A2 and B2) employs a future new vehicle fleet forecast provided by LMC, which is more current than the projection provided by CSM in 2009. Furthermore, the CSM forecast, used for the MY 2008 baseline, appears to have been particularly influenced by the recession, showing major

[13] This was partly due to the earthquake and tsunami in Japan.
[14] OMB Circular A-4 states that agencies should consider measuring a rule's impacts against multiple baselines when more than one baseline might be reasonable and the choice of a different baseline will significantly affect estimated costs and benefits (OMB 2003).
[15] NHTSA made some very minor corrections to vehicle footprint values in the CAFE data (to wheelbase data errors in the certification data that were discovered after publication of the NPRM) and to some technology "overrides" and technology class assignments used in DOT's modeling system.

declines in market share for some manufacturers (e.g., Chrysler), which NHTSA does not believe reasonably reflects future trends.

In addition, although MY 2010 CAFE certification data has become available since publication of the NPRM, it continues to show the effects of the recession. For example, industry-wide sales were skewed down 20 percent compared to pre-recession MY 2008 levels. For some companies, like Chrysler, Mitsubishi, and Subaru, sales were down 30 to 40 percent. For BMW, General Motors, Jaguar/Land Rover, Porsche, and Suzuki, sales were down more than 40 percent. Using the MY 2008 vehicle data avoids using these sudden and perhaps temporary baseline market shifts when projecting the future new vehicle fleet, although it also perpetuates vehicle brands and models (and therefore, their outdated fuel economy levels and engineering characteristics) that have since been discontinued – in all likelihood, permanently. The MY 2010 CAFE certification data accounts for the phase-out of some brands (e.g., Saab, Pontiac, Hummer) and the introduction of some technologies (e.g., Ford's Ecoboost engine), which might be more reflective of the future new vehicle fleet.

Therefore, given the volume of information that goes into creating a baseline forecast and given the significant uncertainty in any projection out to MY 2025, NHTSA believes that the best way to illustrate the possible impacts of this uncertainty for purposes of this Final EIS is to analyze the effects of the Proposed Action and alternatives under both the MY 2008 baseline and the MY 2010 baseline.

2.2.3 Designation of Analyses in this EIS Based on Uncertainties

In light of the uncertainties discussed above, this Final EIS presents the potential environmental impacts for each of the alternatives using two different assumptions regarding market-driven fuel economy improvements and two different sets of fleet-characteristic assumptions. By retaining the assumptions used in Analysis A and Analysis B from the Draft EIS (described above), this approach therefore produces four sets of results for direct and indirect impacts – Analyses A1 and A2 and Analyses B1 and B2 – for each of the alternatives as described below. The two sets of fleet-characteristic assumptions also produce two sets of results for cumulative impacts – Analyses C1 and C2 – for each of the alternatives as described below.

- In Analyses A1 and A2, the agency assumes that the average fleetwide fuel economy for light-duty vehicles would not exceed the minimum level necessary to comply with CAFE standards. Therefore, Analyses A1 and A2 measure the impacts of the action alternatives under which average fleetwide fuel economy in each model year does not exceed the level of the CAFE standards for that model year, compared to a No Action Alternative under which average fleetwide fuel economy after MY 2016 will never exceed the level of the agencies' MY 2016 standards established by final rule in April 2010. Tables and figures in this Final EIS that depict results for Analysis A1 (these have "A1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis A2 (these have "A2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.
- In Analyses B1 and B2, the agency assumes continued improvements in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Therefore, Analyses B1 and B2 measure the impacts of the action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing improvements in new vehicle fuel economy after MY 2025, compared to a No Action Alternative that assumes the average fleetwide fuel

economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards, even in the absence of agency action. Tables and figures in this Final EIS that depict results for Analysis B1 (these have "B1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis B2 (these have "B2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.

- CEQ NEPA implementing regulations require agencies to consider the cumulative impacts of major federal actions. NHTSA refers to the cumulative impacts analysis as Analysis C throughout this EIS. In Analyses C1 and C2, the agency compares action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing fuel economy improvements after MY 2025 with a No Action Alternative under which there are no continued improvements in fuel economy after MY 2016 (i.e., the average fleetwide fuel economy for light-duty vehicles would not exceed the latest existing standard). In this way, the cumulative impacts analysis combines the No Action Alternative from Analyses A1 and A2 with the action alternatives from Analyses B1 and B2. Tables and figures in this Final EIS that depict results for Analysis C1 (these have "C1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis C2 (these have "C2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection. For more explanation of NHTSA's methodology regarding the cumulative impacts analysis, *see* Section 2.5.

Analysis A1 is generally comparable to Analysis A in the Draft EIS and Analysis B1 is generally comparable to Analysis B in the Draft EIS – all of these analyses reflect a MY 2008 baseline fleet, new vehicle sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. However, the Final EIS results reflect updated input values for the Volpe model (further discussed in Section 2.3.1) that result in somewhat lower fuel use and associated environmental impacts than reported in the Draft EIS. In particular, Analyses A1 and B1 reflect vehicle-use estimates based on the 2009 National Household Travel Survey, whereas Analyses A and B in the Draft EIS reflected data from the 2001 survey. The 2009 survey showed somewhat lower average vehicle use (annual vehicle miles traveled [VMT] per vehicle) than had been estimated based on the 2001 survey. This results in lower fuel use and total VMT estimates in the Final EIS than in the Draft EIS.

Analysis A2 and Analysis B2 make the same assumptions about growth during and after the years of the Proposed Action as Analyses A1 and Analysis B1, respectively, except these analyses reflect a MY 2010 baseline fleet (as described above). In addition to reflecting updated model inputs based on the 2009 National Household Travel Survey, Analyses A2 and B2 also reflect updated sales forecasts consistent with the AEO 2012 Early Release. These updated inputs result in a lower forecast growth rate in the light-duty vehicle fleet and in total VMT compared to the inputs for Analyses A1 and B1, which are based on AEO 2011. As a result, fuel use and associated environmental impacts are generally lower for Analysis A2 than for Analysis A1 and lower for Analysis B2 than for Analysis B1.

NHTSA has provided separate tables illustrating the environmental impacts projected under each analysis throughout this Final EIS. In discussing these impacts throughout the EIS, NHTSA often presents the results of Analyses A1 and A2 together and Analyses B1 and B2 together in what appears to be a range (e.g., "light-duty vehicle 2017–2060 fuel consumption is projected to range from 4,987 to 5,372 billion gallons under the Preferred Alternative under Analyses A1 and A2"). This form of presenting the results is not intended to bound all the possible, or even likely, potential impacts that could occur under a given alternative in a given year. In other words, the values should not be interpreted as a true minimum or maximum of potential impacts. Rather, this format presents results using the same methodology but under different assumptions, as described above.

2.2.4 Alternative 1: No Action

The No Action Alternative assumes that NHTSA would not issue a rule regarding CAFE standards for MY 2017–2025 passenger cars and light trucks; rather, consistent with previous EISs, the No Action Alternative assumes that NHTSA's latest CAFE standards (the MY 2016 fuel economy standards, issued in conjunction with EPA's MY 2016 GHG standards) would continue indefinitely, subject to the market and fleet assumptions described above. This alternative provides an analytical baseline against which to compare the environmental impacts of the other alternatives presented in the EIS.[16] 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 action alternatives to demonstrate the environmental effects of the action alternatives. The No Action Alternative assumes that average fuel economy levels and GHG emissions performance in the absence of the agencies' action would equal what manufacturers would achieve without additional regulation. The No Action Alternative would yield no additional environmental improvement other than what might occur from manufacturers changing fuel economy and GHG emissions performance in response to market forces. The environmental impacts of the action alternatives are calculated in relation to the baseline of the No Action Alternative.

Table 2.2.4-1 shows the estimated required and achieved fleetwide fuel economy NHTSA forecasts under the No Action Alternative in Analyses A1, A2, B1 and B2. Because the No Action Alternative assumes that NHTSA would not issue MY 2017–2025 CAFE standards, estimated required values represent what is forecast under the agency's latest CAFE standards (the MY 2016 fuel economy standards, issued in conjunction with EPA's MY 2016 GHG standards), which are assumed to continue indefinitely for purposes of the No Action Alternative in this EIS. The fuel economy numbers presented here are what are forecast to be determined through future laboratory testing and do not include a fuel economy adjustment factor to account for real-world driving conditions (*see* Section 2.2.7 for more discussion about the difference between adjusted and unadjusted mile-per-gallon [mpg] values).

[16] *See* 40 CFR §§ 1502.2(e), 1502.14(d). CEQ has explained that "[T]he regulations require the analysis of the no action alternative even if the agency is under a court order or legislative command to act. 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 (Mar. 23, 1981).

Table 2.2.4-1. Estimated U.S. Passenger Car and Light-Truck Average Fleetwide Fuel Economy (mpg) by Model Year under the No Action Alternative

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Required under MY 2016 CAFE Standards – Analyses A1 and B1									
Passenger cars	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7
Light trucks	29.3	29.3	29.3	29.3	29.3	29.3	29.4	29.4	29.4
Combined cars and trucks	34.6	34.7	34.8	34.8	34.8	34.9	34.9	35.0	35.1
Estimated Average Required under MY 2016 CAFE Standards – Analyses A2 and B2									
Passenger cars	38.2	38.2	38.2	38.1	38.1	38.2	38.1	38.2	38.1
Light trucks	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
Combined cars and trucks	34.3	34.3	34.3	34.3	34.3	34.4	34.4	34.5	34.5
Estimated Average Achieved – Analysis A1									
Passenger cars	37.5	38.0	38.3	38.6	38.7	38.8	38.8	38.8	38.8
Light trucks	28.7	28.8	29.0	29.1	29.3	29.4	29.4	29.5	29.5
Combined cars and trucks	33.7	34.1	34.4	34.6	34.9	34.9	35.0	35.1	35.2
Estimated Average Achieved – Analysis A2									
Passenger cars	37.2	37.7	37.9	38.1	38.2	38.2	38.2	38.2	38.2
Light trucks	28.0	28.2	28.4	28.8	29.0	29.0	29.0	29.1	29.1
Combined cars and trucks	33.3	33.7	33.9	34.3	34.4	34.5	34.5	34.6	34.6
Estimated Average Achieved – Analysis B1									
Passenger cars	38.3	39.0	39.6	39.8	40.1	40.4	40.5	40.5	40.6
Light trucks	29.5	30.1	31.1	31.4	31.6	31.9	32.1	32.2	32.4
Combined cars and trucks	34.5	35.3	36.1	36.4	36.7	37.0	37.2	37.3	37.5
Estimated Average Achieved – Analysis B2									
Passenger cars	38.0	38.6	39.0	39.4	39.6	39.8	39.9	40.0	40.1
Light trucks	28.6	28.9	29.9	30.5	31.0	31.3	31.5	31.7	31.8
Combined cars and trucks	34.1	34.5	35.2	35.7	36.2	36.4	36.6	36.8	36.9

For the No Action Alternative, estimated average *required* fuel economy levels are based on application of the mathematical function defining the alternative (i.e., the curve that defines the MY 2016 CAFE standards) to the market forecast defining the estimated future fleets of new passenger cars and light trucks.[17] For the No Action Alternative, estimated average *achieved* fuel economy levels reflect the agency's estimates of manufacturers' potential responses to these requirements, taking into account available technology, available adjustments to fuel economy levels based on reduction of air conditioner energy consumption, fuel economy calculations specific to electric vehicles (EVs), and EISA (as amended by EPCA) provisions allowing manufacturers to earn CAFE credits by producing flexible-fuel vehicles, to

[17] Both the MY 2012–2016 standards and the proposed standards are attribute-based standards based on vehicle footprint. Under the footprint-based standards, a curve defines a GHG or fuel economy performance target for each separate car or truck footprint. Using the curves, each manufacturer therefore would have a GHG and CAFE average standard that is unique to each of its fleets, depending on the footprints and production volumes of the vehicle models produced by that manufacturer. A manufacturer would have separate footprint-based standards for cars and for trucks. Although a manufacturer's fleet average standards could be estimated throughout the model year based on projected production volume of its vehicle fleet, the standards with which the manufacturer must comply would be based on its final model year production figures. A manufacturer's calculation of its fleet average standards and its fleets' average performance at the end of the model year would therefore be based on the production-weighted average target and performance of each model in its fleet.

pay civil penalties in lieu of achieving compliance with CAFE standards, to carry CAFE credits forward between model years (up to 5 years), and to transfer CAFE credits between the passenger car and light-truck fleets. Table 2.2.4-1 shows different sets of estimated average achieved fuel economy values for Analyses A1, A2, B1, and B2, but only two sets of estimated average required fuel economy (for Analyses A1/B1 and A2/B2) because those values are not affected by assumptions related to market-based improvements in fuel economy in the absence of agency action.

2.2.5 Action Alternatives

In addition to the No Action Alternative, NHTSA analyzed a range of action alternatives with fuel economy stringencies that increase on average 2 percent to 7 percent annually from the MY 2016 standards for passenger cars and for light trucks. As NHTSA stated in the Notice of Intent to issue an EIS, the Draft EIS, and the NPRM, the agency believes that, based on the different ways the agency could weigh EPCA's four statutory factors, the "maximum feasible" level of CAFE stringency falls within this range.[18]

Throughout this EIS, estimated impacts are shown for 3 action alternatives that illustrate this range of average annual percentage increases in fuel economy: a 2 percent per year average increase for both passenger cars and light trucks (Alternative 2); the Preferred Alternative with annual percentage increases for passenger cars and for light trucks that, on average, fall between the 2 percent and 7 percent per year increase (Alternative 3); and a 7 percent per year average increase for both passenger cars and light trucks (Alternative 4).

Alternatives 2 and 4 are intended to provide the lower and upper bounds of a reasonable range of alternatives within which the agency believes the maximum feasible standards fall. This range encompasses a spectrum of possible standards the agency could select, based on the different ways NHTSA could weigh EPCA's four statutory factors. By providing environmental analyses of these points and the Preferred Alternative, the decisionmaker and the public can determine the environmental impacts of points that fall between Alternatives 2 and 4. The action alternatives evaluated in this EIS therefore provide decisionmakers with the ability to select from a wide variety of other potential alternatives with stringencies that increase annually at average percentage rates between 2 and 7 percent. This includes, for example, alternatives with stringencies that increase at different rates for passenger cars and for light trucks and stringencies that increase by different rates in different years.

Tables in this section for each of the regulatory alternatives show estimated average required fuel economy levels reflecting application of the mathematical functions defining the alternatives to the market forecast defining the estimated future fleets of new passenger cars and light trucks. Like Table 2.2.5-1 for the No Action Alternative, estimated average *achieved* fuel economy levels presented for the action alternatives below reflect the agency's estimates of manufacturers' potential responses to these requirements, taking into account available technology, available adjustments to fuel economy levels based on reduction of air conditioner energy consumption, fuel economy calculations specific to EVs, and EISA/EPCA provisions allowing manufacturers to earn CAFE credits by producing flexible fuel vehicles, to pay civil penalties in lieu of achieving compliance with CAFE standards, to carry CAFE credits forward between model years (up to 5 years), and to transfer CAFE credits between the passenger car and light-truck fleets. In addition, for the action alternatives, estimated achieved levels take into account available adjustments to fuel economy levels based on application of technologies (other than

[18] For a full discussion of the agency's balancing of the statutory factors related to "maximum feasible" standards, consult the NPRM.

those that improve air conditioner efficiency) that reduce off-cycle energy consumption. This EIS assumes a weighted average of flexible fuel vehicles' fuel economy levels when operating on gasoline and on E85 (a blend of 15 percent gasoline and 85 percent ethanol, by volume). In particular, this EIS assumes that flexible fuel vehicles operate on gasoline 85 percent of the time and on E85 the remaining 15 percent of the time.

Both required and achieved fuel economy values projected below are determined through laboratory testing and do not include a fuel economy adjustment factor to account for real-world driving conditions. (*See* Section 2.2.7 for more discussion about the difference between adjusted and unadjusted fuel economy.)

2.2.5.1 Alternative 2: 2 Percent per Year Increase in Fuel Economy

Alternative 2 would require a 2 percent average annual fleetwide increase in fuel economy for passenger cars and light trucks for MYs 2017–2025. As noted above, Alternative 2 represents the lower bound of the range of average annual stringency increases that NHTSA believes includes the maximum feasible stringency. Table 2.2.5-1 lists the estimated average required and achieved fleetwide fuel economy NHTSA forecasts under Alternative 2.

Table 2.2.5-1. Estimated U.S. Passenger Car and Light-Truck Average Fleetwide Fuel Economy (mpg) by Model Year under Alternative 2

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Required – Analyses A1 and B1									
Passenger cars	39.5	40.3	41.2	42.0	42.9	43.9	44.7	45.7	46.7
Light trucks	30.1	30.8	31.5	32.1	32.8	33.5	34.2	35.1	35.8
Combined cars and trucks	35.5	36.3	37.2	37.9	38.8	39.6	40.5	41.5	42.5
Estimated Average Required – Analyses A2 and B2									
Passenger cars	39.0	39.8	40.6	41.4	42.3	43.2	44.1	45.0	46.0
Light trucks	29.7	30.3	30.9	31.5	32.2	32.8	33.5	34.3	35.0
Combined cars and trucks	35.1	35.8	36.6	37.4	38.2	39.0	39.8	40.8	41.6
Estimated Average Achieved – Analysis A1									
Passenger cars	38.8	40.1	41.4	42.7	43.6	44.2	44.9	45.8	46.2
Light trucks	30.0	30.7	31.9	32.8	33.8	34.3	34.6	35.1	35.3
Combined cars and trucks	35.0	36.1	37.5	38.6	39.6	40.2	40.8	41.6	41.9
Estimated Average Achieved – Analysis A2									
Passenger cars	38.2	39.4	40.5	41.8	42.8	43.3	44.0	44.9	45.2
Light trucks	29.8	30.2	31.4	32.3	32.9	33.3	33.8	34.3	34.3
Combined cars and trucks	34.7	35.6	36.7	37.9	38.8	39.2	39.9	40.7	40.9
Estimated Average Achieved – Analysis B1									
Passenger cars	39.0	40.3	41.5	42.7	43.4	44.4	44.9	45.8	46.4
Light trucks	30.2	31.1	32.4	33.1	33.6	34.1	34.5	35.0	35.5
Combined cars and trucks	35.2	36.4	37.7	38.8	39.4	40.2	40.7	41.5	42.2

Table 2.2.5-1. Estimated U.S. Passenger Car and Light-Truck Average Fleetwide Fuel Economy (mpg) by Model Year under Alternative 2 (continued)

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Achieved – Analysis B2									
Passenger cars	38.7	39.6	40.6	41.8	42.6	43.2	44.2	45.2	45.8
Light trucks	29.5	30.0	31.3	32.4	33.3	33.6	34.1	34.4	34.8
Combined cars and trucks	34.8	35.6	36.8	38.0	38.9	39.4	40.1	40.9	41.5

2.2.5.2 Alternative 3: Preferred Alternative

Alternative 3 is NHTSA's Preferred Alternative, under which manufacturers would be required to meet an estimated average fleetwide fuel economy level of 40.3 to 41.0 mpg in MY 2021 and 48.7 to 49.7 mpg in MY 2025. These averages are uncertain, because, as discussed in Section 1.3.2.1, the actual average required fuel economy levels in the future will depend on the actual composition of the future fleet, which can only be estimated – with considerable uncertainty – at this time. However, insofar as the target curves defining the standards reflect a mathematical progression (i.e., the curve applicable in 1 year is a multiple of that applicable in the preceding year), rates of increase in mathematical stringency are not subject to such uncertainty because the target curves themselves do not depend on the fleet's composition. The alternatives described in the Final EIS are defined in terms of the mathematical progression of the gallons per mile (gpm)-based target functions and not the fleet-dependent averages of manufacturers' fuel economy levels. The proposed stringency increases to the attribute-based standards (i.e., the target functions as expressed on a gpm basis) for MYs 2017–2021 average 3.6 percent for passenger cars. In recognition of manufacturers' unique challenges in improving the fuel economy and GHG emissions of full-size pickup trucks (a subset of light trucks) as we transition from the MY 2016 standards to MY 2017 and later, while preserving the utility (e.g., towing and payload capabilities) of those vehicles, NHTSA's proposal includes a slower annual rate of improvement for light trucks in the first phase of the program. The proposed stringency increases to the attribute-based standards for MYs 2017–2025 average 2.3 percent (on a gpm basis) for light trucks. For MYs 2022–2025, the annual stringency increases set forth averages 4.4 percent (also on a gpm basis) for both passenger cars and light trucks.

For the Draft EIS, stringency increases were reported as rates of increase in mathematical stringency. They were actually the rates of increase in the average of fuel economy levels required of manufacturers. The target curves identified as the Preferred Alternative and analyzed in this Final EIS are the same as those that defined the Preferred Alternative in the Draft EIS and outlined as the proposal in the NPRM. In other words, the rate of increase in stringency of the Preferred Alternative analyzed in the Final EIS has not changed.

To provide additional perspective, NHTSA also describes the Preferred Alternative in terms of the increase in the average estimated required fuel economy levels. Because the standards are attribute-based, average required fuel economy levels, and therefore rates of increase in those averages, depend on the future composition of the fleet, which is uncertain and subject to change. Because of this uncertainty and updates to the inputs used in the Volpe model, these values have changed slightly from those reported in the Draft EIS. On an mpg basis, the estimated annual increase in the average required fuel economy levels between MYs 2017 and 2021 averages 3.8 to 3.9 percent for passenger cars and 2.5 to 2.7 percent for light trucks. During MYs 2022–2025, estimated annual increases in the average required fuel economy levels – also on an mpg basis – are assumed to average 4.7 percent for passenger cars and 4.8 to 4.9 percent for light trucks.

Table 2.2.5-2 lists the estimated average required and achieved fleetwide fuel economy NHTSA forecasts under the Preferred Alternative.

Table 2.2.5-2. Estimated U.S. Passenger Car and Light-Truck Average Fleetwide Fuel Economy (mpg) by Model Year under the Preferred Alternative

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Required – Analyses A1 and B1									
Passenger cars	40.1	41.6	43.1	44.8	46.8	49.0	51.2	53.6	56.2
Light trucks	29.4	30.0	30.6	31.2	33.3	34.9	36.6	38.5	40.3
Combined cars and trucks	35.4	36.5	37.7	38.9	41.0	43.0	45.1	47.4	49.7
Estimated Average Required – Analyses A2 and B2									
Passenger cars	39.6	41.1	42.5	44.2	46.1	48.2	50.5	52.9	55.3
Light trucks	29.1	29.6	30.0	30.6	32.6	34.2	35.8	37.5	39.3
Combined cars and trucks	35.1	36.1	37.1	38.3	40.3	42.3	44.3	46.5	48.7
Estimated Average Achieved – Analysis A1									
Passenger cars	39.5	41.5	43.8	46.3	47.9	49.3	50.0	51.5	52.9
Light trucks	29.3	30.3	31.9	33.3	35.2	36.1	36.8	37.9	39.0
Combined cars and trucks	35.0	36.6	38.7	40.8	42.6	43.8	44.6	46.0	47.4
Estimated Average Achieved – Analysis A2									
Passenger cars	39.4	41.1	43.3	45.1	47.1	48.1	49.6	51.3	52.1
Light trucks	28.8	29.3	31.3	32.8	34.9	35.5	36.5	37.4	37.6
Combined cars and trucks	34.8	36.0	38.2	39.9	42.0	42.9	44.2	45.6	46.2
Estimated Average Achieved – Analysis B1									
Passenger cars	39.8	41.7	43.8	45.9	47.4	48.7	49.7	51.7	53.8
Light trucks	30.1	31.1	32.7	33.8	35.2	36.2	37.1	38.0	39.4
Combined cars and trucks	35.6	37.1	39.1	40.8	42.3	43.6	44.6	46.1	48.1
Estimated Average Achieved – Analysis B2									
Passenger cars	39.3	41.0	43.5	45.4	47.4	48.5	49.9	51.4	53.3
Light trucks	29.0	29.6	31.5	33.2	34.8	35.6	36.7	37.5	38.1
Combined cars and trucks	34.9	36.1	38.4	40.3	42.1	43.2	44.5	45.7	47.1

2.2.5.3 Alternative 4: 7 Percent per Year Increase in Fuel Economy

Alternative 4 would require a 7 percent average annual fleetwide increase in fuel economy for both passenger cars and light trucks for MYs 2017–2025. As noted above, Alternative 4 represents the upper bound of the range of average annual stringency increases that NHTSA believes includes the maximum feasible stringency. Table 2.2.5-3 lists the estimated average required and achieved fleetwide fuel economy NHTSA forecasts under Alternative 4.

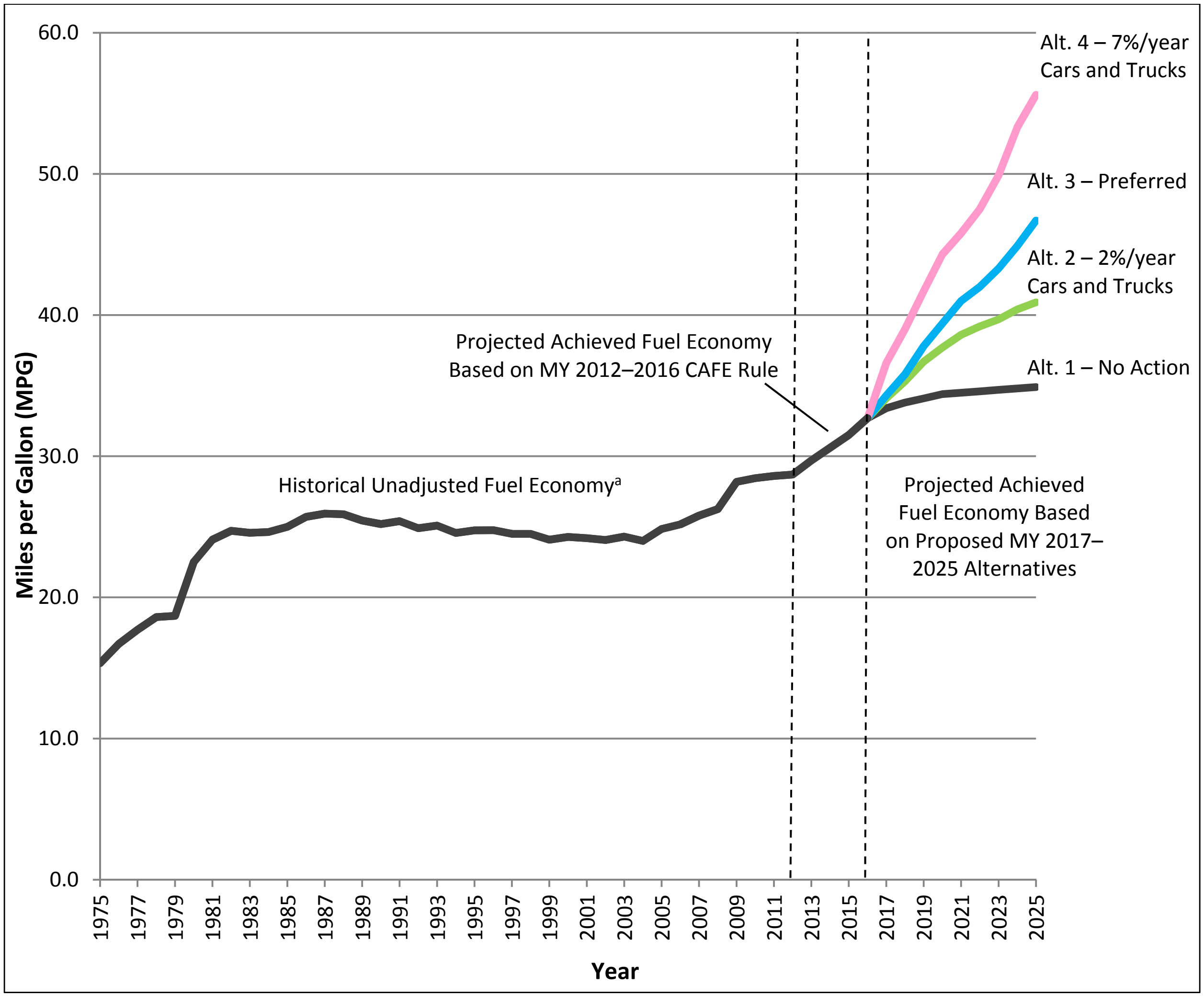
Table 2.2.5-3. Estimated U.S. Passenger Car and Light-Truck Average Fleetwide Fuel Economy (mpg) by Model Year under Alternative 4

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Estimated Average Required – Analyses A1 and B1									
Passenger cars	41.7	44.9	48.4	52.1	56.2	60.6	65.3	70.4	76.0
Light trucks	31.6	34.2	37.0	39.8	43.0	46.3	50.1	54.1	58.4
Combined cars and trucks	37.3	40.3	43.6	47.0	50.8	54.8	59.2	64.0	69.2
Estimated Average Required – Analyses A2 and B2									
Passenger cars	41.2	44.3	47.7	51.4	55.4	59.7	64.3	69.4	74.8
Light trucks	31.1	33.6	36.3	39.1	42.1	45.4	49.0	52.8	57.0
Combined cars and trucks	36.9	39.8	42.9	46.3	49.9	53.9	58.2	62.8	67.8
Estimated Average Achieved – Analysis A1									
Passenger cars	42.0	44.9	47.6	51.1	54.3	57.8	59.2	62.8	64.7
Light trucks	32.2	34.1	37.2	40.2	42.8	44.2	45.6	46.8	48.6
Combined cars and trucks	37.8	40.3	43.4	46.7	49.7	52.3	53.8	56.4	58.4
Estimated Average Achieved – Analysis A2									
Passenger cars	41.7	44.1	47.7	50.3	52.6	55.6	58.0	61.3	64.8
Light trucks	31.1	32.2	34.7	37.8	40.5	41.4	43.1	44.7	46.1
Combined cars and trucks	37.2	39.0	42.1	45.1	47.7	49.7	51.9	54.5	57.1
Estimated Average Achieved – Analysis B1									
Passenger cars	41.8	44.7	47.8	51.0	54.1	56.6	59.3	62.7	64.7
Light trucks	32.5	34.6	38.1	40.4	42.9	44.2	45.5	46.3	48.4
Combined cars and trucks	37.9	40.5	43.9	46.7	49.6	51.6	53.8	56.1	58.3
Estimated Average Achieved – Analysis B2									
Passenger cars	41.2	43.5	47.2	50.7	53.7	56.3	58.1	61.9	64.8
Light trucks	31.1	32.3	35.4	38.2	40.6	41.5	43.0	44.6	45.7
Combined cars and trucks	37.0	38.8	42.2	45.5	48.3	50.2	52.0	54.8	56.9

2.2.6 No Action and Action Alternatives in Historical Perspective

NHTSA has set CAFE standards since 1978. Figure 2.2.6-1 illustrates unadjusted[19] achieved fuel economy for combined passenger cars and light trucks from 1975 through 2011 (EPA 2012a). The figure extends these historic fuel economy levels out to their projected average achieved fuel economy levels under the existing MY 2012–2016 CAFE Final Rule and the Proposed Action discussed above.

Figure 2.2.6-1. Historical and Projected Achieved Fuel Economy (mpg) for Passenger Cars and Light Trucks



a. *See* Section 2.2.7 for a discussion about the difference between adjusted and unadjusted fuel economy levels.

As illustrated in the figure, light-duty vehicle fuel economy has moved through four phases since 1975: (1) a rapid increase from MYs 1975–1981, (2) a slower increase until MY 1987, (3) a gradual decrease until MY 2004, and (4) an increase for the 7 years beginning in MY 2005, with the largest increase in MY

[19] Unadjusted fuel economy measures fuel economy as achieved by vehicles in the laboratory. Adjusted fuel economy includes an adjustment factor to better estimate actual achieved on-road fuel economy, and is generally lower than its corresponding unadjusted fuel economy values. Figure 2.2.6-1 uses historical unadjusted fuel economy data as a basis to compare projected achieved fuel economy (based on existing and proposed CAFE rules) because projected achieved fuel economy data would also be derived from laboratory testing and does not include an adjustment factor. *See* section 2.2.7 for more discussion about the difference between NHTSA laboratory test fuel economy and EPA adjusted fuel economy.

2009. The MY 2012–2016 CAFE standards should extend this increase through 2016, and the MY 2017–2025 Proposed Action would continue this increase in fuel economy through 2025, to varying degrees depending on the alternative selected.

2.2.7 Laboratory Test Fuel Economy versus Adjusted Fuel Economy

Fleetwide average fuel economy levels achieved by light-duty vehicles in on-road driving fall somewhat short of the average levels measured under the laboratory-like test conditions used to establish published fuel economy ratings for different models. Specifically, the fuel economy ratings shown on EPA fuel economy window stickers are lower than the fuel economy ratings used by NHTSA for CAFE rulemaking and compliance purposes, because CAFE ratings do not include EPA adjustment factors, as discussed below, and because CAFE standards include certain credits and flexibilities (EPA 2012a). As a result, sales-weighted EPA adjusted average fuel economy levels[20] are lower than the sales-weighted average CAFE levels in *absolute* terms (both required and achieved). However, in *relative* terms, the percent changes in fuel economy over time are very similar for sales-weighted EPA adjusted fuel economy and sales-weighted CAFE ratings.

EPA fuel economy levels and CAFE standards are both based on laboratory test “drive cycles” for city and highway driving conditions. Overall, CAFE ratings and EPA adjusted fuel economy ratings reflect a weighted average of 55 percent city and 45 percent highway conditions. Beginning in 1985, to bring EPA estimates closer to the on-road fuel economy drivers actually achieve, EPA adjusted window-sticker fuel economy ratings to reduce city and highway laboratory test results by 10 percent and 22 percent, respectively. In 2008, EPA began additional tests to further adjust the ratings for higher speeds, air conditioning, and cold temperatures (EPA 2006a).

Figure 2.2.7-1 compares MY 1975–2011 sales-weighted CAFE laboratory test fuel economy with EPA adjusted fuel economy (including adjustments to MY 1975–2007 EPA fuel economy ratings to provide comparable trend data for adjusted fuel economy). In absolute terms, the CAFE laboratory test fuel economy values are higher than the EPA adjusted fuel economy values for both cars and light trucks.

Despite the difference in absolute fuel economy, Figure 2.2.7-1 shows that changes in CAFE laboratory test fuel economy and EPA adjusted fuel economy over time are very similar. The historical similarity of percent changes in both measures has also been especially strong across years of rising fuel economy, as shown in Table 2.2.7-1. CAFE laboratory test ratings and EPA adjusted ratings recorded very similar percentage gains from 1975 through 1985 and from 2005 through 2011.

Projections of the environmental impacts (e.g., fuel savings, air quality, and climate) of the Proposed Action analyzed in this EIS reflect the projected change in sales-weighted fuel economy in relative terms. Fuel-use projections for each alternative reflect current fuel use and the projected percentage change in unadjusted CAFE ratings associated with each alternative. Therefore, the fact that percent gains in fuel economy over time are very similar for sales-weighted EPA adjusted fuel economy and CAFE compliance ratings means that projected environmental impacts based on increases in CAFE standards can also be interpreted as projected environmental impacts associated with corresponding gains in sales-weighted EPA adjusted fuel economy.

For more discussion of the on-road fuel economy “gap” (the difference between adjusted and unadjusted mpg), *see* Section 4.2.1 of the agencies’ Draft Joint TSD.

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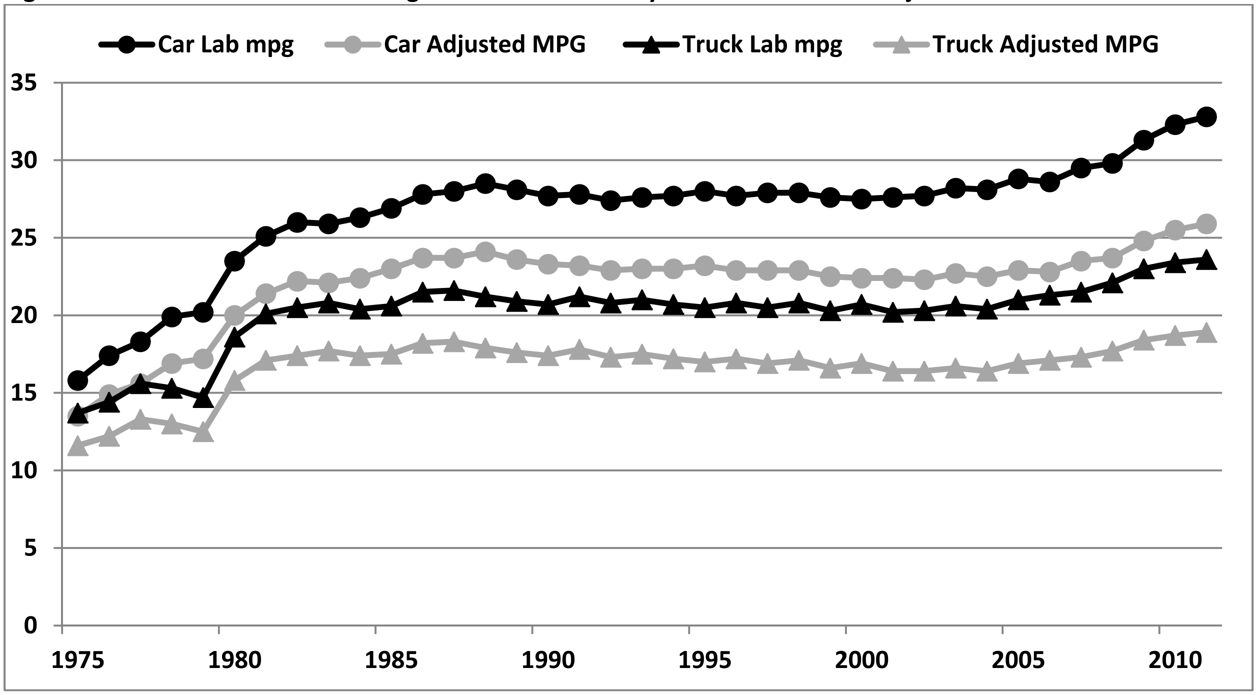
[20] Fleet-wide vehicle fuel economy calculated based on the distribution of vehicle sales.

Figure 2.2.7-1. 1975–2011 Sales-weighted CAFE Laboratory Test MPG and EPA Adjusted MPG[a]



a. Source: EPA 2012a.

Table 2.2.7-1. Change in Sales-weighted CAFE Laboratory Test MPG and EPA Adjusted MPG

Years	Car Laboratory	Car Adjusted	Truck Laboratory	Truck Adjusted
1975–1985	70.3%	70.4%	50.4%	50.9%
1985–1995	4.1%	0.9%	-0.5%	-2.9%
1995–2005	2.9%	-1.3%	2.4%	-0.6%
2005–2011	13.9%	13.1%	12.4%	11.8%

2.2.8 EPA's Proposed Greenhouse Gas Emission Standards

In conjunction with NHTSA's Proposed Action, EPA has proposed GHG emissions standards under Section 202(a) of the Clean Air Act (CAA). EPA's proposed standards begin with MY 2017, increase in stringency through MY 2025, and would require light-duty vehicles to meet an estimated combined average emissions level of 163 grams per mile of carbon dioxide (CO_2) in MY 2025. The National Program represents a harmonized approach that will allow industry to build a single national fleet that will satisfy both the GHG requirements under the CAA and CAFE requirements under EPCA (as amended by EISA). However, given differences in their respective statutory authorities, the agencies' proposed standards include some important differences. *See* Section 1.3.2.1 for a discussion of these differences. Table 2.2.8-1 lists EPA's estimates of its projected overall fleetwide CO_2 emissions compliance targets under the proposed standards. Projections in this section are from the NPRM and are based on the MY 2008 baseline fleet.

EPA anticipates that manufacturers will take advantage of program flexibilities. Table 2.2.8-2 shows EPA's projection of the achieved emission levels of the fleet for MYs 2017–2025. The grams per mile values in Table 2.2.8-2 are CO_2-equivalent values because they include the projected use of air conditioning credits by manufacturers.

Table 2.2.8-1. Projected U.S. Passenger Car and Light-Truck Fleetwide Emissions Compliance Targets under the Proposed CO_2 Standards (grams/mile)

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Passenger cars	213	202	192	182	173	165	158	151	144
Light trucks	295	285	277	270	250	237	225	214	203
Combined cars and trucks	243	232	223	213	200	190	181	172	163

Table 2.2.8-2. Projected U.S. Passenger Car and Light Truck-Fleetwide Achieved CO_2-equivalent Emissions Levels under the Proposed CO_2 Standards (grams/mile)

	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Passenger cars	215	205	194	184	174	165	158	151	144
Light trucks	295	285	278	271	251	238	226	214	204
Combined cars and trucks	245	234	224	214	201	190	181	172	164

2.2.9 Alternatives Considered but not Analyzed in Detail

In response to the agency's Notice of Intent and the Draft EIS, some commenters indicated that a 7 percent per year average annual increase in fuel economy standards was not a proper upper bound without the agency performing a full analysis. The agency has rigorously analyzed the various alternatives in the NPRM and continues to believe that the maximum feasible level of increased stringency on average falls between 2 percent per year and 7 percent per year for passenger cars and for light trucks. The agency has not analyzed an alternative in excess of a 7 percent per year increase for passenger cars and for light trucks because NHTSA believes that such an alternative would fall outside the range of where the maximum feasible level could fall, after a careful balancing of the four EPCA statutory factors discussed in Chapter 1. In particular, such a high level of stringency would place too little weight on economic practicability and technological feasibility.

In addition, one commenter indicated that NHTSA should include as an alternative the "maximum technologically feasible" levels of stringency. The agency does not believe this is a reasonable alternative in light of the four statutory factors. In particular, because technological feasibility is only one of four factors, such an alternative would essentially ignore the three other factors the agency is required to consider when setting CAFE standards. Therefore, NHTSA has not analyzed this alternative.

2.3 Standards-setting and EIS Methodologies and Assumptions

Each of the specific alternatives examined represents, in part, a different way in which NHTSA could conceivably balance conflicting policies and considerations in setting the standards. For example, the most stringent alternative, which increases both passenger car and light-truck fuel economy standards on average by 7 percent per year and reflects the upper bound of where the agency believes the maximum feasible stringency falls, weighs energy conservation and climate change considerations more heavily and economic practicability and technological feasibility less heavily. In contrast, the least stringent alternative, which increases both car and truck fuel economy standards on average by 2 percent per year and reflects the lower bound of where the agency believes the maximum feasible stringency falls, places more weight on economic practicability.

After working with EPA in thoroughly reviewing the effectiveness and costs of technologies, as well as market forecasts and economic assumptions, NHTSA used the Volpe model to assess the technologies that manufacturers could apply to their fleet to comply with each alternative. Section 2.3.1 describes the Volpe model and its inputs and provides an overview of the analytical pieces and tools used in the analysis of alternatives.

2.3.1 Volpe Model

Since 2002, as part of its CAFE analyses NHTSA has employed a modeling system developed specifically to help the agency apply technologies to thousands of vehicles and develop estimates of the costs and benefits of potential CAFE standards. The CAFE Compliance and Effects Modeling System developed by the Volpe National Transportation Systems Center, and commonly referred to as “the Volpe model,” enables NHTSA to efficiently, systematically, and reproducibly evaluate many regulatory options. Generally, the model assumes that manufacturers apply the most cost-effective technologies first, and as more stringent fuel economy standards are evaluated, the model recognizes that manufacturers must apply less cost-effective technologies. The model then compares the discounted present value of costs and benefits associated with any specific potential CAFE standard. The Volpe model calculates average changes in vehicle costs (corresponding to total technology outlays and, where applicable, civil penalties). It does not predict manufacturers’ decisions regarding the pricing or production of specific vehicle models, nor does it currently estimate consumer behavioral responses, such as buying fewer vehicles or buying different types of vehicles.

The Volpe model produces various outputs, including estimates of year-by-year fuel consumption by U.S. passenger car and light-truck fleets. For this EIS, NHTSA used the model to estimate annual fuel consumption and fuel savings for each calendar year from 2017, when the Proposed Action would first take effect, through 2060, when almost all passenger cars and light trucks in use would have been manufactured and sold during model years with CAFE standards at least as stringent as those set forth for MY 2025.[21]

2.3.2 Volpe Model Inputs

The Volpe model requires estimates for the following types of inputs: (1) a forecast of the future vehicle fleet, (2) availability, applicability, and incremental effectiveness and cost of fuel-saving technologies, (3) economic factors including vehicle survival and mileage accumulation patterns, future fuel prices, the rebound effect (the increase in vehicle use that results from improved fuel economy), and the “social cost of carbon,” (4) fuel characteristics and vehicular emissions rates, and (5) coefficients defining the shape and level of CAFE footprint-based curves, which use vehicle footprint (a vehicle’s wheelbase multiplied by the vehicle’s average track width) to determine the required fuel economy level or ‘‘target.’’ The model is a tool NHTSA uses for analysis; it makes no a priori assumptions regarding inputs such as fuel prices and available technologies and does not dictate the stringency or form of the CAFE standards to be examined. NHTSA makes those selections based on the best currently available information and data.

Using NHTSA-selected inputs, the agency projects a set of technologies each manufacturer could apply to each of its vehicle models to comply with the various levels of potential CAFE standards to be examined for each fleet, for each model year. The model then estimates the costs associated with this

[21] This assumes that if NHTSA does not establish more stringent CAFE standards for model years after MY 2025, the standards established for MY 2025 as part of the current rulemaking would be extended to apply to subsequent model years.

additional technology utilization and accompanying changes in travel demand, fuel consumption, fuel outlays, emissions, and economic externalities related to petroleum consumption and other factors.

For more information about the Volpe model and its inputs, *see* the NPRM, the Draft Joint TSD, and NHTSA's Preliminary Regulatory Impact Analysis (Preliminary RIA). Model documentation, publicly available in the rulemaking docket and on NHTSA's website, explains how the model is installed, how the model inputs and outputs are structured, and how the model is used.

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

2.3.2.1 Vehicle Fleet Forecast

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

As discussed above, in the NPRM and the Draft EIS, the agencies used a MY 2008-based fleet projection (Analyses A1, B1, and C1). However, the agencies have also created a MY 2010 baseline and market forecast for use in this Final EIS (Analyses A2, B2, and C2). Through Analyses A1, A2, B1, B2, C1, and C2, this Final EIS analyzes the projected impacts of the proposed alternatives using both vehicle market forecast inputs. More information about the vehicle market forecast used in the Draft EIS is available in Section II.B of the NPRM and Chapter 1 of the Draft Joint TSD. More detail about the agency's vehicle forecasts will appear in the forthcoming Final Joint TSD.

2.3.2.2 Technology Assumptions

The analysis of costs and benefits employed in the Volpe model reflects NHTSA's assessment of a broad range of technologies that can be applied to passenger cars and light trucks. The technologies the model considers encompass four broad categories: engine, transmission, vehicle, and electrification/accessory and hybrid technologies. More information about the technology assumptions used in the Draft EIS can be found in Chapter 3 of the Draft Joint TSD and in Chapter V of NHTSA's Preliminary RIA. The technology assumptions used in this Final EIS are largely similar and will be described in greater detail in the forthcoming NHTSA and EPA Final Joint TSD and in NHTSA's forthcoming RIA. Table 2.3.2-1 lists the types of technologies considered in this analysis for improving fuel economy.

Table 2.3.2-1. Technologies Considered by the Volpe Model that Manufacturers Can Add to their Vehicle Models and Platforms to Improve Fuel Economy

Engine Technologies	Transmission Technologies	Vehicle Technologies	Electrification/Accessory and Hybrid Technologies
• Low-friction lubricants • Engine friction reduction • Second level of low-friction lubricants and engine friction reduction • Cylinder deactivation • Variable valve timing • Discrete variable valve lift • Continuous variable valve lift • Stoichiometric gasoline direct-injection technology • Turbocharging and downsizing • Cooled exhaust-gas recirculation • Advanced diesel engines	• Manual 6-speed transmission • Improved automatic transmission controls • Six- and eight-speed automatic transmissions • Dual clutch transmissions • High Efficiency Gearbox (automatic, dual clutch transmissions, or manual) • Shift optimization	• Low-rolling-resistance tires • Low-drag brakes • Front or secondary axle disconnect for four-wheel drive systems • Aerodynamic drag reduction • Mass reduction	• Electric power steering/Electro-hydraulic power steering • Improved accessories • Air conditioner systems • 12-volt stop-start • Higher voltage stop-start/Belt integrated starter generator • P2 hybrid • Plug-in hybrid electric vehicles • Electric vehicles

2.3.2.3 Economic Assumptions

NHTSA's analysis of the energy savings, changes in emissions, and environmental impacts likely to result from the Proposed Action and alternatives relies on a range of forecasts, economic assumptions, and estimates of parameters used by the Volpe model. These economic values play a significant role in determining the reductions in fuel consumption, changes in emissions of criteria and toxic air pollutants and GHGs, reductions in U.S. petroleum imports, and resulting economic benefits of alternative standards. The Volpe model uses the following forecasts, assumptions, and parameters:

- Forecasts of sales of passenger cars and light trucks for MYs 2017–2025
- Assumptions about the fraction of these vehicles that remain in service at different ages, how rapidly average annual use of passenger cars and light trucks grows over time, and how passenger car and light truck use declines with their increasing age
- Forecasts of fuel prices over the expected lifetimes of MY 2017–2025 passenger cars and light trucks
- Forecasts of expected future growth in total passenger car and light-truck use, including vehicles of all model years comprising the U.S. vehicle fleet
- The size of the gap between test and actual on-road fuel economy
- The magnitude of the fuel economy rebound effect (the increase in vehicle use that results from improved fuel economy)
- Economic costs associated with U.S. consumption and imports of petroleum and refined petroleum products, over and above their market prices
- Changes in emissions of criteria and toxic air pollutants and GHGs that result from saving each gallon of fuel and from each added mile of driving
- The economic values of reductions in damages to human health caused by emissions of criteria and toxic air pollutants and GHGs

- The value of increased driving range and less frequent refueling that results from increases in fuel economy
- The costs of increased congestion, traffic accidents, and noise caused by added passenger car and light-truck use
- The discount rate applied to future benefits

NHTSA's analysis accounts for specific assumptions about how vehicles are used. For example, this analysis recognizes that passenger cars and light trucks typically remain in use for many years, so the changes in fuel use, emissions, and other environmental impacts due to NHTSA's Proposed Action will also continue for many years. However, the contributions to these impacts by vehicles produced during a particular model year decline over time as those vehicles are gradually retired from service, while those that remain in use are driven progressively less as they age. The Volpe model defines vehicle lifetime as the point at which less than 2 percent of the vehicles originally produced in a model year remain in service. Under this definition, passenger cars survive in the fleet for as long as 30 years, while light trucks can survive for up to 36 years. Of course, any individual vehicle is unlikely to survive to these maximum ages; the typical lifetimes for passenger cars and light trucks produced during recent model years are approximately 12 and 14 years, respectively.

In addition, NHTSA's analysis accounts for a rebound effect. Specifically, by reducing the cost of fuel consumed per mile driven, requiring increased fuel economy could create an incentive for additional vehicle use. Any resulting increase in vehicle use will offset part of the fuel savings that would otherwise be expected to result from higher fuel economy. The total passenger car and light-truck VMTs would increase slightly due to the rebound effect, and tailpipe emissions of pollutants strictly related to vehicle use would increase in proportion to increased VMT. In this EIS, the estimated rebound effect for light-duty vehicles is assumed to be 10 percent. These VMT impacts are reflected in the estimates of emissions under each of the alternatives evaluated (*see* Section 2.4.1 for more detail).

Table 2.3.2-2 lists many of the specific forecasts, assumptions, and parameter values used to calculate the energy savings, environmental impacts, and economic benefits of each alternative. The impacts of the alternatives evaluated in this EIS reflect a specific combination of economic inputs in the Volpe model. Detailed descriptions of the sources of forecast information, the rationale underlying each economic assumption, and the agency's choices of specific parameter values are included in Chapter 4 of the Draft Joint TSD and in NHTSA's Preliminary RIA. More information will appear in the forthcoming Joint Final Rule and NHTSA's Final RIA. NHTSA also analyzed the sensitivity of its estimates to plausible variations in the values of many of these variables. The specific values of these variables used in the NHTSA sensitivity analysis and their effects on estimates of fuel consumption and GHG emissions will be reported and discussed in NHTSA's Final RIA. Table 2.3.2-3 lists the social cost of CO_2[22] at various discount rates.

[22] An estimate of the monetized climate-related damages associated with an incremental increase in annual carbon emissions; the estimated price of the damages caused by each ton of CO_2 released into the atmosphere.

Table 2.3.2-2. Forecasts, Assumptions, and Parameters Used to Analyze Impacts of Regulatory Alternatives (2010 U.S. dollars)

Fuel Economy Rebound Effect	10%
"Gap" between Test and On-road mpg for Liquid-fueled Vehicles	20%
"Gap" between Test and On-road Wall Electricity Consumption for EVs	30%
Value of Refueling Time ($/vehicle-hour)	$21.45 (Cars); $21.81 (Trucks)
Average Tank Volume Refilled During Refueling Stop	65%
Annual Growth in Average Vehicle Use	0.6% per year
Fuel Prices (2017–2050 average, $/gallon)	
Retail gasoline price	$4.13
Pre-tax gasoline price	$3.78
Economic Benefits from Reducing Oil Imports ($/gallon)	
"Monopsony" Component	$0.00
Price Shock Component	$0.20 in 2025
Military Security Component	$0.00
Total Economic Costs ($/gallon)	$0.20 in 2025
Emission Damage Costs (2020, $/short ton)	
Carbon monoxide (CO)	$0
Volatile organic compounds (VOCs)	$1,700
Nitrogen oxides (NO_X)	$6,700
Particulate matter ($PM_{2.5}$)	$306,500
Sulfur dioxide (SO_2)	$39,600
Carbon dioxide (CO_2) (social cost of carbon)	Variable (*see* Table 2.3.2-3)
External Costs from Additional Automobile Use ($/vehicle-mile)	
Congestion	$0.056
Accidents	$0.024
Noise	$0.001
Total External Costs	$0.081
External Costs from Additional Light-truck Use ($/vehicle-mile)	
Congestion	$0.050
Accidents	$0.027
Noise	$0.001
Total External Costs	$0.078
Discount Rate Applied to Future Benefits	3%, 7%

Table 2.3.2-3. Social Cost of CO_2 ($/metric ton), 2017 (2010 U.S. $)

Discount Rate	5%	3%	2.5%	3%
Source of Estimate	**Mean of Estimated Values**			**95th Percentile Estimate**
2017 Estimate	$6.39	$25.86	$41.32	$79.10

2.3.2.4 Fuel Characteristics and Vehicular Emissions Rates

Car and light-truck use, fuel refining, and fuel distribution and retailing also generate emissions of certain air pollutants. While reductions in fuel refining and distribution that result from lower fuel consumption will reduce emissions of some of these pollutants, additional vehicle use associated with the rebound effect will increase emissions of most of these pollutants. Therefore, the net effect of stricter fuel economy and GHG standards on total emissions of each pollutant depends on the relative magnitudes of reduced emissions during fuel refining and distribution, and increases in emissions from vehicle use. Because the relationship between emissions rates (emissions per gallon refined of fuel or mile driven) in fuel refining and vehicle use is different for each pollutant, the net effect of increases in fuel economy on total emissions of each pollutant differs.

For more discussion about these Volpe model inputs, *see* Section 4 of the Draft Joint TSD and Section VIII of the Preliminary RIA. More discussion regarding types of emissions also appears below.

2.3.2.5 Coefficients Defining the Shape and Level of CAFE Footprint-based Curves

In the NPRM, NHTSA proposed CAFE standards for MY 2017 and beyond that were expressed as a mathematical function that defines a fuel economy target applicable to each vehicle model and, for each fleet, establishes a required CAFE level determined by computing the sales-weighted harmonic average of those targets. NHTSA described its methodology for developing the coefficients defining the curves for the Proposed Action in the NPRM, the Preliminary RIA, and the Draft Joint TSD.

2.3.3 Volpe Model Updates and Their Effect on Electricity Consumption

Between the Draft EIS and the Final EIS, NHTSA updated several inputs to the agency's analysis and made some corrections to the Volpe model. Together, these updates and corrections led to increases in the amount of electricity estimated to be consumed, particularly under Alternative 4. This increase in the estimated amount of electricity consumption led, in turn, to increased estimates of emissions related to electricity generation.

The most significant factor leading to this increase in estimated electricity consumption is a correction to on-road energy consumption by EVs. DOE provides guidance on calculating the petroleum-equivalent fuel economy of alternative fuel vehicles by the use of a petroleum equivalency factor (PEF). The PEF is used for determining equivalent fuel economy performance for compliance. The PEF accounts for all of the upstream energy associated with the production and distribution of the alternative fuel and gasoline. For electricity, the PEF also includes a 0.15 incentive multiplier to encourage the use of electricity as an alternative fuel. The incentive multiplier effectively counts 15 percent of electrical energy when determining the gasoline "equivalent" performance. For the Draft EIS, the CAFE modeling mistakenly included the 15 percent incentive, meaning that for EVs, only 15 percent of the actual electrical energy used was accounted for in the analysis of environmental impacts. The Final EIS corrects this. This change not only affected per-mile electricity consumption, but also affected per-mile driving costs for EVs and the change in VMT in relation to the baseline run (via the fuel economy rebound effect).

In addition to correctly accounting for the impact of the PEF, the Final EIS uses an updated VMT schedule that affects the calculation of the rebound effect and the on-road efficiency correction. The base year for VMT has also been updated from 2001, when the per-mile cost of travel was relatively low due to historically low fuel prices, to 2008, when the per-mile cost of travel was much higher and economic growth was much slower. (The increase in per-mile fuel costs occurred because fuel prices were considerably higher in 2008 than in 2001, while there had been little change in the overall fuel economy of the fleet since 2001.) As a consequence, average vehicle use (as measured by annual VMT per vehicle) was lower in 2008 than it had been in 2001, and total VMT under the No Action Alternative is estimated to be lower in the Final EIS than previously in the Draft EIS.

However, fuel costs per mile are projected to be higher under the No Action Alternative in the Final EIS than in the Draft EIS because the AEO 2012 Early Release projection of fuel prices is higher than the AEO 2011 projection used in the Draft EIS. Therefore, increases in fuel economy from the application of new technologies are projected to lead to a more significant reduction in per-mile travel costs than reported in the Draft EIS, leading to a larger percentage increase in total VMT from the No Action Alternative under each action alternative than reported in the Draft EIS. On balance, these changes increase the relative importance of rebound-effect travel in the various Final EIS analyses compared to its role in the comparable Draft EIS analyses. With these VMT updates, changes in fuel economy (from the application of new technologies) have a more significant effect on per-mile travel costs than reported in the Draft EIS, leading to more rebound travel than reported in the Draft EIS.

Other changes include updates to gasoline and diesel prices, which have increased compared to the Draft EIS, and small corrections to the footprint of some of the MY 2008 vehicle model footprints. These changes make some technologies more cost-effective for some vehicle models or more cost effective in different model years. That alters technology paths for specific models and impacts the amount and timing of technology applied in both the baseline and the regulatory alternatives.

Each of these changes impacts the total consumption of electricity, and creates a measurable difference between the values in the Draft EIS and Final EIS.

2.3.4 Modeling Software

Table 2.3.4-1 lists the software used for computer simulation modeling of the projected vehicle fleet and its upstream and downstream emissions for the Final EIS. The table documents for each software the common abbreviation, full title, version used, inputs to the software model, and the outputs from the model used in the Final EIS analysis.

Table 2.3.4-1. Inventory of Final EIS Modeling Software

Model	Title	Model Inputs	Model Outputs Used in this Analysis
NEMS (AEO 2012 Early Release version)	DOE - National Energy Modeling System	• Freeze fuel economy standards from 2016 onward • Other inputs are default values for the Annual Energy Outlook (AEO) 2012 Early Release	• Projected fuel prices for all fuels • U.S. average electricity generating mix for future years • Light-duty vehicle sales for future years • Passenger car/light-truck split for future years
GREET (1 2011 Version) Fuel-Cycle model	DOE - Greenhouse Gases and Regulated Emissions in Transportation	• Estimates for nationwide average electricity generating mix estimate from NEMS 2012 Early Release • Other inputs are default GREET 2011 data	• Upstream emissions for EV electricity generation • Estimates of upstream emissions associated with production, transportation, and storage for gasoline, diesel, and ethanol-85
MOVES (2010a)	EPA - Motor Vehicle Emissions Simulator	• Emissions data from in-use chassis testing; remote sensing; state vehicle inspection and maintenance; and other programs	• NOx, SOx, CO, VOCs, $PM_{2.5}$, and toxic emission factors (tailpipe, evaporative, brake and tire wear) for Volpe model for cars and light-duty trucks, for three fuel types: gasoline, diesel, ethanol-85

Table 2.3.4-1. Inventory of Final EIS Modeling Software (continued)

Model	Title	Model Inputs	Model Outputs Used in this Analysis
Volpe (2012 Version)	Volpe - CAFE Compliance and Effects Model	• Characteristics of baseline vehicle fleet • Availability, applicability, and incremental effectiveness and cost of fuel-saving technologies • Vehicle survival and mileage accumulation patterns • Fuel economy rebound effect • Future fuel prices, social cost of carbon, and other economic factors • Fuel characteristics and criteria pollutant emission factors	• Costs associated with utilization of additional fuel-saving technologies • Changes in travel demand, fuel consumption, fuel outlays, • Technology utilization scenarios • Estimated U.S. vehicle fleet criteria and toxic emissions (tons) for future years
SMOKE (version 2.7)	MCNC - Sparse Matrix Operator Kernel Emissions	• Criteria pollutant emissions outputs from MOVES, Volpe, or other models • Emissions data for sources other than light-duty vehicles, from EPA National Emissions Inventory	• Gridded, speciated, hourly emissions for input into CMAQ and other models.
CMAQ (version 4.7)	EPA - Community Multiscale Air Quality model	• SMOKE outputs • Meteorological data	• Estimates of criteria pollutant concentrations and acid deposition. CMAQ includes a meteorological modeling system, emission models, and a chemistry-transport modeling system for simulation of the chemical transformation and fate.
BenMAP (version 4.0.43)	EPA - Environmental Benefits Mapping and Analysis Program	• CMAQ outputs • Population and population distribution data • Concentration-response data for health outcomes • Valuation data for monetization of health outcomes	• Health effects (number of mortality and morbidity outcomes) • Monetized health effects
GCAM RCP Scenario Results	Joint Global Change Research Institute's Global Change Assessment Model's simulations of the Representative Concentration Pathway radiative forcing targets	• Regional population estimates • Labor productivity growth • Energy demand • Agriculture, land cover, and land-use models • Atmospheric gas concentrations	• GCAMReference, GCAM6.0, and RCP4.5 global GHG emission scenarios (baselines).
MAGICC (5.3.v2)	National Center for Atmospheric Research - Model for the Assessment of Greenhouse-gas Induced Climate Change	• Adjusted GCAMReference, GCAM6.0, and RCP4.5 climate scenarios to reflect lower projected emissions from the car and light-duty vehicle fleet in the US from the action alternatives.	• Projected global carbon dioxide concentrations, global mean surface temperature, and sea-level rise from 2017 through 2100.

a. NO_x = nitrogen oxides; SO_x = sulfur oxides; CO = carbon monoxide; VOCs = volatile organic compounds; $PM_{2.5}$ = particulate matter with an aerodynamic diameter equal to or less than 2.5 microns.

2.3.5 Energy Market Forecast Assumptions

In this EIS, NHTSA uses projections of energy consumption and supply derived from the EIA, a DOE agency that collects and provides official energy statistics for the United States. EIA is the primary source of data that government agencies and private firms use to analyze and model energy systems.

Every year, EIA issues projections of energy consumption and supply for the United States (AEO) and the world (International Energy Outlook [IEO]). EIA reports energy forecasts through 2035 for consumption and supply by energy fuel source, sector, and geographic region. The model used to formulate EIA projections incorporates all federal and state laws and regulations in force at the time of modeling. Potential legislation and laws under debate in Congress are not included.

In this EIS, NHTSA uses projections of energy consumption and supply based on the 2011 IEO and 2011 AEO Reference Case[23] for Analyses A1 and B1 (2008 fleet), and uses the 2012 IEO and AEO 2012 Early Release Reference Case for Analyses A2 and B2 (2010 fleet). The AEO projections reflect the impact of market forces, MY 2012–2016 CAFE standards, and assumed increases in MY 2017–2020 CAFE standards to reflect EISA's requirement that the light-duty vehicle fleet achieve a combined fuel economy of 35 mpg by MY 2020. The AEO forecast assumes that CAFE standards are held constant after MY 2020, with forecasted fuel economy improvements after MY 2020 based on economic cost-benefit analysis from a consumer's and manufacturers' perspective, which does not include energy security and GHG emissions reduction benefits (EIA 2011b). The 2012 AEO Early Release does not integrate new EPA Mercury and Air Toxics Standards that were integrated into the just released complete AEO 2012.[24] NHTSA's CAFE requirements are established in consideration of a cost-benefit assessment from a societal perspective, which does include energy security and GHG emissions reduction benefits.

2.3.6 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

[23] The Reference Case is a scenario under which forecasts are made with the following assumptions: (1) all current laws and regulations, including sunset clauses, remain unchanged throughout the forecast period, (2) an annual average real Gross Domestic Product growth rate of 2.7 percent, (3) an annual average growth rate in non-farm business and employment productivity of 2.0 percent, (4) an annual average growth rate in non-farm business and employment of 1.0 percent, and (5) an annual average growth rate in the price of crude oil delivered to refineries in the United States of 2.6 percent. This price of crude oil is expected to reach $113.70 per barrel in 2009 U.S. dollars in 2030. *See* EIA 2011a, "Macroeconomic Growth Cases, the *Reference Case*"; EIA 2011a Table A12. Petroleum Product Prices, AEO 2011 Reference Case (2009 dollars per gallon, unless otherwise noted).

[24] "Expected changes in the AEO 2012 complete release: The Reference Case results shown in the early release AEO 2012 will vary somewhat from those included in the complete AEO that will be released in spring 2012, because some data and model updates were not available for inclusion in the early release. In particular, the complete AEO 2012 will include the EPA December 2011 Mercury and Air Toxics Standards; updated historical data and equations in the transportation sector, based on revised data from NHTSA and the Federal Highway Administration; a new model for cement production in the industrial sector; a revised long-term macroeconomic projection based on an updated long-term projections from IHS Global Insight, Inc.; and an updated representation of biomass supply" (EIA 2012a).

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
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).

In this EIS, NHTSA uses this approach – acknowledging incomplete or unavailable information – to address areas for which the agency cannot develop a reasonably precise estimate of the potential environmental impacts of the Proposed Action and alternatives. For example, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of CO_2 and other GHGs and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. NHTSA relies on the Intergovernmental Panel on Climate Change (IPCC) 2007 Fourth Assessment Report (IPCC 2007a, 2007b, 2007c, 2007d, 2007e) 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).

2.4 Resource Areas Affected and Types of Emissions

The major resource areas affected by the Proposed Action and alternatives are energy, air quality, and climate. Chapter 3 describes the affected environment for energy and energy impacts under each alternative. Chapters 4 and 5 describe the affected environments and impacts for air quality and climate change, respectively.

2.4.1 Types of Emissions

Emissions, including 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 the vehicle's fuel storage and delivery system, and particulates generated by brake and tire wear.[25] All downstream emissions were estimated using the most recent version of EPA's Motor Vehicle Emission Simulator (MOVES2010a) model (EPA 2010a). Upstream emissions related to the Proposed Action are those associated with crude-petroleum extraction and transportation, and with the refining, storage, and distribution of transportation fuels. Upstream emissions from EVs also include emissions associated with using primary fuels (e.g., coal, natural gas, nuclear) to generate the electricity needed to run these vehicles. The amount of emissions created when generating electricity depends on the composition of fuels used for generation, which varies regionally. NHTSA estimated both domestic and international upstream emissions of CO_2, and only domestic upstream emissions of criteria air

[25] NHTSA's authority under EISA does not extend to regulating HFCs, which are released to the atmosphere through air-conditioning system leakage and are not directly related to fuel efficiency.

pollutants and airborne toxics. Estimates of all upstream emissions were based on the Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET, version 1 2011) model developed by the DOE Argonne National Laboratory (Argonne 2002) and modified by EPA as described in the TSD. Sections 2.4.1.1 and 2.4.1.2 describe analytical methodologies and assumptions used in this EIS for emissions modeling, including the impact of the rebound effect. Chapters 4 and 5 discuss modeling issues related specifically to the air quality and climate change analyses, respectively.

2.4.1.1 Downstream Emissions

Most downstream emissions are exhaust (tailpipe) emissions. The basic method used to estimate tailpipe emissions entails multiplying the total miles driven by cars and light trucks of each model year and age by their estimated emission rates per vehicle-mile of each pollutant. These emission rates differ between cars and light trucks, between gasoline and diesel vehicles, and by age. With the exception of SO_2, the agencies calculated the increase in emissions of these criteria pollutants from added car and light truck use by multiplying the estimated increases in vehicle use during each year over their expected lifetimes by per-mile emission rates appropriate to each vehicle type, fuel used, model year, and age as of that future year.

The Volpe model uses emission factors developed by EPA using the most recent version of the Motor Vehicle Emission Simulator (MOVES2010a) (EPA 2010a). MOVES2010a incorporates EPA's updated estimates of real-world emissions from passenger cars and light trucks and accounts for emission control requirements on exhaust emissions and evaporative emissions, including the Tier 2 Vehicle & Gasoline Sulfur Program (EPA 2011a) and the mobile source air toxics (MSAT) rule (EPA 2007a). The MOVES2010a database includes default distributions of vehicles by type and age, vehicle activity levels, vehicle characteristics, national-level fuel quality estimates, and other key parameters used to generate emission estimates. In modeling downstream 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. MOVES2010a defaults were used for all other parameters to estimate tailpipe and other components of downstream emissions under the No Action Alternative.

NHTSA's and EPA's emissions analysis methodology assumes that no reduction in tailpipe emissions of criteria pollutants or air toxics will occur solely as a consequence of improvements in fuel economy that are not already accounted for in MOVES2010a. In its emissions calculations, MOVES2010a accounts for the amount of power required of the engine under different operating conditions, such as vehicle weight, speed, and acceleration. Changes to the vehicle that result in reduced engine load, such as from more efficient drivetrain components, improved aerodynamics, and lower rolling-resistance tires, are therefore already reflected in the MOVES2010a calculations of both fuel economy and emissions. Because the proposed standards are not intended to dictate the design and technology choices manufacturers must make to comply, a manufacturer could employ technologies that increase fuel economy (and therefore reduce CO_2 and SO_2 emissions), while at the same time increasing emissions of other criteria pollutants or air toxics, as long as the manufacturer's production still meets both the fuel economy standards and prevailing EPA emission standards. Depending on which strategies are pursued to meet the increased fuel economy standards, emissions of these other pollutants could increase or decrease.

In calculating emissions, two sets of units can be used depending on how activity levels are measured:

- Activity expressed as VMT, and emission factors expressed as grams emitted per VMT
- Activity expressed as fuel consumption in gallons, and emission factors expressed as grams emitted per gallon of fuel

Considering both sets of units provides insight into how emissions of different GHGs and air pollutants vary with fuel economy and VMT.

Almost all of the carbon in fuels that are combusted in vehicle engines is oxidized to CO_2, and essentially all of the sulfur content of the fuel is oxidized to SO_2. As a result, emissions of CO_2 and SO_2 are constant in terms of grams emitted per gallon of fuel; their total emissions vary directly with the total volume of fuel used, and inversely with fuel economy (mpg). Therefore, emission factors for CO_2 and SO_2 are not constant in terms of grams emitted per VMT of a specific vehicle, because fuel economy – and therefore the amount of fuel used per VMT – varies with vehicle operating conditions.

In contrast to CO_2 and SO_2, downstream emissions of the other criteria pollutants and the toxic air pollutants are not constant in terms of grams emitted per gallon of fuel. This is because the formation of these pollutants is affected by the continually varying conditions of engine and vehicle operation dictated by the amount of power required, and by the type and efficiency of emission controls with which a vehicle is equipped. For other criteria pollutants and airborne toxics, MOVES2010a calculates emission rates individually for specific combinations of inputs, including various vehicle types, fuels, ages, and other key parameters noted above.

Emission factors in the MOVES2010a database are expressed in the form of grams per vehicle-hour of operation. To convert these emission factors to grams per mile, MOVES2010a was run for the year 2050, and was programmed to report aggregate emissions from vehicle start, running, brake and tire wear and crankcase exhaust operations. EPA selected the year 2050 in order to generate emission factors that were representative of lifetime average emission rates for vehicles meeting the Tier 2 emission standard.[26] Separate estimates were developed for each vehicle type and model year, as well as for each state and month, in order to reflect the effects of regional and temporal variation in temperature and other relevant variables on emissions.

The MOVES2010a emissions estimates were then summed to the model year level and divided by total distance traveled by vehicles of that model year in order to produce per-mile emission factors for each pollutant. The resulting emission rates represent average values across the nation, and incorporate typical variation in temperature and other operating conditions affecting emissions over an entire

[26] Because all light-duty emission rates in MOVES2010a are assumed to be invariant after MY 2010, a calendar-year 2050 run produced a full set of emission rates that reflect anticipated deterioration in the effectiveness of vehicles' emission control systems with increasing age and accumulated mileage for post-MY 2010 vehicles.

calendar year.[27] These national average rates also reflect county-specific differences in fuel composition, as well as in the presence and type of vehicle inspection and maintenance programs.[28]

Emission rates for the criteria pollutant SO_2 were calculated by using average fuel sulfur content estimates supplied by EPA, together with the simplifying assumption that the entire sulfur content of fuel is emitted in the form of SO_2. These calculations assumed that national average gasoline and diesel sulfur levels would remain at current levels,[29] because there are currently no open regulatory actions to change those levels. Therefore, unlike many emissions of other criteria pollutants that are affected by exhaust after-treatment devices (e.g., a catalytic converter), sulfur dioxide emissions from vehicle use (in terms of emissions per VMT) decline in proportion to the decrease in fuel consumption.

The agencies assume that as a result of the rebound effect, total VMT would increase slightly with increases in fuel economy, thereby causing tailpipe emissions of each air pollutant generated by vehicle use (rather than by fuel consumption) to increase in proportion to this increase in VMT. However, emissions on a per-VMT basis as calculated by MOVES2010a could decline as a result of increased fuel economy, as discussed above.[30] If the increases in fuel consumption and emissions associated with the higher VMT (due to the rebound effect) are small compared to the decrease in fuel use (due to increased fuel economy), then the net result can be a reduction in total emissions.

2.4.1.2 Upstream Emissions

NHTSA also estimated the impacts of the action alternatives on upstream emissions associated with petroleum extraction and transportation, and the refining, storage, and distribution of transportation fuels, as well as upstream emissions associated with generation of electricity used to power EVs. NHTSA and EPA project that the Proposed Action will lead to reductions in upstream emissions from fuel production and distribution, because the total amount of fuel used by passenger cars and light trucks will decline under the action alternatives compared to the No Action Alternative. To the extent that any of the action alternatives would lead to an increase in use of EVs, upstream emissions associated with charging EVs could increase as a result of adopting that alternative. These increases would offset part of the reduction in upstream emissions resulting from reduced production of motor vehicle fuels. The net effect on national upstream emissions would depend on the relative magnitudes of the reductions in

[27] The emission rates calculated by EPA for this analysis using MOVES2010a include only those components of emissions expected to vary in response to changes in vehicle use. These include exhaust emissions associated with starting and operating vehicles, and particulate emissions resulting from brake and tire wear. However, they *exclude* emissions associated with activities such as vehicle storage, because those do not vary directly with vehicle use. Therefore, the estimates of aggregate emissions reported for the No Action Alternative and action alternatives do not represent total emissions of each pollutant under any of those alternatives. However, the difference in emissions of each pollutant between any action alternative and the No Action Alternative does represent an accurate estimate of the change in total emissions of that pollutant that would result from adopting that action alternative.

[28] The national mix of fuel types includes county-level market shares of conventional and reformulated gasoline, as well as county-level variation in sulfur content, ethanol fractions, and other fuel properties. Inspection/maintenance programs at the county level account for detailed program design elements such as test type, inspection frequency, and program coverage by vehicle type and age.

[29] These are 30 and 15 parts per million (ppm, measured on a mass basis) for gasoline and diesel respectively, which produces emission rates of 0.17 grams of SO_2 per gallon of gasoline and 0.10 grams per gallon of diesel.

[30] However, NHTSA notes that increased use of EVs might not reduce average emissions on a per-VMT basis, because producers of EVs could allow the per-VMT emission rates of their conventionally fueled vehicles to increase to levels that still enable them to comply with EPA regulations on manufacturers' fleet average emission rates. Such a response would leave each manufacturer's average emissions per VMT unchanged, regardless of the extent to which it produced EVs as a compliance strategy.

motor fuel production and the increases in electric power production, and would vary by pollutant. (*See* Section 6.2.2 for a discussion of emissions differences between conventional vehicles and EVs).

Although the rebound effect is assumed to result in identical percentage increases in VMT and downstream 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 and electric power plants are not uniformly distributed across the country. Therefore, an individual geographic region could experience either a net increase or a net decrease in emissions of each pollutant due to the proposed fuel economy standards, depending on the relative magnitudes of the increase in emissions from additional vehicle use (the rebound effect) and electric power production and the decline in emissions resulting from reduced fuel production and distribution in that geographic region.

The National Energy Modeling System (NEMS) is an energy-economy modeling system from the EIA. For the analyses presented throughout this Final EIS, NHTSA used the NEMS AEO 2012 Early Release version to project the U.S. average electricity generating fuel mix (e.g., coal, natural gas, and petroleum) for the reference year 2020 and used the GREET model (1 2011 version developed by DOE Argonne National Laboratory [Argonne 2002]) to estimate upstream emissions. The analysis assumed that the vehicles would be sold and operated (refueled or charged) during the 2017–2060 timeframe. NHTSA also performed an additional analysis to illustrate the effects of a cleaner future electrical grid on air quality, as described below.

The GREET model used to project impacts analyzed in this EIS was last modified by EPA for use in analyzing its 2009 Renewable Fuel Standard 2 (RFS2) proposed rulemaking. The updates EPA made to the GREET model for purposes of that rulemaking include 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 air toxics acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde. NHTSA used data from the EPA-modified GREET model for the Volpe model calculations.

For the action alternatives in this EIS, NHTSA assumed that increased fuel economy affects upstream emissions by causing decreases in the volumes of gasoline and diesel produced and consumed,[31] and by causing changes in emissions related to electricity generation due to the different EV deployment levels projected under each action alternative. NHTSA calculated the impacts of decreased fuel production on total emissions of each pollutant using 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. The emission factors derived from GREET (expressed as grams of pollutant per million British thermal units 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 derive the total emissions from fuel production and distribution resulting from each action alternative. This process was repeated for each alternative, and the change in upstream emissions of each pollutant resulting from each action alternative was estimated as the difference between upstream emissions of that pollutant under the action alternative and its upstream emissions under the No Action Alternative.

[31] NHTSA assumed that the proportions of total fuel production and consumption 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.

Due to modeling limitations, the analysis presented throughout this EIS assumes that the future EV fleet would charge from a grid whose mix is both similar to today's grid mix and also uniform across the country. The modeling tools used for this analysis, which are among the best available, necessarily have limitations when used to predict the state of the electrical grid in the distant future. As noted above, the analysis used in this EIS uses the GREET model, whose emissions intensities extend only to 2020, and an average U.S. electricity generating fuel mix for the reference year 2020 from the NEMS model AEO 2012 Early Release version. These assumptions result in a temporally static and geographically homogeneous grid that overstates air quality impacts under alternatives that predict a high level of EV deployment. It is more reasonable to assume steady improvements to the grid during the course of the next several decades – the period during which any EV deployment associated with this program would occur – and, if the current early trends continue, a higher concentration of EVs in areas served by cleaner electrical grids. For this reason, NHTSA reviewed several projections by the EIA, the Federal Government's expert source for forecasting energy use, which show a cleaner grid in future years based on a variety of assumptions and possible scenarios. NHTSA then performed an additional analysis to illustrate the effects of a cleaner future grid on air quality, described below.

Across the alternatives analyzed in this EIS, most EV sales are projected to occur near the end of the 2017–2025 timeframe. The EVs sold in the later years would not accrue 50 percent of their mileage until 7 to 10 years after sale. Therefore, NHTSA looked to EIA projections of the future state of the electrical grid, selecting an EIA side case projection in 2035 for analytical purposes.

NHTSA performed its additional analysis in two steps. An early evaluation was performed with the goal of determining the range of alternative feasible scenarios of the future U.S. electricity generation mix that could be used to meet the overall electricity demand from all end uses from 2010 (the baseline) through 2035. In its final release of AEO 2011, EIA examined a broad range of economic, technology, and other side cases. NHTSA evaluated eight emissions-related side cases from EIA's AEO 2011 for their prediction of the future national power generation fuel mixes (using coal, petroleum, natural gas, nuclear power, renewable sources,[32] and other sources[33]), the total and net-to-the-grid electric generation levels, and total emissions of CO_2 and criteria and hazardous air pollutants (SO_2, NO_x, and mercury) through 2035. These cases accounted for regulations that could be in effect during the period covered by the Proposed Action. These scenarios account for the potential effects of future air regulations affecting the sector (including more stringent National Ambient Air Quality Standards, Maximum Achievable Control Technology, New Source Performance Standards, and Mercury and Air Toxics Standards), although they do not represent the final proposed rules for the Cross-State Air Pollution Rule, Mercury and Air Toxics Standards, or New Source Performance Standards rules.[34] The

[32] Includes conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, landfill gas, other biomass, solar, and wind power.

[33] Includes pumped storage, non-biogenic municipal waste, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

[34] The AEO emission side cases reviewed for this EIS were the following: (1) The GHG Price Economy-wide case, which assumes an economy-wide carbon allowance price beginning at $25 per metric ton of CO_2 in 2013 and rising to $75 per metric ton of CO_2 in 2035 (2009 dollars), consistent with the cost containment provisions in both the Kerry-Lieberman and Waxman-Markey GHG legislation. No assumptions are made for offsets, bonus allowances for CCS [carbon capture and storage], or specific allocation of allowances. (2) The Transport Rule Mercury MACT [maximum achievable control technology] 5 case, which assumes implementation of the Air Transport Rule limits on SO_2 and NO_x and a 90 percent mercury MACT. A 5-year recovery period for investments in environmental control projects is assumed. (3) The Transport Rule Mercury MACT 20 case, which assumes the same rules as above, but assumes a 20-year recovery period for investments in environmental control projects. (4) The Retrofit Required 5 case, which represents stringent requirements for reductions in airborne emissions from coal-fired power plants, including assuming that utility boilers fall under the MACT rule, which requires all plants to install FGD [flue gas desulfurization] scrubbers by 2020 and that all plants install SCR [selective catalytic reduction] systems to meet future NO_X and ozone emission

AEO 2011 reference case indicated the 2010 mix of power generation was derived from projections for 2009 and 2035 which forecasted, respectively, approximately 45 and 42 percent coal-fired power, 24 and 25 percent natural gas, 17 and 20 percent nuclear, 10 and 13 percent renewable resources, and a constant 1 percent petroleum.

In comparison, all eight emissions side cases were consistent in predicting lower upstream emissions of criteria pollutants per unit of electricity used to charge EVs under a different future electric generating grid than the AEO 2011 reference case. The future scenarios predicted CO_2 emissions in 2035 that ranged from a reduction of 53 percent from the 2010 levels to an increase of 8 percent. Due to the estimation of the impact of various pending rules limiting smokestack criteria emissions from electric power generation (including the Clean Air Interstate Rule[35] and state-level RPS requirements[36] but not Mercury and Air Toxics Standards,[37] New Source Performance Standards,[38] and the revision of Clean Air Interstate Rule/Cross-State Air Pollution Rule[39]), all eight scenarios predicted feasible ranges of criteria emissions that were far below the 2010 reference levels. Specifically, as shown in Table 2.4.1-1, SO_2 was predicted to be reduced 33 to 73 percent by 2035, NO_x reduced by 15 to 64 percent, and mercury reduced by 26 to 82 percent.

Table 2.4.1-1. Range of Predicted Change in Electric Power Sector Emissions Between 2010 and 2035 (eight emissons-related side cases), AEO 2011

Electric Power Sector Emission[a]	Range of Predicted Change in Electric Power Sector Emissions Between 2010 and 2035	
	Minimum	Maximum
Carbon Dioxide (million metric tons)	+8%	-53%
Sulfur Dioxide (million tons)	-33%	-73%
Nitrogen Oxide (million tons)	-15%	-64%
Mercury (tons)	-26%	-82%

a. Includes electricity only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

The agency performed an additional analysis using one of the scenarios for a cleaner future grid drawn from AEO 2011 (retaining 2020 GREET emissions intensities).[40] This scenario assumes high levels of

reduction requirements. If the investment in an FGD scrubbers and SCR systems is not economical, the plant is retired. Investments in retrofits are assumed to be recovered over a 5-year period. (5) The Retrofit Required 20 case, which assumes the same requirements as above, but investments in retrofits are assumed to be recovered over a 20-year period. (6) The Low Gas Price Retrofit Required 5 case, which is identical to the Retrofit Required 5 case but adds an assumption of increased availability domestic shale availability and utilization rate. Increased access to natural gas lowers the natural gas prices paid by the electric power sector. (7) The Low Gas Price Retrofit Required 20 case, which is identical to the Low Gas Price Retrofit Required 5 case, but investments in retrofits are assumed to be recovered over a 20-year period. (8) The Low Renewable Technology Cost case assumes greater improvements in residential and commercial PV and wind systems than in the Reference case. The assumptions result in capital cost estimates that are 20 percent below Reference Case assumptions in 2011, and decline to at least 40 percent lower than Reference Case costs in 2035.

[35] *See* 70 FR 25162 (May 12, 2005), effective July 11, 2005.

[36] *See* Clean Air Act, 42 U.S.C. §7401 et seq., effective various dates.

[37] *See* 77 FR 9304 (Feb. 16, 2012), effective April 16, 2012.

[38] *See* 40 CFR Part 60, effective July 1, 2011.

[39] *See* 76 FR 48208 (Aug. 8, 2011), effective October 7, 2011.

[40] NHTSA analyzed the “GHG Price, Economy-wide” case from AEO 2011 (referred to as the “Alternate Grid Mix Case” in this document), which assumes future carbon trading. The Base Grid Mix Case, analyzed throughout this document, does not include the impacts of EPA’s recent Mercury and Air Toxics Standards for power plants, which are expected to significantly reduce emissions of some of the pollutants discussed in this section and are a significant step toward the levels assumed in the Alternate Grid Mix Case. The just released AEO 2012 Reference Case accounts for those standards and shows significant reductions in emissions of some criteria pollutants compared to the Base Grid Mix Case, a showing that is consistent with NHTSA’s decision to use the “GHG Price, Economy-wide” case for the Alternate Grid Mix analysis.

natural gas and renewables for electricity generation, with generation from coal-fired power plants reduced to 21 percent from the projected contribution of 40 percent used in EIA's 2020 reference case. Table 2.4.1-2 details the assumed generating mix for the analysis generally used throughout this EIS (referred to here and in Chapter 4 as the "Base Grid Mix Case"), which uses the NEMS AEO 2012 Early Release fuel mix data for 2020 with GREET emissions intensity data for 2020. Those assumptions are compared to the alternate analysis (referred to as the "Alternate Grid Mix Case"), which uses the AEO 2011 GHG Price, Economy-Wide case for 2035 and GREET emissions intensity data for 2020. The mix of generation fuel in the alternate analysis is within the variation that appears in the eight potential cases examined in AEO 2011. Table 2.4.1-3 details the upstream emissions factors for electrical power generation for the Base Grid Mix Case and the Alternate Grid Mix Case.

Table 2.4.1-2. Electricity Generation Mix (GWH)[a] by Fuel Source, for the Base and Alternate Grid Mix Cases

Generation Fuel	Base Grid Mix Case (AEO 2012 Early Release)	Alternate Grid Mix Case (AEO 2011)
Coal	40%	21%
Petroleum	1%	1%
Natural Gas	25%	35%
Nuclear Power	20%	21%
Renewable Sources[b]	14%	22%
Other	0%	0%
Totals	100%	100%

a. GWH = gigawatt-hour.
b. Includes conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, landfill gas, other biomass, solar, and wind power.

Table 2.4.1-3. Upstream Emissions Factors for Electrical Power Generation for the Base and Alternate Grid Mix Cases

Pollutant	Base Grid Mix Case (AEO 2012 Early Release) Emissions (g/MMBtu)[a]	Alternate Grid Mix Case (AEO 2011) Emissions (g/MMBtu)
Carbon Monoxide (CO)	138.6485	37.8353
Volatile Organic Compounds (VOCs)	2.922598	3.2260
Nitrogen Oxides (NO_x)	170.2071	92.9752
Sulfur Oxide (SO_x)	283.0997	165.7129
Particulates ($PM_{2.5}$)	6.950113	4.3995
Carbon Dioxide (CO_2)	172,962.6	127,877.6
Methane (CH_4)	4.070038	4.1062
Nitrous Oxide (N_2O)	2.681632	2.3464

a. g/MMBTU = grams per million British thermal units.

Both modeling runs were performed using the same methodology and generated the inputs to allow modeling of air quality impacts and their resulting direct and indirect health outcomes and monetized health effects. The results of the health outcomes and monetized health effects for these two cases are reported alongside each other for comparison in Tables 4.2.1-7-A1 through -B2, Tables 4.2.1-8-A1 through -B2, Tables 4.2.2-7-C1 and -C2, and Tables 4.2.2-8-C1 and -C2. The supporting calculations appear in Appendix H.

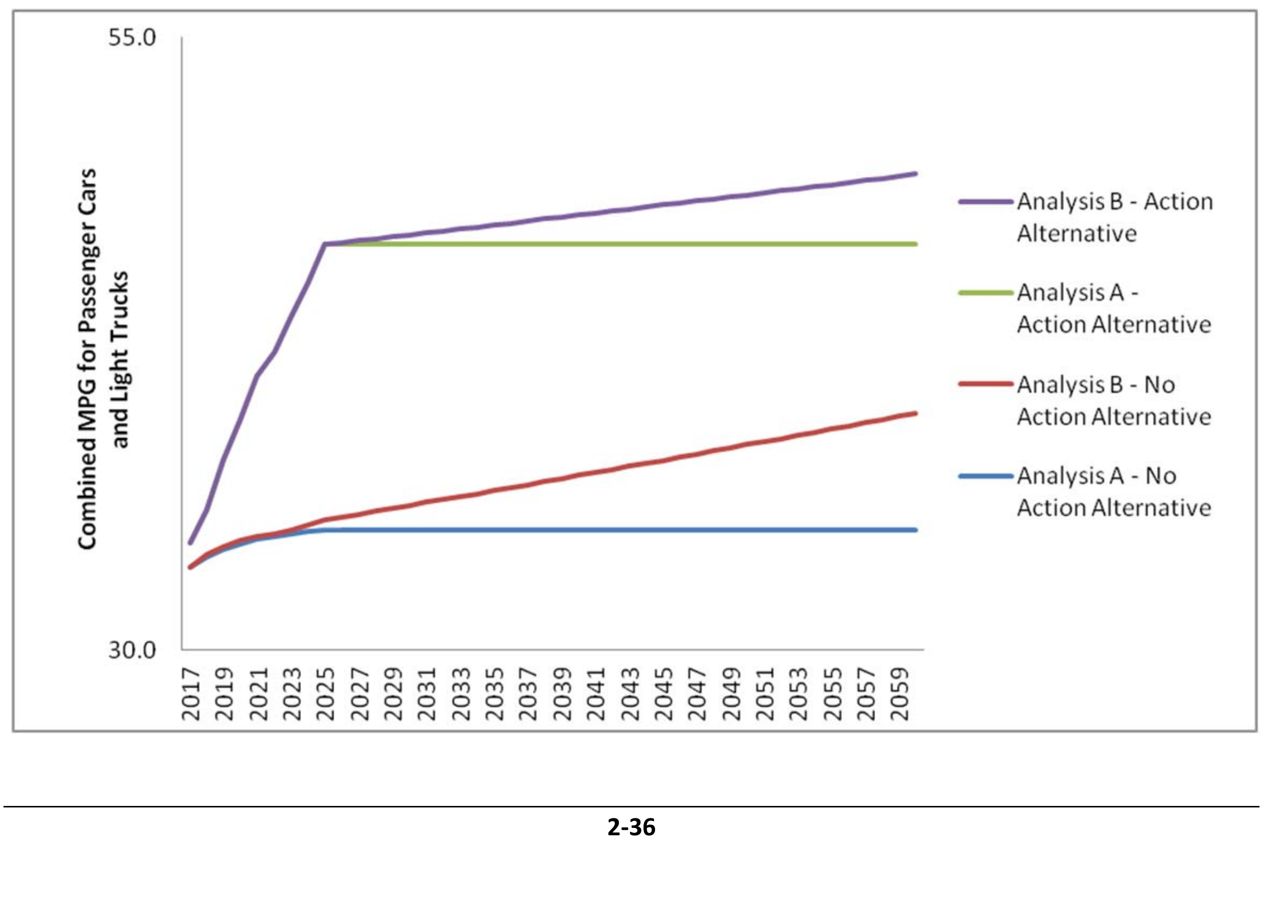
2.5 Direct and Indirect versus Cumulative Impacts

CEQ NEPA implementing regulations require agencies to consider the direct and indirect effects and cumulative impacts of major federal actions. CEQ regulations define direct effects as those that "are caused by the action and occur at the same time and place" and 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." 40 CFR § 1508.8. CEQ regulations define cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 CFR § 1508.7.

To derive the impacts of the action alternatives reported throughout this document, NHTSA compares the action alternatives to the No Action Alternative. As described in detail above, based on the considerable uncertainty regarding whether and to what degree fleetwide fuel economy would change in the absence of agency action, NHTSA has included separate analyses of the direct and indirect impacts of the proposal – Analyses A1 and A2 assume essentially no change in the average level of fuel economy under the No Action Alternative and in the action alternatives following the rulemaking period, and Analyses B1 and B2 assume market-based growth both under the No Action Alternative and under the action alternatives following the rulemaking period. Both sets of analyses account for the direct effects of the rule (i.e., fuel economy improvements in MYs 2017–2025) and the indirect effects of the rule (i.e., fuel economy levels in MY 2026 and after that would not have occurred but for the agency action).

Figure 2.5-1 is a representative illustration of the fuel economy levels that would be obtained based on the underlying assumptions for the two perspectives (Analyses A1 and A2 and Analyses B1 and B2).

Figure 2.5-1. Representations for Analyses A1, A2, B1, and B2 under the No Action Alternative and Action Alternatives



In Analyses A1 and A2, the direct and indirect impacts of the Proposed Action stem from the fuel economy improvements represented in Figure 2.5-2-A (the difference between the No Action Alternative and action alternatives for Analyses A1 and A2). In Analyses B1 and B2, direct and indirect impacts of the proposed rule stem from the fuel economy improvements represented in Figure 2.5-2-B (the difference between the No Action Alternative and action alternatives for Analyses B1 and B2).

Figure 2.5-2-A. Representation of Direct and Indirect Impacts for Analyses A1 and A2

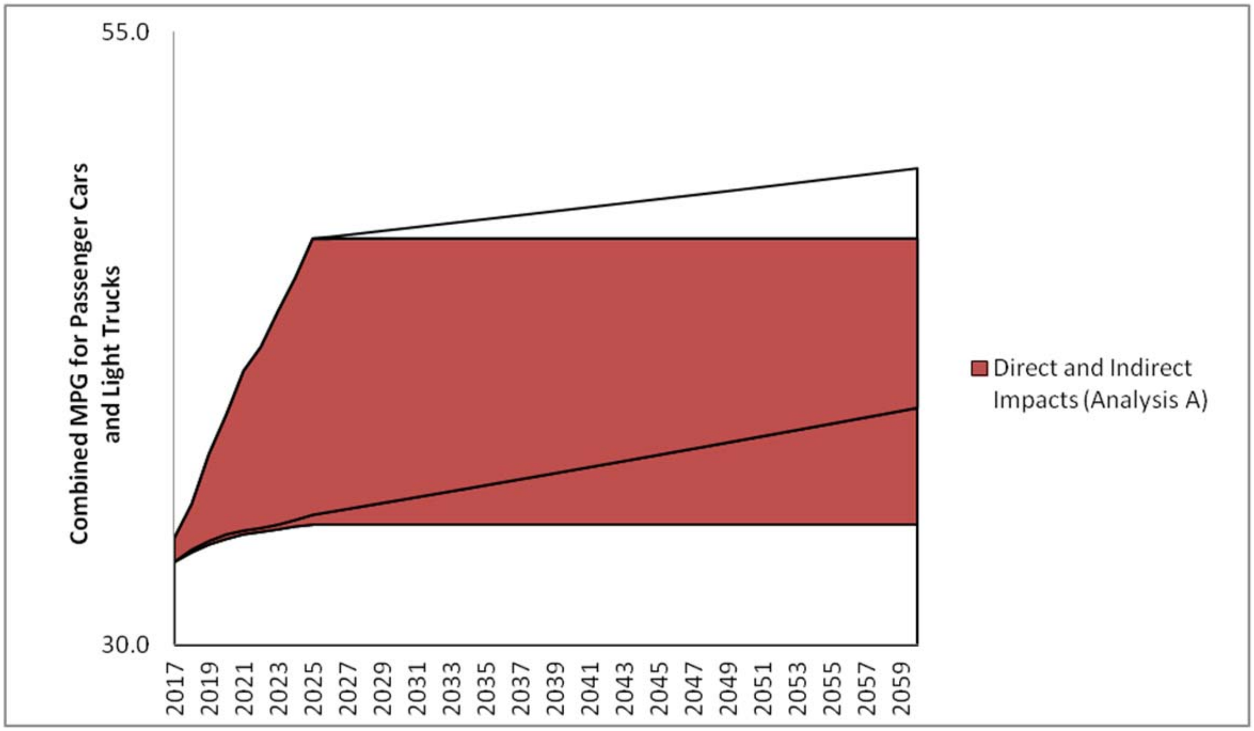
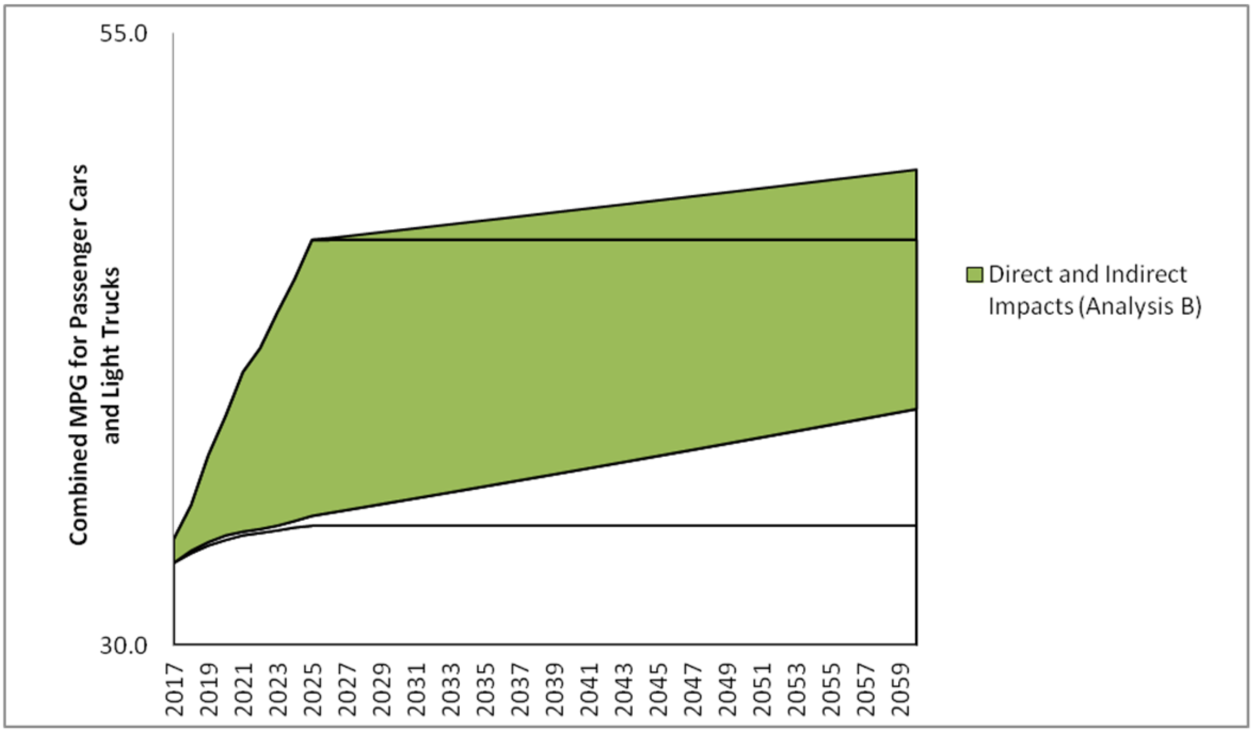
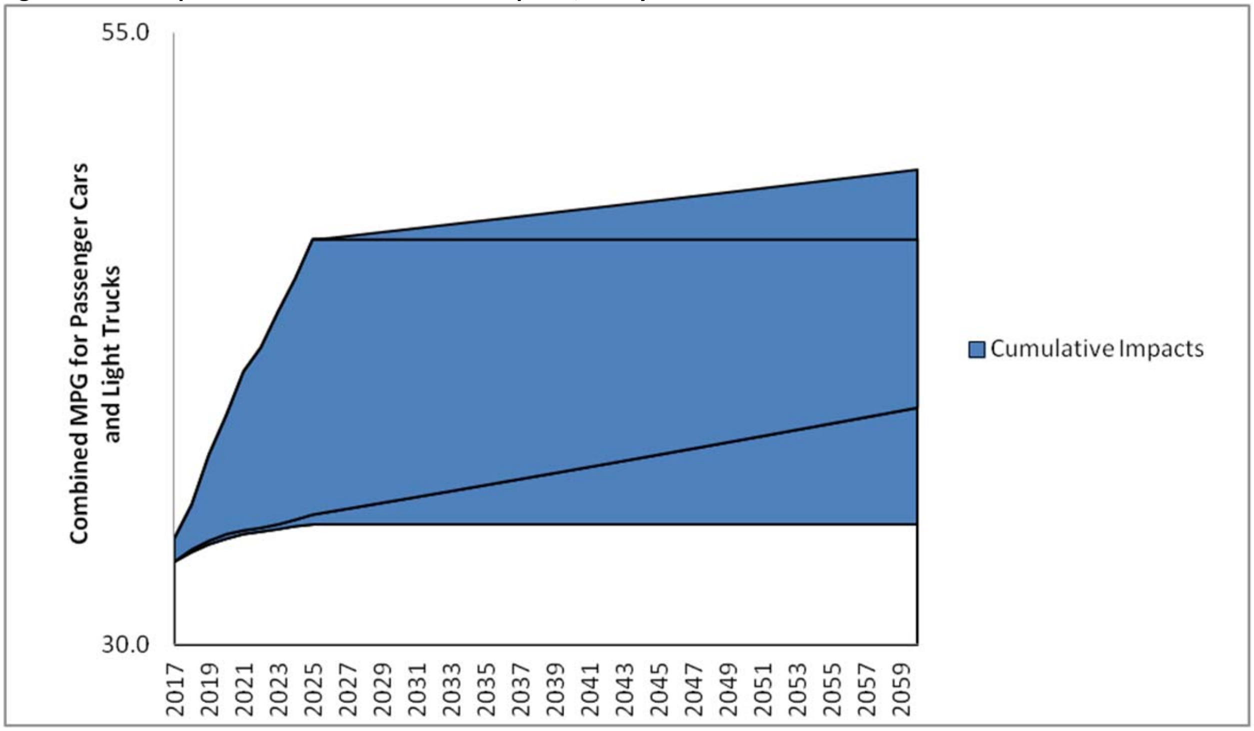


Figure 2.5-2-B. Representation of Direct and Indirect Impacts for Analyses B1 and B2



To analyze the cumulative impacts of the Proposed Action, the agency accounted for the fuel economy improvements that result directly or indirectly from the proposed rule in addition to reasonably foreseeable improvements in fuel economy stemming from other sources – specifically, fuel economy improvements that would result from actions taken by manufacturers in the absence of the agency's action (Analyses C1 and C2). Figure 2.5-3 illustrates fuel economy improvements by manufacturers due directly and indirectly to this rule in addition to those due to other potential market forces (i.e., increased consumer demand for fuel economy). The environmental benefits stemming from all of these improvements beyond those needed to comply with the MY 2016 CAFE standards therefore take into account the past, present, and reasonably foreseeable future actions of both the Federal Government (in the form of CAFE standards) and manufacturers (in response to market demands for increased fuel economy). The cumulative impacts analyses in Chapters 3, 4, and 5 demonstrate the environmental impacts (including impacts to energy, air quality, and climate) resulting from CAFE standards and other reasonably foreseeable fuel economy improvements.

Figure 2.5-3. Representation of Cumulative Impacts, Analyses C1 and C2



2.6 Comparison of Alternatives

The CEQ NEPA implementing 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." This section summarizes and compares the direct, indirect, and cumulative impacts of all the alternatives, including the Preferred Alternative, on energy, air quality, and climate, as presented in Chapters 3, 4, and 5. No quantifiable, alternative-specific effects were identified for the other resource areas discussed in Chapters 6 and 7 of this EIS, so they are not summarized here.

Under the alternatives analyzed in this EIS, the growth in the number of passenger cars and light trucks in use throughout the United States and in the annual VMT by these vehicles outpaces improvements in fuel economy under each action alternative, resulting in projected increases in total fuel consumption by passenger cars and light trucks. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks. NHTSA estimates that the proposed CAFE standards and each of the analyzed alternatives would reduce fuel consumption and CO_2 emissions from the future levels that would otherwise occur in the absence of the new CAFE standards (i.e., fuel consumption and CO_2 emissions under the No Action Alternative).

2.6.1 Direct and Indirect Impacts

This section compares the direct and indirect impacts of the No Action Alternative and the three action alternatives on energy, air quality, and climate, as presented in Chapters 3, 4, and 5. Table 2.6.1-1-A presents results for Analyses A1 and A2, which assume a small increase in new vehicle fuel economy under the No Action Alternative in MYs 2017–2025, and no additional increases in fuel economy under any of the alternatives after MY 2025. Table 2.6.1-1-B presents results for Analyses B1 and B2, which assume larger increases in new vehicle fuel economy under the No Action Alternative beginning in MY 2017, and additional increases in fuel economy under all of the alternatives after MY 2025. Both tables include results for health impacts analyzed under the Base Grid Mix Case and Alternate Grid Mix Case described in Section 2.4.1.2.

Table 2.6.1-1-A. Direct and Indirect Impacts, Analyses A1 and A2[a,b,c]

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Consumption for 2017–2060	6,052 to 6,562 billion gallons	5,400 to 5,812 billion gallons	4,987 to 5,372 billion gallons	4,456 to 4,795 billion gallons
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Savings Compared to No Action for 2017–2060	–	652 to 751 billion gallons	1,066 to 1,190 billion gallons	1,597 to 1,767 billion gallons
Air Quality	Criteria Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, SO_2, and VOCs) would decrease compared to the No Action Alternative, while emissions of CO would increase.	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, SO_2, and VOCs) would decrease compared to the No Action Alternative, while emissions of CO would increase. The increase in CO emissions would be more than the increase under Alternative 2, while the decreases in other emissions would be greater than the decreases under Alternative 2.	Emissions of most criteria pollutants (CO, $PM_{2.5}$, and VOCs) would decrease compared to the No Action Alternative, while emissions of NO_x and SO_2 would increase. The decreases/increases in emissions would be greater than those under Alternatives 2 and 3.
Air Quality	Toxic Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of benzene, formaldehyde, and DPM would decrease compared to the No Action Alternative, while emissions of acetaldehyde, acrolein, and 1,3-butadiene, would increase.	Emissions of benzene and DPM would decrease compared to the No Action Alternative; these decreases would be greater than the decreases under Alternative 2. Emissions of acetaldehyde, acrolein, and 1,3-butadiene would increase; these increases would be slightly greater than the increases under Alternative 2. Emissions of formaldehyde would either increase or decrease compared to the No Action Alternative, depending on the analysis.	Emissions of 1,3-butadiene and benzene would decrease compared to the No Action Alternative; these would be the greatest emissions decreases of all alternatives for these pollutants. Emissions of acrolein and formaldehyde would increase; these would be the greatest emissions increases of all alternatives for these pollutants. Emissions of acetaldehyde and DPM would increase or decrease, depending on the analysis.

Table 2.6.1-1-A. Direct and Indirect Impacts, Analysis A1 and A2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Air Quality (cont'd)	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions used) Using Base Grid Mix	–	Premature mortality: reduced by 206 to 549 cases Work-loss days: reduced by 22,572 to 23,538 days	Premature mortality: reduced by 315 to 888 cases Work-loss days: reduced by 34,581 to 38,095 days	Premature mortality: reduced by 100 to 572 cases Work-loss days: reduced by 11,671 to 24,987 days
	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions[d] used) Using Alternate Grid Mix	–	Premature mortality: reduced by 211 to 594 cases Work-loss days: reduced by 23,179 to 25,499 days	Premature mortality: reduced by 355 to 922 cases Work-loss days: reduced by 38,965 to 39,605 days	Premature mortality: reduced by 460 to 1,205 cases Work-loss days: reduced by 51,243 to 52,265 days
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions used) Using Base Grid Mix	–	3%: \$1.6 billion to \$4.1 billion 7%: \$1.5 billion to \$3.8 billion	3%: \$2.5 billion to \$6.7 billion 7%: \$2.3 billion to \$6.1 billion	3%: \$830 million to \$4.4 billion 7%: \$750 million to \$4.0 billion
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions used) Using Alternate Grid Mix	–	3%: \$1.7 billion to \$4.5 billion 7%: \$1.5 billion to \$4.1 billion	3%: \$2.8 billion to \$6.9 billion 7%: \$2.5 billion to \$6.3 billion	3%: \$3.6 million to \$9.1 billion 7%: \$3.3 billion to \$8.3 billion

Table 2.6.1-1-A. Direct and Indirect Impacts, Analysis A1 and A2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Climate	Total GHG Emissions from U.S. Passenger Cars and Light Trucks for 2017– 2100	138,800 to 155,400 $MMTCO_2$	122,100 to 135,700 $MMTCO_2$	111,200 to 124,100 $MMTCO_2$	100,000 to 112,400 $MMTCO_2$
	Atmospheric Carbon Dioxide Concentrations in 2100	784.9 ppm	783.0 to 783.3 ppm	781.9 to 782.3 ppm	780.7 to 781.2 ppm
	Increase in Global Mean Surface Temperature by 2100	3.064 °C (5.515 °F)	3.058 °C (5.504 °F)	3.054 to 3.055 °C (5.497 to 5.499 °F)	3.049 to 3.050 °C (5.488 to 5.490 °F)
	Global Sea-level Rise by 2100	37.40 centimeters (14.72 inches)	37.34 to 37.35 centimeters (14.70 inches)	37.30 to 37.31 centimeters (14.69 inches)	37.26 to 37.27 centimeters (14.67 inches)
	Global Mean Precipitation Increase by 2090	4.50%	4.49%	4.48 to 4.49%	4.48%

a. The numbers in this table have been rounded for presentation purposes. Therefore, the reductions might not reflect the exact difference of the values in all cases.
b. °C = degrees Celsius; °F = degrees Fahrenheit; DPM = diesel particulate matter; $MMTCO_2$ = million metric tons of carbon dioxide; NO_x = nitrogen oxides; $PM_{2.5}$ = particulate matter 2.5 microns in diameter or less; ppm = parts per million; SO_2 = sulfur dioxide; VOCs = volatile organic compounds;
c. The "Base Grid Mix" in the Final EIS is based on NEMS AEO 2012 Early Release fuel mix and emissions projections for 2020, which do not include the Mercury and Air Toxics Standards issued by EPA in December 2011. The "Alternate Grid Mix" is based on the fuel mix and emissions projections of the cleaner "GHG Price Economy-wide" emissions side case in the final AEO 2011 for 2035 (full results are in Appendix H).
d. Benefits are measured under the Pope methodology (Pope et al. 2002) and the Laden methodology (Laden et al. 2006).

Table 2.6.1-1-B. Direct and Indirect Impacts, Analyses B1 and B2[a,b,c]

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Consumption for 2017–2060	5,280 to 5,694 billion gallons	5,080 to 5,476 billion gallons	4,694 to 5,054 billion gallons	4,261 to 4,559 billion gallons
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Savings Compared to No Action for 2017–2060	–	200 to 219 billion gallons	585 to 640 billion gallons	1,019 to 1,135 billion gallons
Air Quality	Criteria Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, SO_2, and VOCs) would decrease compared to the No Action Alternative, while emissions of CO would increase.	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, and VOCs) would decrease compared to the No Action Alternative. Emissions of CO and SO_2 would increase in the year 2040. The decreases in emissions would be greater than the decreases under Alternative 2.	Emissions of most criteria pollutants (CO, $PM_{2.5}$, and VOCs) would decrease compared to the No Action Alternative, while SO_2 and NO_x emissions would increase. The decreases/increases in emissions would be greater than those under Alternatives 2 and 3. NO_x emissions would increase compared to the No Action Alterative.
Air Quality	Toxic Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of benzene, formaldehyde, and DPM would decrease compared to the No Action Alternative, while emissions of acetaldehyde, acrolein, and 1,3-butadiene would increase.	Emissions of benzene and DPM would decrease compared to the No Action Alternative; the decrease in benzene and DPM emissions would be greater than the decrease under Alternative 2. Emissions of acrolein would remain roughly equal or would increase compared to the No Action Alternative. Emissions of 1,3-butadiene and formaldehyde would either increase or decrease compared to the No Action Alternative, depending on the analysis.	Emissions of benzene and 1,3-butadiene would decrease compared to the No Action Alternative, the greatest decreases of all alternatives for these pollutants. Emissions of acrolein, DPM, and formaldehyde would increase, and would be the greatest increases of all alternatives for these pollutants. Emissions of acetaldehyde would either increase or decrease compared to the No Action Alternative, depending on the analysis.

Table 2.6.1-1-B. Direct and Indirect Impacts, Analysis B1 and B2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Air Quality (cont'd)	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions used) Using Base Grid Mix	–	Premature mortality: reduced by 77 to 198 cases Work-loss days: reduced by 8,472 to 8,497 days	Premature mortality: reduced by 136 to 486 cases Work-loss days: reduced by 14,929 to 20,876 days	Premature mortality: reduced by 236 to increased by 16 cases Work-loss days: reduced by 10,543 to increased by 125 days
	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions used) Using Alternate Grid Mix	–	Premature mortality: reduced by 83 to 226 cases Work-loss days: reduced by 9,068 to 9,700 days	Premature mortality: reduced by 199 to 546 cases Work-loss days: reduced by 21,850 to 23,429 days	Premature mortality: reduced by 314 to 838 cases Work-loss days: reduced by 35,187 to 36,446 days
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions used) Using Base Grid Mix	–	3%: $610 million to $1.5 billion 7%: $550 million to $1.4 billion	3%: $1.1 billion to $3.7 billion 7%: $970 million to $3.3 billion	3%: disbenefit of $40 million to benefit of $1.8 billion 7%: disbenefit of $48 million to benefit of $1.7 billion
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions[d] used) Using Alternate Grid Mix	–	3%: $649 million to $1.7 billion 7%: $590 million to $1.5 billion	3%: $1.6 billion to $4.1 billion 7%: $1.4 billion to $3.7 billion	3%: $2.5 billion to $6.3 billion 7%: $2.3 billion to $5.8 billion

Table 2.6.1-1-B. Direct and Indirect Impacts, Analysis B1 and B2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Climate	Total GHG Emissions from U.S. Passenger Cars and Light Trucks for 2017–2100	111,400 to 124,100 $MMTCO_2$	108,900 to 121,400 $MMTCO_2$	100,200 to 111,800 $MMTCO_2$	91,600 to 102,100 $MMTCO_2$
	Atmospheric Carbon Dioxide Concentrations in 2100	784.9 ppm	784.6 to 784.7 ppm	783.7 to 783.8 ppm	782.8 to 783.0 ppm
	Increase in Global Mean Surface Temperature by 2100	3.064 °C (5.515 °F)	3.063 °C (5.513 °F)	3.060 °C (5.508 °F)	3.056 to 3.057 °C (5.501 to 5.503 °F)
	Global Sea-level Rise by 2100	37.40 centimeters (14.72 inches)	37.39 centimeters (14.72 inches)	37.35 to 37.36 centimeters (14.70 to 14.71 inches)	37.32 to 37.33 centimeters (14.69 to 14.70 inches)
	Global mean Precipitation Increase by 2090	4.50%	4.50%	4.49%	4.49%

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

b. °C = degrees Celsius; °F = degrees Fahrenheit; DPM = diesel particulate matter; $MMTCO_2$ = million metric tons of carbon dioxide; NO_x = nitrogen oxides; $PM_{2.5}$ = particulate matter 2.5 microns in diameter or less; ppm = parts per million.

c. The "Base Grid Mix" in the Final EIS is based on the AEO 2012 Early Release fuel mix and emissions projections for 2020, which do not include the Mercury and Air Toxics Standards issued by EPA in December 2011. The "Alternate Grid Mix" is based on the fuel mix and emissions projections of the cleaner "GHG Price Economy-wide" emissions side case in the final AEO 2011 for 2035 (full results are in Appendix H).

d. Benefits are measured under the Pope methodology (Pope et al. 2002) and the Laden methodology (Laden et al. 2006).

2.6.2 Cumulative Impacts

This section compares the cumulative impacts of the action alternatives on energy, air quality, and climate, as presented in Chapters 3, 4, and 5. By forecasting future fuel economy improvements resulting directly or indirectly from the action alternatives, in addition to other reasonably foreseeable fuel economy improvements, and comparing the benefits of those new vehicles to a light-duty vehicle fleet comprised increasingly of vehicles complying only with MY 2016 standards, this analysis accounts for the overall benefits of past, present, and reasonably foreseeable fuel economy increases. Table 2.6.2-1 presents the cumulative impacts for Analyses C1 and C2. The table includes results for health impacts analyzed under the Base Grid Mix Case and Alternate Grid Mix Case described above in Section 2.4.1.2.

Table 2.6.2-1-C. Cumulative Impacts, Analyses C1 and C2[a,b,c]

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Consumption for 2017–2060	6,052 to 6,562 billion gallons	5,080 to 5,476 billion gallons	4,694 to 5,054 billion gallons	4,261 to 4,559 billion gallons
Energy	Total Combined U.S. Passenger Car and Light Truck Fuel Savings Compared to No Action for 2017–2060	–	973 to 1,087 billion gallons	1,358 to 1,508 billion gallons	1,792 to 2,003 billion gallons
Air Quality	Criteria Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, SO_2, and VOCs) would decrease compared to the No Action Alternative, while emissions of CO would increase.	Emissions of most criteria pollutants (NO_x, $PM_{2.5}$, SO_2, and VOCs) would decrease compared to the No Action Alternative, while CO emissions would increase. Emissions decreases would generally be greater than the decreases under Alternative 2. The increase in CO emissions would generally be greater than the increase under Alternative 2.	Emissions of most criteria pollutants (CO, $PM_{2.5}$, and VOCs) would decrease compared to the No Action Alternative, while SO_2 and NO_x emissions would increase. The decreases/increases in emissions would be greater than those under Alternatives 2 and 3.
Air Quality	Toxic Air Pollutant Emissions Reductions in 2040 Compared to No Action	–	Emissions of benzene, formaldehyde, and DPM would generally decrease compared to the No Action Alternative, while emissions of acetaldehyde, acrolein, and 1,3-butadiene would increase.	Emissions of benzene, and DPM would decrease compared to the No Action Alternative; this decrease would be greater than the decrease under Alternative 2 for these pollutants. Emissions of acetaldehyde, acrolein, and 1,3-butadiene would increase; these increases would be greater than the increases under Alternative 2. Emissions of formaldehyde would either increase or decrease compared to the No Action Alternative, depending on analysis.	Emissions of benzene, 1,3-butadiene, and DPM would generally decrease compared to the No Action Alternative; these would be the greatest decreases of all alternatives for benzene and 1,3-butadiene. Emissions of acrolein and formaldehyde would increase; these increases would be greater than the increases under Alternative 3. Emissions of acetaldehyde would either increase or decrease compared to the No Action Alternative, depending on analysis.

Table 2.6.2-1-C. Cumulative Impacts, Analyses C1 and C2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Air Quality (cont'd)	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions[d] used) Using Base Grid Mix	–	Premature mortality: reduced by 281 to 772 cases Work-loss days: reduced by 30,764 to 33,120 days	Premature mortality: reduced by 360 to 1,006 cases Work-loss days: reduced by 39,553 to 43,168 days	Premature mortality: reduced by 218 to 756 cases Work-loss days: reduced by 24,498 to 32,835 days
	Reductions in Premature Mortality Cases and Work-loss Days in 2040 Compared to No Action (values within ranges depend on assumptions used) Using Alternate Grid Mix	–	Premature mortality: reduced by 286 to 799 cases Work-loss days: reduced by 31,359 to 34,272 days	Premature mortality: reduced by 417 to 1,080 cases Work-loss days: reduced by 45,721 to 46,422 days	Premature mortality: reduced by 531 to 1,377 cases Work-loss days: reduced by 58,738 to 59,759 days
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions used) Using Base Grid Mix	–	3%: $2.2 billion to $5.8 billion 7%: $2.0 billion to $5.3 billion	3%: $2.8 billion to $7.6 billion 7%: $2.6 billion to $6.9 billion	3%: $1.7 billion to $5.7 billion 7%: $1.6 billion to $5.2 billion
	Range of Monetized Health Benefits in 2040 Compared to No Action Under a 3% and 7% Discount Rate (values within ranges depend on assumptions used) Using Alternate Grid Mix	–	3%: $2.2 billion to $6.0 billion 7%: $2.0 billion to $5.5 billion	3%: $3.3 billion to $8.1 billion 7%: $3.0 billion to $7.4 billion	3%: $4.2 billion to $10.0 billion 7%: $3.8 billion to $9.4 billion

Table 2.6.2-1-C. Cumulative Impacts, Analyses C1 and C2[a,b,c] (continued)

		Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Climate	Total GHG Emissions from U.S. Passenger Cars and Light Trucks for 2017– 2100	138,800 to 155,400 $MMTCO_2$	108,900 to 121,400 $MMTCO_2$	100,200 to 111,800 $MMTCO_2$	91,600 to 102,100 $MMTCO_2$
	Atmospheric Carbon Dioxide Concentrations in 2100	677.8 ppm	674.7 to 675.1 ppm	673.8 to 674.3 ppm	672.9 to 673.5 ppm
	Increase in Global Mean Surface Temperature by 2100	2.564 °C (4.615 °F)	2.551 to 2.553 °C (4.592 to 4.595 °F)	2.548 to 2.550 °C (4.586 to 4.590 °F)	2.543 to 2.546 °C (4.577 to 4.583 °F)
	Global Sea-level Rise by 2100	33.42 centimeters (13.16 inches)	33.32 to 33.33 centimeters (13.12 inches)	33.29 to 33.30 centimeters (13.11 inches)	33.25 to 33.27 centimeters (13.09 to 13.10 inches)
	Global mean Precipitation Increase by 2090	3.89%	3.87%	3.87%	3.86%

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

b. °C = degrees Celsius; °F = degrees Fahrenheit; DPM = diesel particulate matter; $MMTCO_2$ = million metric tons of carbon dioxide; NO_x = nitrogen oxides; $PM_{2.5}$ = particulate matter 2.5 microns diameter or less; ppm = parts per million; SO_2 = sulfur dioxide; VOCs = volatile organic compounds.

c. The "Base Grid Mix" in the Final EIS is based on NEMS AEO 2012 Early Release fuel mix and emissions projections for 2020, which do not include the Mercury and Air Toxics Standards issued by the U.S. Environmental Protection Agency (EPA) in December 2011. The "Alternate Grid Mix" is based on the fuel mix and emissions projections of the cleaner "GHG Price Economy-wide" emissions side case in the final AEO 2011 for 2035 (full results are in Appendix H).

d. Benefits are measured under the Pope methodology (Pope et al. 2002) and the Laden methodology (Laden et al. 2006).

CHAPTER 3 ENERGY

NHTSA's proposed standards would regulate fuel economy and therefore impact U.S. transportation sector fuel consumption. Transportation fuel comprises a large portion of total U.S. energy consumption and energy imports and has a significant impact on the functioning of the energy sector as a whole. Because automotive fuel consumption is expected to account for most U.S. net energy imports through 2035, the United States has the potential to achieve large reductions in imported oil use and, consequently, in the country's net energy imports during this time, by increasing the fuel economy of its fleet of passenger cars and light trucks.

Increasing the fuel economy of the light-duty fleet is likely to have far-reaching impacts related to reducing U.S. dependence on foreign oil. Reducing dependence on energy imports is a key component of the President's March 30, 2011, *Blueprint for a Secure Energy Future*, which states that increasing transportation efficiency is an essential step toward that goal (White House 2011b). The 1-year progress report to the President's Blueprint reaffirms the major role increased fuel efficiency in transportation has already played in reducing U.S. dependence on foreign oil (White House 2012). Similarly, the U.S. Department of Energy (DOE) acknowledges that vehicle efficiency has the greatest short- to mid-term impact on oil consumption (DOE 2011c).

In light of the U.S. energy sector and automotive fuel dynamic, this chapter discusses past, present, and forecast U.S. energy production and consumption and compares this affected environment to the potential energy impacts under NHTSA's Proposed Action (including the No Action Alternative, the Preferred Alternative, and two other action alternatives selected to provide the lower and upper bounds of a reasonable range of alternatives within which the agency believes the maximum feasible standards fall). The chapter is organized as follows:

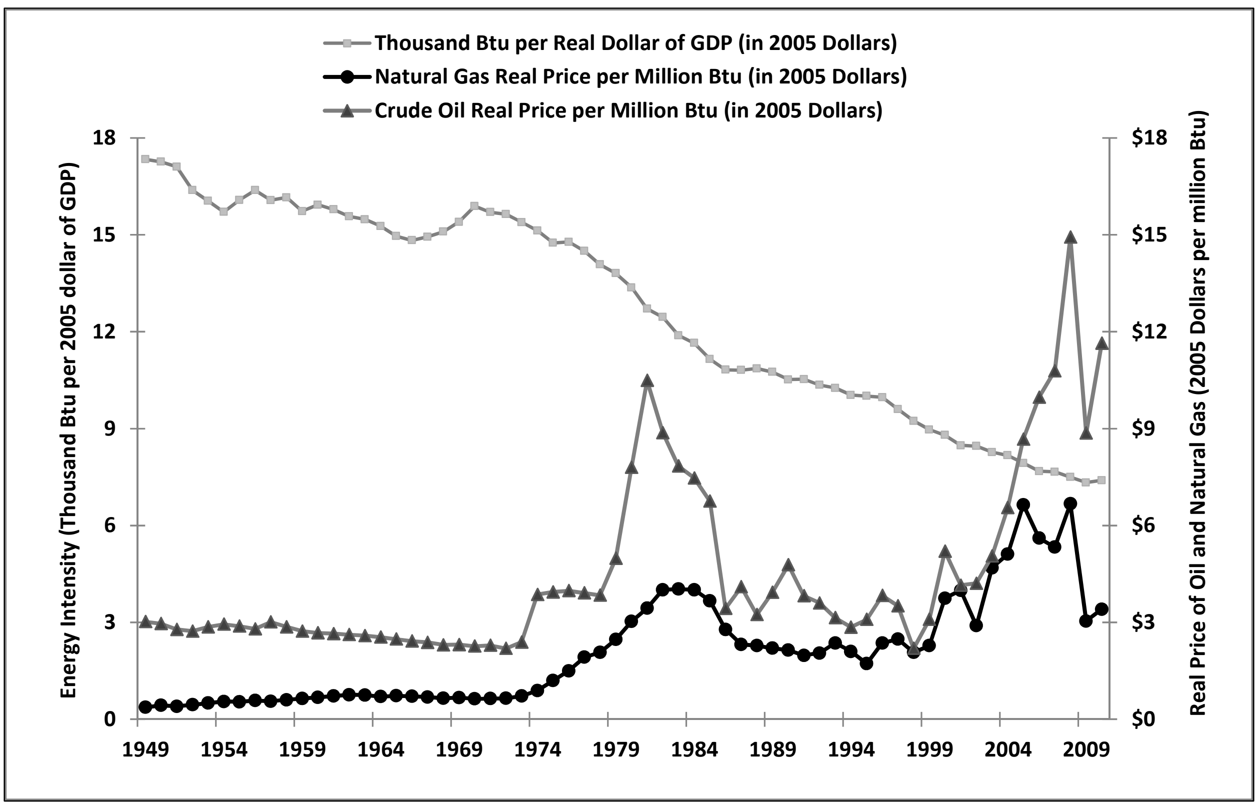
- Section 3.1 describes energy intensity and consumption and how past and future trends in U.S. energy intensity relate to trends in the U.S. share of global energy consumption and U.S. energy imports.
- Section 3.2 describes the affected environment for U.S. energy production and consumption by primary fuel source (coal, natural gas, petroleum, and other) and consumption sectors (residential, commercial, industrial, and transportation), and how the light-duty vehicle sector impacts overall energy use.
- Section 3.3 describes the energy impacts of NHTSA's Proposed Action and alternatives, including direct and indirect (Section 3.3.1) and cumulative impacts (Section 3.3.2).

3.1 Energy Intensity and Consumption

Energy intensity is calculated as the sum of all energy supplied to an economy divided by its real (inflation-adjusted) Gross Domestic Product (GDP; the combined market price of all the goods and services produced in an economy at a given time). Through this calculation, energy intensity measures the efficiency at which energy is converted to GDP, with a high value indicating an inefficient conversion of energy to GDP and a lower value indicating a more efficient conversion. By providing the relationship between energy use and GDP instead of absolute energy use, energy intensity offers a better unit for looking at the energy efficiency of an economy than overall energy consumption. On the other hand, energy consumption is useful to determine absolute energy use, but does not indicate the efficiency at which this energy is used. For example, all things being equal, increased vehicle fuel efficiency would yield a lower energy intensity for a particular economy and a reduction in fuel consumption per vehicle, but overall energy consumption might continue to increase if economic growth and increased vehicle use more than offset the increase in average fuel efficiency per vehicle. As discussed throughout this chapter, increasing vehicle fuel efficiency has the potential to contribute to decreases in U.S. energy intensity and net energy consumption. However, before analyzing the impacts of NHTSA's proposed standards on U.S. energy consumption, it is useful to examine how trends in U.S. energy intensity over recent decades have been more than offset by energy demand associated with economic growth, resulting in an increase in the absolute amount of U.S. energy consumption even as energy intensity declines.

Figure 3.1-1 shows that the energy intensity of the U.S. economy (in thousand British thermal units [Btu] per real dollar of GDP) and the real price of fuel (in 2005 dollars per million Btu) did not change substantially from the early 1950s through the early 1970s. During that time, economic growth seemed to be directly linked to proportionate growth in energy supply. That relationship changed when the real price of oil and natural gas surged during the 1970s. As a result of many subsequent economic changes, the energy intensity of the U.S. economy was reduced by 54 percent over 4 decades (from 15,890 Btu per real dollar of GDP in 1970 to 7,400 Btu per real dollar of GDP in 2010), indicating an overall increase in the efficiency with which the U.S. uses energy (EIA 2011d). The Annual Energy Outlook (AEO) 2012 Early Release forecasts a continuing decline in U.S. energy intensity and a corresponding anticipated increase in the efficiency of energy use in the United States (falling to 4,382 Btu per real dollar of GDP by 2035) (EIA 2012a).

Figure 3.1-1. Energy Intensity and Real Price of Oil and Natural Gas, 1949–2010[a,b]



a. Source: EIA 2011d, Table 1.5, Energy Consumption, Expenditures, and Emissions Indicators, 1949–2010 and Table 3.1, Fossil Fuel Production Prices, 1949–2010. Renewable Energy Consumption by Sector and Source.

b. Btu = British thermal unit; GDP = Gross Domestic Product.

The decline in U.S. energy intensity (and corresponding improvement in the economy's energy efficiency) over recent decades, combined with rapid economic growth and increased energy demand in many developing nations, has significantly reduced the U.S. share of international energy consumption. In 1980, the United States accounted for 27.6 percent of world energy consumption and, by 2008, the U.S. share of global consumption had fallen to 20.4 percent (EIA 2011e[1]). The 2011 International Energy Outlook forecasts a continuation of this trend, with the U.S. share of global consumption expected to fall to 17.8 percent by 2015, and 14.8 percent by 2035 (EIA 2011c[2]).

Although both U.S. energy intensity and the U.S. share of global energy consumption have been declining in recent decades, total U.S. energy consumption has been increasing over that same time period. Therefore, although the U.S. continues to use energy more efficiently, the U.S. economy also continues to use more energy overall. However, this growth in energy consumption remains smaller than the growth in GDP, allowing energy intensity to continue to decline. For example, real GDP has increased from $4.3 trillion in 1970 to $13.2 trillion in 2010 (both in 2005 dollars), while U.S. energy consumption during that period has increased, although at a slower rate (EIA 2011d). Similarly, increases in U.S. energy consumption did not keep pace with increases in global energy consumption, resulting in a decline in the U.S. share of global energy consumption since 1980 despite overall increases in U.S. energy consumption during that period (EIA 2011d).

Most of the increase in U.S. energy consumption over the past decades has not come from increased domestic energy production, but instead from the increase in imports from foreign energy producers. Indeed, in recent decades, the United States has experienced a significant increase in net imports of crude oil and natural gas and a decrease in net exports of coal (EIA 2011d). From 1970 to 2010, U.S. net imports of crude oil increased 616 percent, net imports of natural gas increased 247 percent, and net exports of coal decreased 16 percent, all measured in quads (quadrillion Btu). While energy imports (total quads of oil and natural gas) have been increasing since 1970, the price of energy imports (inflation-adjusted dollar per quad) during that period has also been increasing, meaning that the overall inflation-adjusted dollar value of net energy imports has risen at a much faster rate than the rise in net quad imports. Therefore, not only has the United States been importing more oil and gas to meet its increasing energy consumption, but it has also been spending significantly more money per unit imported since 1970, exacerbating the country's trade deficit (earnings from exports minus cost of imports).

As explained below, the United States is now poised to reverse the trend of the last four decades and achieve reductions in net energy imports through 2035 and beyond, due to ongoing declines in U.S. energy intensity and recent developments in U.S. energy production. More stringent fuel economy standards proposed in the form of the action alternatives included in this EIS have the potential to further decrease U.S. energy intensity by increasing energy efficiency in the transportation sector (the largest consumer of petroleum and contributor to U.S. net energy imports) compared to the No Action Alternative.

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[1] International Energy Statistics, Total Primary Energy Statistics; *Available at:* <http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=44&aid=2&cid=ww,US,&syid=1980&eyid=2008&unit=QBTU>. (Accessed: July 5, 2012).

[2] World total primary energy consumption by region, Reference case; *See Interactive Table Viewer available at*: <http://www.eia.gov/forecasts/ieo/index.cfm>. (Accessed: July 5, 2012).

3.2 Affected Environment

Because energy impacts under the Proposed Action have the potential to affect U.S. energy availability and use, the affected environment for energy encompasses current and projected U.S. energy consumption and production across all fuels and sectors. Section 3.2.1 discusses U.S. energy production and consumption by primary fuel source (petroleum, coal, natural gas, and other); Section 3.2.2 discusses U.S. energy consumption by sector (residential, commercial, industrial, and transportation). Energy data in these sections are drawn from the AEO 2012 Early Release forecast (EIA 2012a[3]), which reflects previously adopted CAFE standards through MY 2016 and assumed MY 2017–2020 fuel economy standards that reflect EISA's requirement that the light-duty fleet achieve a combined fuel economy of 35 mpg by MY 2020.[4]

3.2.1 U.S. Production and Consumption of Primary Fuels

Primary fuels are energy sources consumed in the initial production of energy. Energy sources used in the United States include nuclear power, coal, natural gas, and crude oil (converted to petroleum and other liquid fuels for consumption), which together account for 89 percent of U.S. energy consumption. Other sources, such as hydropower, biomass, and other types of renewable energy, account for 11 percent of U.S. energy consumption.

By 2035, the top 4 aforementioned energy sources are forecast to account for 83 percent of U.S. energy consumption, a reduction of 6 percent from their previous share, while the overall share of other fuels is forecast to rise to 17 percent (EIA 2012a). Figure 3.2.1-1 illustrates this change in U.S. fuel consumption and production from 2009 to 2035, not including the impacts of the proposed rule. As illustrated in the figure, fuel patterns during the period 2009 to 2035 are anticipated to remain relatively proportionate, with the exception of relative increases in renewable energy.

Although passenger cars and light trucks have the potential to use a number of the different primary fuels currently available in the United States (e.g., biofuels for biofuel vehicles and numerous energy sources with potential for conversion to electricity for electric vehicles), petroleum is overwhelmingly their primary source of energy. As technology and fuel costs and availability change, automotive fuel sources could also change. By requiring increased fuel economy, CAFE standards also have the potential to reduce demand for petroleum in the transportation sector, while potentially increasing the demand for other fuel sources, such as biofuels and fuels used to generate electricity. Understanding how markets for primary fuels will evolve in the coming years is therefore relevant to considerations of the impacts of the Proposed Action and alternatives.

The remainder of this section provides detailed projections for each primary fuel through 2035, drawn from AEO 2012 Early Release, including how production and consumption impact net imports or exports of each fuel.

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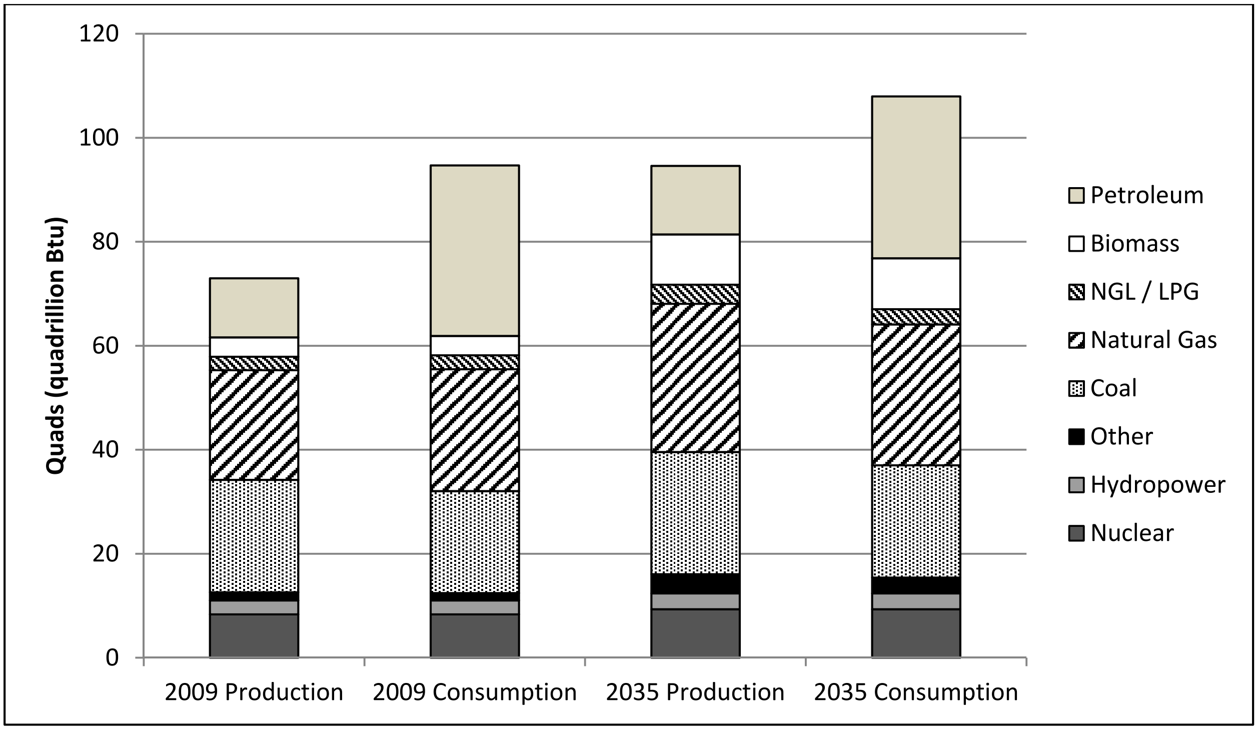
[3] Table 1, Total Energy Supply, Disposition, and Price Summary; Table 2, Energy Consumption by Sector and Source; and Table 17, Renewable Energy Consumption by Sector and Source.

[4] The AEO 2012 Early Release forecast reflects the impacts of the MY 2014–2018 Medium- and Heavy-Duty (HD) Fuel Efficiency Improvement Program but does not reflect proposed MY 2017–2025 CAFE standards that exceed the 35 mpg EISA requirement for 2020. The AEO 2012 forecast assumes that CAFE standards are held constant after MY 2020, with forecasted fuel economy improvements after 2020 based on economic cost-benefit analysis from a consumer's and manufacturers' perspective, which does not include energy security and GHG emissions reduction benefits.

Figure 3.2.1-1. U.S. Energy Production and Consumption by Source in 2009 and Projected in 2035[a,b] (excluding impacts of Proposed Action[c])



a. Source: EIA 2012b, Table 1, Total Energy Supply, Disposition, and Price Summary; Table 2, Energy Consumption by Sector and Source; and Table 17, Renewable Energy Consumption by Sector and Source.
b. Btu = British thermal units; NGL = natural gas liquid; LPG = liquefied petroleum gas.
c. As noted above, the AEO 2012 Early Release projections for 2035 (shown in this figure) do not reflect proposed MY 2017–2025 CAFE standards that exceed the 35 mpg EISA requirement for 2020.

From 2009 to 2035, production and consumption of nuclear power is forecast to increase from 8.4 to 9.3 quads, and production and consumption of hydropower is forecast to increase from 2.7 to 3.1 quads. Because production and consumption values are roughly equivalent for these energy sources, there are virtually no net imports or exports associated with nuclear power or hydropower.[5] Together, these fuels supplied 11.6 percent of total U.S. energy consumption in 2009, and their share of total consumption is forecast to increase to 12.2 percent by 2024 and then fall to 11.5 percent by 2035.

U.S. coal production is forecast to increase from 21.6 quads in 2009 to 23.5 quads in 2035. Coal consumption is expected to rise from 19.6 quads in 2009 to 21.6 quads in 2035. The United States is

[5] There are virtually no U.S. net imports of nuclear power in the sense that U.S. consumption of electricity generated by nuclear power is supplied by U.S. nuclear power plants. Supply and consumption of nuclear fuel at different stages of processing is more complex, with new U.S. supply sources expected to reduce U.S. dependence on nuclear fuel imports by 2020. The nuclear fuel cycle includes the mining of uranium ore, conversion into uranium hexafluoride, and enrichment to increase the concentration of uranium-235 in uranium hexafluoride (USNRC 2011). The United States produced only 5 percent of the uranium consumed by U.S. nuclear plants in 2003, relying on substantial imports from Canada and Australia, but ranks sixth in the world for known uranium resources, and there has been a significant increase in exploration and plans to reopen old mines as the price of uranium has increased in recent years. There are also significant expansions planned for U.S. conversion capacity to produce uranium hexafluoride, and a substantial increase in U.S. enrichment capacity is expected from three new enrichment plants likely to begin operation before 2020 (USNRC 2011).

currently, and is expected to remain, a net exporter of coal energy through 2035, because the country is anticipated to continue to produce slightly more coal than it consumes.

U.S. production of dry natural gas (separated from natural gas liquids, discussed below) is forecast to increase from 21.1 quads in 2009 to 28.5 quads in 2035. This forecast growth is due to new production technologies that can extract U.S. shale gas, a specific form of natural gas that has previously been too difficult to utilize commercially. U.S. shale gas production specifically is expected to rise six fold between 2008 and 2035, more than offsetting an expected decline in conventional natural gas production. U.S. consumption of natural gas is expected to rise at a slower rate than its production – from 23.4 quads in 2009 to 27.1 quads in 2035 – thereby making the U.S. a net exporter of dry natural gas in 2022 through 2035.

Production of natural gas liquid (a similar but heavier hydrocarbon compared to dry natural gas) is forecast to increase from 2.6 quads in 2009 to 3.7 quads in 2035. After extraction, natural gas liquid is separated from dry natural gas in processing plants and sold as ethane, propane, and other liquefied petroleum gases for consumption. Consumption of liquefied petroleum gas is forecast to increase from 2.7 quads in 2009 to 2.9 quads in 2035. Therefore, the increase in natural gas liquid production is expected to outpace the increase in liquefied petroleum gas consumption, resulting in net exports for this subset of liquid fuels in 2010 through 2035.

U.S. production of biomass energy (e.g., grid-connected electricity from wood and wood waste; liquid fuels production from crops; and direct (non-electric) energy from wood) is forecast to increase from 3.7 quads in 2009 to 9.7 quads in 2035. Biomass energy consumption is forecast to rise even faster, from 3.7 quads in 2009 to 9.8 quads in 2035. Excess energy consumption in 2035 is anticipated to be met by importing 0.1 quads of ethanol. Almost half of the projected growth in biomass energy use is due to a forecast increase in ethanol, biodiesel, and other biomass liquids used in transportation, from 1.0 quads in 2009 to 3.9 quads in 2035.

U.S. production of crude oil is forecast to increase from 11.4 quads in 2009 to 13.2 quads in 2035. Crude oil is refined into petroleum (including liquid fuel such as gasoline and diesel, but not including non-petroleum liquid fuels, such as biofuels and liquefied petroleum gas) for consumption. U.S. consumption of petroleum is forecast to decline slightly from 32.8 quads in 2009 to 31.1 quads in 2035. Therefore, U.S. net imports of petroleum are forecast to decline from approximately 21 quads (3,570 million barrels) in 2009 to 18 quads (3,060 million barrels) in 2035. Reductions in net petroleum imports are anticipated to result from ongoing declines in energy intensity, as discussed in Section 3.1 (as stated, these figures do not include impacts from the Proposed Action and alternatives, which would contribute to additional declines in petroleum imports).

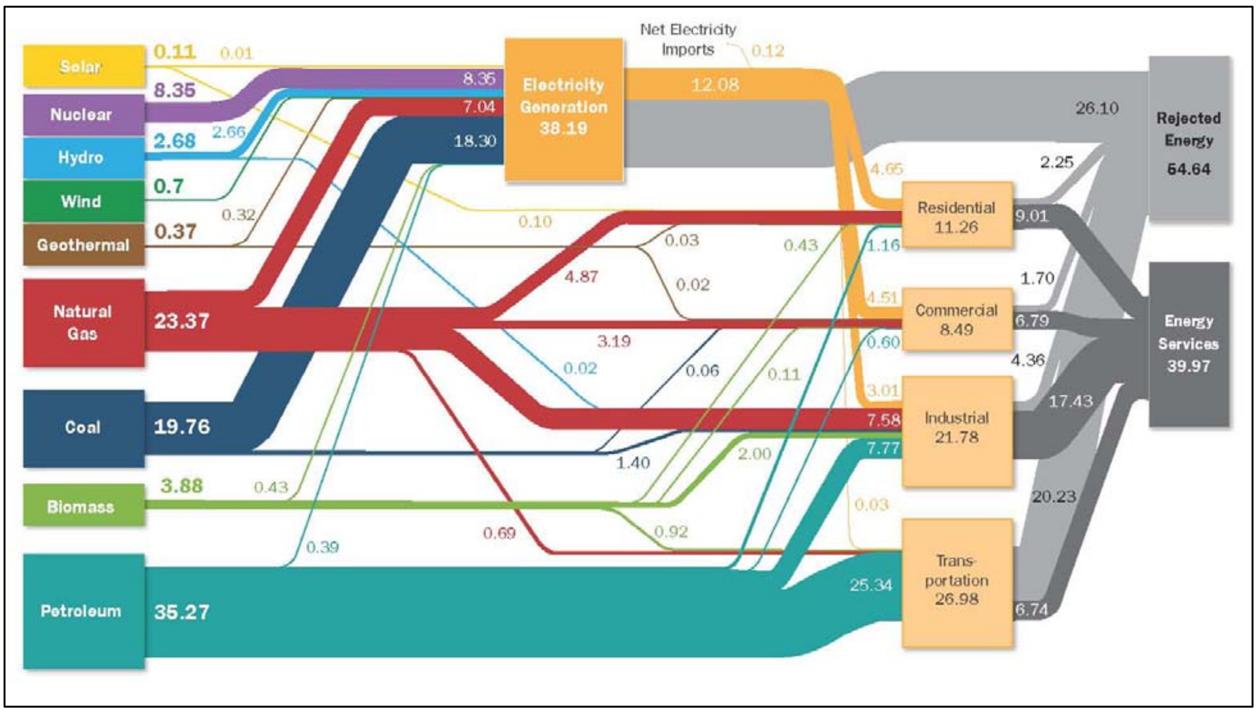
The primary fuel projections discussed above demonstrate that there are likely to be essentially no U.S. net imports of nuclear power, hydropower, and biomass and other renewable energy, and minor U.S. net exports of coal, natural gas, and natural gas liquid and liquefied petroleum gas by 2035. However, petroleum will continue to require significant net imports to meet consumption demands. Despite modest reductions in net petroleum imports by 2035, petroleum imports will continue to be magnitudes greater than net energy exports, resulting in a continued U.S. trade deficit from the energy sector.

3.2.2 U.S. Energy Consumption by Sector

While Section 3.2.1 describes overall U.S. production and consumption of primary fuels, this section discusses the usage of primary fuels by sector. Energy consumption occurs in four broad economic sectors: industrial, residential, commercial, and transportation. These sectors can be categorized as either stationary (including industrial, residential, and commercial sectors) or mobile (i.e., transportation). Stationary and transportation sectors consume primary fuels, as described above (e.g., nuclear, coal, and petroleum), and electricity. Electric power generation consumes primary fuel to provide electricity to the industrial, residential, commercial, and transportation sectors. This section describes how different fuels, including electricity, are more or less conducive to use in the different sectors. Consequently, regulations by sector (such as the proposed CAFE standards, which primarily impact the transportation sector) will have different implications for specific fuel usage and overall impacts to the U.S. economy.

Figure 3.2.2-1 shows the relative amounts of energy produced from each energy source and consumed by each sector in 2009; Figure 3.2.2-2 illustrates the different fuel uses for each sector as projected in 2035. As shown in these figures, stationary and transportation sectors use a sharply contrasting profile of fuels, with stationary sources consuming more electricity and natural gas, and the transportation sector consuming primarily petroleum. Sections 3.2.2.1 and 3.2.2.2 discuss the specifics of fuel use by stationary and transportation sectors, respectively. Section 3.3 describes the impacts on transportation fuel consumption associated with the action alternatives examined in this EIS.

Figure 3.2.2-1. U.S. Energy Flows in 2009[a,b,c]

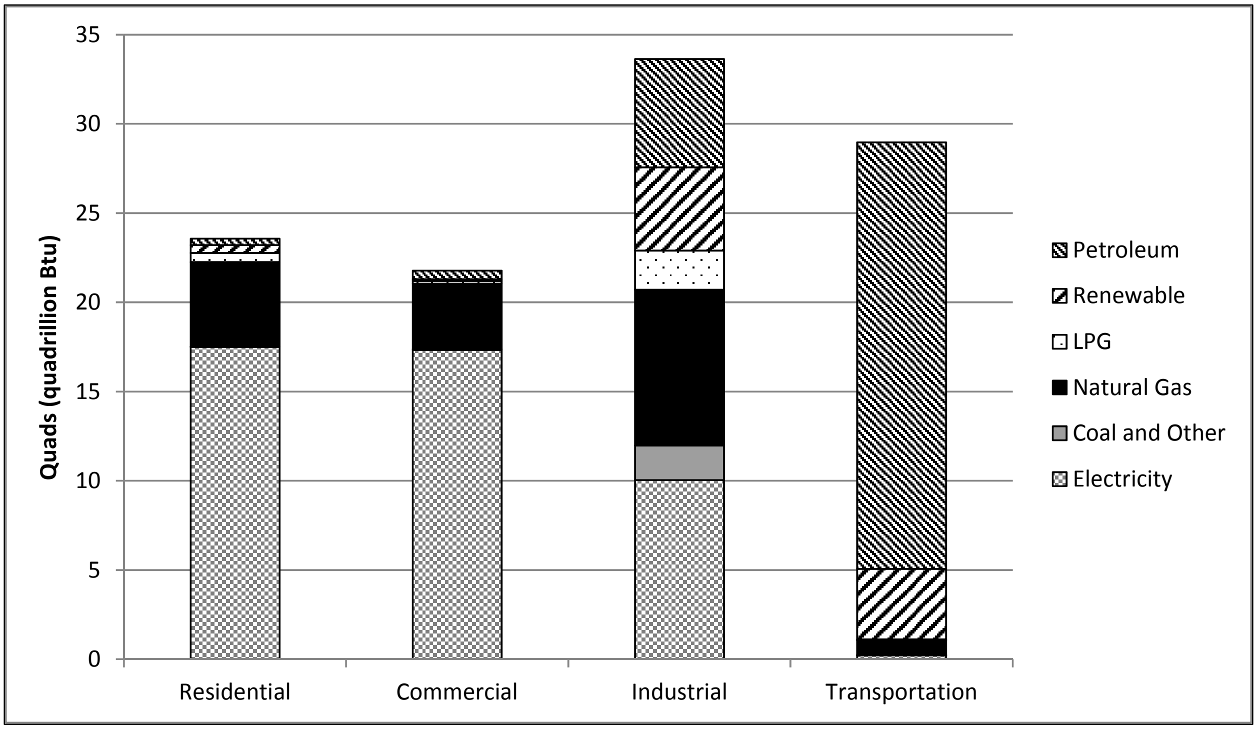


a. Source: DOE 2011c citing LLNL 2009.

b. Values are in quadrillion Btu; total energy is approximately 95 quads.

c. *Rejected energy* is energy lost as waste heat throughout the generation and transmission process. Most of these losses occur when energy is converted from one form to another. *Energy services* refers to the energy successfully transmitted to its end designation.

Figure 3.2.2-2. U.S. Energy Consumption by End-Use Sector and Source Fuel Projected in 2035[a,b] (excluding impacts of the Proposed Action[c])



a. Source: EIA 2012b, Table 2. Energy Consumption by Sector and Source; and Table 17. Renewable Energy Consumption by Sector and Source.
b. Btu = British thermal units; LPG = liquefied petroleum gas.
c. As noted above, the AEO 2012 Early Release projections for 2035 (shown in this figure) do not reflect proposed MY 2017–2025 CAFE standards that exceed the 35 mpg EISA requirement for 2020.

3.2.2.1 Stationary-sector Fuel Consumption

This section provides background information addressing stationary-sector fuel consumption, on which the Proposed Action would have little impact. Section 3.2.2.2 discusses transportation-sector fuel consumption, on which the Proposed Action would be expected to have a large impact.

Electricity and natural gas (used on sites to produce heat) are the principal forms of energy used by the residential and commercial sectors, accounting for 94 percent of these sectors' energy use and almost 40 percent of total U.S. primary energy consumption. The industrial sector has more diverse energy consumption patterns, including electricity, natural gas, and renewable energy. This sector consumes another 30 percent of the Nation's total energy. New energy technologies to supply stationary energy to consumers must compete with an existing infrastructure that delivers these fuels reliably and at a relatively low cost.

Residential-sector energy consumption is forecast to rise from 20.9 quads in 2009 to 23.6 quads in 2035. In 2009, electricity (including energy lost during generation and transmission, when one form of energy is converted to another, referred to herein as "losses") supplied 69 percent of residential demand and natural gas (not converted to electricity) supplied 23 percent. In 2035, electricity is expected to supply 74 percent and natural gas 20 percent. The liquefied petroleum gas share is forecast to decline from 2.4 percent in 2009 to 2.1 percent in 2035, and the renewable energy (e.g., wood and solar) share is expected to decline from 2.0 percent in 2009 to 1.9 percent in 2035. The fuel oil share of residential energy is also expected to decline from 2.9 percent in 2009 to 1.5 percent in 2035.

Commercial-sector energy consumption is forecast to rise from 17.9 quads in 2009 to 23.8 quads in 2035. In 2009, electricity (including losses) supplied 77 percent of commercial energy demand, and natural gas supplied 18 percent. In 2035, electricity is expected to supply 80 percent and natural gas 17 percent. The liquid fuel share of commercial energy, including liquefied petroleum gas and petroleum, is expected to decline from 3.8 percent in 2009 to 2.9 percent in 2035.

Industrial-sector energy consumption is projected to rise from 28.8 quads in 2009 to 33.6 quads in 2035. In 2009, electricity (including losses) supplied 34 percent of industrial demand, coal supplied 5 percent, natural gas supplied 27 percent, and biofuels, their co-products (including other products produced as by-products during ethanol fuel and biodiesel production), and other renewable energy supplied 8 percent. In 2035, electricity (including losses) is expected to supply 30 percent of industrial energy use, with coal supplying 6 percent, natural gas supplying 26 percent, and biofuels, their co-products, and renewable energy supplying 14 percent. The liquid fuel share of industrial energy use is anticipated to decline from 28 percent in 2009 to 25 percent in 2035, with liquefied petroleum gas supplying approximately one-fourth of this industrial liquid fuel demand.

Total energy consumption from electric power, which feeds into all stationary-sector activities (as described in this section) and some transportation activities (as described in Section 3.2.2.2), is forecast to rise from 38.1 quads in 2009 to 45.1 quads in 2035. In 2009, nuclear power supplied 22 percent of electric power generation source fuel, coal 48 percent, natural gas 19 percent, and hydropower and other renewable energy 10 percent. In 2035, nuclear power is predicted to supply 21 percent, coal 43 percent, natural gas 21 percent, and hydropower and other renewable energy 14 percent. The petroleum share of electric power fuel supply is anticipated to decline from 1.0 percent in 2009 to 0.8 percent in 2035.

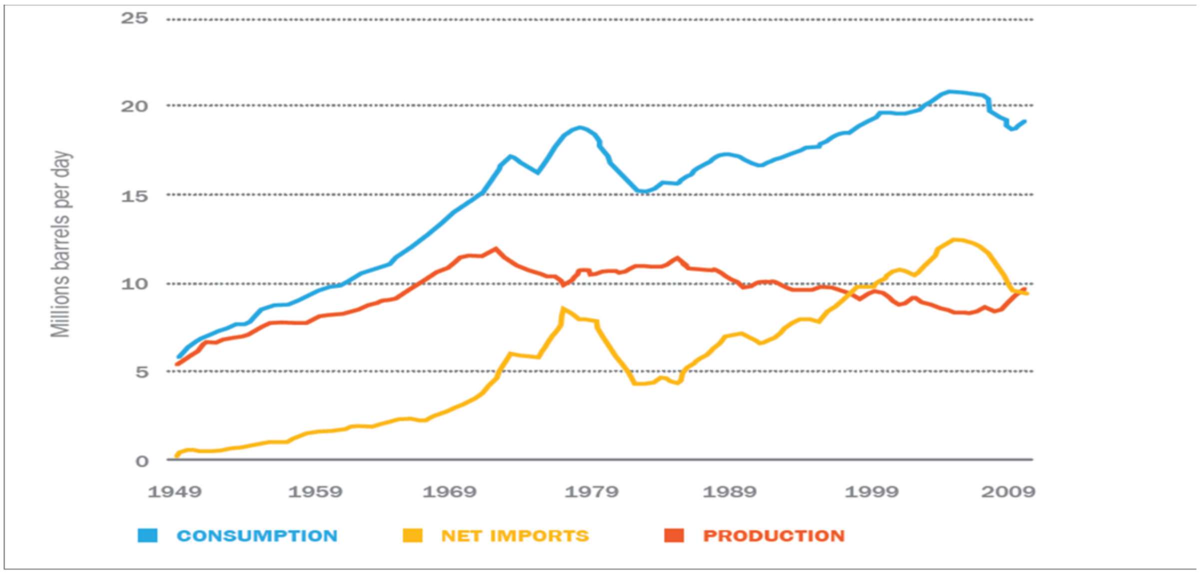
3.2.2.2 Transportation-sector Fuel Consumption

Transportation energy consumption is forecast to rise from 27 quads in 2009 to 29 quads in 2035. In 2009, petroleum and other liquid fuel supplied 97.3 percent of transportation energy demand, and natural gas supplied 2.4 percent. In 2035, petroleum and other liquid fuel are expected to supply 96.3 percent, and natural gas is expected to supply 2.9 percent. The biofuel share of transportation liquid fuel is projected to rise from 3.8 percent in 2009 to 14.2 percent in 2035. Liquefied petroleum gas accounts for less than 0.2 percent of liquid fuel consumption in the transportation sector.

In 2010, 72 percent of the petroleum the U.S. consumed was for transportation, and 63 percent of petroleum used in transportation is used to fuel passenger cars and light trucks. Almost 95 percent of U.S. transportation-sector energy comes from petroleum, nearly half of which is imported. In 2035, jet fuel is forecast to account for 12 percent of transportation-sector petroleum consumption, and medium, heavy, and light-duty vehicles are forecast to account for 87 percent. With petroleum expected to account for the most energy imports, and transportation expected to account for 77 percent of petroleum consumption in 2035, U.S. net energy imports in 2035 are forecast to result primarily from fuel consumption by medium, heavy, and light-duty vehicles. Negligible U.S. net energy imports in 2035 are anticipated to be related to the residential or commercial sectors because petroleum accounts for only a very small fraction of source fuel used in these sectors, while the fuels that are used in these sectors account for a very small fraction of energy imports.

As shown in Figure 3.2.2-3, the net import fraction of petroleum and other liquid fuels has dropped from more than 60 percent in 2005 to approximately 50 percent in 2010. As reported by DOE (EIA 2012c), the net import fraction of petroleum and other liquid fuels is expected to drop to 37 percent in 2035, due to a combination of more stringent vehicle fuel economy standards and increased domestic production of both crude oil and biofuels. (This 2035 forecast does not include the impacts of the Proposed Action.) In absolute terms, the volume of liquid fuel imports for the United States in 2020 through 2035 is projected to be more than 20 percent below the absolute volume of liquid fuel imports in 2010.

Figure 3.2.2-3. Consumption, Production, and Net Imports of Petroleum and Other Liquid Fuels, 1949–2009[a]



a. Source: DOE 2011c citing EIA 2011.

Section 3.3 discusses potential impacts of the Proposed Action and alternatives on fuel consumption and fuel savings through 2050. As demonstrated by the current and projected statistics described in this section, the affected environment of energy consumption and production in the United States strongly suggests a potential for reduced petroleum consumption and, correspondingly, a reduction in net energy imports.

3.3 Environmental Consequences

Section 3.3.1 examines the direct and indirect impact on fuel consumption associated with the action alternatives under Analysis A and Analysis B. Section 3.3.2 examines the effects on fuel consumption under the cumulative impacts analysis. As explained in Chapter 2:

- In Analyses A1 and A2, the agency assumes that the average fleetwide fuel economy for light-duty vehicles would not exceed the minimum level necessary to comply with CAFE standards. Therefore, Analyses A1 and A2 measure the impacts of the action alternatives under which average fleetwide fuel economy in each model year does not exceed the level of the CAFE standards for that model year, compared to a No Action Alternative under which average fleetwide fuel economy after MY 2016 will never exceed the level of the agencies' MY 2016 standards established by final rule in April 2010. Tables and figures in this Final EIS that depict results for Analysis A1 (these have "A1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM Worldwide-based fleet projection. Tables and figures that depict results for Analysis A2 (these have "A2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC Automotive-based fleet projection.

- In Analyses B1 and B2, the agency assumes continued improvements in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Therefore, Analyses B1 and B2 measure the impacts of the action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing improvements in new vehicle fuel economy after MY 2025, compared to a No Action Alternative that assumes the average fleetwide fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards, even in the absence of agency action. Tables and figures in this Final EIS that depict results for Analysis B1 (these have "B1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis B2 (these have "B2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.
- In Analyses C1 and C2, the agency compares action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing fuel economy improvements after MY 2025 with a No Action Alternative under which there are no continued improvements in fuel economy after MY 2016 (i.e., the average fleetwide fuel economy for light-duty vehicles would not exceed the latest existing standard). In this way, the cumulative impacts analysis combines the No Action Alternative from Analyses A1 and A2 with the action alternatives from Analyses B1 and B2. Tables and figures in this Final EIS that depict results for Analysis C1 (these have "C1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis C2 (these have "C2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection. For more explanation of NHTSA's methodology regarding the cumulative impacts analysis, *see* Section 2.5.

3.3.1 Direct and Indirect Impacts

Tables 3.3.1-1-A1 and -A2 list combined direct and indirect fuel consumption under Analysis A for each alternative for 2017–2060, when essentially the entire light-duty vehicle fleet will be composed of MY 2025 or later vehicles. Tables 3.3.1-1-B1 and -B2 list combined direct and indirect fuel consumption for Analysis B. These four tables report total 2017–2060 light-duty vehicle consumption in gasoline gallon equivalents, which includes consumption of gasoline, diesel, biofuel, and electricity used to power the light-duty vehicle fleet. The tables list results for cars, light trucks, and all light-duty vehicles. These tables also show light-duty vehicle 2017–2060 fuel savings resulting from each action alternative compared to the No Action Alternative.

Figures 3.3.1-1-A1 and -A2 and 3.3.1-1-B1 and -B2 show fuel savings for cars and light trucks by alternative for Analyses A and B. Under Analysis A, light-duty vehicle fuel consumption from 2017–2060 under the No Action Alternative is projected to range from 6,052 to 6,562 billion gallons. Light-duty vehicle 2017–2060 fuel consumption is projected to range from 5,400 to 5,812 billion gallons under Alternative 2, 4,987 to 5,372 billion gallons under the Preferred Alternative, and 4,456 to 4,795 billion gallons under Alternative 4. Compared to the No Action Alternative, light-duty vehicle 2017–2060 fuel savings would range from 652 to 751 billion gallons under Alternative 2, 1,597 to 1,767 gallons under Alternative 4, and 1,066 to 1,190 billion gallons under the Preferred Alternative.

Table 3.3.1-1-A1. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A1

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	3,241	2,871	2,623	2,348
Light trucks	3,321	2,941	2,749	2,448
All light-duty vehicles	6,562	5,812	5,372	4,795
Fuel Savings Compared to the No Action Alternative				
Cars		370	618	893
Light trucks		381	572	873
All light-duty vehicles		751	1,190	1,767

Table 3.3.1-1-A2. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	2,991	2,674	2,421	2,146
Light trucks	3,062	2,726	2,565	2,310
All light-duty vehicles	6,052	5,400	4,987	4,456
Fuel Savings Compared to the No Action Alternative				
Cars		317	569	844
Light trucks		336	496	752
All light-duty vehicles		652	1,066	1,597

Table 3.3.1-1-B1. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B1

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	2,906	2,785	2,533	2,298
Light trucks	2,788	2,690	2,522	2,261
All light-duty vehicles	5,694	5,476	5,054	4,559
Fuel Savings Compared to the No Action Alternative				
Cars		120	373	608
Light trucks		98	266	527
All light-duty vehicles		219	640	1,135

Table 3.3.1-1-B2. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	2,701	2,583	2,335	2,109
Light trucks	2,579	2,497	2,360	2,151
All light-duty vehicles	5,280	5,080	4,694	4,261
Fuel Savings Compared to the No Action Alternative				
Cars		118	366	592
Light trucks		82	219	427
All light-duty vehicles		200	585	1,019

Figure 3.3.1-1-A1. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A1

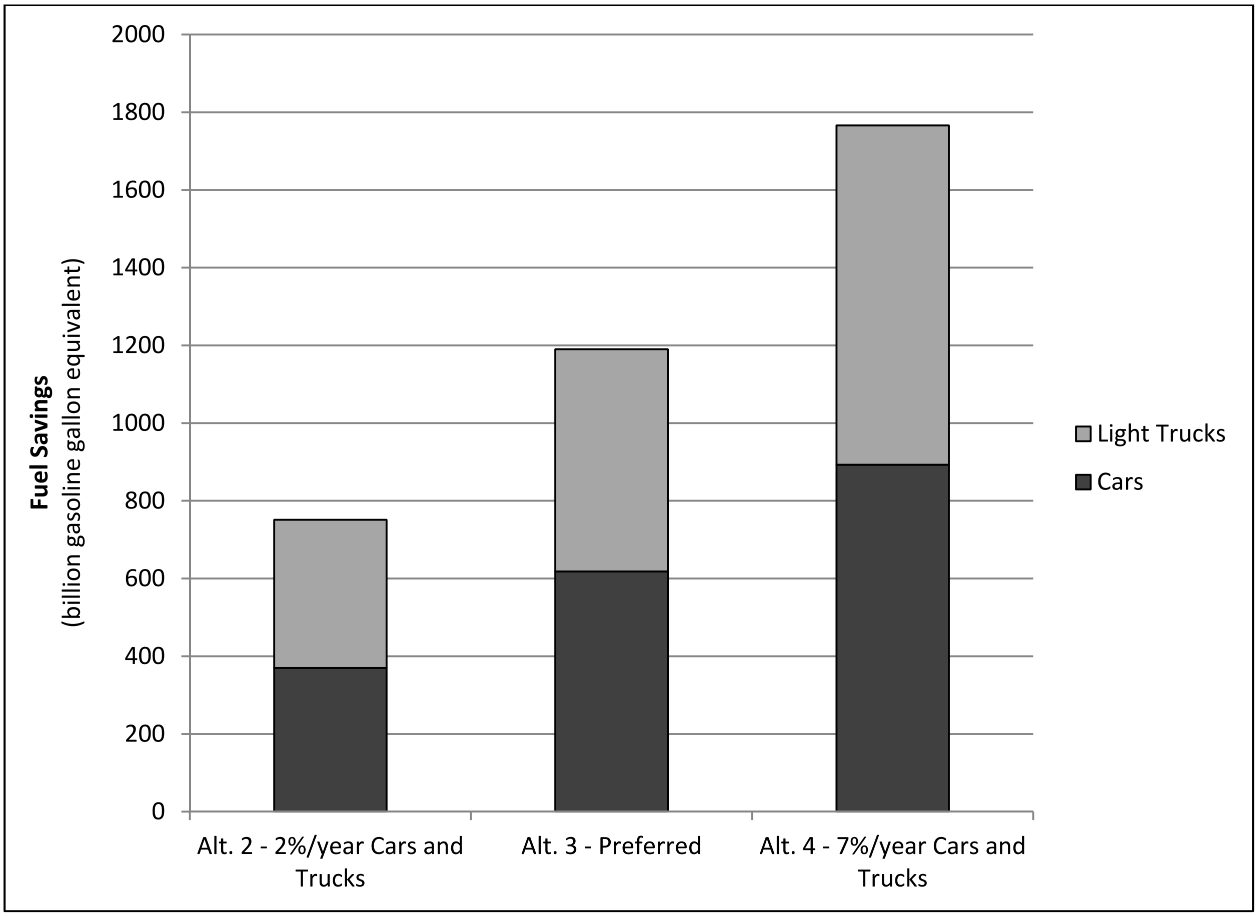


Figure 3.3.1-1-A2. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis A2

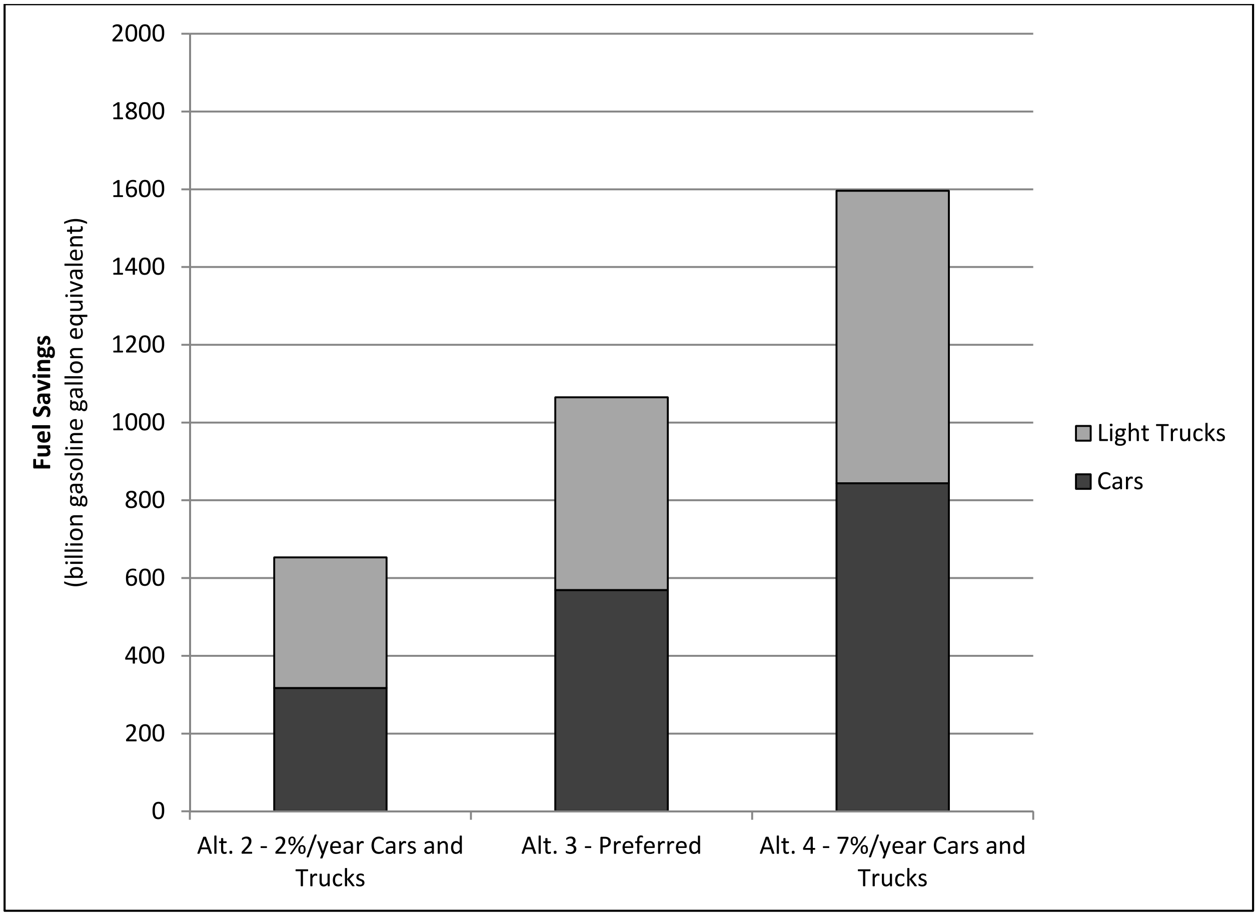


Figure 3.3.1-1-B1. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B1

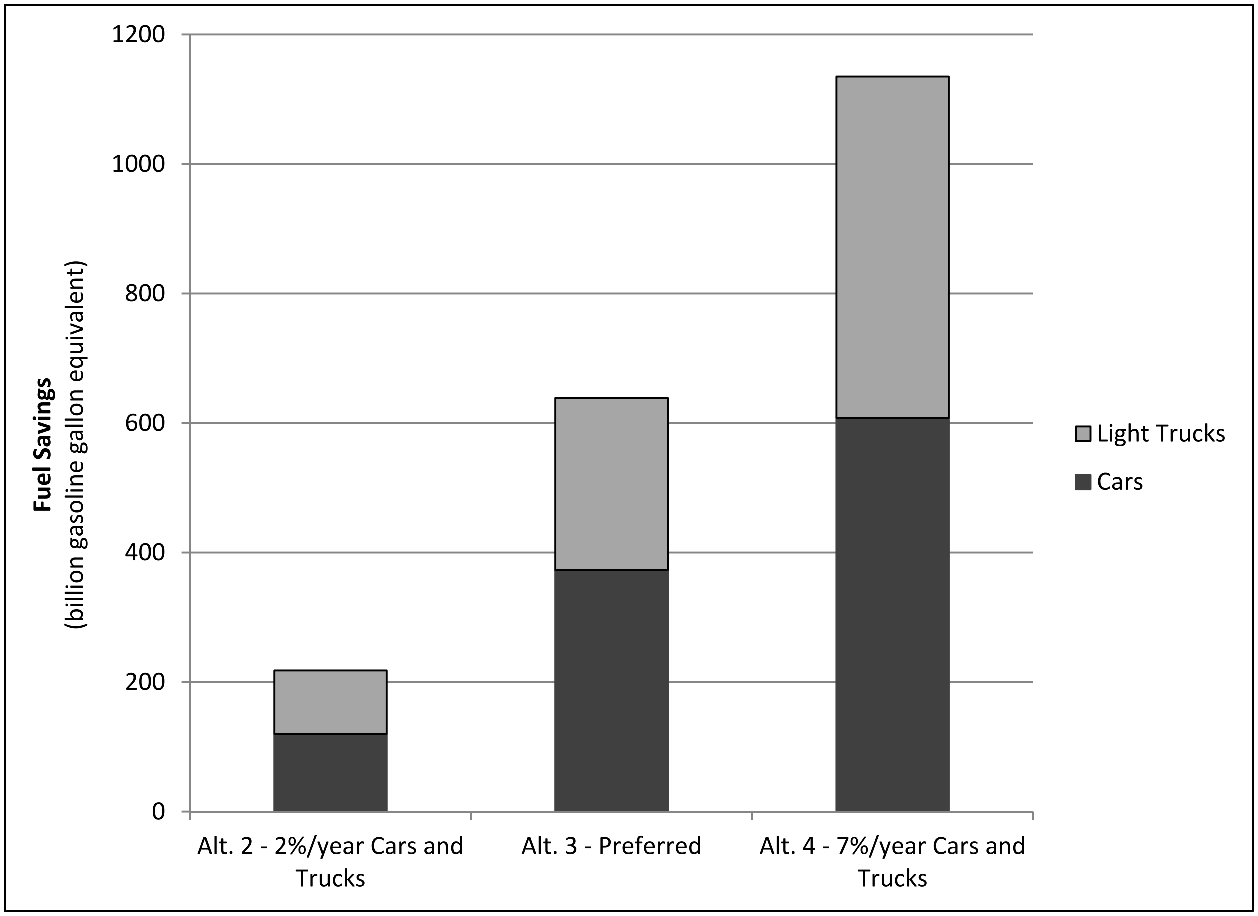
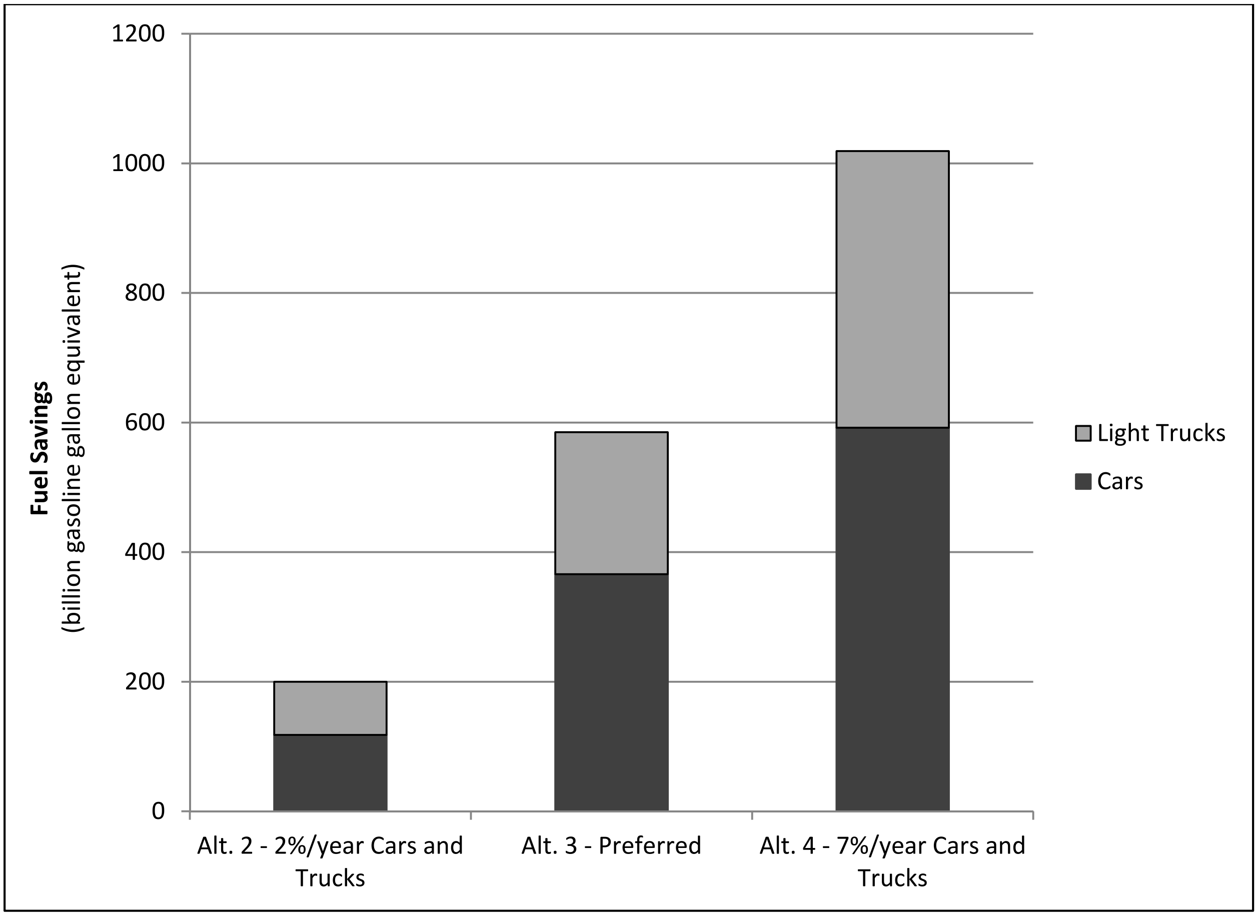


Figure 3.3.1-1-B2. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis B2



Under Analysis B, light-duty vehicle fuel consumption from 2017–2060 under the No Action Alternative is projected to range from 5,280 to 5,694 billion gallons. Light-duty vehicle 2017–2060 fuel consumption is projected to range from 5,080 to 5,476 billion gallons under Alternative 2, 4,694 to 5,054 under the Preferred Alternative, and 4,261 to 4,559 billion gallons under Alternative 4. Compared to the No Action Alternative, light-duty vehicle 2017–2060 fuel savings would range from 200 to 219 billion gallons under Alternative 2, 1,019 to 1,135 billion gallons under Alternative 4, and 585 to 640 billion gallons under the Preferred Alternative.

3.3.2 Cumulative Impacts

Tables 3.3.2-1-C1 and -C2 list the total fuel consumption and savings for each alternative for 2017–2060 under the cumulative impacts analysis. Values are reported in gasoline gallon equivalents, including gasoline, diesel, biofuel, and electricity. Separate results are shown for cars, light trucks, and for all light-duty vehicles. Figures 3.3.2-1-C1 and -C2 show fuel savings under the cumulative impacts analysis for each action alternative for cars and light trucks compared to the No Action Alternative.

Table 3.3.2-1-C1. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C1

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	3,241	2,785	2,533	2,298
Light trucks	3,321	2,690	2,522	2,261
All light-duty vehicles	6,562	5,476	5,054	4,559
Fuel Savings Compared to No Action Alternative				
Cars		455	708	943
Light trucks		631	800	1,060
All light-duty vehicles		1,087	1,508	2,003

Table 3.3.2-1-C2. Fuel Consumption and Fuel Savings by Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Fuel Consumption				
Cars	2,991	2,583	2,335	2,109
Light trucks	3,062	2,497	2,360	2,151
All light-duty vehicles	6,052	5,080	4,694	4,261
Fuel Savings Compared to No Action Alternative				
Cars		408	656	882
Light trucks		565	702	910
All light-duty vehicles		973	1,358	1,792

Figure 3.3.2-1-C1. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C1

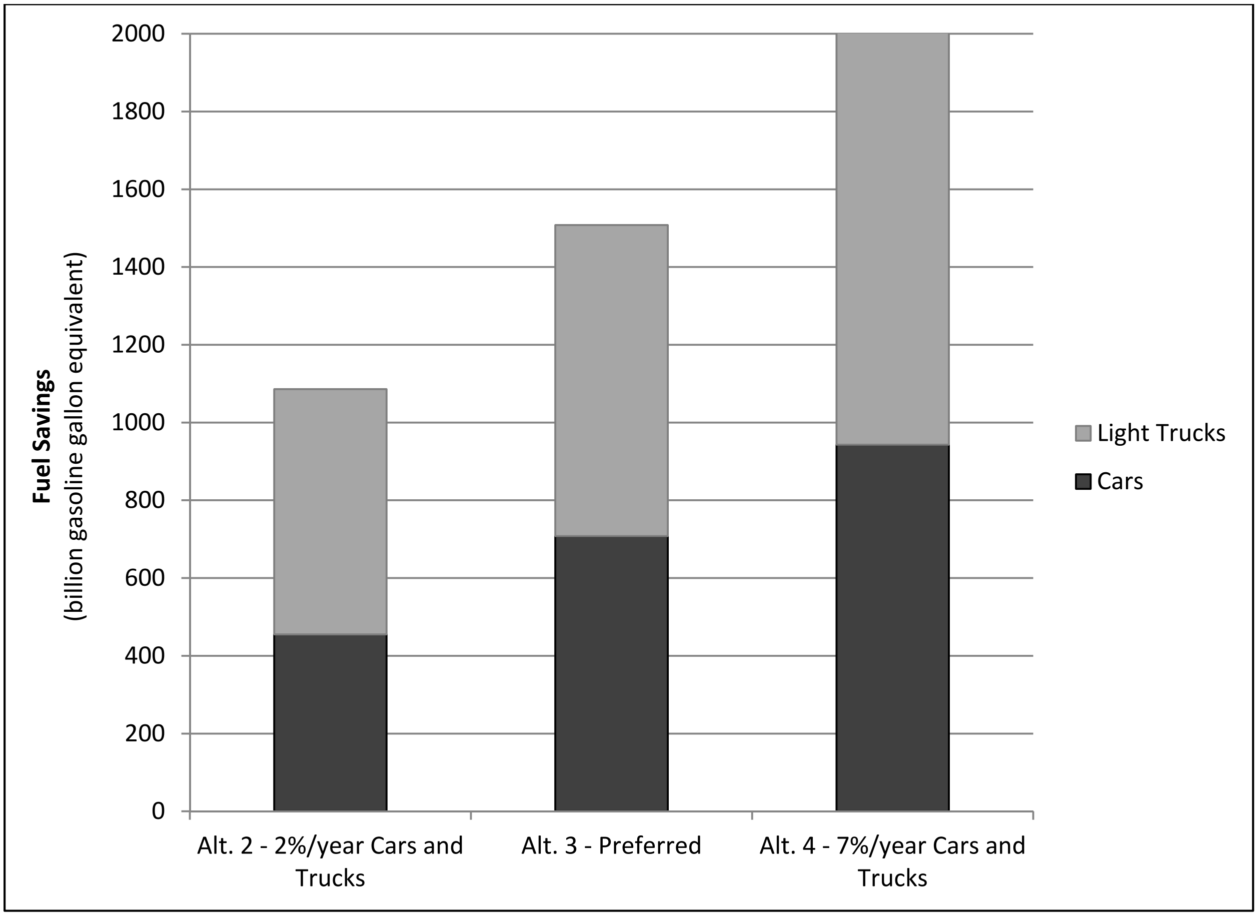
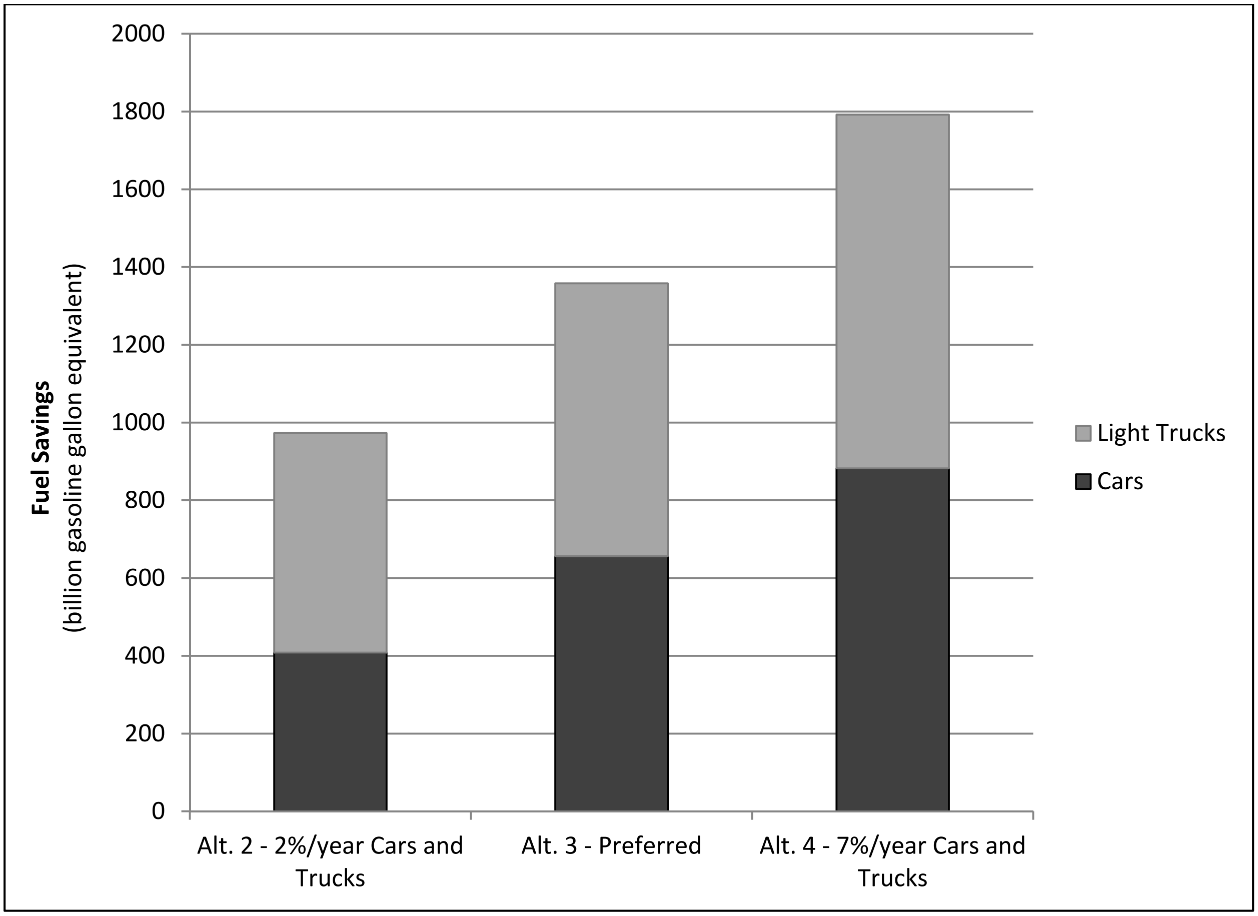


Figure 3.3.2-1-C2. U.S. Passenger Car and Light Truck Fuel Savings by Action Alternative (billion gasoline gallon equivalent total for calendar years 2017–2060), Analysis C2



Under the cumulative impacts analysis, light-duty vehicle fuel consumption for years 2017–2060 under the No Action Alternative is projected to range from 6,052 to 6,562 billion gallons. Total 2017–2060 fuel consumption for the cumulative impacts analysis is projected to range from 5,080 to 5,476 billion gallons under Alternative 2, 4,694 to 5,054 under the Preferred Alternative, and 4,261 to 4,559 billion gallons under Alternative 4. Compared to the No Action Alternative, the cumulative impacts analysis projects total 2017–2060 fuel savings ranging from 973 to 1,087 billion gallons under Alternative 2, 1,792 to 2,003 billion gallons under Alternative 4, and 1,358 to 1,508 billion gallons under the Preferred Alternative.

CHAPTER 4 AIR QUALITY

4.1 Affected Environment

4.1.1 Relevant Pollutants and Standards

The Proposed Action (including the No Action Alternative, Alternative 2, the Preferred Alternative, and Alternative 4) would affect air pollutant emissions and air quality, which in turn would affect public health and welfare and the natural environment. Many human activities cause gases and particles to be emitted into the atmosphere. These activities include driving cars and trucks; burning coal, oil, and other fossil fuels; manufacturing chemicals and other products; and smaller, everyday activities such as dry-cleaning, degreasing, and painting operations, and the use of consumer products. When these gases and particles accumulate in the air in high enough concentrations, they can harm humans, especially children, the elderly, the ill, and other sensitive individuals, and can damage crops, vegetation, buildings, and other property. Many air pollutants remain in the environment for long periods and are carried by the wind hundreds of miles from their origins. People exposed to high enough levels of certain air pollutants can experience burning in their eyes, an irritated throat, breathing difficulties, or other respiratory symptoms. Long-term exposure to air pollution can cause cancer, heart and lung diseases, and long-term damage to the immune, neurological, reproductive, and respiratory systems. In extreme cases, it can even cause death (EPA 2012d).

To reduce air pollution levels, the Federal Government and state agencies have passed legislation and established regulatory programs to control sources of emissions. The Clean Air Act (CAA) is the primary federal legislation that addresses air quality. Under the CAA, as amended, 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).[1] The criteria pollutants analyzed in this EIS are carbon monoxide (CO), nitrogen dioxide (NO_2) (one of several oxides of nitrogen), ozone, sulfur dioxide (SO_2), particulate matter (PM) with a nominal aerodynamic diameter equal to or less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$, or fine particles), and lead. Vehicles do not directly emit ozone, but this pollutant is evaluated based on emissions of the ozone precursor pollutants nitrogen oxides (NO_x) and volatile organic compounds (VOCs). This air quality analysis assesses the impacts of the No Action Alternative and action alternatives in relation to these criteria pollutants. It also assesses how the alternatives are projected to impact the emissions of certain hazardous air pollutants.

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 2011, emissions from on-road mobile sources declined 80 percent for CO, 70 percent for NO_x, 80 percent for PM_{10}, 88 percent for SO_2, and 83 percent for VOCs. Emissions of $PM_{2.5}$ from on-road mobile sources declined 75 percent from 1990, the earliest year for which data are available, to 2011 (EPA 2011b).

[1] "Criteria pollutants" is a term used to collectively describe the six common air pollutants for which the CAA requires EPA to set NAAQS. EPA calls these pollutants criteria air pollutants because it regulates them by developing human-health based or environmentally based criteria (science-based guidelines) for setting permissible levels. "Hazardous air pollutants" 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.

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 33,100,000 tons per year of CO (53 percent of total U.S. emissions), 80,600 tons per year (1.7 percent) of $PM_{2.5}$ emissions, and 94,500 tons per year (1.2 percent) of PM_{10} emissions (EPA 2009a). 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 2,940,000 tons per year (24 percent of total nationwide emissions) of VOCs and 3,760,000 tons per year (31 percent) of NO_x emissions, which are chemical precursors of ozone. In addition, NO_x is a $PM_{2.5}$ precursor and VOCs can be $PM_{2.5}$ precursors.[2] SO_2 and other oxides of sulfur (SO_x) are important because they contribute to the formation of $PM_{2.5}$ in the atmosphere; however, on-road mobile sources account for less than 0.39 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. Therefore, this analysis does not address lead.

Table 4.1.1-1 lists the primary and secondary NAAQS for each criteria pollutant. Under the CAA, EPA sets primary standards at levels intended to protect against adverse effects on human health; secondary standards are intended to protect against adverse effects on public welfare, such as damage to agricultural crops or vegetation and damage to buildings or other property. Because each criteria pollutant has different potential effects on human health and public welfare, the NAAQS specify different permissible levels for each pollutant. NAAQS for some pollutants include standards for short- and long-term average levels. Short-term standards 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.

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 in 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 in a geographic region are less than those permitted by NAAQS, EPA designates the region as an "attainment" area for that pollutant; regions where concentrations of criteria pollutants exceed federal standards are called "nonattainment" areas. Former nonattainment areas that are now in compliance with NAAQS are designated as "maintenance" areas. Each state with a nonattainment area is required to develop and implement a State Implementation Plan (SIP) documenting how the region will reach attainment levels within periods specified in the CAA. For maintenance areas, the SIP must document how the state intends to maintain compliance with NAAQS. When EPA changes a NAAQS, each state must revise its SIP to address how it plans to attain the new standard.

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

Table 4.1.1-1. National Ambient Air Quality Standards[a]

Pollutant	Primary Standards		Secondary Standards	
	Level[b]	Averaging Time	Level[b]	Averaging Time
Carbon monoxide	9 ppm (10 mg/m^3)	8 hours[c]	None	
	35 ppm (40 mg/m^3)	1 hour[c]		
Lead	0.15 $\mu g/m^3$	Rolling 3-month average	Same as Primary	
Nitrogen dioxide	0.053 ppm (100 $\mu g/m^3$)	Annual (arithmetic mean)	Same as Primary	
	0.100 ppm (200 $\mu g/m^3$)	1 hour[d]	None	
Particulate matter (PM_{10})	150 $\mu g/m^3$	24 hours[e]	Same as Primary	
Particulate matter ($PM_{2.5}$)	15.0 $\mu g/m^3$	Annual (arithmetic mean)[f]	Same as Primary	
	35 $\mu g/m^3$	24 hours[g]	Same as Primary	
Ozone	0.075 ppm	8 hours[h]	Same as Primary	
Sulfur dioxide	0.075 ppm (200 $\mu g/m^3$)	1 hour[i]	0.5 ppm (1,300 $\mu g/m^3$)	3 hours[c]

a. Source: 40 CFR Part 50, as presented in EPA 2011c.
b. Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter ($\mu g/m^3$) of air.
c. Not to be exceeded more than once per year.
d. To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average at each monitor within an area must not exceed 0.100 ppm (effective January 22, 2010).
e. Not to be exceeded more than once per year on average over 3 years.
f. To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 $\mu g/m^3$.
g. To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$ (effective December 17, 2006).
h. To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor in an area over each year must not exceed 0.075 ppm (effective May 27, 2008).
i. 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.

NAAQS have not been established for hazardous air pollutants. Hazardous air pollutants 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).[3] 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 2007a, FHWA 2009). DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the $PM_{2.5}$ particle-size class. On-road mobile sources (highway vehicles) are responsible for 47,340,000 tons per year (38 percent of total U.S. emissions) of acetaldehyde emissions, 4,209,000 tons per year (15 percent) of acrolein emissions, 232,557,000 tons per year (53 percent) of benzene emissions, 26,715,000 tons per

[3] A list of all MSATs identified by EPA to date can be found in the *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 (EPA 2007a).

year (52 percent) of 1,3-butadiene emissions, and 84,957,000 tons per year (34 percent) of formaldehyde emissions (EPA 2009b).[4]

Concentrations of traffic-generated air pollutants can be elevated for up to 300 to 500 meters (980 to 1,640 feet) downwind of roads with high traffic volumes (Zhou and Levy 2007). Concentrations of traffic-generated air pollutants can be elevated for as much as 2,600 meters (8,500 feet) downwind of roads under meteorological conditions that tend to inhibit the dispersion of emissions (Hu et al. 2009b, 2012). Vehicle-related sources that contribute to these elevated roadside concentrations include exhaust emissions, evaporative emissions, resuspension of road dust, and tire and brake wear. Air pollution near major roads has been shown to increase the risk of adverse health effects in populations who live, work, or attend school near major roads. Because a large percentage of the U.S. population lives in near major roads (17 percent of all homes are within 300 feet of a highway with 4 or more lanes, a railroad, or an airport [HUD 2009]), it is important to understand how traffic-generated pollutants collectively affect the health of exposed populations. Reviews of the health literature have concluded that current evidence is suggestive of causal association between traffic exposure and new-onset asthma and cardiovascular conditions. Reviews also have concluded that current evidence supports a causal association for exacerbation of symptoms (HEI 2010, Salam et al. 2008) and cardiovascular conditions (HEI 2010, Adar and Kaufman 2007). Several studies have found associations between traffic exposure and adverse birth outcomes (HEI 2010) and childhood cancer (HEI 2010, Raaschou-Nielsen and Reynolds 2006); however, this evidence is based on a limited number of studies with limited consistency across studies. There is also an insufficient number of well-designed studies to address associations for other health conditions. Sections 4.1.1.1 and 4.1.1.2 discuss specific health effects associated with each of the criteria and hazardous air pollutants analyzed in this EIS.

Section 5.4 addresses the major GHGs – CO_2, methane (CH_4), and N_2O; this air quality analysis does not include these GHGs.

4.1.1.1 Health Effects of Criteria Pollutants

Sections 4.1.1.1.1 through 4.1.1.1.6 briefly describe the health effects of the six criteria pollutants. This information is adapted from the EPA Green Book, Criteria Pollutants (EPA 2011d). The most recent EPA technical reports and *Federal Register* notices for NAAQS reviews provide more information on the health effects of criteria pollutants (EPA 2011f).

4.1.1.1.1 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.

[4] Nationwide total emissions data are not available for DPM.

In addition to its human health impacts, ozone has the potential to affect the health of vegetation and ecosystems. Ozone in the atmosphere is absorbed by plants and disturbs the plant's carbon sequestration process, thereby limiting its available energy supply. Consequently, exposed plants can lose their vigor, become more susceptible to disease and other environmental stressors, and demonstrate lessened growth, visual abnormalities, or accelerated aging. According to EPA (2006c), ozone affects crops, vegetation, and ecosystems more than any other air pollutant. Ozone can produce both acute and chronic injury in sensitive species, depending on the concentration level, the duration of the exposure, and the plant species under exposure. Because of the differing sensitivities among plants to ozone, ozone pollution can also exert a selective pressure that leads to changes in plant community composition. Given the range of plant sensitivities and the fact that numerous other environmental factors modify plant uptake and response to ozone, it is not possible to identify threshold values above which ozone is consistently toxic for all plants.

VOCs, a chemical precursor to ozone, also can play a role in vegetation damage (Foster 1991). For some sensitive plants under exposure, VOCs have been demonstrated to impact seed production, photosynthetic efficiency, leaf water content, seed germination, flowering, and fruit ripening (Cape et al. 2003). NO_x, the other chemical precursor to ozone, has also been demonstrated to have impacts on vegetation health (Viskari 2000, Ugrekhelidze et al. 1997, Kammerbauer et al. 1987). Most of the studies of the impacts of VOCs and NO_x on vegetation have focused on short-term exposure; and few studies have focused on long-term effects on vegetation and the potential for metabolites of these compounds to affect herbivores or insects.

4.1.1.1.2 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 (also called black carbon). 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.

PM also can contribute to poor visibility by scattering and absorbing light, consequently making the terrain appear hazy. To address visibility concerns, EPA developed the regional haze program,[5] which was put in place in July 1999 to protect the visibility in Mandatory Class I Federal Areas (national parks and wilderness areas). EPA has also set secondary NAAQS to regulate non-Class I areas outside the regional haze program. Deposition of PM (especially secondary PM formed from NO_x and SO_x) can damage materials, adding to the effects of natural weathering processes by potentially promoting or accelerating the corrosion of metals, degrading paints, and deteriorating building materials (especially concrete and limestone). Section 7.3 provides more information about materials damage and soiling impacts.

As noted above, EPA regulates PM according to two particle-size classifications, PM_{10} and $PM_{2.5}$. This analysis considers only $PM_{2.5}$ because almost all of the PM emitted in exhaust from passenger cars and

[5] Final Rule: Regional Haze Regulations, 64 FR 35714 (July 1, 1999).

light trucks is $PM_{2.5}$. EPA classifies DPM as a mobile source air toxic, so it is addressed in the air toxics section (*see* Section 4.1.1.2.5).

4.1.1.1.3 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.[6] 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 adverse health effects at birth, such as decreased birth weight.

4.1.1.1.4 Lead

Lead is a toxic heavy metal used in industrial manufacturing and production, 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 cause central nervous system damage. Because of the prohibition of lead as an additive in motor vehicle liquid fuels, lead is no longer emitted from motor vehicles in more than negligible quantities. Therefore, this analysis does not address lead.

4.1.1.1.5 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 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 (constriction of the airways). Asthmatics are more sensitive to the effects of SO_2, likely because of preexisting bronchial inflammation. 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.

4.1.1.1.6 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, 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

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

respiratory infections. NO_2 has also been linked to other health endpoints, including all-cause (non-accidental) 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 ozone and acid rain, and can affect terrestrial and aquatic ecosystems.

4.1.1.2 Health Effects of Mobile Source Air Toxics

Sections 4.1.1.2.1 through 4.1.1.2.6 briefly describe the health effects of the six priority MSATs analyzed in this EIS. This information is adapted from the Preamble in Proposed Rule: Mandatory Reporting of Greenhouse Gases (EPA 2009g).

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 2005a). 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 and have significant inventory contributions from mobile sources (EPA 2005a). This EIS does not analyze POM separately, but POM can occur as a component of DPM and is addressed in Section 4.1.1.2.5. Naphthalene also is not analyzed separately in this EIS, but it is a member of the POM class of compounds discussed in Section 4.1.1.2.5.

4.1.1.2.1 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 1998). In its Twelfth Report on Carcinogens (NTP 2011), the U.S. Department of Health and Human Services (HHS) "reasonably anticipates" acetaldehyde to be a human carcinogen, and the International Agency for Research on Cancer (IARC) (IARC 1999) classifies acetaldehyde as possibly carcinogenic to humans (Group 2B). EPA is reassessing cancer risk from inhalation exposure to acetaldehyde and intends to end the draft development phase in late 2012; hold a period of agency, interagency, and external peer/public review; and by the end of the first quarter of 2014, finish the final agency review cycle.

The primary noncancer effects of exposure to acetaldehyde vapors include eye, skin, and respiratory-tract irritation (EPA 1998). 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 inhaling acetaldehyde (Myou et al. 1993). EPA is reassessing the health hazards from inhalation exposure to acetaldehyde on the same schedule as noted above for reassessing cancer risk.

4.1.1.2.2 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). The EPA 2003 IRIS human health risk assessment for acrolein (EPA 2003a) summarizes these data and additional studies regarding acute effects of human exposure to acrolein. Evidence available from studies in humans indicate that levels as low as 0.09 ppm (0.21 milligram per cubic meter) 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). 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). 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 compared 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 and asthma) are expected to be at increased risk of developing adverse responses to strong respiratory irritants such as acrolein.

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

4.1.1.2.3 Benzene

EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia) by all routes of exposure, and concludes that exposure is associated with additional health effects, including genetic changes in both humans and animals and increased proliferation of bone marrow cells in mice (EPA 2000a, IARC 1982, Irons et al. 1992). 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 and HHS have characterized benzene as a human carcinogen (IARC 1987, NTP 2011).

Several adverse noncancer health effects, including blood disorders such as pre-leukemia 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 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.

4.1.1.2.4 1,3-butadiene

EPA has characterized 1,3-butadiene as carcinogenic to humans through inhalation (EPA 2002b, 2002c). IARC has determined that 1,3-butadiene is a probable human carcinogen, and HHS has characterized 1,3-butadiene as a known human carcinogen (IARC 1999, NTP 2011). Numerous experiments have demonstrated that animals and humans metabolize 1,3-butadiene into compounds that are genotoxic (capable of causing damage to a cell's genetic material such as DNA [deoxyribonucleic acid]). The specific mechanisms of 1,3-butadiene-induced carcinogenesis are not known; however, scientific evidence strongly suggests that the carcinogenic effects are mediated by genotoxic metabolites. Animal data suggest that females could be more sensitive than males for cancer effects associated with 1,3-butadiene exposure; there are insufficient data on humans from which to draw conclusions about sensitive subpopulations. 1,3-butadiene also causes a variety of reproductive and developmental effects in mice; there are no available human data on these effects. The most sensitive effect was ovarian atrophy observed in a lifetime bioassay of female mice (Bevan et al. 1996).

4.1.1.2.5 Diesel Particulate Matter (DPM)

DPM is a component 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 with condensed organic compounds such as POM, which include mutagens and carcinogens. DPM also includes elemental carbon (also called black carbon) particles emitted from diesel engines. 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 or 212 degrees Fahrenheit. 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. Cancer is the major concern from exposure to POM. Epidemiologic studies have reported an increase in lung cancer in humans exposed to diesel exhaust, coke-oven emissions, roofing tar emissions, and cigarette smoke; all of these mixtures contain POM compounds (ATSDR 1995, EPA 2002d). Animal studies have reported respiratory-tract tumors from inhalation exposure to benzo[a]pyrene, and alimentary tract and liver tumors from oral exposure to benzo[a]pyrene (IARC 2012). In 1997, EPA classified seven PAHs (benzo[a]pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) as Group B2, probable human carcinogens (EPA 1997b). Since then, 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 in preschool children (3 years of age) (Perera et al. 2003, 2006). EPA is evaluating these and similar studies as a part of the ongoing IRIS assessment of health effects associated with exposure to benzo[a]pyrene.

4.1.1.2.6 Formaldehyde

In 1991, EPA concluded that formaldehyde is a carcinogen based on nasal tumors in animal bioassays (EPA 1989). EPA developed an Inhalation Unit Risk for cancer and a Reference Dose for oral non-cancer effects and posted them in the IRIS database. Since that time, the National Toxicology Program and International Agency for Research on Cancer have concluded that formaldehyde is a known human carcinogen (NTP 2011, IARC 2006, and IARC 2012).

The conclusions by the Agency for Research on Cancer and the National Toxicology Program reflect the results of epidemiologic research published since 1991, in combination with previous animal, human, and mechanistic evidence. Research by the National Cancer Institute reported an increased risk of nasopharyngeal (nose and throat) cancer and specific lymphohematopoietic (lymph and blood) malignancies among workers exposed to formaldehyde (Hauptmann et al. 2003, 2004, and Beane Freeman et al. 2009). A National Institute of Occupational Safety and Health study of garment workers also reported increased risk of death due to leukemia among workers exposed to formaldehyde

(Pinkerton et al. 2004). Extended follow-up of a cohort of British chemical workers did not report evidence of an increase in nasopharyngeal or lymphohematopoietic cancers, but a continuing statistically significant excess in lung cancers was reported (Coggon et al. 2003). Finally, a study of embalmers reported formaldehyde exposures to be associated with an increased risk of myeloid (bone marrow cell) leukemia, but not brain cancer (Hauptmann et al. 2009).

Health effects of formaldehyde in addition to cancer were reviewed by the Agency for Toxics Substances and Disease Registry in 1999 (ATSDR 1999) and supplemented in 2010 (ATSDR 2010), and by the World Health Organization (IPCS 2010). These organizations reviewed the literature concerning effects on the eyes and respiratory system, the primary point of contact for inhaled formaldehyde, including sensory irritation of eyes, and respiratory tract, pulmonary function, nasal histopathology, and immune system effects. In addition, research on reproductive and developmental effects and neurological effects were discussed. EPA released a draft Toxicological Review of Formaldehyde – Inhalation Assessment through the IRIS program for peer review by the National Research Council (NRC) and public comment in June 2010 (EPA 2010f). The draft assessment reviewed more recent research from animal and human studies on cancer and other health effects. The NRC released their review report in April 2011 (NRC 2011b). The EPA is currently revising the draft assessment in response to this review.

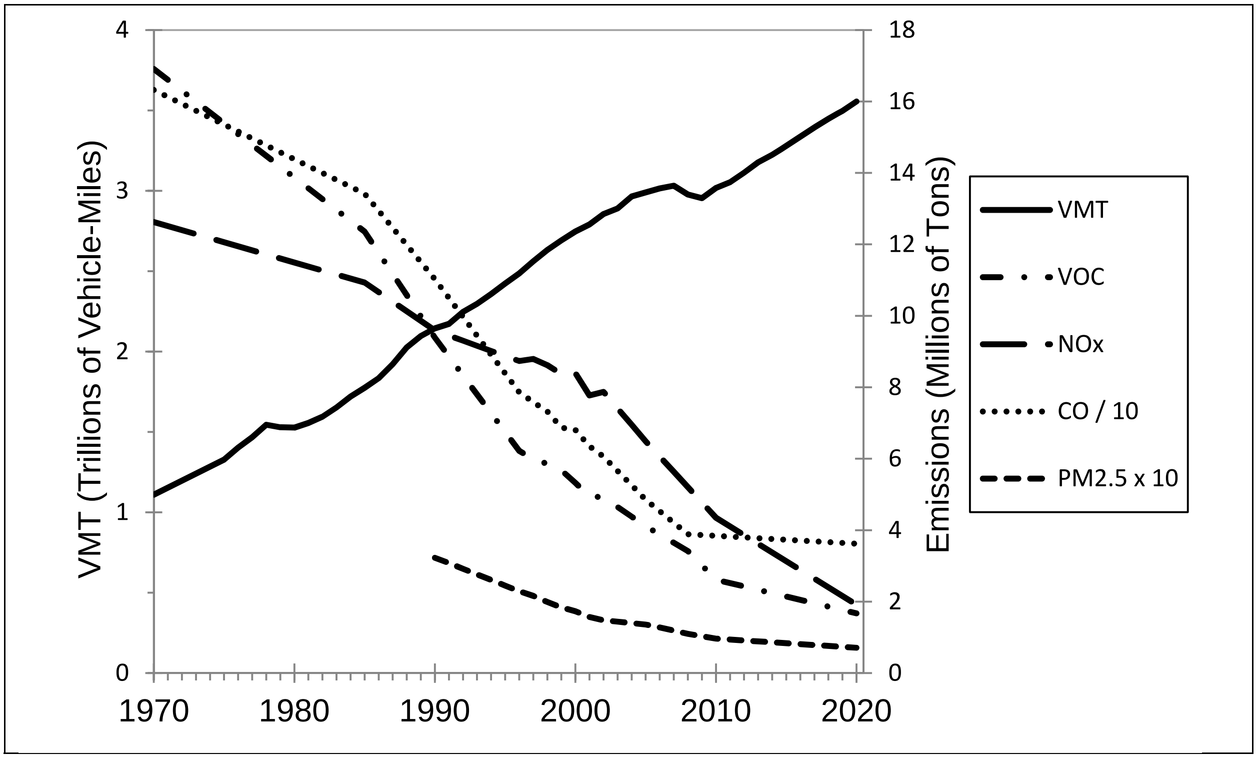
4.1.1.3 Vehicle Emissions Standards and Conformity Regulations

4.1.1.3.1 Vehicle Emission Standards

EPA has established criteria pollutant emission standards for vehicles under the CAA. EPA has tightened these emission standards over time as more effective emission-control technologies have become available. These stricter 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 in Section 4.1.1. The EPA Tier 2 Vehicle & Gasoline Sulfur Program, which went into effect in 2004, established the CAA emissions standards that will apply to MY 2017–2025 passenger cars and light trucks (EPA 2000b). Under the Tier 2 standards, manufacturers of passenger cars and light trucks are required to meet stricter vehicle emissions limits than under the previous Tier 1 standards. Other emissions regulations, such as potential Tier 3 standards, might apply in the future. By 2006, U.S. refiners and importers of gasoline were required to manufacture gasoline with an average sulfur level of 30 ppm, a 90 percent reduction from earlier sulfur levels. These fuels enable post-2006 model year vehicles to use emission control technologies that reduce tailpipe emissions of NO_x by 77 percent for passenger cars and by as much as 95 percent for pickup trucks, vans, and sport utility vehicles compared to 2003 levels. Figure 4.1.1-1 illustrates current trends in travel and emissions from highway vehicles, not accounting for the effects of the alternatives; *see* Section 4.2.

Since 1970, aggregate emissions traditionally associated with vehicles have decreased substantially even as vehicle miles traveled (VMT) increased by approximately 149 percent from 1970 to 1999, and approximately 220 percent from 1970 to 2010, as shown in Figure 4.1.1-1. For example, NO_x emissions, due mainly to light trucks and heavy-duty vehicles, decreased by 70 percent between 1970 and 2011, as shown in Figure 4.1.1-1. However, as future trends show, 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.

Figure 4.1.1-1. Vehicle Miles Traveled Compared to Vehicle Emissions[a,b,c]



a. Sources: Davis et al. 2011, EPA 2011b, EIA 2011a, IEC 2011.

b. VMT = vehicle miles traveled; VOCs = volatile organic compounds; NO_x = nitrogen oxides; CO = carbon monoxide; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

c. Because CO emissions are generally about 10 times higher than emissions of NO_x, SO_x, and VOCs, and emissions of $PM_{2.5}$ are about 10 times lower than emissions of NO_x, SO_x, and VOCs, the scales for CO and $PM_{2.5}$ are proportionally adjusted to enable comparison of trends among pollutants.

MSAT emissions will likely decrease in the future because of new EPA rules (EPA 2007a). These rules limit the benzene content of gasoline beginning in 2011. They also limit exhaust emissions of hydrocarbons (many VOCs and MSATs are hydrocarbons) from passenger cars and light trucks when they are operated at cold temperatures. The cold-temperature standard is being phased in from 2010 through 2015. EPA projects that these controls will substantially reduce emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde.

4.1.1.3.2 Conformity Regulations

CAA Section 176(c) 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 FHWA or the Federal Transit Administration (FTA) usually are subject to transportation conformity (*see* 40 CFR § 93.102).

- The General Conformity Rule (40 CFR Part 93, Subpart B) applies 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 emission 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, consultations 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 economy standards and associated program activities are not funded or approved under U.S.C. Title 23 or the Federal Transit Act. Further, the proposed standards are not a highway or transit project funded or approved by the FHWA or the FTA. Accordingly, the proposed 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 at 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 would only set fuel economy standards for passenger cars and light trucks, it causes no direct emissions within the meaning of the General Conformity Rule.

Indirect emissions under the General Conformity Rule include emissions or precursors that "(1) Are caused by the Federal action, but may occur later in time and/or may be further removed in distance from the action itself but are still reasonably foreseeable; and (2) The Federal agency can practicably control and will maintain control over due to a continuing program responsibility of the Federal agency." 40 CFR § 93.152. Each element of the definition must be met to qualify as an indirect emission. NHTSA has determined that, for purposes of general conformity, emissions as a result of the fuel economy standards would not be caused by NHTSA's action, but rather occur due to subsequent activities 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."[7] 40 CFR § 93.152.

NHTSA cannot control vehicle manufacturers' production of passenger cars and light trucks, or consumer purchasing and driving behavior. For purposes of analyzing the environmental impacts of the Proposed Action under NEPA, NHTSA has made assumptions regarding the technologies manufacturers will install and how companies will react to increased fuel economy standards. Specifically, NHTSA's NEPA analysis predicts that increases in air toxic and criteria pollutants would occur in some nonattainment areas under certain alternatives based on the rebound effect. However, NHTSA's Proposed Action does not mandate specific manufacturer decisions or driver behavior. 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

[7] Final Rule: Revisions to the General Conformity Regulations, 75 FR 17254 (Apr. 5, 2010).

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 VMT by drivers. Accordingly, changes in any emissions that result from NHTSA's proposed standards are not changes the agency can practicably control; therefore, the Proposed Action would cause no indirect emissions, and a general conformity determination is not required.

4.1.2 Methodology

4.1.2.1 Overview

To analyze air quality and human health impacts, NHTSA calculated the emissions of criteria pollutants and MSATs from passenger cars and light trucks 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. The resulting changes in air quality and effects on human health were assumed to be proportional to the changes in emissions 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 2.4.1. In summary, the change in emissions resulting from each alternative is the sum of: (1) changes in upstream emissions, which usually are reductions due to the decline in fuel consumption and therefore 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-economy rebound effect.

As discussed in Chapter 2, the air quality results presented in this chapter, including impacts to human health, are based on a number of assumptions about the type and rate of emissions from the combustion of fossil fuels. In addition to tailpipe emissions, this analysis accounts for upstream emissions from the production and distribution of fuels, including contributions from the power plants that generate the electricity used to recharge electric vehicles (EVs) and from the production of the fuel burned in those power plants. Emissions and other environmental impacts from electricity production depend on the efficiency of the power plant and the mix of fuel sources used, sometimes referred to as the "grid mix." In the United States, the current grid mix is composed of coal, nuclear, natural gas, hydroelectric, oil, and renewable energy sources, with the largest single source of electricity being from coal.

Due to modeling limitations, the analysis presented throughout this EIS assumes that the future EV fleet would charge from a grid whose mix is similar to today's grid mix and uniform across the country. To estimate upstream emissions, the analysis uses the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (1 2011 version developed by the U.S. Department of Energy [DOE] Argonne National Laboratory), which contains data on emissions intensities (amount of pollutant emitted per unit of electrical energy generated) that extend only to 2020. To project the U.S. average electricity generating fuel mix for the reference year 2020, the analysis uses the National Energy Modeling System (NEMS) AEO 2012 Early Release version, an energy-economy modeling system from the Department of Energy.

These modeling tools, which are among the best available, necessarily have limitations when used to predict the state of the electrical grid in the distant future. The assumptions result in a temporally static and geographically homogeneous grid that overstates air quality impacts under alternatives that predict a high level of EV deployment. It is more reasonable to assume steady improvements to the grid during the course of the next several decades – the period during which any EV deployment associated with this program would occur – and, if the current early trends continue, a higher concentration of EVs in areas served by cleaner electrical grids. For this reason, NHTSA reviewed several projections by the EIA, the Federal Government's expert source for forecasting energy use, which show a cleaner grid in future years based on a variety of assumptions and possible scenarios. NHTSA then conducted an additional analysis to illustrate the effects of a cleaner future grid on air quality, described below.

Across the alternatives analyzed in this EIS, most EV sales are projected to occur near the end of the 2017–2025 timeframe. The EVs sold in the later years would not accrue 50 percent of their mileage until 7 to 10 years after sale. Therefore, NHTSA looked to EIA projections of the future state of the electrical grid, selecting an EIA "side case" projection in 2035 for analytical purposes. AEO 2011 examined a broad range of economic, technology, and other side cases. (Side-case analyses were not available for the AEO 2012 Early Release.) These cases account for regulations that could be in effect during the period covered by the Proposed Action. The results of all eight emissions side cases indicate that the future makeup of the grid mix is likely to produce lower upstream emissions per unit of electricity used to charge EVs than the EIA 2020 projection, especially in terms of reductions in criteria pollutant emissions. The agency performed an additional analysis using one of the scenarios for a cleaner future grid drawn from AEO 2011 (retaining 2020 GREET emissions intensities).[8] This scenario assumes high levels of natural gas and renewables for electricity generation, with generation from coal-fired power plants reduced to 21 percent from the projected contribution of 40 percent used in EIA's 2020 reference case. Both modeling runs were performed using the same methodology and generated the inputs to allow modeling of air quality impacts and their resulting direct and indirect health outcomes and monetized health effects. The results of the health outcomes and monetized health effects for this alternate analysis are reported alongside the base analysis results in Tables 4.2.1-7-A1 through B2, 4.2.1-8-A1 through -B2, 4.2.2-7-C1 and -C2, and 4.2.2-8-C1 and -C2, identified in the tables as the "Base Grid Mix" and the "Alternate Grid Mix." Additional detail is provided in Appendix H.

4.1.2.2 Regional Analysis

Over the course of the CAFE program, NHTSA has received comments requesting that the agency consider the sub-national air quality impacts of its CAFE program. NHTSA has included the following information about regional air quality impacts of the Proposed Action in response to such comments and because the agency believes that such an analysis provides valuable information for the decisionmaker and the public. Performing this analysis does not affect the agency's conclusion that a general conformity determination is not required. While a truly local analysis (i.e., at the individual roadway level) is impractical for a nationwide EIS, NHTSA believes a regional emissions analysis still provides valuable information and is feasible for the scope of this EIS.

To assess regional differences in the effects of the alternatives, NHTSA estimated net emission changes for individual nonattainment and maintenance areas.[9] The distribution of emissions is not uniform

[8] NHTSA analyzed the "GHG Price, Economy-wide" case from AEO 2011, which assumes future carbon trading. The Base Grid Mix case analyzed throughout this document does not include the impacts of EPA's recent Mercury and Air Toxics Standards for power plants, which are expected to significantly reduce emissions of some of the pollutants discussed in this section and are a significant step toward the levels assumed in the Alternate Grid Mix case. The just released AEO 2012 Reference Case accounts for those standards and shows significant reductions in emissions of some criteria pollutants compared to the Base Grid Mix, a showing that is consistent with NHTSA's decision to use the "GHG Price, Economy-wide" case for the Alternate Grid Mix analysis.

[9] In Section 4.1.2.2, where the term nonattainment is used, it includes both nonattainment areas and maintenance areas.

nationwide, and either increases or decreases in emissions can occur within individual nonattainment or 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 passenger cars and light trucks are of greatest concern. At present, there are no NO_2 nonattainment areas, and only one area is designated as being in 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 passenger cars and light trucks is $PM_{2.5}$.[10] Appendix B provides emission estimates for all nonattainment areas for all criteria pollutants (except lead, as explained in Section 4.1.1.1.4). On-road motor vehicles are a minor contributor to SO_2 emissions (less than 0.39 percent of national emissions, as noted above) and are unlikely to affect the attainment status of SO_2 nonattainment and maintenance areas.

NHTSA's emissions 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 passenger cars and light trucks operating on entire regional roadway networks, so that any emission increases due to the VMT rebound effect would be distributed throughout a region's entire road network, and at any specific location would be uniformly proportional to VMT increases at that location. 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 Action 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.

4.1.2.3 Timeframes 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.[11] This air quality analysis considers emissions that would occur over annual periods, consistent with the NAAQS.

To evaluate impacts to air quality, specific years must be selected for which emissions will be estimated and their effects on air quality calculated. NHTSA selected calendar years that are meaningful for the timing of likely effects of the alternatives, as follows:

- 2021 – First year of complete implementation of the MY 2017–2021 fuel economy standards.
- 2025 – Last year of the Proposed Action.
- 2040 – A mid-term forecast year; by this point a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet standards as set forth under the Proposed Action.

[10] In addition to exhaust $PM_{2.5}$, the analysis included the brake wear and tire wear components of $PM_{2.5}$.
[11] 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.

- 2060 – By 2060, almost all passenger cars and light trucks in operation would meet standards as set forth under the Proposed Action, and the impact of these standards would be determined primarily by VMT growth rather than by MY 2017–2025 vehicles replacing older, less fuel-efficient vehicles.

4.1.2.4 Incomplete or Unavailable Information

Where information in the analysis included in this EIS is incomplete or unavailable, NHTSA relies on CEQ regulations regarding incomplete or unavailable information (*see* 40 CFR § 1502.22(b)). 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 about vehicle technology and design, the mix of vehicle types and model years comprising the passenger car and light-truck fleet, VMT projections, emissions from fuel refining and distribution, and economic factors.

To support the information in this EIS, 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. Nonetheless, NHTSA notes that there are limitations to current modeling capabilities. For example, uncertainties can derive from model formulation (including numerical approximations and the definition of physical and chemical processes) and inaccuracies in the input data (e.g., emission inventory estimates).

As described in Section 4.1.2.1, forecasting future upstream emissions related to the use of electricity to power EVs is challenging. There are substantial uncertainties associated with that analysis and limitations in the existing models. For this reason, NHTSA performed an additional analysis using one of the scenarios for a cleaner future grid drawn from AEO 2011. The results of the health outcomes and monetized health effects for this alternate analysis are reported alongside the results of the base analysis for comparison in Tables 4.2.1-7-A1 through -B2, 4.2.1-8-A1 through -B2, 4.2.2-7-C1 and -C2, and 4.2.2-8-C1 and -C2.

Additional limitations are associated with the estimates of health benefits. 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. However, the use of such dollars-per-ton numbers does not account for all potential health and environmental benefits because the information necessary to monetize all potential health and environmental benefits is not available. Therefore, NHTSA has likely underestimated the total benefits of reducing criteria pollutants. Reductions in emissions of toxic air pollutants should also result in health benefits, but scientific data that would support quantification and monetization of these benefits are not available.

4.1.2.5 Allocation of Exhaust Emissions to Nonattainment Areas

For each alternative, the Volpe model 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 passenger car and light-truck VMT data for all counties in the United States for 2014, 2020, 2030, and 2050, consistent with EPA's National Emissions Inventory (NEI).[12] These VMT projections were based on growth in specific factors affecting passenger car and light-truck use projected for individual counties (EIA 2006). VMT data used in the NEI were

[12] The VMT data provided by EPA are based on data generated by the Federal Highway Administration.

estimated from traffic counts taken by counties and states on major roadways, and therefore are subject to some uncertainty. NHTSA derived VMT for the air quality analysis years 2021, 2025, 2040, and 2060 by interpolation of the EPA data. 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 Volpe model.

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 county-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’s 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 2040 and 2060 compared to analysis years 2021 and 2025.

The geographic definitions of ozone and $PM_{2.5}$ nonattainment areas NHTSA uses in this document came from the current EPA Green Book Nonattainment Areas for Criteria Pollutants (EPA 2011d). 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 in 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 technique for allocating VMT to partial counties involves some additional uncertainty 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 4.1.2-1 lists the current nonattainment and maintenance areas for ozone and $PM_{2.5}$ and their status/classification and general conformity threshold.

Table 4.1.2-1. Nonattainment Areas for Ozone and $PM_{2.5}$[a]

Nonattainment/Maintenance Area	Pollutant	Status[b]	General Conformity Threshold[c]
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
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
Detroit-Ann Arbor, MI	$PM_{2.5}$	Nonattainment	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

Table 4.1.2-1. Nonattainment Areas for Ozone and $PM_{2.5}$[a] (continued)

Nonattainment/Maintenance Area	Pollutant	Status[b]	General Conformity Threshold[c]
Detroit-Ann Arbor, MI	Ozone	Maintenance	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
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
Knoxville, TN	Ozone	Former Subpart 1	50
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

Table 4.1.2-1. Nonattainment Areas for Ozone and $PM_{2.5}$[a] (continued)

Nonattainment/Maintenance Area	Pollutant	Status[b]	General Conformity Threshold[c]
Knoxville, TN	Ozone	Former Subpart 1	50
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	$PM_{2.5}$	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
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-N. 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

Table 4.1.2-1. Nonattainment Areas for Ozone and $PM_{2.5}$[a] (continued)

Nonattainment/Maintenance Area	Pollutant	Status[b]	General Conformity Threshold[c]
Raleigh-Durham-Chapel Hill, NC	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
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
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

Table 4.1.2-1. Nonattainment Areas for Ozone and $PM_{2.5}$[a] (continued)

Nonattainment/Maintenance Area	Pollutant	Status[b]	General Conformity Threshold[c]
York, PA	Ozone	Maintenance	100
York, PA	$PM_{2.5}$	Nonattainment	100
Youngstown-Warren-Sharon, OH-PA	Ozone	Maintenance	100

a. Source: EPA 2011d. $PM_{2.5}$ = particulate matter with a nominal aerodynamic diameter equal to or less than 2.5 microns.
b. Pollutants for which the area is designated in nonattainment or maintenance as of 2010. For ozone nonattainment areas, the status given is the severity classification. "Former subpart 1" indicates an area that had been subject to nonattainment classification and implementation requirements under Title I, Part D, Subpart 1 of the Clean Air Act. Portions of Subpart 1 were struck down by court decision. As a result of that decision, former Subpart 1 areas are now subject to the classification and implementation requirements of Subpart 2.
c. Emissions thresholds in tons/year. In ozone NAAs the thresholds given are for the precursor pollutants VOC or NO_x; in $PM_{2.5}$ NAAs the thresholds represent primary $PM_{2.5}$. Source: 40 CFR 51.853. These thresholds are provided for information only; a general conformity determination is not required for the Proposed Action. N/A = conformity does not apply.

4.1.2.6 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, 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.[13] Emissions of pollutants at each stage are associated with expenditure of energy and with leakage or spillage and evaporation of fuel products.

Although not specifically required to do so by the CAA, NHTSA has allocated upstream emissions to individual nonattainment areas to provide additional information in its regional air quality analysis to the decisionmaker and the public, consistent with previous CAFE EISs. As noted below, NHTSA made a number of important assumptions for this analysis due to uncertainty over the accuracy of the allocation of upstream emissions. To analyze the impacts 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 9 are in nonattainment areas. These 9 fields account for just 10 percent of domestic production, or 3 percent of total crude-oil imports plus domestic production (EIA 2006, 2008). Therefore, because relatively little extraction occurs in nonattainment areas, NHTSA did not account for 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

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

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 account for emission changes from the first two upstream stages, the 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 modeling using GREET). NHTSA used projected emission data from the EPA 2005-based air quality modeling platform (EPA 2005b) to allocate reductions in nationwide total emissions from fuel refining to individual nonattainment areas. These EPA data were for 2022, the most representative year available in the EPA dataset. The EPA NEI includes estimates of emissions of criteria and toxic pollutants by county and by 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 fuel-refining emissions are assumed to change uniformly across all refineries nationwide as a result of each alternative.[14]
- TS&D – NHTSA used data from the EPA modeling platform (EPA 2005b) 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 2005b) 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 believed to behave most similarly to the pollutant in question, as follows:

- For acetaldehyde, the EPA data 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., 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). EPA's 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. Therefore, 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.

[14] Upstream emissions for EVs (i.e., emissions from power generation) were allocated geographically in the same way as refinery emissions. The actual distribution of upstream emissions for EVs is affected by geographical and temporal patterns of EV use, the mix of fuels used for power generation, the configurations of the regional electric grids serving each nonattainment area, and the forecast trends in all of these factors. As a result, the geographic distribution of upstream emissions from power generation is subject to a high level of uncertainty.

- 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 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 closest to the ratio for formaldehyde emissions.

4.1.2.7 Health Outcomes and Monetized Benefits

4.1.2.7.1 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 anticipated to result from the changes in pollutant emissions and related changes in human exposure to air pollutants under each alternative. NHTSA evaluated the changes to several health outcomes and the monetized benefits associated with avoided health outcomes. Table 4.1.2-2 lists the health outcomes NHTSA quantified and monetized. This methodology estimates the health impacts of each alternative for each analysis year, expressed as the number of additional or avoided adverse health outcomes per year.

Table 4.1.2-2. Human Health and Welfare Effects of $PM_{2.5}$[a]

Effects Quantified and Monetized	Effects Excluded from Quantification or Monetization
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	

a. Source: EPA 2009f.

Health and monetary outcomes are calculated from factors for each primary pollutant (NO_x, directly emitted $PM_{2.5}$, SO_2, and VOCs), expressed as adverse health outcomes avoided or monetized 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 that would be achieved under 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 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 $PM_{2.5}$). As discussed further in Section 4.1.2.7.2, reductions in NO_x and VOC emissions would also reduce ozone formation and the health effects associated with ozone exposure, but there are no benefit-per-ton estimates for NO_x and VOCs because of the complexity of the atmospheric air chemistry and nonlinearities associated with ozone formation. This analysis does not include any reductions in health impacts resulting from lower population exposure to other criteria air pollutants and air toxics because there are not enough data available to quantify these effects.

4.1.2.7.2 Monetized Health Impacts

The benefit-per-ton factors represent the total monetized human health benefits due to a suite of monetized PM-related health impacts for each ton of emissions reduced. The factors are specific to an individual pollutant and source. The $PM_{2.5}$ benefit-per-ton estimates apply to directly emitted $PM_{2.5}$ or its precursors (NO_x, SO_2, and VOCs). NHTSA followed the benefit-per-ton technique used in EPA's Ozone NAAQS Regulatory Impact Analysis (RIA) (EPA 2008a), Portland Cement National Emission Standards for Hazardous Air Pollutants RIA (EPA 2009c), and NO_2 NAAQS RIA (EPA 2009d). Table 4.1.2-2 lists the quantified $PM_{2.5}$-related benefits captured in those benefit-per-ton estimates, and potential $PM_{2.5}$-related benefits that were not quantified in this analysis.

The benefits estimates use the concentration-response functions[15] 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 EPA's Technical Support Document accompanying the final ozone NAAQS RIA (EPA 2008a). Readers can also consult Fann et al. (2009) for a detailed description of the benefit-per-ton methodology.[16]

As described in the documentation cited above for the benefit-per-ton estimates, EPA developed national per-ton estimates for selected pollutants emitted through 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 upstream emissions, and the mobile per-ton estimates by total mobile emissions. NHTSA's 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.

PM-related mortality provides most of the monetized value in each benefit-per-ton estimate. EPA 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

[15] Concentration-response functions measure the relationship between exposure to pollution as a cause and specific outcomes as an effect (e.g., the incremental number of hospitalizations that would result from exposure of a population to a specified concentration of an air pollutant over a specified period).

[16] 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 its value of a statistical life (VSL) 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). (VSL refers to the aggregate estimated value of reducing small risks across a large number of people. It is based on how people themselves would value reducing these risks.) Since making these changes to its benefits methods, EPA revised its VSL to $7.8 million in 2009 dollars. NHTSA's analysis follows this EPA method, except that NHTSA uses DOT's estimate of the value of VSL as discussed in this section (DOT 2011).

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. (2002) and Laden et al. (2006) to be co-equal in terms of strengths and weaknesses and the quality of results. According to EPA, both studies should be used to generate benefits estimates. Throughout the discussion of mortality in this section, the mortality rates calculated from each of these studies are presented side by side.

For both studies, the benefits of mortality reductions do not occur in the year of analysis. Instead, EPA's methodology assumes that there is a cessation lag – that is, the benefits are distributed across 20 years following the year of exposure (the emissions analysis year). Because of this, the monetized value of the reduced mortality depends on the discount rate applied to future-year benefits from the cessation lag. To account for this factor, the monetized benefits of reduced mortality are presented using a 3 percent discount rate and 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 is approximately 10 percent smaller under the 7 percent discount rate than under the 3 percent discount rate.

The benefits-per-ton estimates used in this analysis are based on the above mortality health outcome factors, combined with data on the monetized value of each health outcome. These monetized values are expressed through several metrics; premature mortality is monetized using DOT's estimate of the value of statistical life (VSL) (DOT 2011). Morbidity impacts are measured either through willingness-to-pay (WTP) or cost-of-illness (COI) measures that account for either desire to avoid the health outcome or actual medical costs and wage lost associated with a specific case.

NHTSA adjusted EPA's benefit-per-ton values to change the value of VSL from the EPA VSL of $7.8 million in 2009 dollars to the DOT VSL of $6.2 million (in 2011 dollars).[17] Note that because the benefits-per-ton data combine mortality and morbidity benefits, the adjustment for DOT VSL is applied to both mortality and morbidity components of the data. Because VSL represents only mortality, this adjustment likely results in the analysis underestimating the total benefits per ton. However, because mortality accounts for most of total monetized health benefits, any underestimation is likely to be small. Table 4.1.2-3 lists the dollar-per-ton estimates used in this analysis.[18] Table 4.1.2-4 lists the valuation metrics for the mortality and morbidity endpoints.

[17] Departmental guidance on valuing reduction of fatalities was first published in 1993, and subsequently updated in 2008 on the basis of later research. Since then, DOT has updated this VSL to 2011 values in accordance with changes in prices and incomes over the past 2 years.

[18] The VSL derived by DOT and used for this EIS is $6.2 million in 2011 dollars. This value differs from the VSL adopted by EPA in the 2010 Update of the Guidelines for Preparing Economic Analyses (EPA 2010b) and estimated at $7.8 million in 2009 dollars. The discrepancy between these estimates is not unexpected, because no single dollar value has been accepted in the academic community or across the Federal Government.

Table 4.1.2-3. Benefit-per-ton Values (in 2011 dollars) Derived for PM-related Mortality and Morbidity, Adjusted to Reflect DOT's Value of Statistical Life[a]

Year[b]	All Sources[c]		Stationary Sources[d]		Mobile Sources	
	SO_2	VOCs	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
3-Percent Discount Rate						
Mortality (ages 30 and older) and Morbidity, Pope et al. (2002)						
2021	$26,000	$1,000	$4,300	$200,000	$4,500	$240,000
2025	$28,000	$1,100	$4,600	$210,000	$4,800	$260,000
2040	$35,000	$1,500	$6,000	$270,000	$6,300	$340,000
2060	$35,000	$1,500	$6,000	$270,000	$6,300	$340,000
Mortality (ages 30 and older) and Morbidity, Laden et al. (2006)						
2021	$63,000	$2,600	$11,000	$490,000	$11,000	$590,000
2025	$68,000	$2,800	$11,000	$520,000	$12,000	$640,000
2040	$86,000	$3,700	$15,000	$660,000	$15,000	$840,000
2060	$86,000	$3,700	$15,000	$660,000	$15,000	$840,000
7-Percent Discount Rate						
Mortality (ages 30 and older) and Morbidity, Pope et al. (2002)						
2021	$23,000	$970	$3,900	$180,000	$4,000	$230,000
2025	$25,000	$1,000	$4,200	$190,000	$4,400	$240,000
2040	$32,000	$1,400	$5,400	$250,000	$5,700	$310,000
2060	$32,000	$1,400	$5,400	$250,000	$5,700	$310,000
Mortality (ages 30 and older) and Morbidity, Laden et al. (2006)						
2021	$57,000	$2,400	$9,500	$440,000	$9,900	$550,000
2025	$61,000	$2,500	$10,000	$470,000	$11,000	$590,000
2040	$78,000	$3,300	$13,000	$600,000	$14,000	$760,000
2060	$78,000	$3,300	$13,000	$600,000	$14,000	$760,000

a. The benefits-per-ton estimates in this table are based on an EPA estimate of premature mortality under Pope et al. and Laden et al., and a suite of morbidity endpoints (*see* Table 4.1.2-2). NO_x = nitrogen oxides; SO_2 = sulfur dioxide; $PM_{2.5}$ = particulate matter with an aerodynamic diameter equal to or less than 2.5 microns; VOCs = volatile organic compounds.
b. Benefit-per-ton values were estimated for 2015, 2020, and 2030. For 2021 and 2025, values were interpolated exponentially between 2020 and 2030. For 2040, values were extrapolated exponentially based on the growth between 2020 and 2030. For 2060, values were held constant from 2040 values because of the high level of uncertainty in projections to 2060. All values have been rounded.
c. Note that the benefit-per-ton value for SO_2 is based on the value for stationary sources other than electric generating units; no SO_2 value was estimated for mobile sources. The benefit-per-ton value for VOCs was estimated across all sources.
d. Other than electric generating units (power plants).

Table 4.1.2-4 Valuation Metrics for Mortality and Morbidity Endpoints [a] (in 2009 dollars except as noted)

Health Outcome	Valuation Method[b]	Valuation [c]
Premature Mortality		
Premature Mortality	DOT Mean VSL	$6,200,000[d]
Chronic Illness		
Chronic Bronchitis	WTP: Average Severity	$424,193
Myocardial Infarctions, Nonfatal	Medical costs over 5 years; varies by age and discount rate.	--
Hospital Admissions		
Respiratory, Age 65+	COI: Medical Costs + Wage Lost	$26,433
Respiratory, Ages 0-2	COI: Medical Costs	$11,149
Chronic Lung Disease (less Asthma)	COI: Medical Costs + Wage Lost	$17,827
Pneumonia	COI: Medical Costs + Wage Lost	$21,161
Asthma	COI: Medical Costs + Wage Lost	$9,555
Cardiovascular	COI: Medical Costs + Wage Lost (20–64) COI: Medical Costs + Wage Lost (65–96)	$32,806 $30,520
Emergency Room Visits		
Asthma	COI: 2 Studies	$376–449
Other Health Endpoints		
Acute Bronchitis	WTP: 6 Day Illness, CV Studies	$444
Upper Respiratory Symptoms	WTP: 1 Day, CV Studies	$31
Lower Respiratory Symptoms	WTP: 1 Day, CV Studies	$20
Asthma Exacerbation	WTP: Bad Asthma Day	$54
Work Loss Days	Median Daily Wage, County-Specific	--
Minor Restricted Activity Days	WTP: 1 Day, CV Studies	$64
School Absence Days	Median Daily Wage, Women 25+	$93
Worker Productivity	Median Daily Wage, Outdoor Workers, County-Specific	--

a. Source: EPA 2011c.
b. VSL = value of statistical life. WTP = willingness to pay. COI = cost of illness, CV = contingent valuation.
c. Dollar amounts for each valuation method were extracted by EPA from BenMAP and adjusted to 2009 dollars (from 2000 dollars) using the Consumer Price Urban Index (CPI-U). For endpoints valued using measures of VSL, WTP, or endpoints that are wage-based, EPA used the CPI-U for "all items": 214.537 (2009) and 172.2 (2000). For endpoints valued using a COI measure, EPA used the CPI-U for "medical care": 375.613 (2009) and 260.8 (2000).
d. The DOT-derived VSL used for this EIS is $6.2 million in year 2011 dollars.

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

- The benefit-per-ton estimates used in this analysis incorporate projections of key variables, including atmospheric conditions, source level emissions, population, health baselines, and incomes. These projections introduce some uncertainties to the benefit-per-ton estimates.
- 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 ($PM_{2.5}$). 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 impacts on human health and welfare. This modeling provides insight into the uncertainties associated with the use of benefit-per-ton estimates. Appendix E provides the results of photochemical air quality modeling for the EIS.

- 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. However, there are no clear scientific grounds to support estimating differential effects by particle type.
- NHTSA assumed that the health impact (concentration-response) function for fine particles is linear within the range of ambient concentrations under consideration. Therefore, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including regions that are in attainment with the fine-particle standard and those that do not meet the standard, down to the lowest modeled concentrations.
- Other uncertainties associated with the health impact functions include the following: within-study variability (the precision with which a given study estimates the relationship between air quality changes and health effects); across-study variation (different published studies of the same pollutant/health effect relationship typically do not report identical findings, and in some cases the differences are substantial); the application of concentration-response functions nationwide (does not account for any relationship between region and health effect, to the extent that there is such a relationship); and extrapolation of impact functions across population (NHTSA assumed that certain health impact functions applied to age ranges broader than those considered in the original epidemiological study). These uncertainties could under- or overestimate benefits.
- 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 due to limitations on the availability of data to quantify these effects of pollutant emissions.

The RIA for the final $PM_{2.5}$ NAAQS (EPA2006b) provides more information about the overall uncertainty in the estimates of the benefits of reducing $PM_{2.5}$ emissions.

4.1.2.7.3 Quantified Health Impacts

Table 4.1.2-5 lists the incidence-per-ton estimates for select PM-related health impacts – mortality and four major morbidity outcomes (derived by the same process as described above for the dollar-per-ton estimates). For the analysis of direct and indirect impacts (*see* Section 4.2.1) and cumulative impacts (*see* Section 4.2.2), NHTSA used the values for 2021, 2025, 2040, and 2060 (*see* Section 4.1.2.3).

Table 4.1.2-5. Incidence-per-ton Values for Health Outcomes[a,b]

Outcome and Year[c]	All Sources[d]		Stationary Sources[e]		Mobile Sources	
	SO_2	VOCs	NO_x	Direct $PM_{2.5}$	NO_x	Direct $PM_{2.5}$
Premature mortality						
2021	0.0035104035	0.0001457593	0.0005801679	0.0270955066	0.0006061440	0.0331811737
2025	0.0037173345	0.0001552068	0.0006173945	0.0286153483	0.0006466903	0.0353498335
2040	0.0044933256	0.0001906348	0.0007569943	0.0343147546	0.0007987392	0.0434823075
2060	0.0044933256	0.0001906348	0.0007569943	0.0343147546	0.0007987392	0.0434823075
Premature mortality – Laden et al. (2006)						
2021	0.0089988138	0.0003740400	0.0014888337	0.0694727045	0.0015538608	0.0851037230
2025	0.0095217733	0.0003979224	0.0015828501	0.0733127312	0.0016561450	0.0905861087
2040	0.0114828715	0.0004874814	0.0019354115	0.0877128310	0.0020397108	0.1111450551
2060	0.0114828715	0.0004874814	0.0019354115	0.0877128310	0.0020397108	0.1111450551
Chronic bronchitis						
2021	0.0024055463	0.0001023039	0.0004217800	0.0183488438	0.0004408958	0.0235551886
2025	0.0025012984	0.0001065498	0.0004403295	0.0190431008	0.0004608627	0.0245785837
2040	0.0028603691	0.0001224718	0.0005098898	0.0216465645	0.0005357386	0.0284163154
2060	0.0028603691	0.0001224718	0.0005098898	0.0216465645	0.0005357386	0.0284163154
Emergency room visits – respiratory						
2021	0.0032604950	0.0001079846	0.0004739106	0.0267517217	0.0004639658	0.0269131875
2025	0.0033811644	0.0001117557	0.0004903325	0.0277109109	0.0004808543	0.0279197760
2040	0.0038336749	0.0001258975	0.0005519148	0.0313078705	0.0005441861	0.0316944828
2060	0.0038336749	0.0001258975	0.0005519148	0.0313078705	0.0005441861	0.0316944828
Work-loss days						
2021	0.4488013904	0.0191539328	0.0800821743	3.4328917338	0.0837563171	4.4231975782
2025	0.4578329216	0.0195173244	0.0818057725	3.4997171779	0.0856397276	4.5237084013
2040	0.4917011636	0.0208800429	0.0882692658	3.7503125933	0.0927025166	4.9006239880
2060	0.4917011636	0.0208800429	0.0882692658	3.7503125933	0.0927025166	4.9006239880

a. Source: Pope et al. 2002, except as noted.
b. NO_x = nitrogen oxides; SO_2 = sulfur dioxide; $PM_{2.5}$ = particulate matter with an aerodynamic diameter equal to or less than 2.5 microns; VOCs = volatile organic compounds.
c. Benefit-per-ton values were estimated for 2015, 2020, 2030, and 2040. For 2021 and 2025, values were interpolated exponentially between 2020 and 2030. For 2060, values were held constant from 2040 values.
d. Note that the benefit-per-ton value for SO_2 is based on the value for stationary sources other than electric generating units; no SO_2 value was estimated for mobile sources. The benefit-per-ton value for VOCs was estimated across all sources.
e. Other than electric generating units (power plants).

4.2 Environmental Consequences

4.2.1 Direct and Indirect Impacts

4.2.1.1 Results of the Analysis

As discussed in Section 4.1, 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. However, as future trends show, vehicle travel is having a decreasing impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternatives.

The analysis in this section shows that the action alternatives result in different levels of emissions from passenger cars and light trucks when measured against projected trends under the No Action Alternative. 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.

This section examines the direct and indirect impacts on air quality associated with the action alternatives in Analyses A1 and A2 and Analyses B1 and B2. Section 4.2.2 examines cumulative air quality impacts of the action alternatives in Analyses C1 and C2. Appendix A to this EIS provides results for passenger cars and light trucks separately. Using the assumptions listed in Section 2.3.2, this chapter presents Analyses A, B, and C to show a complete range of results.

As described in Chapter 2, in Analyses A1 and A2, the agency assumes that the average fleetwide fuel economy for light-duty vehicles would not exceed the minimum level necessary to comply with CAFE standards. Therefore, Analyses A1 and A2 measure the impacts of the action alternatives under which average fleetwide fuel economy in each model year does not exceed the level of the CAFE standards for that model year, compared to a No Action Alternative under which average fleetwide fuel economy after MY 2016 will never exceed the level of the agencies' MY 2016 standards established by final rule in April 2010. Tables and figures in this Final EIS that depict results for Analysis A1 (these have "A1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM Worldwide-based fleet projection. Tables and figures that depict results for Analysis A2 (these have "A2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC Automotive-based fleet projection.

In Analyses B1 and B2, the agency assumes continued improvements in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Therefore, Analyses B1 and B2 measure the impacts of the action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing improvements in new vehicle fuel economy after MY 2025, compared to a No Action Alternative that assumes the average fleetwide fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards, even in the absence of agency action. Tables and figures in this Final EIS that depict results for Analysis B1 (these have "B1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis B2 (these have "B2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.

In Analyses C1 and C2, the agency compares action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing fuel economy improvements after MY 2025 with a No Action Alternative under which there are no continued improvements in fuel economy after MY 2016 (i.e., the average fleetwide fuel economy for light-duty vehicles would not exceed the latest existing standard). In this way, the cumulative impacts analysis combines the No Action Alternative from Analyses A1 and A2 with the action alternatives from Analyses B1 and B2. Tables and figures in this Final EIS that depict results for Analysis C1 (these have "C1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis C2 (these have "C2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection. For more explanation of NHTSA's methodology regarding the cumulative impacts analysis, *see* Section 2.5.

The tables and figures in Section 4.2.1 and its subsections present the projected direct and indirect impacts of the action alternatives on air quality. Following the comparative overview in this section, Sections 4.2.1.2 through 4.2.1.5 describe the results of the analysis of emissions under Alternatives 1 through 4 in more detail.

4.2.1.1.1 Criteria Pollutants Overview

Tables 4.2.1-1-A1 and -A2 and 4.2.1-1-B1 and -B2 summarize the total upstream and downstream[19] national emissions from passenger cars and light trucks by alternative for each of the criteria pollutants and analysis years for Analyses A1 and A2 and Analyses B1 and B2, respectively. Figures 4.2.1-1-A1 and -A2 and 4.2.1-1-B1 and -B2 illustrate this information for 2040, the forecast year by which a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet standards as set forth under the Proposed Action.

Figures 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 summarize the changes over time in total national emissions of criteria pollutants from passenger cars and light trucks under the Preferred Alternative. These figures show a consistent trend among the criteria pollutants. Emissions of CO and $PM_{2.5}$ increase under the Preferred Alternative from 2021 to 2060 due to continuing growth in VMT (note that continued growth in VMT is projected to occur under all alternatives). Emissions of VOCs, SO_2, and NO_x decline from 2021 to 2025 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles and from reductions in upstream emissions from fuel production, which more than offset emissions increases due to growth in VMT. Emissions reach a minimum typically between 2025 and 2040, and increase from 2040 to 2060 due to continuing growth in VMT.

[19] Downstream emissions do not include evaporative emissions from vehicle fuel systems due to modeling limitations.

Table 4.2.1-1-A1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A1

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,972,643	14,990,780	14,997,481	14,977,598
2025	15,008,505	15,052,636	15,073,748	14,806,582
2040	18,045,534	18,216,981	18,247,119	16,386,643
2060	24,167,562	24,549,758	24,657,387	21,910,990
Nitrogen oxides (NO_x)				
2021	1,255,518	1,250,229	1,248,370	1,245,945
2025	1,071,605	1,060,400	1,055,063	1,068,009
2040	963,690	938,906	926,134	972,622
2060	1,278,260	1,250,789	1,236,354	1,306,561
Particulate matter ($PM_{2.5}$)				
2021	54,081	53,435	53,210	52,261
2025	57,224	55,803	55,099	53,183
2040	77,415	74,011	71,905	65,282
2060	104,073	99,900	97,181	87,209
Sulfur dioxide (SO_2)				
2021	141,793	138,213	136,598	134,205
2025	145,194	137,953	134,118	153,684
2040	176,325	159,862	156,981	265,128
2060	234,964	213,080	210,366	367,576
Volatile organic compounds (VOCs)				
2021	1,289,873	1,280,301	1,277,075	1,262,155
2025	1,137,616	1,116,356	1,105,911	1,070,235
2040	910,137	858,283	824,364	690,176
2060	1,184,742	1,118,849	1,073,475	876,212

Table 4.2.1-1-A2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,657,379	14,676,948	14,683,532	14,662,163
2025	14,620,666	14,669,255	14,689,325	14,473,816
2040	16,607,692	16,788,626	16,882,383	15,449,066
2060	20,788,696	21,143,841	21,341,441	19,363,533
Nitrogen oxides (NO_x)				
2021	1,238,977	1,233,645	1,231,613	1,230,067
2025	1,052,633	1,041,621	1,035,916	1,046,521
2040	891,753	869,220	856,853	895,945
2060	1,105,686	1,082,150	1,069,816	1,126,949
Particulate matter ($PM_{2.5}$)				
2021	52,563	51,929	51,682	50,873
2025	55,420	54,075	53,302	51,614
2040	71,183	68,192	66,094	60,293
2060	89,552	86,112	83,590	75,402
Sulfur dioxide (SO_2)				
2021	136,436	132,418	130,853	128,875
2025	138,792	130,487	125,762	139,593
2040	157,963	139,572	127,041	206,578
2060	197,281	174,131	158,054	267,203
Volatile organic compounds (VOCs)				
2021	1,273,510	1,264,282	1,260,729	1,247,976
2025	1,118,000	1,098,346	1,087,091	1,056,603
2040	840,558	796,352	765,176	651,425
2060	1,020,744	968,170	929,646	772,192

Table 4.2.1-1-B1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B1

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,991,422	15,002,175	15,008,611	14,976,431
2025	15,040,709	15,067,547	15,081,718	14,819,971
2040	18,218,258	18,282,305	18,226,596	16,582,923
2060	24,941,196	24,914,947	24,833,759	22,349,229
Nitrogen oxides (NO_x)				
2021	1,251,770	1,248,863	1,246,865	1,246,643
2025	1,065,694	1,059,229	1,054,276	1,069,606
2040	938,616	929,417	918,999	968,719
2060	1,217,717	1,217,919	1,209,402	1,281,722
Particulate matter ($PM_{2.5}$)				
2021	53,624	53,273	53,020	52,142
2025	56,501	55,677	54,958	53,117
2040	74,321	72,983	70,854	64,556
2060	96,040	95,883	93,667	84,244
Sulfur dioxide (SO_2)				
2021	138,796	136,781	135,274	134,719
2025	140,410	136,331	133,833	152,508
2040	155,057	150,053	156,945	244,467
2060	174,206	178,306	190,508	313,042
Volatile organic compounds (VOCs)				
2021	1,283,305	1,278,104	1,274,379	1,259,736
2025	1,127,179	1,114,801	1,103,745	1,068,814
2040	864,839	844,123	807,107	685,662
2060	1,063,866	1,059,953	1,019,822	848,129

Table 4.2.1-1-B2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,671,611	14,682,880	14,684,965	14,661,610
2025	14,647,878	14,677,118	14,688,365	14,478,066
2040	16,767,345	16,845,377	16,876,576	15,457,857
2060	21,464,663	21,466,322	21,518,739	19,514,510
Nitrogen oxides (NO_x)				
2021	1,235,910	1,232,862	1,231,300	1,230,761
2025	1,047,282	1,040,540	1,035,836	1,048,650
2040	868,741	860,018	850,361	903,223
2060	1,053,674	1,053,758	1,048,823	1,123,271
Particulate matter ($PM_{2.5}$)				
2021	52,196	51,845	51,575	50,807
2025	54,780	53,974	53,169	51,548
2040	68,369	67,172	65,049	59,346
2060	82,687	82,592	80,551	72,439
Sulfur dioxide (SO_2)				
2021	134,041	131,818	130,217	128,983
2025	134,575	129,737	125,539	139,364
2040	138,839	132,542	126,605	197,350
2060	146,008	147,700	144,471	236,352
Volatile organic compounds (VOCs)				
2021	1,268,195	1,263,105	1,259,153	1,246,633
2025	1,108,714	1,096,929	1,085,078	1,054,968
2040	799,459	781,478	748,840	636,947
2060	917,523	915,236	883,100	733,171

Figure 4.2.1-1-A1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis A1

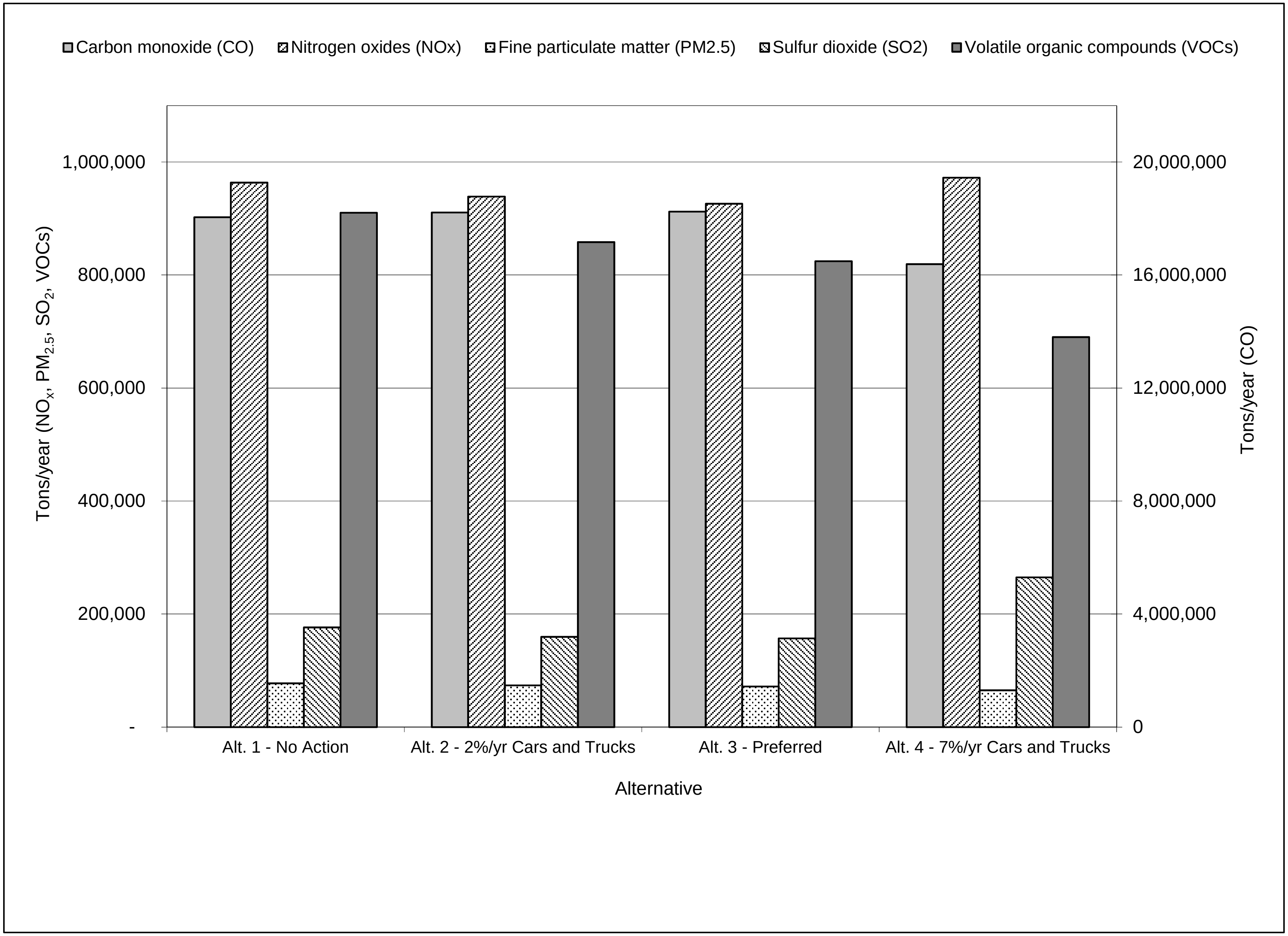


Figure 4.2.1-1-A2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis A2

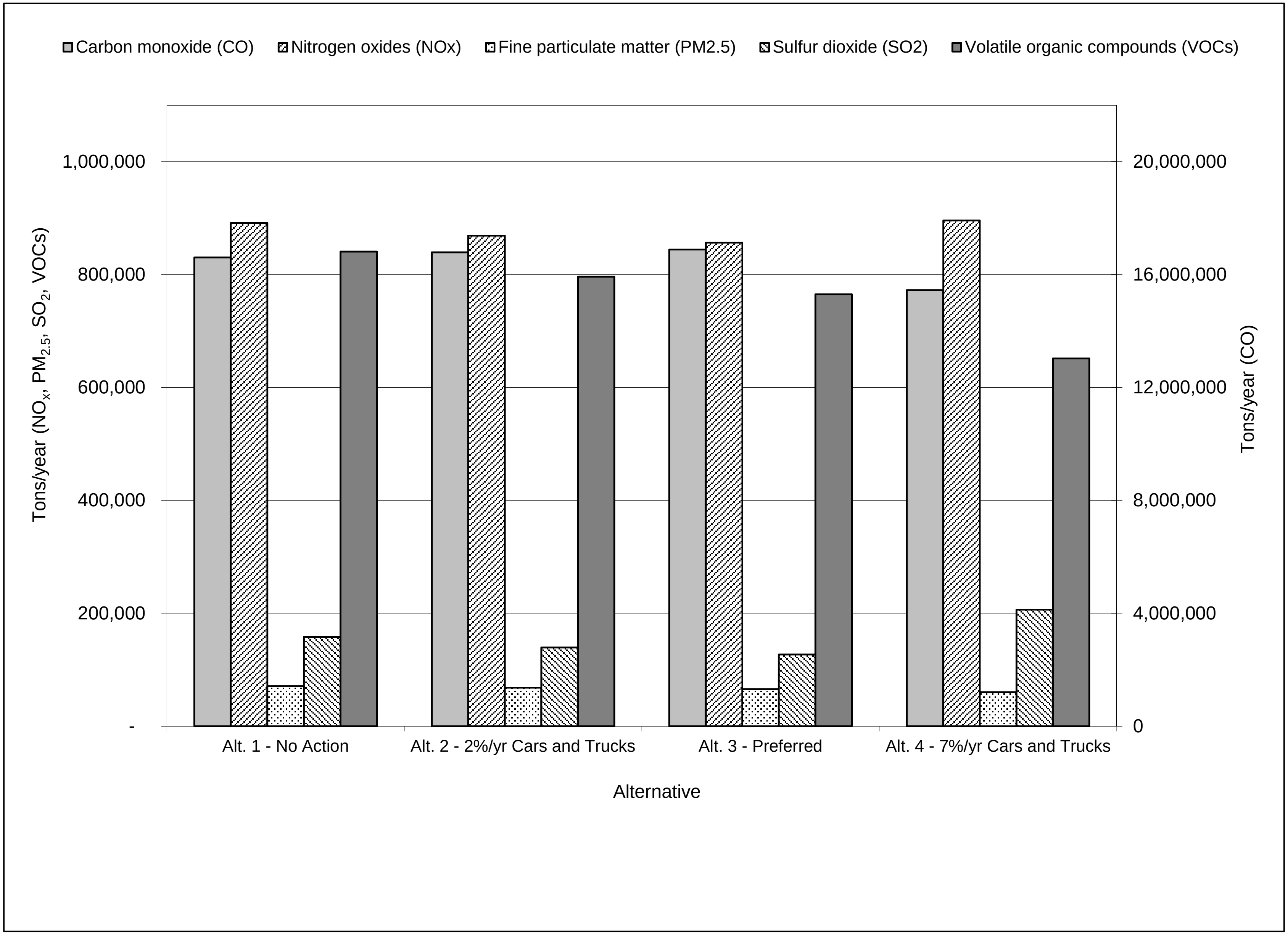


Figure 4.2.1-1-B1. Nationwide Criteria Pollutant Emissions from U.S. Passengar Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis B1

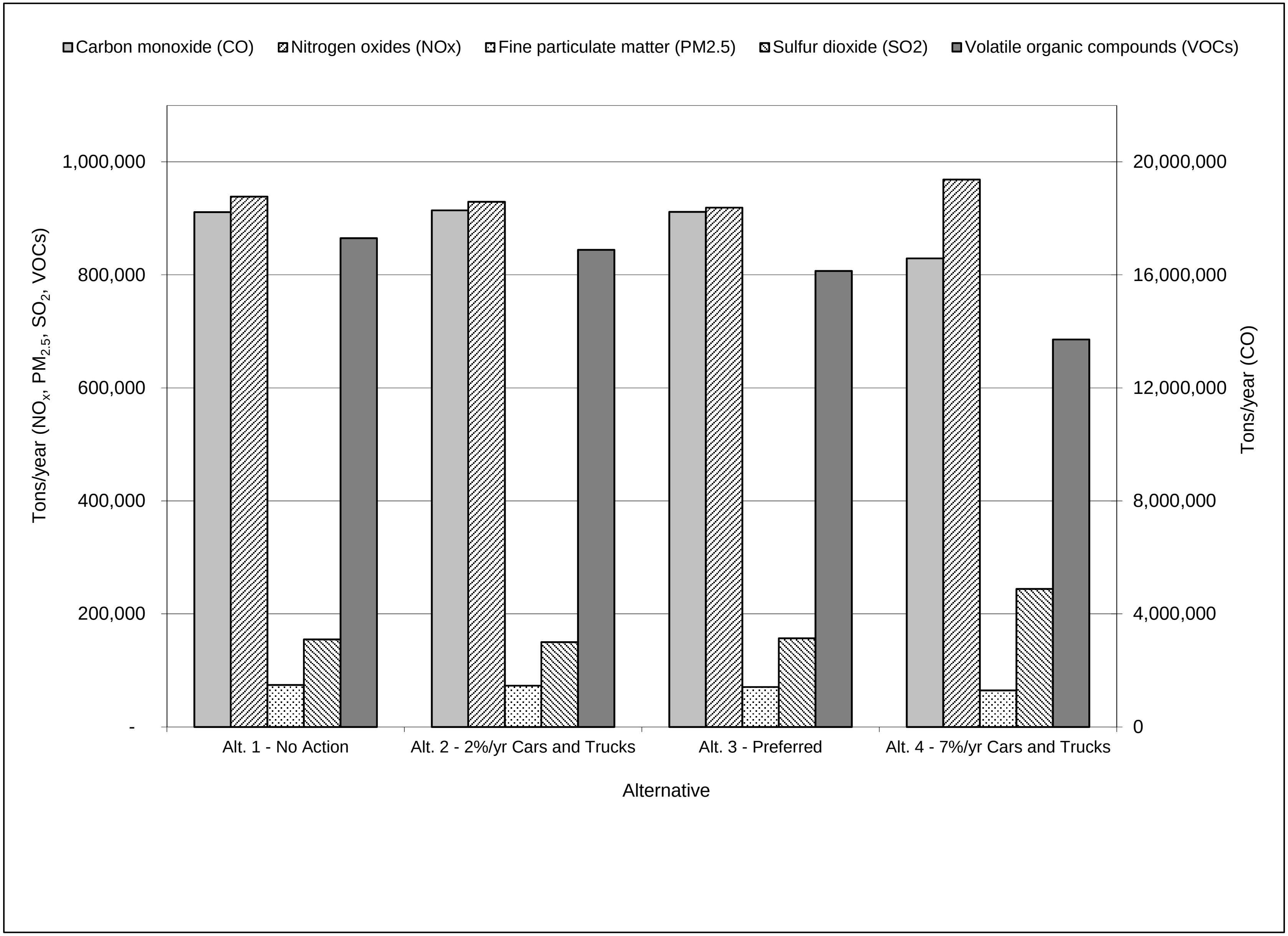


Figure 4.2.1-1-B2. Nationwide Criteria Pollutant Emissions from U.S. Passengar Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis B2

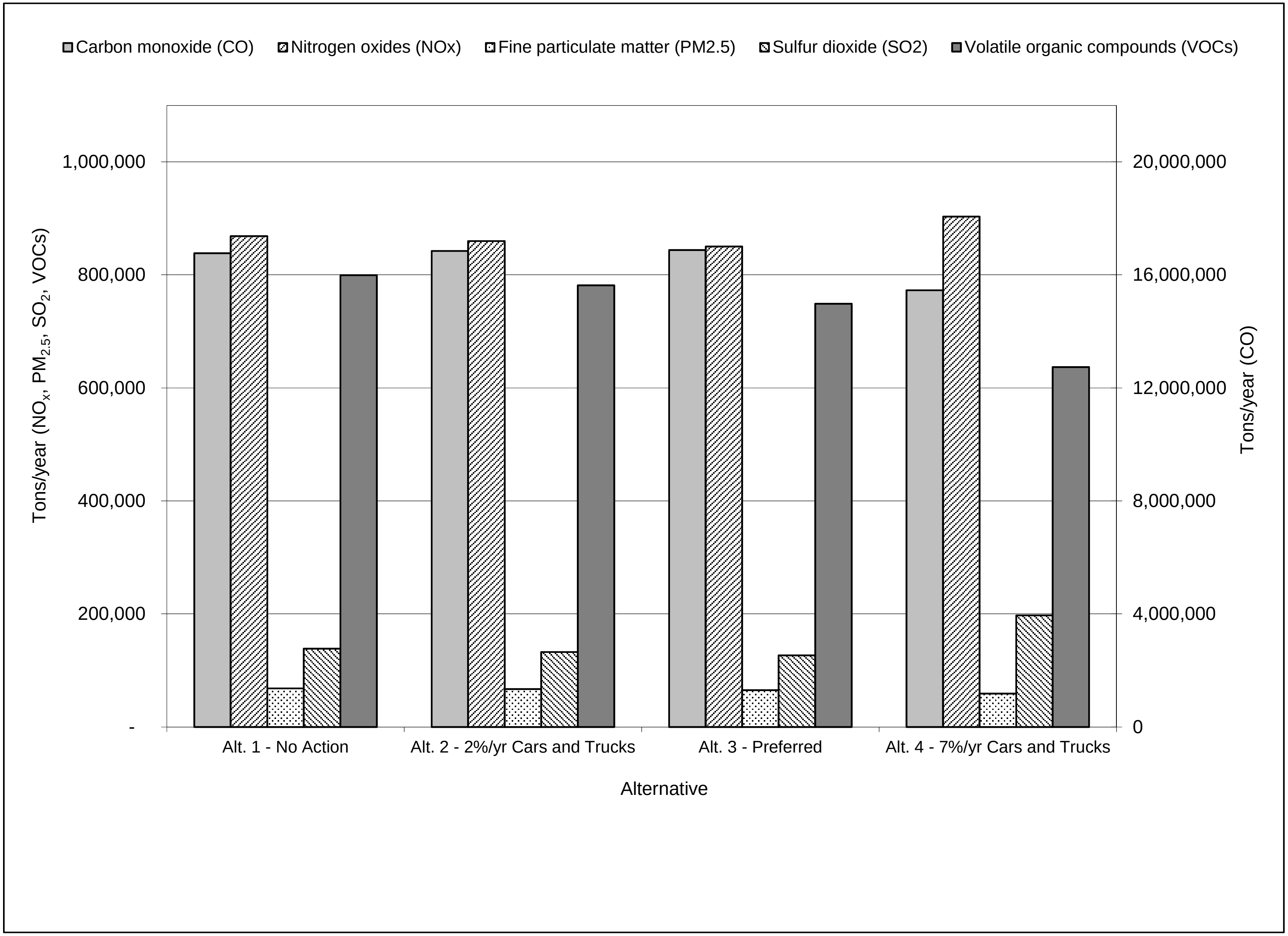


Figure 4.2.1-2-A1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis A1

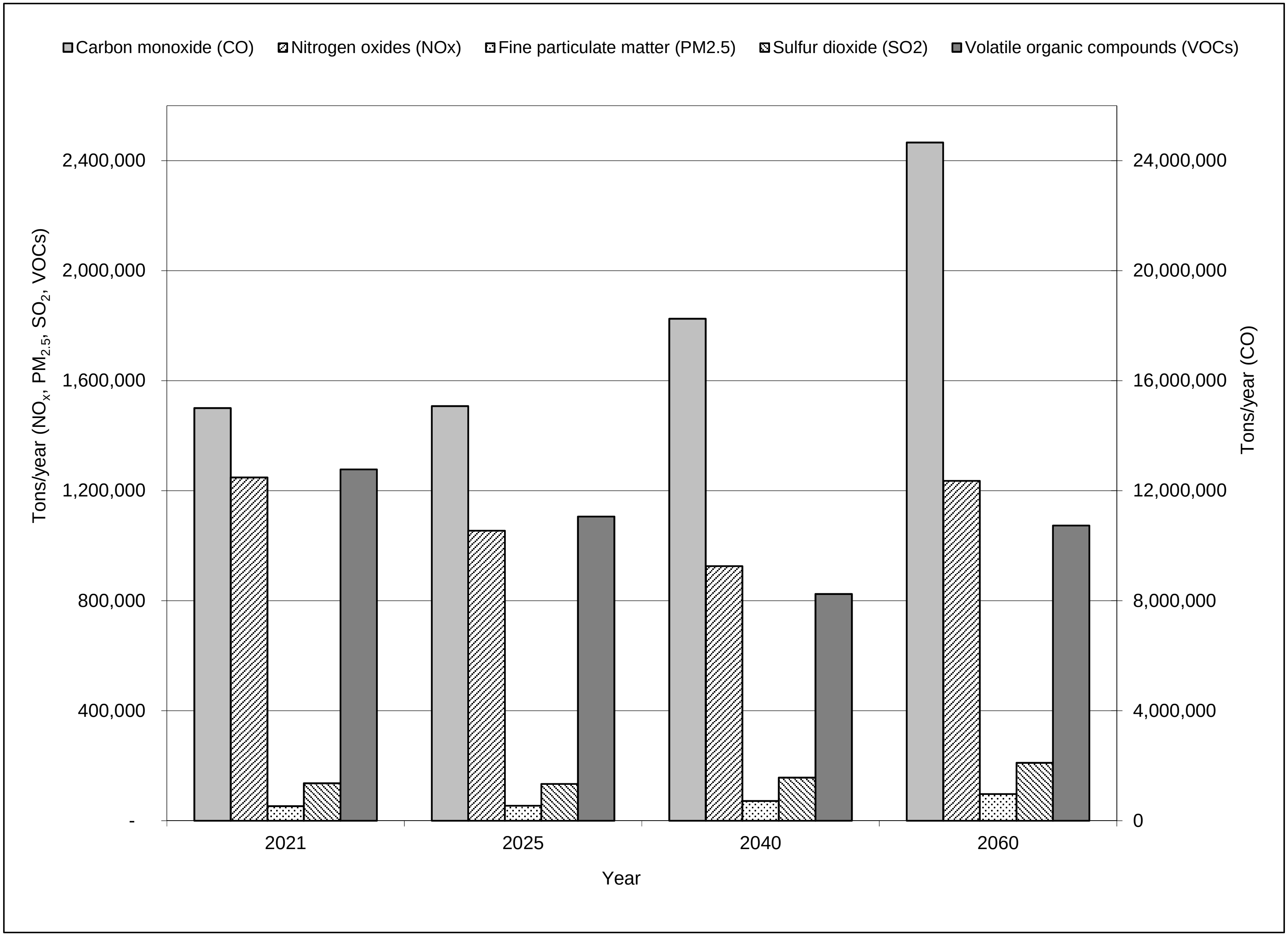


Figure 4.2.1-2-A2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis A2

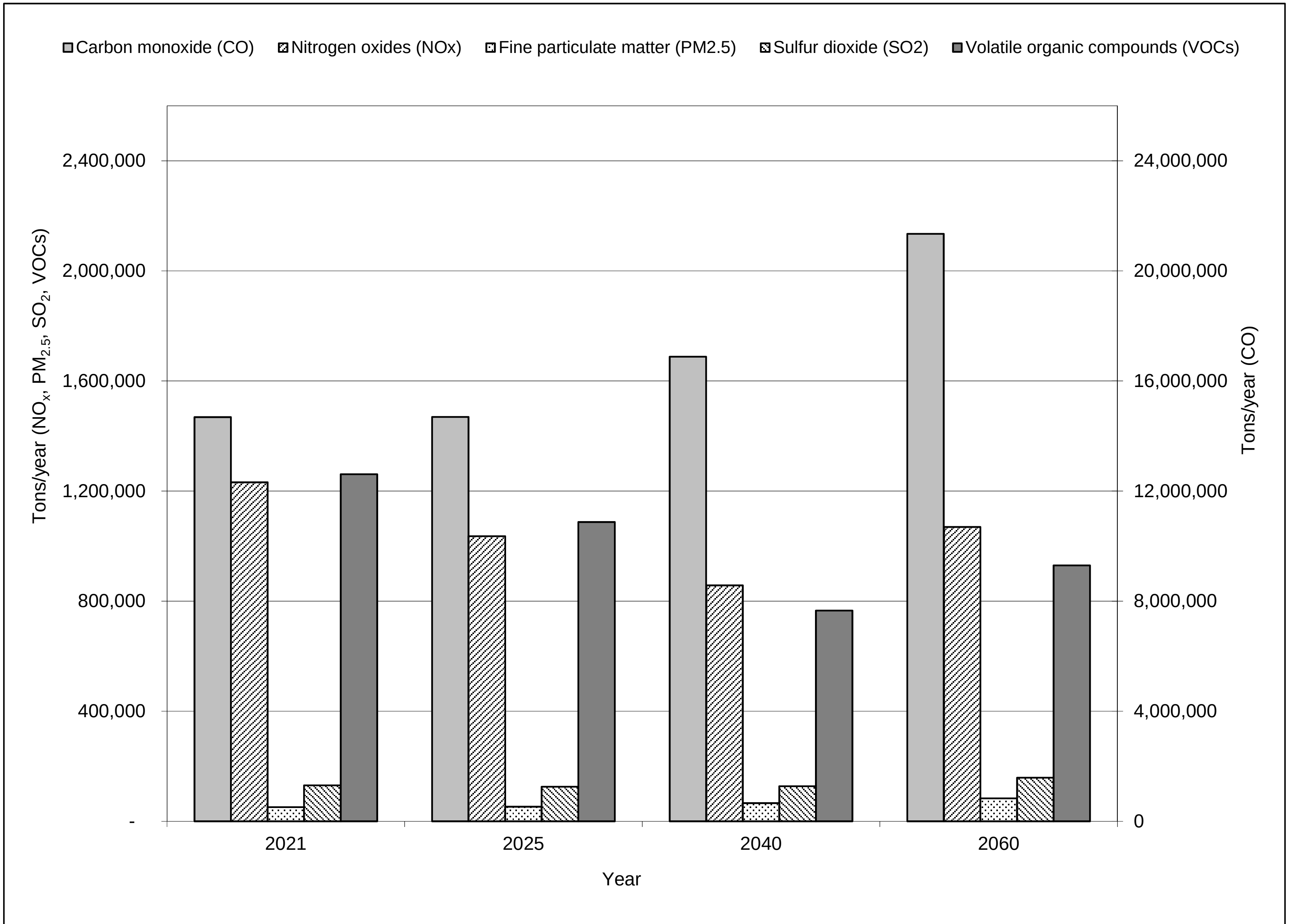


Figure 4.2.1-2-B1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis B1

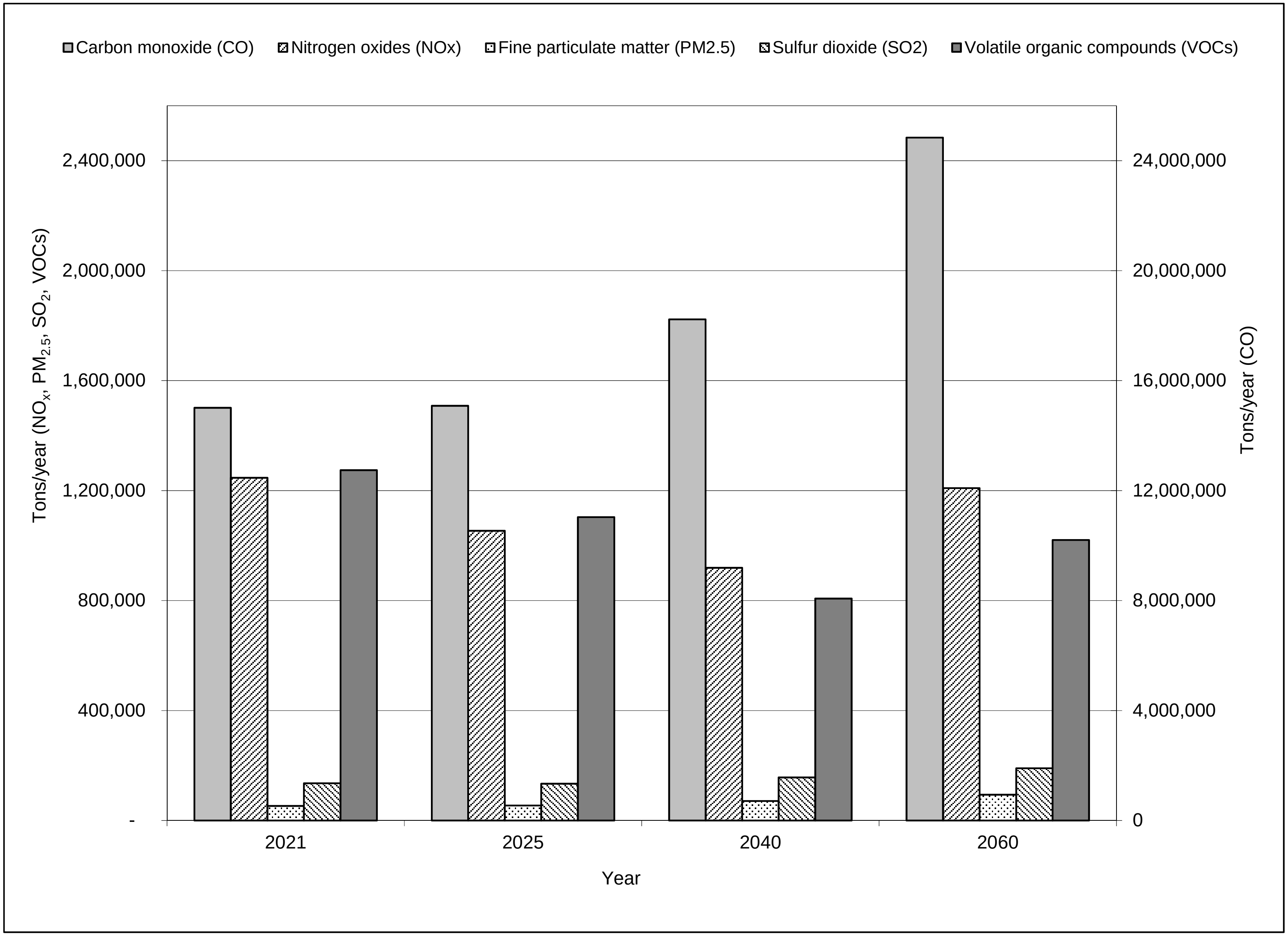
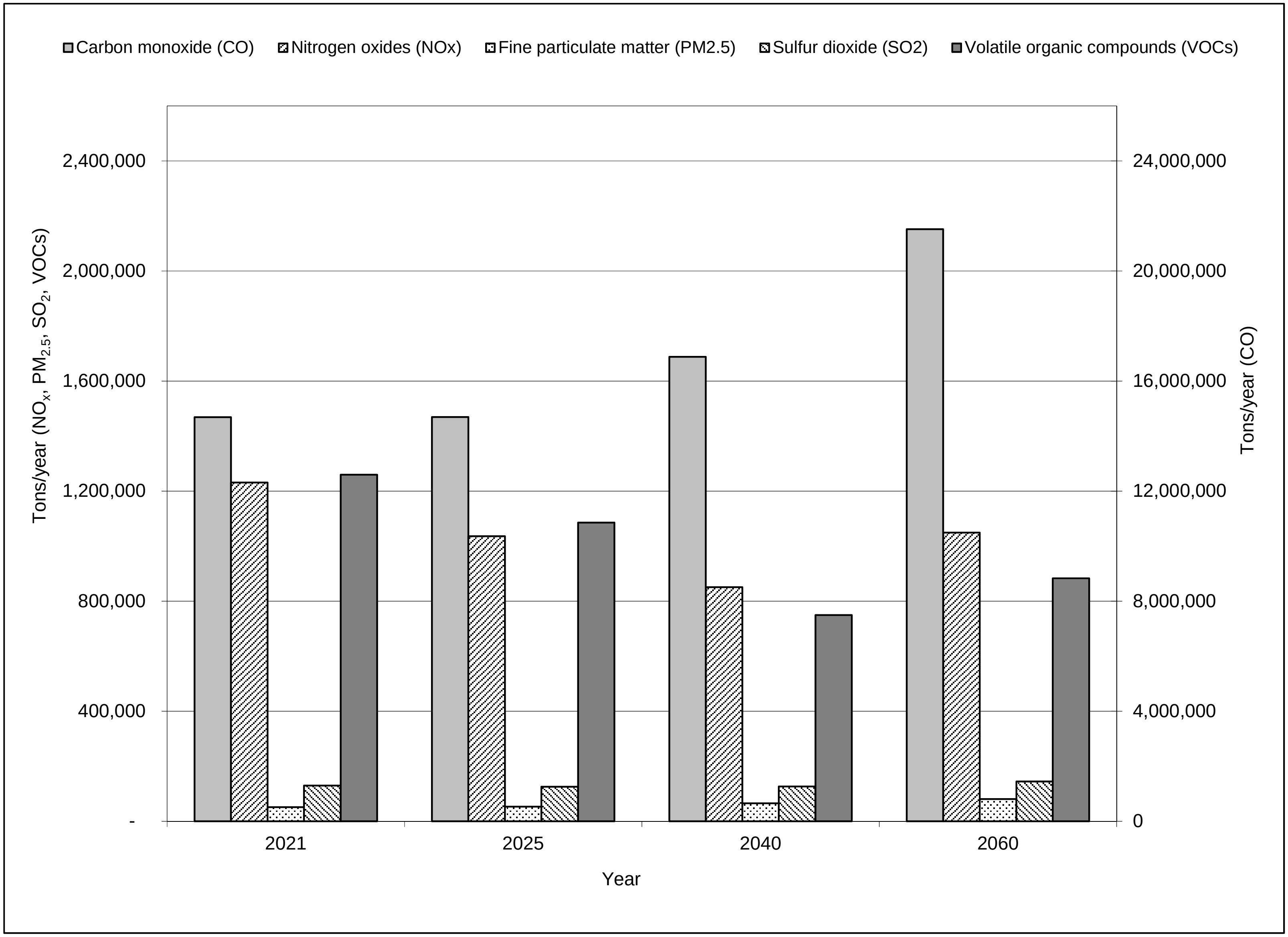


Figure 4.2.1-2-B2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis B2



Total emissions are made up of four components consisting of two sources of emissions (downstream and upstream) for each of the two vehicle classes (passenger cars and light trucks) covered by the Proposed Action. To show the relationship among these four components for criteria pollutants, tables in Appendix A break down the total emissions of criteria pollutants by component.

Tables 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 list the net change in nationwide criteria pollutant emissions from passenger cars and light trucks for each action alternative for each criteria pollutant and analysis year compared to the No Action Alternative. Figures 4.2.1-3-A1 and -A2 and 4.2.1-3-B1 and -B2 show these changes in percentages for 2040. As a general trend, emissions of each pollutant decrease from Alternatives 2 through 4, as each successive alternative becomes more stringent. However, the magnitudes of the declines are not consistent across all pollutants, and there are some emission increases, which reflects 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. As a result of these interactions, emissions in some years are greater for more-stringent alternatives than for less-stringent alternatives. For example, NO_x and SO_2 emissions generally decrease from Alternatives 1 through 3, but increase after 2025 under Alternative 4. Conversely, CO emissions generally increase from Alternatives 1 through 3 and decrease under Alternative 4. VOCs and $PM_{2.5}$ emissions decrease steadily from Alternatives 1 through 4.

Under Alternative 2 and the Preferred Alternative, the greatest relative reductions in emissions among the criteria pollutants occur for SO_2 and VOCs, for which emissions decrease by as much as 20 percent by 2060 compared to the No Action Alternative. Emissions of SO_2 in Analysis B1 are an exception in some years, for which SO_2 emissions increase by as much as 9 percent by 2060 compared to the No Action Alternative. Emissions of NO_x and $PM_{2.5}$ under Alternative 2 and the Preferred Alternative decrease by 7 percent or less compared to the No Action Alternative, while CO emissions increase up to 3 percent. Under Alternative 4, the greatest relative reductions in emissions among the criteria pollutants compared to the No Action Alternative occur for CO, $PM_{2.5}$, and VOCs, for which emissions decrease by as much as 26 percent by 2060. Emissions of NO_x and SO_2 are an exception in some years, for which NO_x emissions increase by as much as 7 percent by 2060 and SO_2 emissions increase by as much as 80 percent by 2060 compared to the No Action Alternative.[20]

[20] Note that the maximum of 80 percent does not refer to all power plant emissions but only to the SO_2 associated with the charging of EVs. Total power plant emissions are limited by "caps" under the EPA Acid Rain Program and the Cross-State Air Pollution Rule (76 FR 48208 (Aug. 8, 2011), effective October 7, 2011) and Clean Air Interstate Rule (70 FR 25162 (May 12, 2005), effective July 11, 2005), and will also be reduced through emissions standards such as the recent Mercury and Air Toxics Standards rule (77 FR 9304 (Feb. 16, 2012), effective April 16, 2012). As a result of these rules and advances in technology, emissions from the power-generation sector are expected to decline over time (the grid is expected to become cleaner, as exemplified by the Alternate Grid Mix). Any economic activity or trend that leads to an increase in electrical demand – including increases in EV sales and use – would be accommodated by the power industry in planning for compliance with applicable emissions limitations.

Table 4.2.1-2-A1. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A1[a,b]

	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	0	18,138	24,838	4,956
2025	0	44,131	65,244	-201,923
2040	0	171,448	201,585	-1,658,891
2060	0	382,196	489,825	-2,256,572
Nitrogen oxides (NO_x)				
2021	0	-5,288	-7,148	-9,572
2025	0	-11,206	-16,542	-3,596
2040	0	-24,784	-37,555	8,932
2060	0	-27,471	-41,906	28,301
Particulate matter ($PM_{2.5}$)				
2021	0	-646	-871	-1,819
2025	0	-1,420	-2,125	-4,041
2040	0	-3,404	-5,510	-12,133
2060	0	-4,172	-6,891	-16,863
Sulfur dioxide (SO_2)				
2021	0	-3,580	-5,195	-7,588
2025	0	-7,241	-11,076	8,490
2040	0	-16,463	-19,344	88,803
2060	0	-21,884	-24,598	132,612
Volatile organic compounds (VOCs)				
2021	0	-9,572	-12,798	-27,718
2025	0	-21,259	-31,705	-67,381
2040	0	-51,854	-85,773	-219,961
2060	0	-65,893	-111,267	-308,530

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

Table 4.2.1-2-A2. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A2[a,b]

	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	0	19,568	26,153	4,784
2025	0	48,588	68,659	-146,850
2040	0	180,934	274,691	-1,158,626
2060	0	355,145	552,745	-1,425,163
Nitrogen oxides (NO_x)				
2021	0	-5,332	-7,364	-8,910
2025	0	-11,012	-16,717	-6,112
2040	0	-22,533	-34,899	4,192
2060	0	-23,536	-35,870	21,262
Particulate matter ($PM_{2.5}$)				
2021	0	-634	-881	-1,690
2025	0	-1,344	-2,118	-3,806
2040	0	-2,991	-5,089	-10,890
2060	0	-3,439	-5,962	-14,150
Sulfur dioxide (SO_2)				
2021	0	-4,017	-5,583	-7,561
2025	0	-8,304	-13,030	802
2040	0	-18,391	-30,922	48,615
2060	0	-23,150	-39,227	69,922
Volatile organic compounds (VOCs)				
2021	0	-9,229	-12,781	-25,534
2025	0	-19,654	-30,909	-61,396
2040	0	-44,206	-75,383	-189,133
2060	0	-52,574	-91,098	-248,551

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

Table 4.2.1-2-B1. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B1[a,b]

	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	**No Action**	**2%/year Cars and Trucks**	**Preferred**	**7%/year Cars and Trucks**
Carbon monoxide (CO)				
2021	0	10,753	17,189	-14,991
2025	0	26,838	41,009	-220,738
2040	0	64,047	8,338	-1,635,335
2060	0	-26,249	-107,437	-2,591,967
Nitrogen oxides (NO_x)				
2021	0	-2,908	-4,906	-5,127
2025	0	-6,465	-11,418	3,911
2040	0	-9,199	-19,617	30,103
2060	0	203	-8,314	64,005
Particulate matter ($PM_{2.5}$)				
2021	0	-351	-604	-1,482
2025	0	-824	-1,543	-3,384
2040	0	-1,337	-3,467	-9,765
2060	0	-157	-2,373	-11,796
Sulfur dioxide (SO_2)				
2021	0	-2,015	-3,522	-4,077
2025	0	-4,079	-6,577	12,098
2040	0	-5,004	1,888	89,410
2060	0	4,100	16,302	138,836
Volatile organic compounds (VOCs)				
2021	0	-5,201	-8,925	-23,568
2025	0	-12,378	-23,434	-58,365
2040	0	-20,716	-57,731	-179,177
2060	0	-3,913	-44,044	-215,737

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

Table 4.2.1-2-B2. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B2[a,b]

Pollutant and Year	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	0	11,269	13,354	-10,001
2025	0	29,240	40,487	-169,812
2040	0	78,032	109,231	-1,309,488
2060	0	1,660	54,076	-1,950,153
Nitrogen oxides (NO_x)				
2021	0	-3,048	-4,610	-5,149
2025	0	-6,741	-11,446	1,368
2040	0	-8,724	-18,381	34,481
2060	0	85	-4,850	69,597
Particulate matter ($PM_{2.5}$)				
2021	0	-351	-621	-1,389
2025	0	-806	-1,610	-3,232
2040	0	-1,197	-3,320	-9,023
2060	0	-95	-2,136	-10,248
Sulfur dioxide (SO_2)				
2021	0	-2,222	-3,824	-5,058
2025	0	-4,838	-9,036	4,789
2040	0	-6,297	-12,234	58,511
2060	0	1,692	-1,536	90,344
Volatile organic compounds (VOCs)				
2021	0	-5,090	-9,042	-21,562
2025	0	-11,785	-23,636	-53,746
2040	0	-17,981	-50,619	-162,512
2060	0	-2,287	-34,424	-184,352

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

Figure 4.2.1-3-A1 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis A1

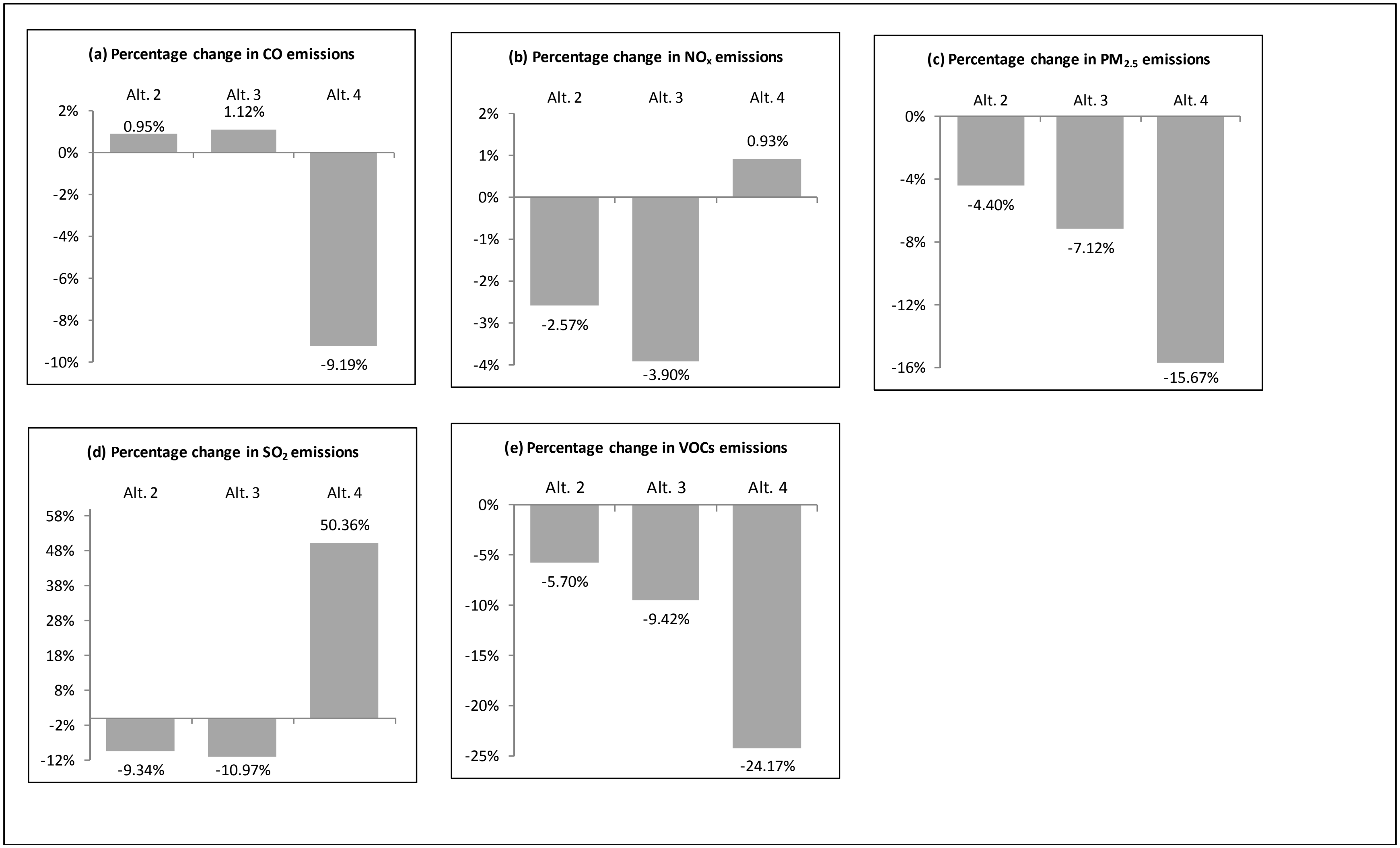


Figure 4.2.1-3-A2 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis A2

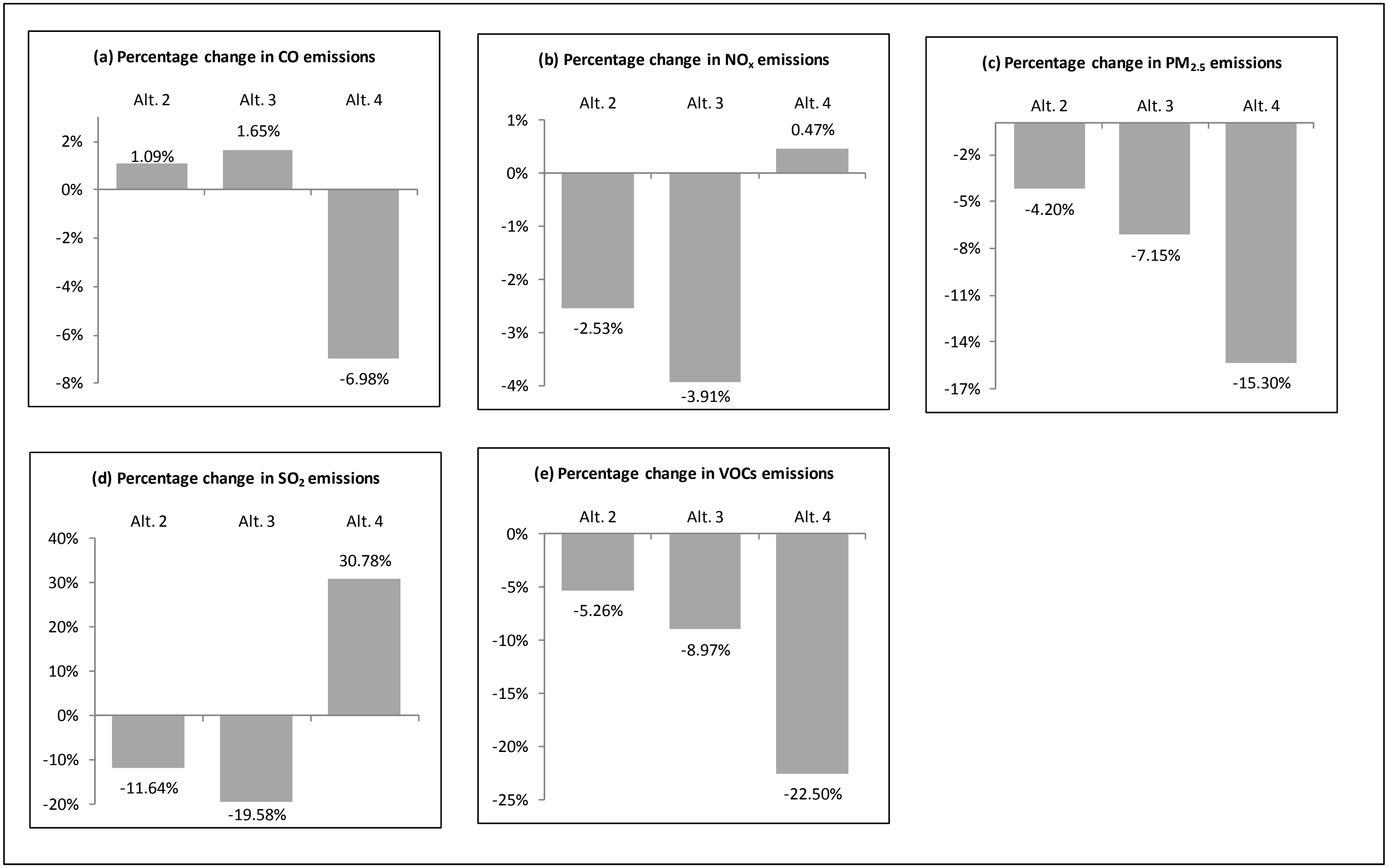


Figure 4.2.1-3-B1 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis B1

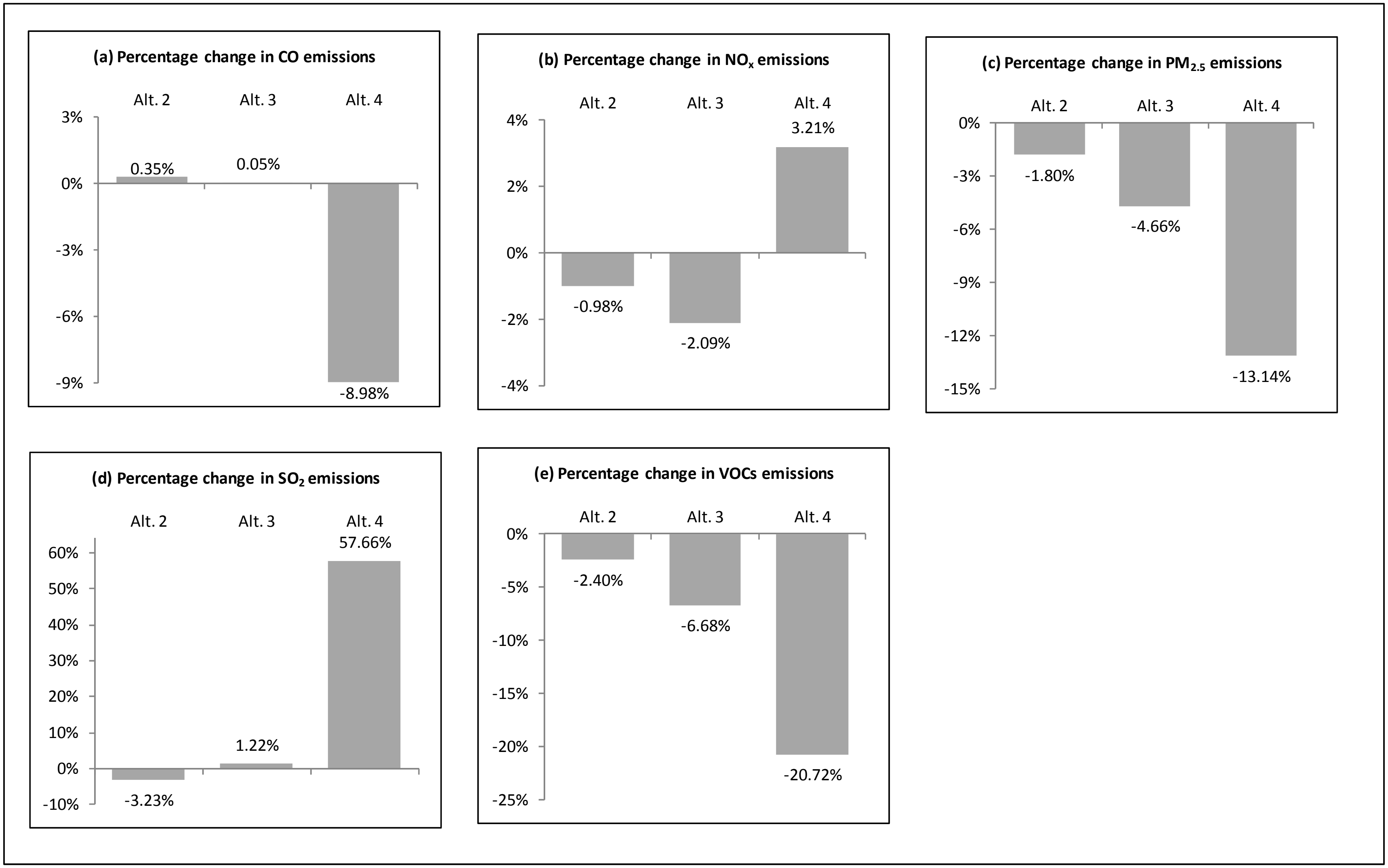
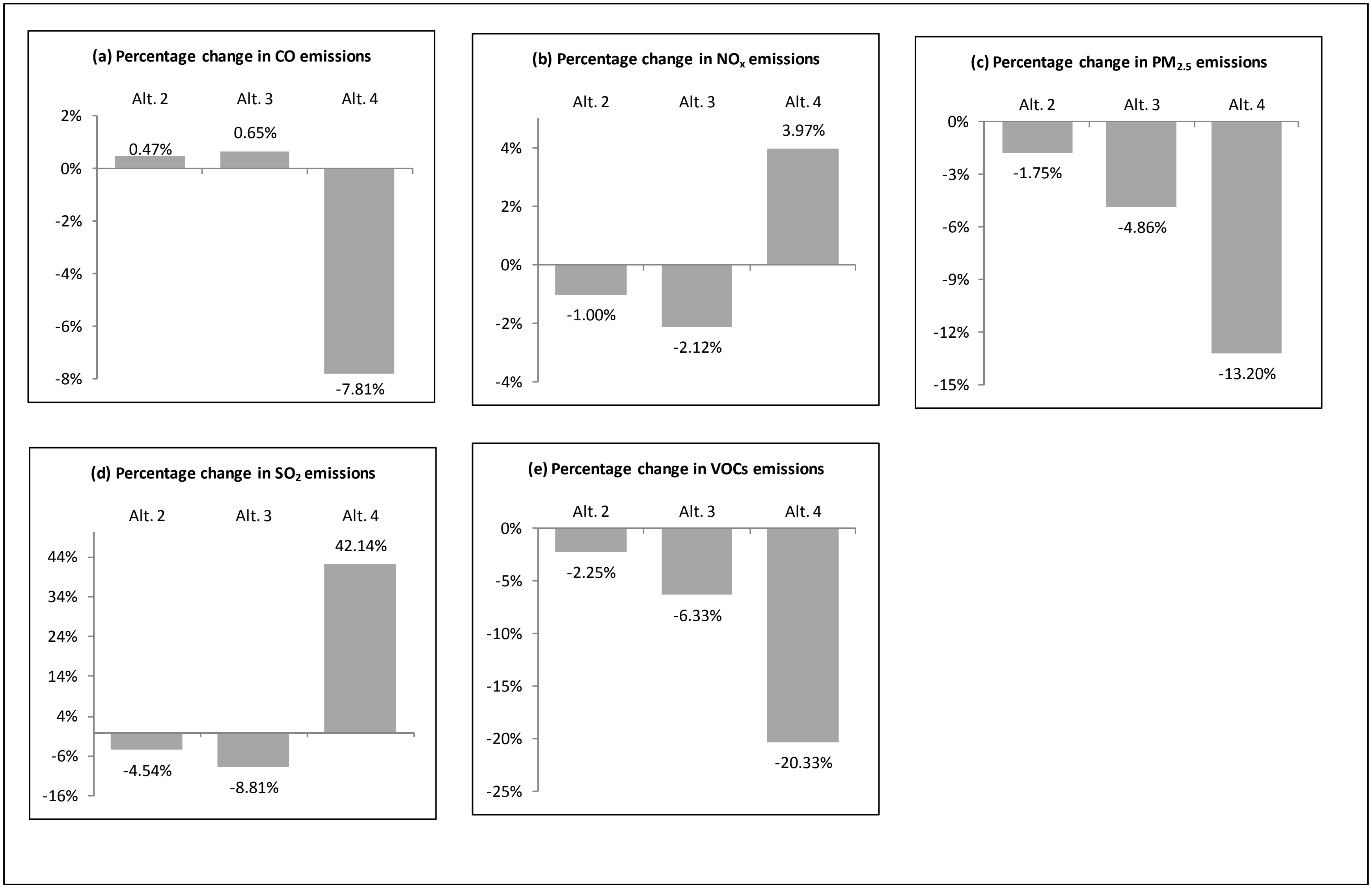


Figure 4.2.1-3-B2 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis B2



Instances where downstream (tailpipe) emissions are predicted to increase[42] in the action alternatives are attributable to shifts in modeled technology adoption from the baseline. Although electric propulsion produces no downstream emissions, upstream SO_2 emissions include contributions from the power plants that generate the electricity to recharge EVs and from the production of the fuel burned in those power plants. For instances where upstream emissions in SO_2 are predicted to increase in later years under the action alternatives, this occurs due to increased electricity demand related to increases in the number of EVs introduced under each alternative (the largest increases occur in Analysis B1).

The differences in national emissions of criteria air pollutants among the action alternatives compared to the No Action Alternative range from small (less than 1 percent) to large (up to 80 percent) due to the interactions of the multiple factors described above. The small differences are not expected to lead to measurable changes in concentrations of criteria pollutants in the ambient air. The large differences in emissions could lead to changes in ambient pollutant concentrations.

Tables 4.2.1-3-A1 and -A2 and 4.2.1-3-B1 and -B2 summarize the criteria air pollutant analysis results by nonattainment area. Tables in Appendix B list the emissions changes for each nonattainment area. For CO and $PM_{2.5}$, most nonattainment areas would experience increases in emissions across most years under Alternatives 2 and the Preferred Alternative, but decreases in emissions across most years under Alternative 4. For NO_x, most nonattainment areas would experience increases in emissions across all alternatives and years. For SO_2 and VOCs, most nonattainment areas would experience decreases in emissions across all alternatives and years.

Table 4.2.1-3-A1. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis A1[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	23,710	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-109,370	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	1,267	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-4,987	2060	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	32	2060	3	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-986	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Sulfur dioxide (SO_2)	Maximum Increase	17,374	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-2,100	2060	2	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	5	2060	2	Riverside County (Coachella Valley), CA (O_3)
	Maximum Decrease	-9,060	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.

[42] Criteria pollutant emissions do not increase above the vehicle emissions standards but rather increase within the allowable "headroom" of the standard.

Table 4.2.1-3-A2. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis A2[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	26,801	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-69,026	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	1,657	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-4,986	2060	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	32	2060	3	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-909	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Sulfur dioxide (SO_2)	Maximum Increase	9,624	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-3,990	2060	3	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	8	2060	3	Riverside County (Coachella Valley), CA (O_3)
	Maximum Decrease	-7,133	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.

Table 4.2.1-3-B1. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis B1[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	3,044	2040	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-125,565	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	4,192	2060	4	Houston-Galveston-Brazoria, TX (O_3)
	Maximum Decrease	-1,792	2040	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	4	2040	2	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-558	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Sulfur dioxide (SO_2)	Maximum Increase	17,437	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-622	2025	3	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	–b	–	–	–
	Maximum Decrease	-6,883	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.
b. No increases are expected under any alternative.

Table 4.2.1-3-B2. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis B2[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	5,203	2040	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-94,423	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	2,766	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-2,215	2040	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	5	2040	2	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-494	2040	4	Houston-Galveston-Brazoria, TX (O_3)
Sulfur dioxide (SO_2)	Maximum Increase	11,515	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-1,109	2040	3	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	<1	2040	2	Kent and Queen Annes Counties, MD (O_3)
	Maximum Decrease	-5,810	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.

4.2.1.1.2 Toxic Air Pollutants Overview

Tables 4.2.1-4-A1 and -A2 and 4.2.1-4-B1 and -B2 summarize the total upstream and downstream[43] emissions of toxic air pollutants from passenger cars and light trucks 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 4.2.1.1.1). These tables show that emissions of acetaldehyde, acrolein, and formaldehyde generally increase from Alternative 1 to Alternative 4. This trend is least pronounced for formaldehyde, for which emissions decrease under Alternative 2 and the Preferred Alternative for several combinations of analyses and years. Acetaldehyde emissions also decrease under Alternative 4 for certain analyses and years. Emissions of 1,3-butadiene are approximately equivalent for each alternative and year (except for decreases under Alternative 4 in 2040 and 2060). Benzene emissions decrease from Alternative 1 to Alternative 4 (except for Alternative 2 in 2060 in Analysis A2). DPM emissions generally decrease from Alternative 1 to Alternative 3 for all analysis years. Under Alternative 4, DPM emissions are the lowest of all alternatives until approximately 2025, after which they increase to just below or above the No Action Alternative levels (except in Analysis A1).[44] 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 economy requirements.

[43] Downstream emissions do not include evaporative emissions from vehicle fuel systems due to modeling limitations.
[44] As shown in Tables 4.2.4-1-A1 and -A2 and 4.2.4-1-B1 and -B2, the predicted DPM emissions under the action alternatives are generally similar in Analysis A and Analysis B. However, DPM emissions under the No Action Alternative are lower in Analysis B than in Analysis A, leading to the calculated emissions increases in Analysis B. These differences occur because of the interaction of gains in new vehicle fuel economy after 2025 with changes in the diesel share of the vehicle population and the diesel share of total fuel usage. As a result, the trends in DPM emissions are subject to considerable uncertainty.

Table 4.2.1-4-A1. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A1

Pollutant and Year	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	6,731	6,735	6,737	6,757
2025	6,258	6,268	6,274	6,316
2040	6,742	6,793	6,803	6,559
2060	9,019	9,146	9,183	8,808
Acrolein				
2021	317	317	316	320
2025	289	288	289	305
2040	309	310	311	379
2060	414	419	421	526
Benzene				
2021	31,252	31,220	31,209	31,118
2025	25,262	25,194	25,157	24,765
2040	17,856	17,752	17,610	14,708
2060	23,262	23,257	23,113	18,607
1,3-Butadiene				
2021	3,500	3,501	3,502	3,504
2025	2,998	3,002	3,005	2,987
2040	2,696	2,719	2,721	2,436
2060	3,578	3,631	3,644	3,196
Diesel particulate matter (DPM)				
2021	8,982	8,716	8,631	8,427
2025	9,119	8,524	8,246	8,246
2040	10,981	9,467	8,584	10,256
2060	14,630	12,584	11,363	14,296
Formaldehyde				
2021	7,505	7,494	7,493	7,570
2025	6,813	6,790	6,788	7,133
2040	7,150	7,123	7,110	8,594
2060	9,557	9,576	9,581	11,921

Table 4.2.1-4-A2. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A2

Pollutant and Year	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	6,633	6,638	6,640	6,661
2025	6,133	6,145	6,155	6,201
2040	6,261	6,322	6,376	6,242
2060	7,815	7,942	8,046	7,860
Acrolein				
2021	314	314	314	318
2025	286	286	287	302
2040	291	294	300	364
2060	364	370	380	476
Benzene				
2021	30,938	30,910	30,897	30,817
2025	24,858	24,801	24,761	24,429
2040	16,488	16,424	16,310	13,916
2060	20,001	20,031	19,935	16,428
1,3-Butadiene				
2021	3,457	3,460	3,460	3,461
2025	2,943	2,948	2,951	2,939
2040	2,498	2,522	2,535	2,313
2060	3,090	3,140	3,167	2,839
Diesel particulate matter (DPM)				
2021	8,778	8,531	8,433	8,293
2025	8,895	8,361	8,084	8,143
2040	10,117	8,847	8,172	9,696
2060	12,636	11,032	10,205	12,735
Formaldehyde				
2021	7,434	7,428	7,425	7,504
2025	6,729	6,717	6,723	7,046
2040	6,717	6,726	6,832	8,239
2060	8,380	8,441	8,638	10,754

Table 4.2.1-4-B1. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B1

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	6,735	6,738	6,739	6,763
2025	6,267	6,273	6,277	6,331
2040	6,791	6,812	6,790	6,658
2060	9,270	9,262	9,232	9,010
Acrolein				
2021	317	317	316	322
2025	289	288	289	308
2040	311	311	311	390
2060	423	422	422	543
Benzene				
2021	31,235	31,219	31,205	31,100
2025	25,238	25,200	25,156	24,742
2040	17,776	17,737	17,516	14,759
2060	23,295	23,261	22,997	18,702
1,3-Butadiene				
2021	3,501	3,503	3,503	3,503
2025	3,002	3,004	3,005	2,989
2040	2,718	2,727	2,717	2,461
2060	3,683	3,680	3,665	3,257
Diesel particulate matter (DPM)				
2021	8,791	8,646	8,547	8,400
2025	8,814	8,466	8,177	8,274
2040	9,645	9,037	8,138	10,176
2060	10,834	10,743	9,808	13,438
Formaldehyde				
2021	7,499	7,493	7,492	7,592
2025	6,805	6,791	6,787	7,191
2040	7,128	7,116	7,073	8,803
2060	9,598	9,586	9,547	12,253

Table 4.2.1-4-B2. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B2

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Acetaldehyde				
2021	6,637	6,638	6,644	6,666
2025	6,140	6,146	6,160	6,216
2040	6,307	6,333	6,374	6,333
2060	8,036	8,038	8,104	8,044
Acrolein				
2021	313	314	314	319
2025	285	285	288	304
2040	293	293	300	385
2060	371	371	382	510
Benzene				
2021	30,924	30,908	30,891	30,808
2025	24,836	24,802	24,747	24,407
2040	16,420	16,405	16,226	13,640
2060	20,049	20,044	19,851	16,024
1,3-Butadiene				
2021	3,459	3,460	3,461	3,462
2025	2,946	2,948	2,951	2,940
2040	2,518	2,530	2,533	2,307
2060	3,182	3,183	3,190	2,850
Diesel particulate matter (DPM)				
2021	8,626	8,487	8,411	8,296
2025	8,630	8,301	8,068	8,199
2040	8,917	8,379	7,787	10,057
2060	9,425	9,360	8,897	12,694
Formaldehyde				
2021	7,429	7,425	7,436	7,523
2025	6,722	6,709	6,740	7,103
2040	6,699	6,697	6,822	8,705
2060	8,428	8,427	8,641	11,480

Figures 4.2.1-4-A1 and -A2 and 4.2.1-4-B1 and -B2 show toxic air pollutant emissions for each alternative in 2040, the forecast year by which a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet standards as set forth under the Proposed Action.

Figure 4.2.1-4-A1. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis A1

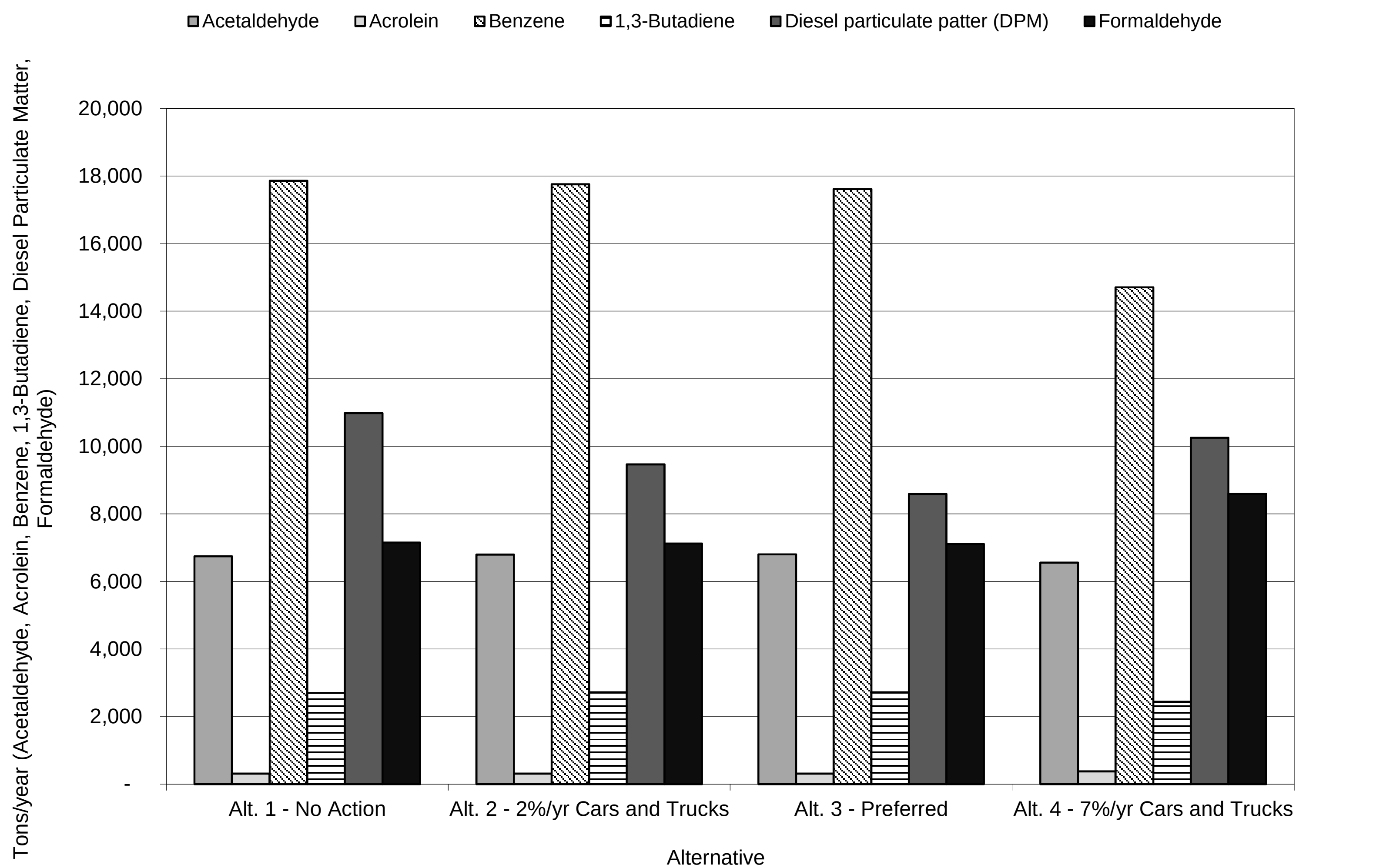


Figure 4.2.1-4-A2. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis A2

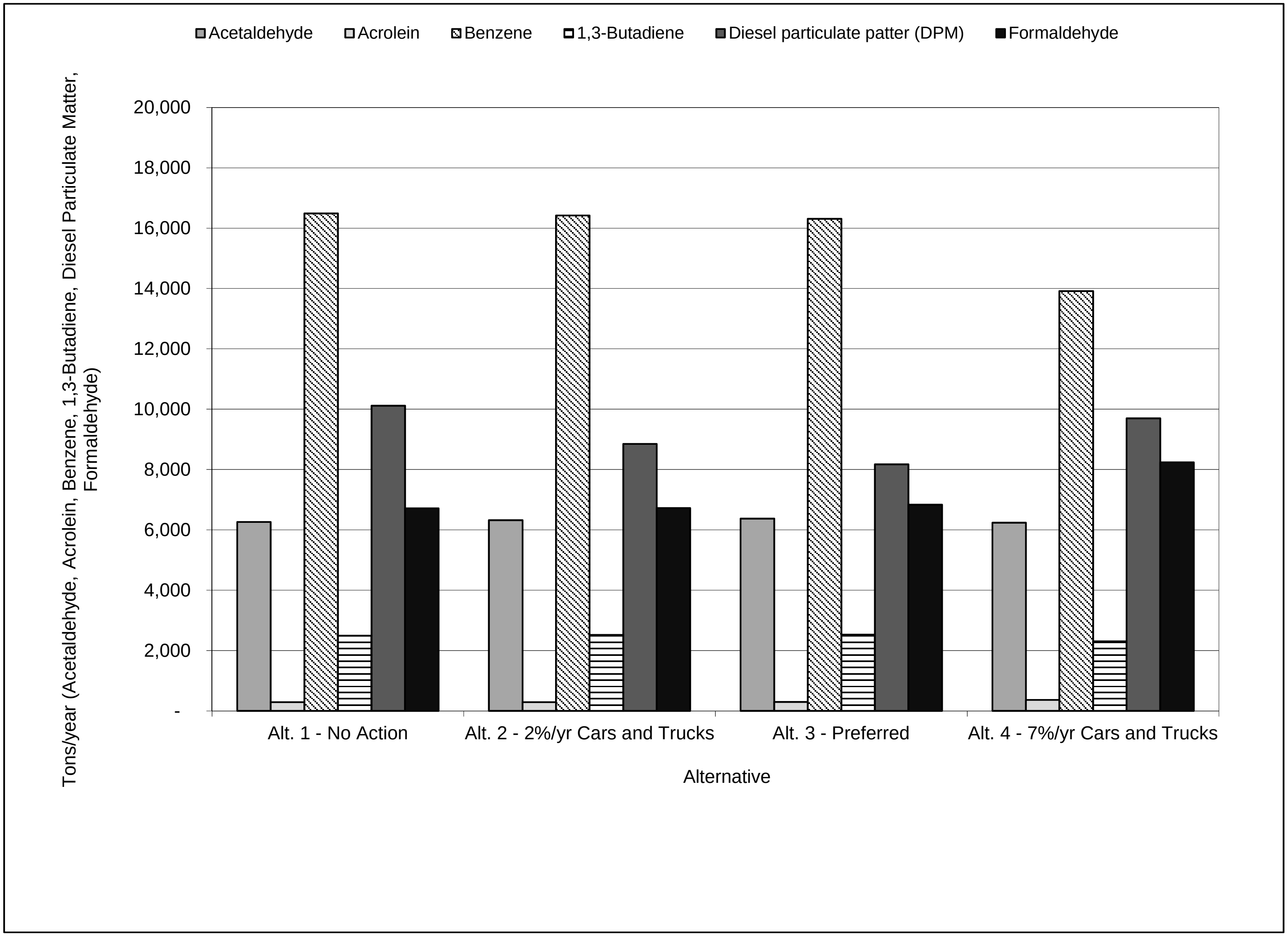


Figure 4.2.1-4-B1. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis B1

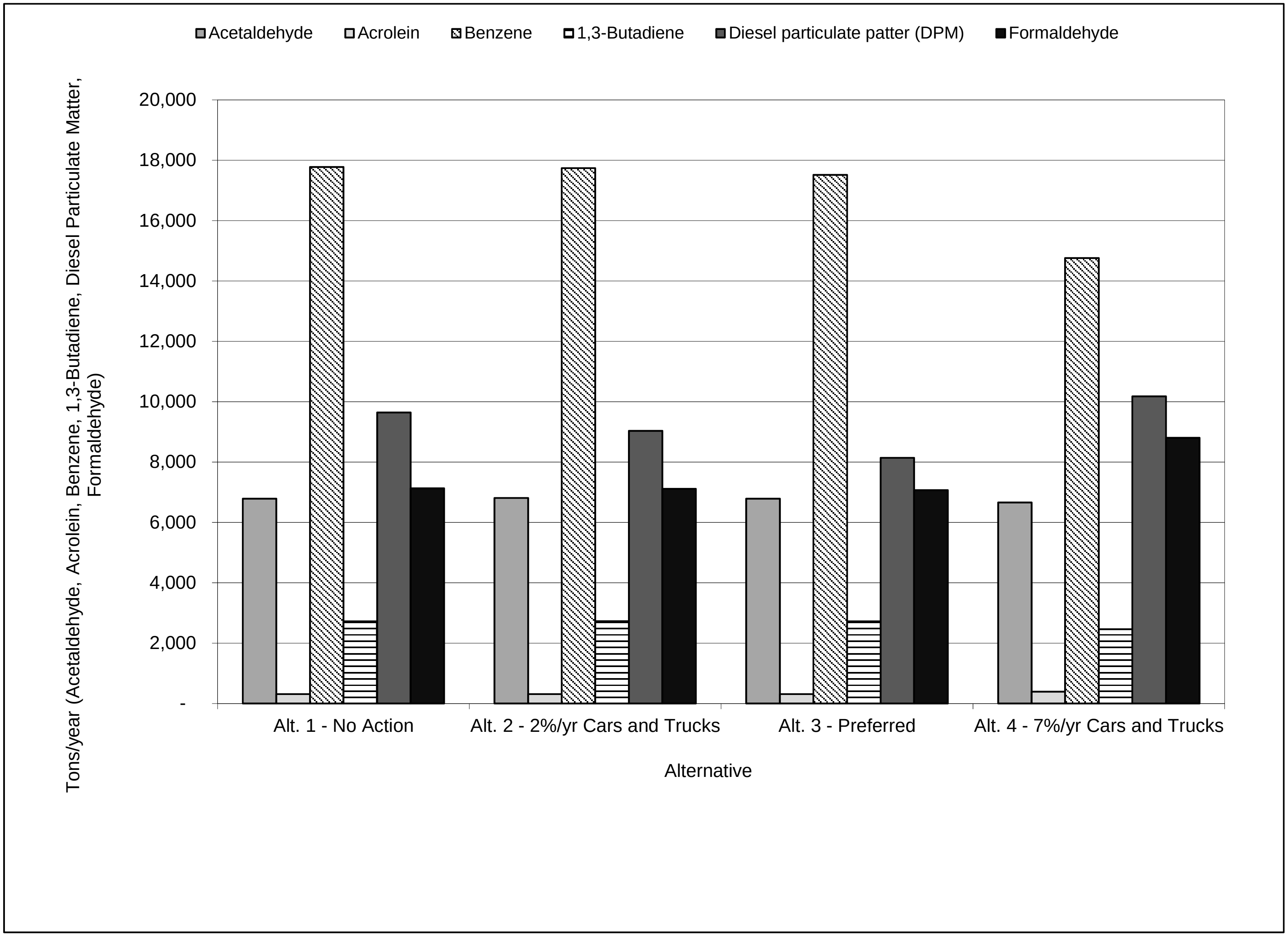
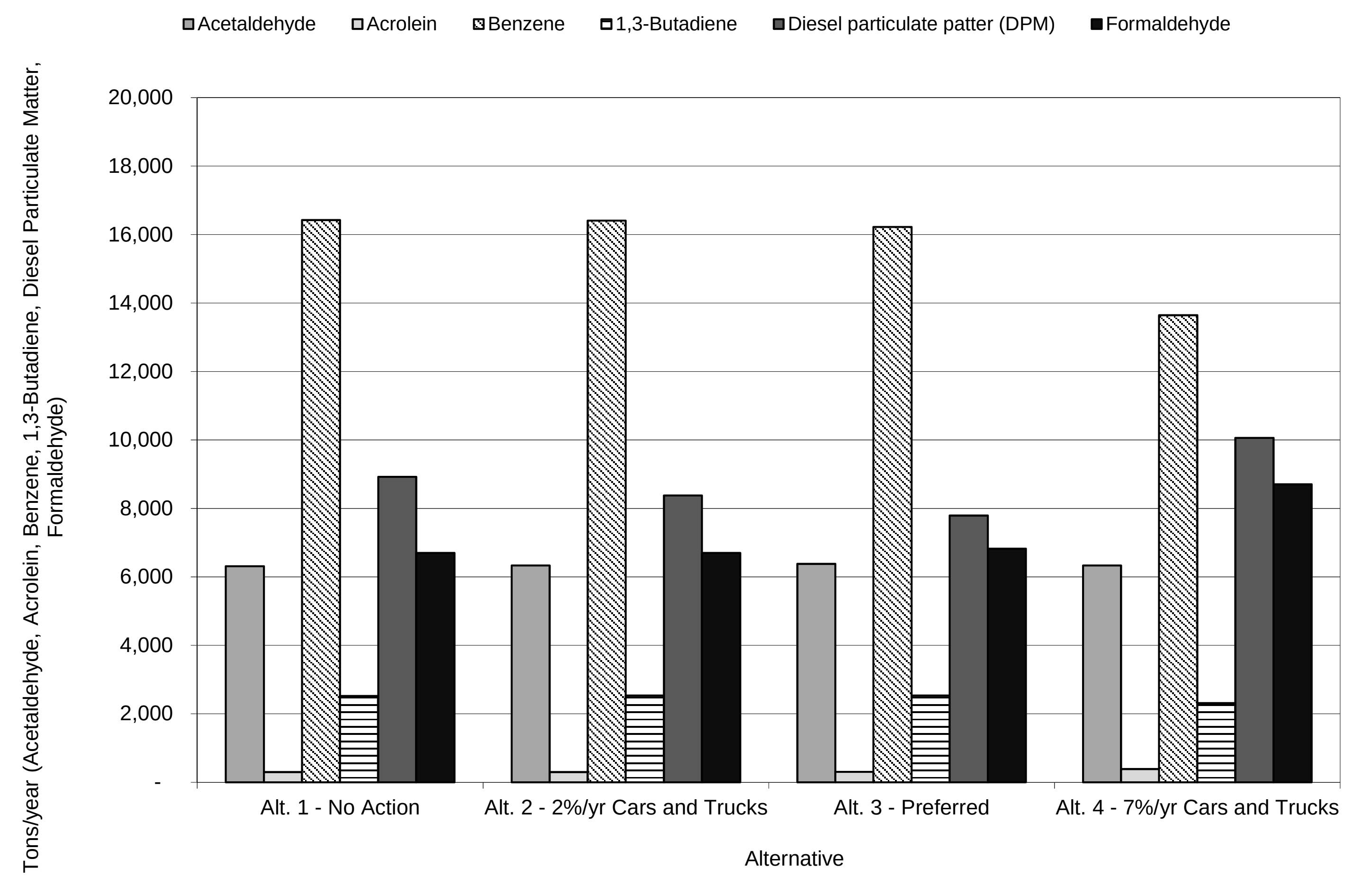


Figure 4.2.1-4-B2. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis B2



Figures 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 summarize the changes over time in total national emissions of toxic air pollutants from passenger cars and light trucks under the Preferred Alternative. These figures indicate a consistent trend among the toxic air pollutants. Emissions decline from 2021 to 2025 due to increasingly stringent EPA regulation of emissions from vehicles and from reductions in upstream emissions from fuel production, but reach a minimum typically between 2025 and 2040, and increase from 2040 to 2060 due to continuing growth in VMT.

As with criteria pollutant emissions (*see* Section 4.2.1.1.1), total toxic pollutant emissions are made up of four components, consisting of two sources of emissions (downstream and upstream) for each of the two vehicle classes (passenger cars and light trucks) covered by the proposed rule. To show the relationship among these four components for toxic air pollutants, tables in Appendix A break down the total emissions of toxic air pollutants by component.

Tables 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 list the net change in nationwide emissions from passenger cars and light trucks for each of the toxic air pollutants and analysis years under the action alternatives compared to the No Action Alternative. Figures 4.2.1-6-A1 and -A2 and 4.2.1-6-B1 and -B2 show these changes in percentages for 2040. Together, these tables and figures show that the magnitude of nationwide emission changes tends to increase from 2021 to 2060, and that emissions under Alternative 2 and the Preferred Alternative are similar to each other for most combinations of analyses (A1/A2/B1/B2), pollutant, and year. Emissions of benzene and DPM under the Preferred Alternative are generally less than under Alternative 2, but emissions of acetaldehyde, acrolein, 1,3-butadiene and formaldehyde under the Preferred Alternative are greater than or less than under Alternative 2, depending on the analysis, pollutant, and year. The magnitude of the emissions changes under Alternative 4 is generally greater than under Alternative 2 and the Preferred Alternative, except for 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.

Figure 4.2.1-5-A1. Nationwide Toxics Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis A1

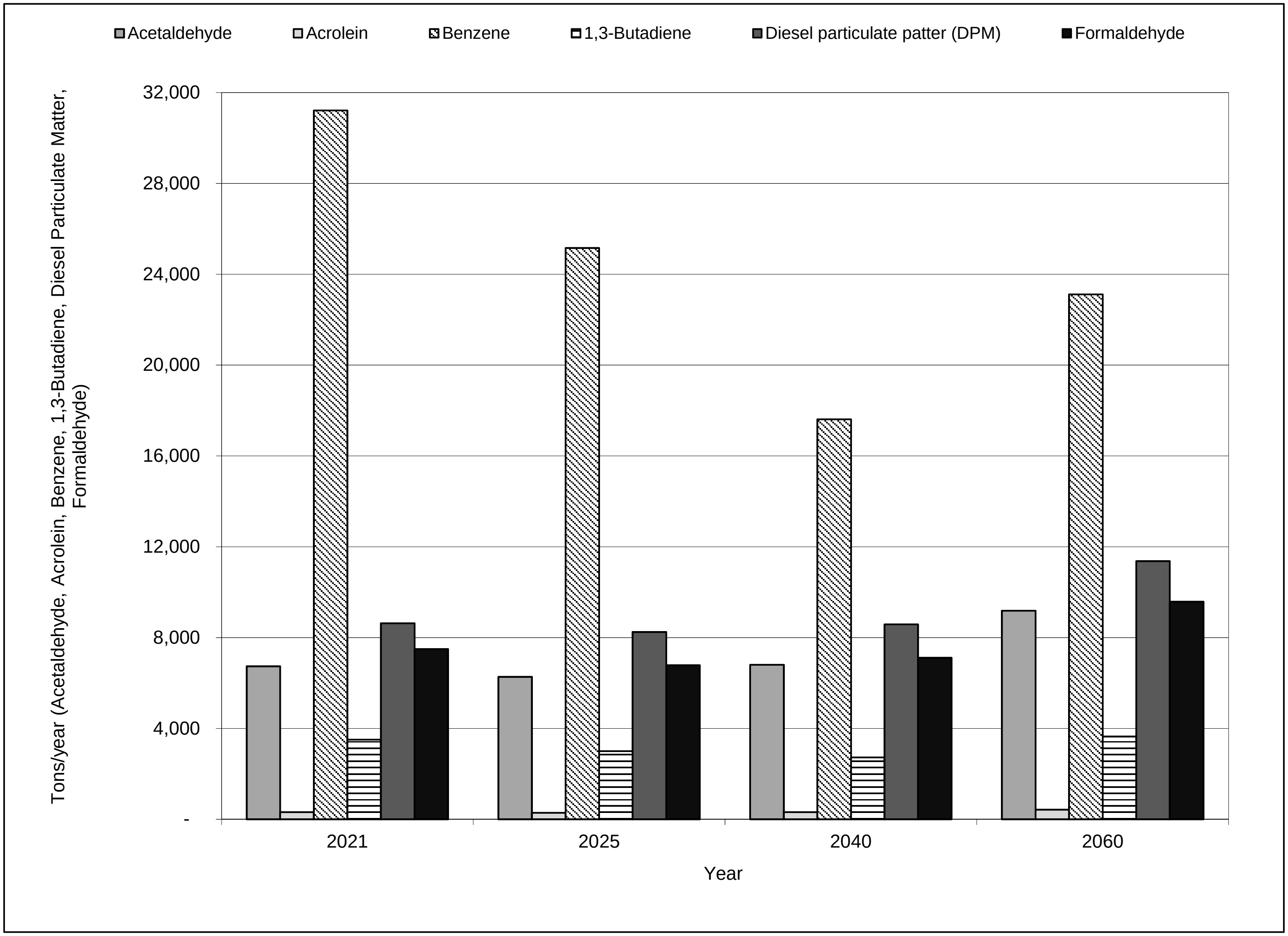


Figure 4.2.1-5-A2. Nationwide Toxics Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis A2

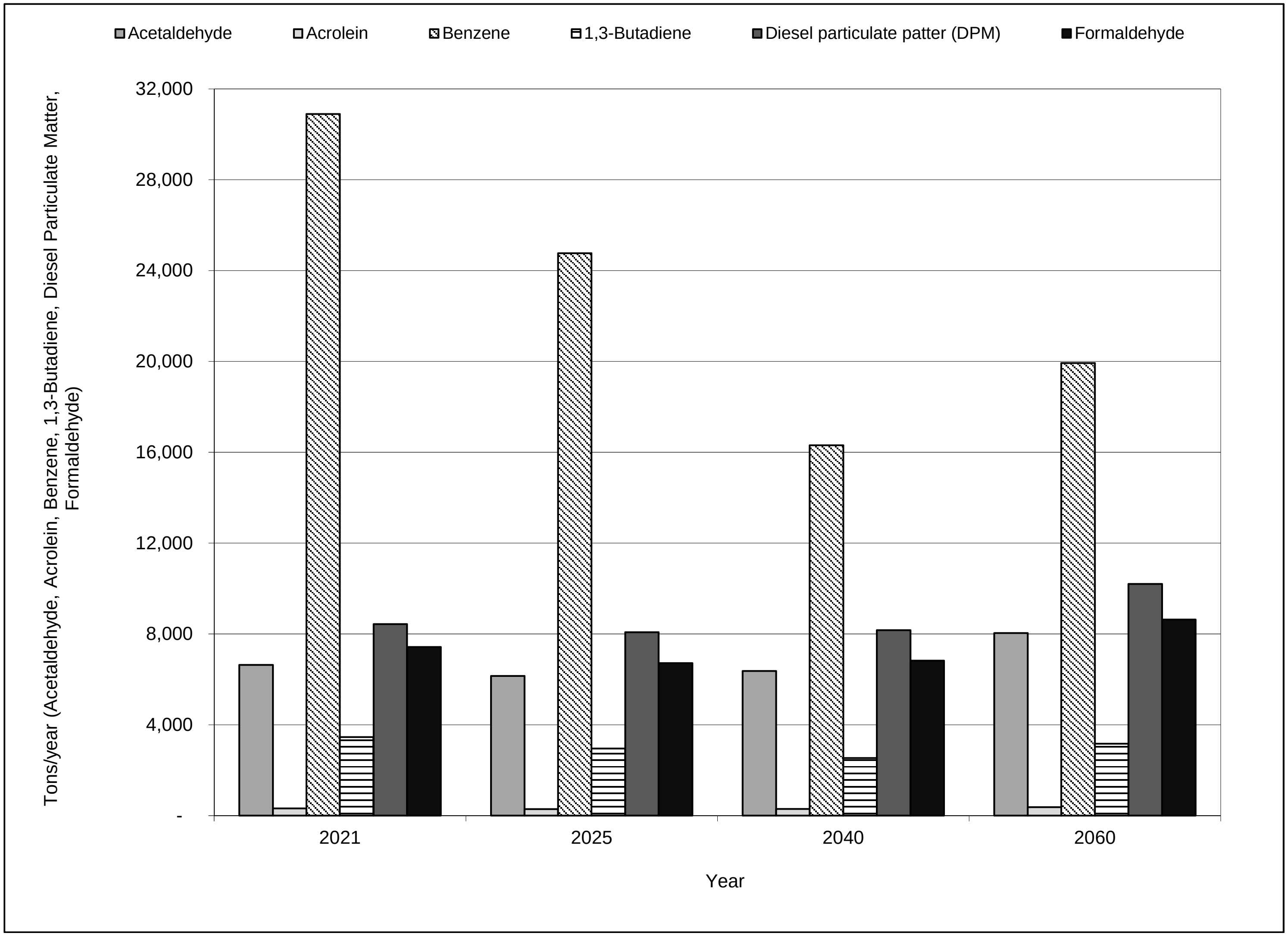


Figure 4.2.1-5-B1. Nationwide Toxics Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis B1

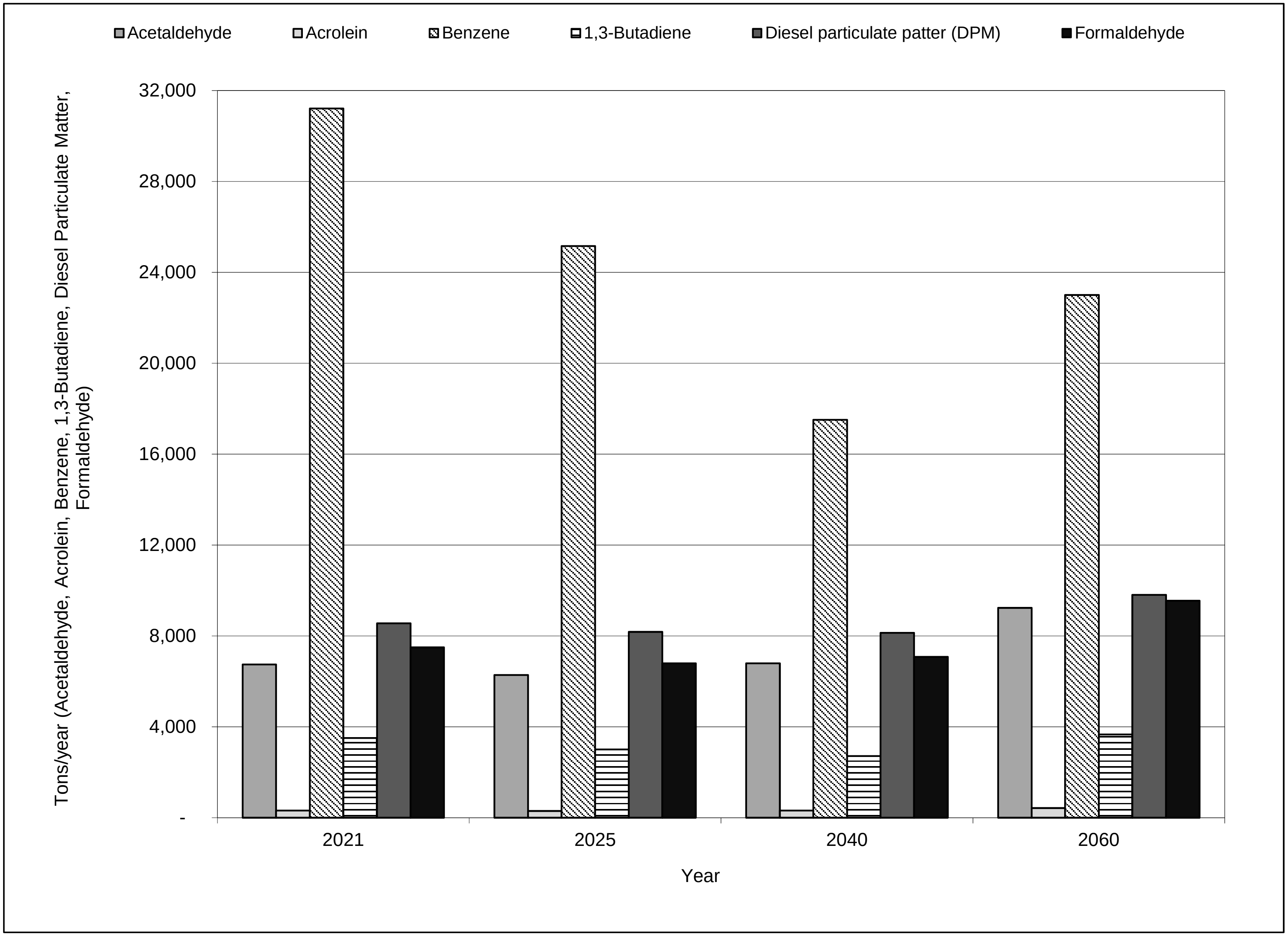


Figure 4.2.1-5-B2. Nationwide Toxics Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis B2

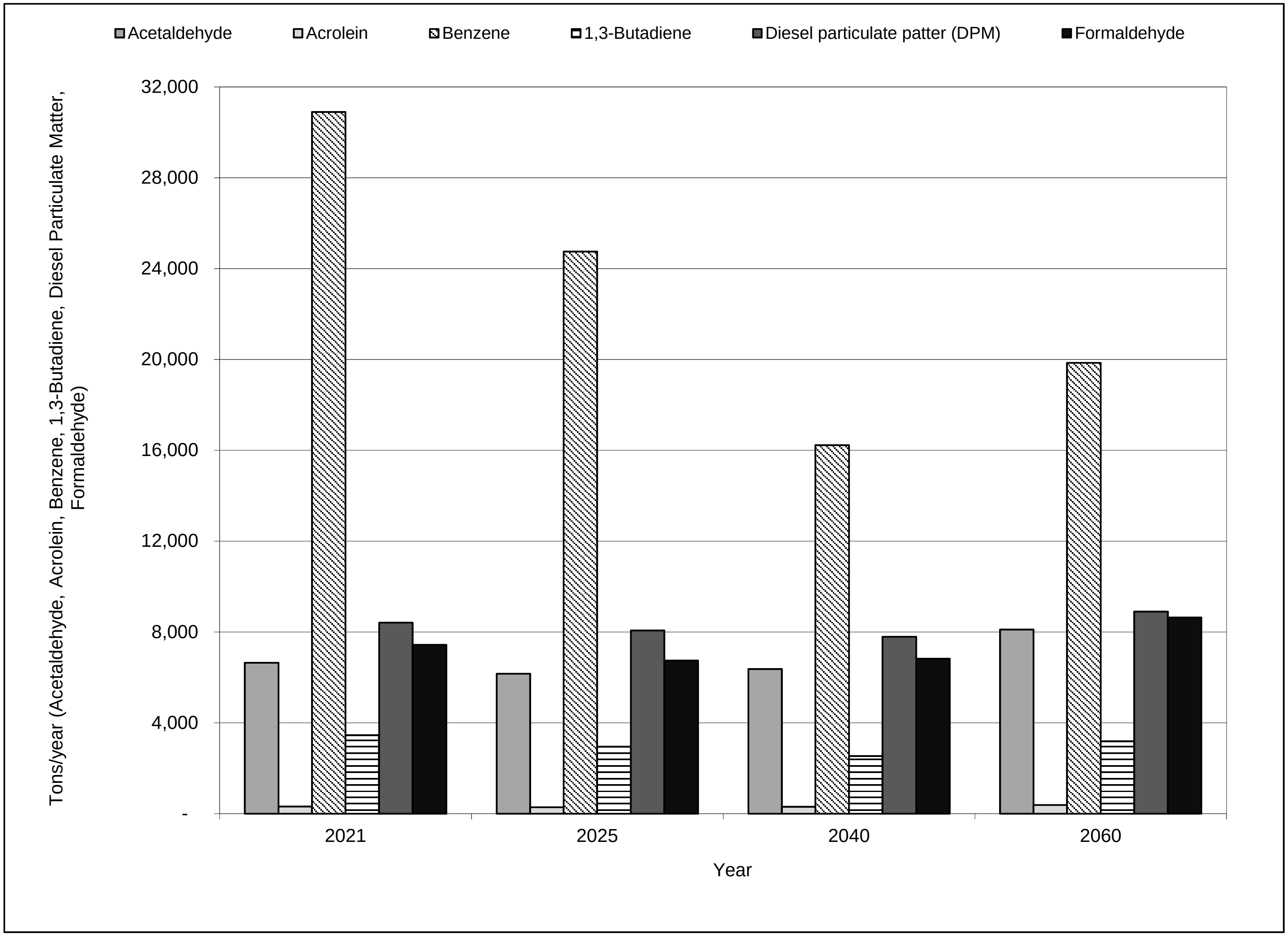


Table 4.2.1-5-A1. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A1[a,b]

Pollutant and Year	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	0	4	6	26
2025	0	9	16	58
2040	0	52	61	-183
2060	0	127	164	-211
Acrolein				
2021	0	0	0	3
2025	0	-1	0	16
2040	0	1	2	70
2060	0	5	6	112
Benzene				
2021	0	-32	-43	-134
2025	0	-68	-105	-497
2040	0	-104	-246	-3,148
2060	0	-5	-149	-4,655
1,3-Butadiene				
2021	0	2	2	4
2025	0	4	6	-11
2040	0	22	25	-261
2060	0	53	66	-382
Diesel particulate matter (DPM)				
2021	0	-266	-351	-555
2025	0	-595	-873	-873
2040	0	-1,514	-2,397	-726
2060	0	-2,046	-3,268	-334
Formaldehyde				
2021	0	-11	-12	65
2025	0	-22	-25	320
2040	0	-28	-41	1,444
2060	0	19	24	2,364

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

Table 4.2.1-5-A2. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis A2[a,b]

Pollutant and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Acetaldehyde				
2021	0	5	7	28
2025	0	13	22	68
2040	0	61	116	-18
2060	0	128	232	46
Acrolein				
2021	0	1	1	4
2025	0	0	1	16
2040	0	3	9	73
2060	0	6	16	112
Benzene				
2021	0	-29	-41	-121
2025	0	-57	-97	-429
2040	0	-64	-178	-2,572
2060	0	30	-66	-3,573
1,3-Butadiene				
2021	0	3	2	4
2025	0	5	8	-3
2040	0	25	37	-185
2060	0	50	77	-251
Diesel particulate matter (DPM)				
2021	0	-246	-345	-484
2025	0	-534	-811	-752
2040	0	-1,269	-1,944	-421
2060	0	-1,604	-2,431	99
Formaldehyde				
2021	0	-6	-9	69
2025	0	-11	-6	317
2040	0	9	114	1,521
2060	0	61	258	2,374

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

Table 4.2.1-5-B1. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B1[a,b]

Pollutant and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Acetaldehyde				
2021	0	3	4	27
2025	0	6	10	64
2040	0	21	-1	-132
2060	0	-9	-38	-260
Acrolein				
2021	0	0	0	5
2025	0	0	0	20
2040	0	0	0	79
2060	0	-1	-1	120
Benzene				
2021	0	-16	-30	-135
2025	0	-38	-82	-496
2040	0	-39	-260	-3,017
2060	0	-34	-298	-4,593
1,3-Butadiene				
2021	0	2	2	2
2025	0	2	4	-12
2040	0	9	-1	-257
2060	0	-3	-18	-427
Diesel particulate matter (DPM)				
2021	0	-145	-244	-391
2025	0	-348	-637	-540
2040	0	-608	-1,507	532
2060	0	-91	-1,027	2,603
Formaldehyde				
2021	0	-6	-7	93
2025	0	-14	-19	386
2040	0	-12	-55	1,676
2060	0	-13	-52	2,655

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

Table 4.2.1-5-B2. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis B2[a,b]

Pollutant and Year	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	0	2	7	30
2025	0	6	20	76
2040	0	27	67	26
2060	0	1	68	8
Acrolein				
2021	0	1	1	5
2025	0	0	2	19
2040	0	0	7	92
2060	0	0	11	139
Benzene				
2021	0	-16	-34	-117
2025	0	-34	-88	-429
2040	0	-15	-195	-2,781
2060	0	-5	-197	-4,024
1,3-Butadiene				
2021	0	1	2	3
2025	0	2	5	-6
2040	0	12	16	-210
2060	0	1	7	-333
Diesel particulate matter (DPM)				
2021	0	-139	-214	-330
2025	0	-329	-561	-431
2040	0	-538	-1,130	1,140
2060	0	-66	-529	3,268
Formaldehyde				
2021	0	-5	6	94
2025	0	-12	19	382
2040	0	-2	122	2,006
2060	0	-1	213	3,052

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

Figure 4.2.1-6-A1 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis A1

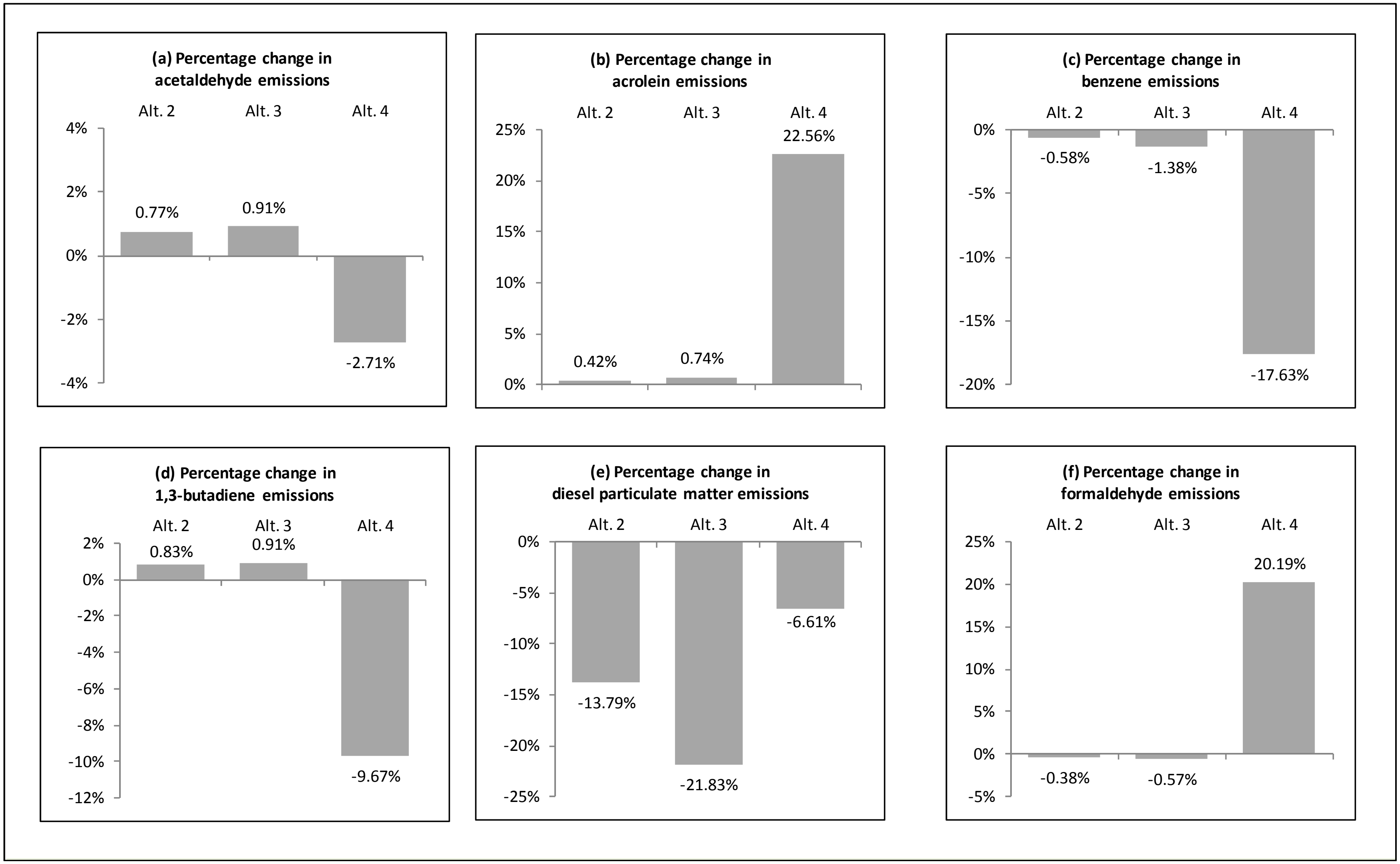


Figure 4.2.1-6-A2 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis A2

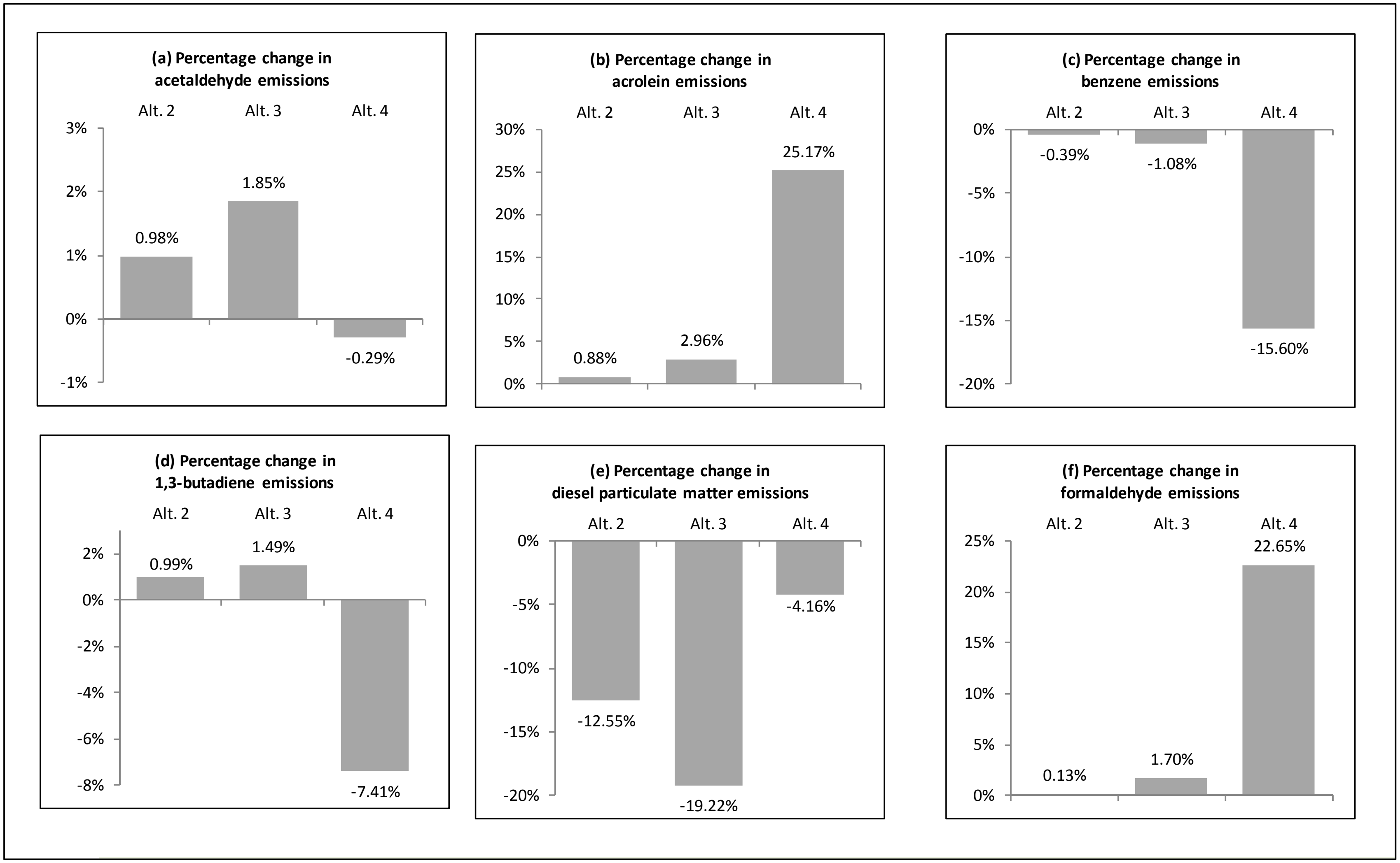


Figure 4.2.1-6-B1 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis B1

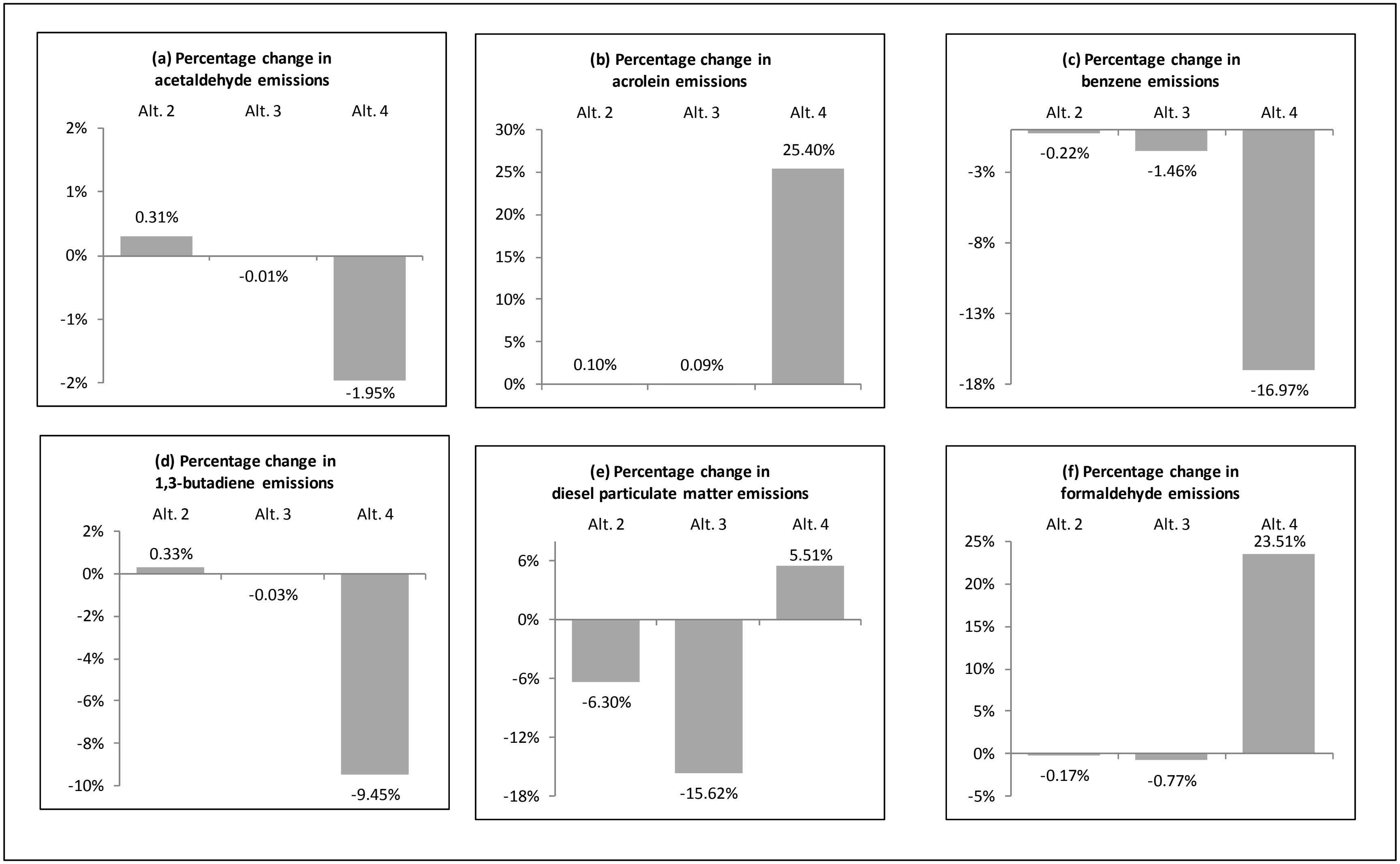
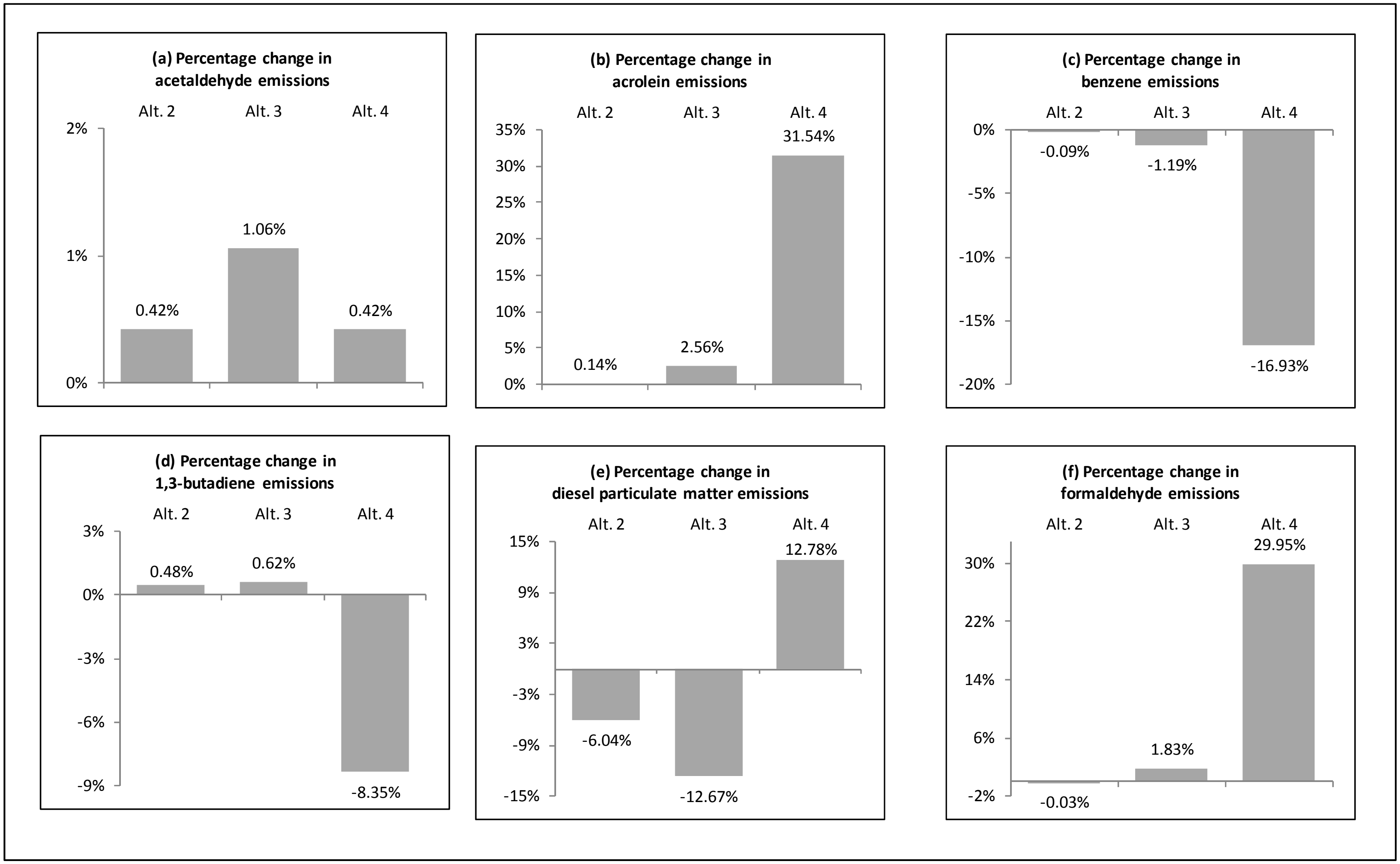


Figure 4.2.1-6-B2 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis B2



Tables 4.2.1-6-A1 and -A2 and 4.2.1-6-B1 and -B2 summarize the air toxics analysis results by nonattainment area.[48] Tables in Appendix B list the estimated emission changes for each nonattainment area. For acetaldehyde (except under Alternative 4 in 2040 and 2060), acrolein, DPM, and formaldehyde, most nonattainment areas experience increases in emissions across all years under all alternatives. For benzene and 1,3-butadiene the results are mixed. As the stringency of the alternative increases, the number of nonattainment areas that experience increases in emissions of benzene and 1,3-butadiene becomes fewer, and the number that experience decreases becomes greater.

Table 4.2.1-6-A1. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis A1[a]

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Acetaldehyde	Maximum Increase	8	2060	3	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
	Maximum Decrease	-18	2060	4	Houston-Galveston-Brazoria, TX (O3)
Acrolein	Maximum Increase	6	2060	4	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
	Maximum Decrease	-1	2060	4	Beaumont-Port Arthur, TX (O3)
Benzene	Maximum Increase	16	2060	3	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
	Maximum Decrease	-191	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O3, PM2.5)
1,3-Butadiene	Maximum Increase	3	2060	3	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
	Maximum Decrease	-18	2060	4	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
Diesel particulate matter (DPM)	Maximum Increase	177	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O3, PM2.5)
	Maximum Decrease	-424	2060	4	Houston-Galveston-Brazoria, TX (O3)
Formaldehyde	Maximum Increase	129	2060	4	Los Angeles South Coast Air Basin, CA (CO, NOx, O3, PM10, PM2.5)
	Maximum Decrease	-94	2060	4	Houston-Galveston-Brazoria, TX (O3)

a. Emissions changes are rounded to the nearest whole number.

[48] EPA has not established NAAQS for airborne toxics. Therefore, none of these areas is classified as a nonattainment area as a result of airborne toxics emissions. Toxic air pollutant emissions data for nonattainment areas are provided for information only.

Table 4.2.1-6-A2. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis A2[a]

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Acetaldehyde	Maximum Increase	12	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-11	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Acrolein	Maximum Increase	6	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-1	2060	4	Beaumont-Port Arthur, TX (O_3)
Benzene	Maximum Increase	16	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-146	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	4	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-12	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	163	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-345	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Formaldehyde	Maximum Increase	127	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-71	2060	4	Houston-Galveston-Brazoria, TX (O_3)

a. Emissions changes are rounded to the nearest whole number.

Table 4.2.1-6-B1. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis B1[a]

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Acetaldehyde	Maximum Increase	3	2025	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-12	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Acrolein	Maximum Increase	6	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-1	2040	4	Beaumont-Port Arthur, TX (O_3)
Benzene	Maximum Increase	2	2040	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-197	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	<1	2040	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-20	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	209	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-215	2040	4	Houston-Galveston-Brazoria, TX (O_3)
Formaldehyde	Maximum Increase	135	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-47	2040	4	Houston-Galveston-Brazoria, TX (O_3)

a. Emissions changes are rounded to the nearest whole number.

Table 4.2.1-6-B2. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis B2[a]

Hazardous Air Pollutant	Maximum Increase/ Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Acetaldehyde	Maximum Increase	4	2025	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-6	2040	4	Houston-Galveston-Brazoria, TX (O_3)
Acrolein	Maximum Increase	7	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-1	2040	4	Beaumont-Port Arthur, TX (O_3)
Benzene	Maximum Increase	3	2040	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-173	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	1	2040	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-16	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	220	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-178	2040	4	Houston-Galveston-Brazoria, TX (O_3)
Formaldehyde	Maximum Increase	153	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-35	2040	3	Houston-Galveston-Brazoria, TX (O_3)

a. Emissions changes are rounded to the nearest whole number.

4.2.1.1.3 Health Effects and Monetized Health Benefits Overview

Under Analysis A, adverse health effects would decrease nationwide under each of the action alternatives compared to the No Action Alternative (*see* Tables 4.2.1-7-A1 and -A2). As described in Section 4.1.2.7.2, the changes in PM mortality shown in these tables are measured in several ways; benefits are measured under the Pope methodology and the Laden methodology and at discount rates of 3 and 7 percent (*see* Section 4.1.2.7.2). While the number of PM mortalities varies between the two methods, the percent change in mortality across alternatives and years is equal. The tables in this section include the Base Grid Mix (used throughout this EIS), which is based on NEMS AEO 2012 Early Release version fuel mix and emissions projections for 2020, which do not include the Mercury and Air Toxics Standards issued by the EPA in December 2011. These numbers are followed by a slash and then projections using the Alternate Grid Mix (full results are in Appendix H), which is based on the fuel mix and emissions projections of the cleaner "GHG Price Economy-Wide" emissions side case from AEO 2011 for 2035.

In Analysis A, the health benefits across all outcomes increase from Alternative 2 to the Preferred Alternative and from near-future (2021) to later years (2060). Under Alternative 4 in the later years, benefits are generally greater than under Alternative 2 but less than under the Preferred Alternative.

Table 4.2.1-7-A1. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis A1[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-34/-35	-47/-48	-85/-92
2025	0	-77/-81	-120/-120	-100/-170
2040	0	-210/-230	-320/-360	-100/-460
2060	0	-260/-290	-390/-450	-91/-610
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-88/-91	-120/-120	-220/-240
2025	0	-200/-210	-300/-310	-260/-430
2040	0	-550/-590	-810/-920	-260/-1,200
2060	0	-680/-740	-990/-1,200	-230/-1,600
Chronic bronchitis				
2021	0	-23/-24	-32/-33	-58/-63
2025	0	-52/-55	-78/-82	-68/-110
2040	0	-140/-150	-200/-230	-66/-300
2060	0	-170/-180	-240/-290	-61/-390
Emergency room visits for asthma				
2021	0	-32/-34	-45/-46	-81/-87
2025	0	-72/-76	-110/-110	-93/-150
2040	0	-190/-200	-280/-320	-64/-370
2060	0	-240/-260	-350/-400	-46/-490
Work-loss days				
2021	0	-4,400/-4,500	-6,100/-6,200	-11,000/-12,000
2025	0	-9,500/-10,000	-14,000/-15,000	-13,000/-21,000
2040	0	-24,000/-25,000	-35,000/-40,000	-12,000/-51,000
2060	0	-29,000/-32,000	-42,000/-50,000	-11,000/-68,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.1-7-A2. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis A2[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-35/-35	-49/-49	-81/-86
2025	0	-78/-79	-120/-120	-120/-170
2040	0	-210/-210	-350/-360	-220/-470
2060	0	-240/-250	-410/-420	-250/-590
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-91/-91	-130/-130	-210/-220
2025	0	-200/-200	-310/-320	-310/-430
2040	0	-530/-540	-890/-910	-570/-1,200
2060	0	-610/-630	-1,100/-1,100	-640/-1,500
Chronic bronchitis				
2021	0	-24/-24	-34/-34	-56/-59
2025	0	-53/-53	-82/-83	-82/-110
2040	0	-130/-130	-220/-230	-140/-300
2060	0	-150/-160	-260/-270	-160/-380
Emergency room visits for asthma				
2021	0	-34/-34	-47/-47	-77/-82
2025	0	-73/-74	-110/-120	-110/-150
2040	0	-180/-190	-310/-310	-180/-390
2060	0	-220/-220	-370/-380	-200/-480
Work-loss days				
2021	0	-4,500/-4,500	-6,300/-6,300	-10,000/-11,000
2025	0	-9,600/-9,700	-15,000/-15,000	-15,000/-21,000
2040	0	-23,000/-23,000	-38,000/-39,000	-25,000/-52,000
2060	0	-26,000/-27,000	-45,000/-46,000	-28,000/-65,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.1-7-B1. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis B1[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-19/-19	-33/-33	-61/-70
2025	0	-44/-47	-78/-86	-63/-130
2040	0	-77/-88	-140/-200	7/-310
2060	0	12/-1	-25/-110	145/-290
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-48/-50	-83/-85	-160/-180
2025	0	-110/-120	-200/-220	-160/-320
2040	0	-200/-230	-350/-510	16/-800
2060	0	31/-3	-64/-270	371/-740
Chronic bronchitis				
2021	0	-13/-13	-22/-23	-42/-48
2025	0	-30/-31	-53/-58	-43/-86
2040	0	-49/-56	-86/-130	2/-200
2060	0	8/-1	-16/-67	88/-190
Emergency room visits for asthma				
2021	0	-18/-18	-31/-32	-58/-67
2025	0	-41/-44	-73/-80	-58/-120
2040	0	-69/-78	-120/-170	29/-240
2060	0	10/-1	-22/-90	168/-200
Work-loss days				
2021	0	-2,400/-2,500	-4,200/-4,300	-7,800/-9,000
2025	0	-5,400/-5,800	-9,700/-11,000	-7,800/-16,000
2040	0	-8,500/-9,700	-15,000/-22,000	125/-35,000
2060	0	1,310/-140	-2,800/-12,000	15,000/-33,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.1-7-B2. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis B2[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Preferred (Base Grid Mix/ Alternate Grid Mix)	7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-20/-20	-34/-34	-62/-68
2025	0	-46/-47	-90/-92	-86/-130
2040	0	-77/-83	-190/-210	-92/-330
2060	0	4/-2	-90/-120	8/-290
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-50/-50	-87/-87	-160/-170
2025	0	-120/-120	-230/-240	-220/-340
2040	0	-200/-210	-490/-550	-240/-840
2060	0	11/-6	-230/-310	19/-750
Chronic bronchitis				
2021	0	-13/-13	-23/-23	-42/-46
2025	0	-31/-32	-60/-62	-58/-89
2040	0	-49/-53	-120/-140	-60/-210
2060	0	3/-2	-57/-76	2/-190
Emergency room visits for asthma				
2021	0	-19/-19	-32/-32	-58/-64
2025	0	-43/-44	-83/-85	-79/-120
2040	0	-69/-73	-170/-190	-62/-260
2060	0	3/-2	-80/-110	38/-220
Work-loss days				
2021	0	-2,500/-2,500	-4,300/-4,400	-7,900/-8,700
2025	0	-5,700/-5,800	-11,000/-11,000	-11,000/-16,000
2040	0	-8,500/-9,100	-21,000/-23,000	-11,000/-36,000
2060	0	460/-260	-9,900/-13,000	191/-33,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

In Analysis B, adverse health effects decrease compared to the No Action Alternative under Alternative 2 (except in 2060), the Preferred Alternative, and Alternative 4 (except in 2040 and 2060 in Analysis B1 and 2060 in Analysis B2). Adverse health effects increase compared to the No Action Alternative under Alternative 2 (in 2060) and Alternative 4 (in 2040 and 2060 in Analysis B1 and 2060 in Analysis B2) (*see* Tables 4.2.1-7-B1 and -B2). These increases in adverse health effects are due to emission increases that occur in later years as a result of 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.

In Analysis B, as described above, health benefits increase for most alternatives under most analyses and years, except under Alternative 2 in 2060 and Alternative 4 in 2040 and/or 2060. As a result, the health benefits in Analysis B after 2021 are greatest under the Preferred Alternative.

The monetized health benefits follow similar trends to the changes in health outcomes. Tables 4.2.1-8-A1 and -A2 and 4.2.1-8-B1 and -B2 list the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative. In Analysis A in 2021, the monetized health benefits of each action alternative generally increase from Alternative 2 (least stringent) to Alternative 4 (most stringent). After 2021, the monetized health benefits generally increase from Alternative 2 to the Preferred Alternative. However, after 2021, the greater benefits between Alternative 2 and Alternative 4 depend on the emissions case. As in Analysis A, the monetized health benefits in Analysis B in 2021 increase from Alternative 2 (least stringent) to Alternative 4 (most stringent). Because Analysis B projections made with the Base Grid Mix indicated adverse health effects would increase under Alternative 2 in 2060 and under Alternative 4 in 2040 and/or 2060, there would be corresponding monetized health costs under these alternatives for these years. Monetized health benefits were indicated for all alternatives under all analyses and years using the Alternate Grid Mix.

Monetized health benefits are measured in several ways; benefits are measured under the Pope methodology and the Laden methodology and at discount rates of 3 and 7 percent (*see* Section 4.1.2.7.2).

Sections 4.2.1.2 through 4.2.1.5 describe the results of the analysis of emissions for Alternatives 1 through 4 in more detail. The magnitude of emissions change from one alternative to the next generally increases, with a number of exceptions that are discussed in these sections, between Alternative 2 and Alternative 4 consistent with increases in overall fuel economy.

Table 4.2.1-8-A1. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A1[a], Base Grid Mix and Alternate Grid Mix[b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton assuming premature mortality based on Pope et al. (2002)				
2021	$0	$250/260	$350/360	$630/680
2025	$0	$570/610	$860/910	$750/1,200
2040	$0	$1,700/1,800	$2,500/2,800	$830/3,600
2060	$0	$2,100/2,300	$3,000/3,600	$770/4,800
Benefits-per-ton assuming premature mortality based on Laden et al. (2006)				
2021	$0	$620/640	$860/870	$1,600/1,700
2025	$0	$1,400/1,500	$2,100/2,200	$1,800/3,000
2040	$0	$4,100/4,500	$6,100/6,900	$2,000/8,900
2060	$0	$5,100/5,600	$7,400/8,700	$1,900/12,000
7-Percent Discount Rate				
Benefits-per-ton assuming premature mortality based on Pope et al. (2002)				
2021	$0	$230/230	$310/320	$560/610
2025	$0	$510/540	$770/810	$670/1,100
2040	$0	$1,500/1,700	$2,300/2,600	$750/3,300
2060	$0	$1,900/2,100	$2,800/3,200	$690/4,400
Benefits-per-ton assuming premature mortality based on Laden et al. (2006)				
2021	$0	$550/570	$770/780	1,400/1,500
2025	$0	$1,300/1,300	$1,900/2,000	1,700/2,700
2040	$0	$3,800/4,100	$5,500/6,300	1,800/8,100
2060	$0	$4,600/5,100	$6,800/7,900	1,700/11,000

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.1-8-A2. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A2[a], Base Grid Mix and Alternate Grid Mix[b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton assuming premature mortality based on Pope et al. (2002)				
2021	$0	$260/260	$360/360	$600/640
2025	$0	$580/590	$920/920	$910/1,300
2040	$0	$1,600/1,700	$2,700/2,800	$1,800/3,700
2060	$0	$1,900/1,900	$3,200/3,300	$2,000/4,600
Benefits-per-ton assuming premature mortality based on Laden et al. (2006)				
2021	$0	$640/640	$890/890	$1,500/1,600
2025	$0	$1,400/1,400	$2,200/2,300	$2,200/3,100
2040	$0	$4,000/4,100	$6,700/6,800	$4,400/9,100
2060	$0	$4,600/4,800	$7,900/8,100	$4,900/11,000
7-Percent Discount Rate				
Benefits-per-ton assuming premature mortality based on Pope et al. (2002)				
2021	$0	$230/230	$320/320	$540/570
2025	$0	$520/530	$820/830	$820/1,100
2040	$0	$1,500/1,500	$2,500/2,500	$1,600/3,400
2060	$0	$1,700/1,800	$2,900/3,000	$1,800/4,200
Benefits-per-ton assuming premature mortality based on Laden et al. (2006)				
2021	$0	$570/570	$790/800	$1,300/1,400
2025	$0	$1,300/1,300	$2,000/2,000	$2,000/2,800
2040	$0	$3,600/3,700	$6,100/6,200	$4,000/8,300
2060	$0	$4,200/4,300	$7,200/7,400	$4,500/10,000

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.1-8-B1. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B1[a], Base Grid Mix and Alternate Grid Mix[b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$140/140	$240/250	$450/520
2025	$0	$330/350	$590/640	$470/950
2040	$0	$610/690	$1,100/1,600	$-16/2,500
2060	$0	$-93/10	$210/830	$-1,100/2,300
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$340/350	$590/600	$1,100/1,300
2025	$0	$810/860	$1,400/1,600	$1,200/2,300
2040	$0	$1,500/1,700	$2,600/3,800	$-40/6,100
2060	$0	$-230/25	$500/2,000	$-2,700/5,600
7-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$120/130	$220/220	$400/470
2025	$0	$290/310	$520/570	$420/850
2040	$0	$550/630	$970/1,400	$-19/2,300
2060	$0	$-84/9	$190/760	$-1,000/2,100
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$300/310	$530/540	$990/1,100
2025	$0	$720/770	$1,300/1,400	$1,000/2,100
2040	$0	$1,400/1,500	$2,400/3,500	$-48/5,500
2060	$0	$-210/23	$460/1,800	$-2,500/5,100

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.

b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.

c. 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.

Table 4.2.1-8-B2. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B2[a], Base Grid Mix and Alternate Grid Mix[b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix / Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$150/150	$250/250	$460/500
2025	$0	$350/350	$670/690	$640/990
2040	$0	$610/650	$1,500/1,700	$750/2,600
2060	$0	$-32/19	$710/950	$-25/2,300
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$360/360	$620/620	$1,100/1,200
2025	$0	$850/860	$1,600/1,700	$1,600/2,400
2040	$0	$1,500/1,600	$3,700/4,100	$1,800/6,300
2060	$0	$-79/47	$1,700/2,300	$-62/5,700
7-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$130/130	$220/220	$410/450
2025	$0	$310/320	$600/610	$570/880
2040	$0	$550/590	$1,400/1,500	$680/2,300
2060	$0	$-29/17	$640/860	$-31/2,100
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$320/320	$550/550	$1,000/1,100
2025	$0	$760/770	$1,500/1,500	$1,400/2,200
2040	$0	$1,400/1,400	$3,300/3,700	$1,700/5,800
2060	$0	$-71/42	$1,600/2,100	$-75/5,200

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

4.2.1.2 Alternative 1: No Action

4.2.1.2.1 Criteria Pollutants

Under the No Action Alternative in Analysis A, there is no change after 2016 in the forecast for new vehicle passenger car and light-truck fuel economy. The No Action Alternative in Analysis B shows market-based gains in new vehicle passenger car and light-truck fuel economy after 2016. Current trends in the levels of criteria pollutant emissions from vehicles would continue under the No Action Alternative in Analyses A and B, with emissions of NO_x and VOCs continuing to decline due to the EPA emission standards (*see* Section 4.1), despite a growth in total VMT from 2021 to 2040, but increasing from 2040 to 2060 due to growth in total VMT during that period overwhelming the initial decreases (*see* Tables 4.2.1-1-A1 and -A2 and 4.2.1-1-B1 and -B2 and Figures 4.2.1-1-A1 and -A2 and 4.2.1-1-B1 and -B2). Emissions of CO, $PM_{2.5}$, and SO_2 are predicted to increase from 2021 to 2060 because declines due to the EPA emission standards are more than offset by growth in VMT beginning before 2021. The No Action Alternative would not change these trends and therefore would not result in any change in criteria pollutant emissions nationally or in nonattainment areas beyond changes projected to result from future trends in emissions and VMT (*see* Tables 4.2.1-1-A1 and -A2 and 4.2.1-1-B1 and -B2).

Emissions of CO under the No Action Alternative are generally less than emissions under Alternative 2 and the Preferred Alternative, but generally greater than emissions under Alternative 4. Emissions of NO_x and SO_2 under the No Action Alternative are generally greater than emissions under Alternative 2 and the Preferred Alternative, but less than emissions under Alternative 4. Emissions of $PM_{2.5}$ and VOCs under the No Action Alternative are greater than emissions under all action alternatives. For all analyses, changes in emissions of all criteria pollutants are generally greatest in 2060 under Alternative 4, in which emissions range up to 80 percent greater or 26 percent less than under the No Action Alternative.

4.2.1.2.2 Toxic Air Pollutants

EPA regulates toxic air pollutants from motor vehicles through vehicle emission standards and fuel quality standards, as discussed in Section 4.1.1. As with the criteria pollutants, current trends in the levels of toxic air pollutant emissions from vehicles would continue under the No Action Alternative. In both Analysis A and Analysis B, emissions (except DPM) would continue to decline in early years due to the EPA emission standards (*see* Section 4.1.1) despite a growth in total VMT, reaching a minimum in 2025 or 2040 (depending on the pollutant), but increasing in 2060 due to growth in total VMT during that period overwhelming the initial decreases (*see* Tables 4.2.1-4-A1 and -A2 and 4.2.1-4-B1 and -B2 and Figures 4.2.1-4-A1 and -A2 and 4.2.1-4-B1 and -B2). DPM emissions are lowest in 2021 and increase through 2060. The No Action Alternative would not change the current CAFE standards and therefore would not result in any change in toxic air pollutant emissions throughout the United States beyond projected trends shown for the No Action Alternative in Tables 4.2.1-4-A1 and -A2 and 4.2.1-4-B1 and -B2.

Emissions under the No Action Alternative are generally less than emissions under each of the action alternatives for acrolein and acetaldehyde, but greater for benzene and DPM (except for Alternative 4 in later years of Analysis B). Results are mixed for 1,3-butadiene and formaldehyde. Under the No Action Alternative, emissions of 1,3-butadiene will generally be lower than under Alternative 2 and the Preferred Alternative for most analysis years, but higher than under Alternative 4.

Conversely, for formaldehyde, emissions under the No Action Alternative are lower or higher than under Alternative 2 and the Preferred Alternative (depending on year and analysis), but lower than under Alternative 4. For all analyses, changes in emissions of all toxic air pollutants are generally greatest in 2060 under Alternative 4, in which emissions range up to 37 percent greater or less than under the No Action Alternative.

4.2.1.2.3 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 of most criteria pollutants decreasing initially and then increasing to 2060 due to growth in total VMT, which more than offsets reductions due to the EPA vehicle emission standards (*see* Section 4.1.1). In both Analysis A and Analysis B, the human health-related trends would continue (*see* Tables 4.2.1-7-A1 and -A2, 4.2.1-7-B1 and -B2, 4.2.1-8-A1 and -A2, and 4.2.1-8-B1 and -B2). The No Action Alternative would not result in any additional increase or decrease in human health effects throughout the United States.

4.2.1.3 Alternative 2: 2 Percent per Year Increase in Fuel Economy

4.2.1.3.1 Criteria Pollutants

Tables 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 show the changes in nationwide emissions of criteria pollutants under Alternative 2 compared to the No Action Alternative and the action alternatives. Figures 4.2.1-3-A1 and -A2 and 4.2.1-3-B1 and -B2 show these changes in percentages for 2040. Under Alternative 2, nationwide emissions of $PM_{2.5}$, NO_x, SO_2, and VOCs decrease compared to the No Action Alternative (except under Analyses B1 and B2, in which emissions would increase for NO_x and SO_2 in 2060). Alternative 2 is the least stringent of all the action alternatives, and the emission reductions under Alternative 2 are less than those under the Preferred Alternative and Alternative 4 for $PM_{2.5}$ and VOCs, but larger than those under Alternative 4 for CO, NO_x, and SO_2 after 2021. Emissions of CO increase under Alternative 2 compared to the No Action Alternative in all years (except under Analysis B1 in 2060) because declines due to EPA's emission standards and greater fuel economy are more than offset by growth in VMT.

Under Alternative 2, all nonattainment areas would experience reductions in emissions of SO_2 in 2021 through 2040, and most would experience reductions in emissions of VOCs in all years and SO_2 in 2060, compared to the No Action Alternative. Most nonattainment areas would experience slight increases in CO, NO_x, and $PM_{2.5}$ emissions (except for Analysis B1 in 2060, in which most nonattainment areas would experience slight decreases in these emissions). Emissions increases are due to the rebound effect, which more than offsets emission reductions from decreased fuel usage. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.1.3.2 Toxic Air Pollutants

Tables 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 show the changes in nationwide emissions of toxic air pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figures 4.2.1-6-A1 and -A2 and 4.2.1-6-B1 and -B2 show these changes in percentages for 2040. Compared to the No Action Alternative, Alternative 2 would generally result in reduced emissions of benzene (except in 2060 in Analysis A2), DPM, and formaldehyde (except in 2060 in Analysis A1 and 2040 and 2060 in Analysis A2) and increased emissions (except in 2060 in Analysis B1) of acetaldehyde, acrolein, and 1,3-butadiene. Alternative 2 would generally result in lower emissions than would the other action alternatives for acetaldehyde (except for Alternative 4 in 2040 and 2060), acrolein, and formaldehyde (except for the Preferred Alternative in Analyses A2 and B2 in some analysis years). Alternative 2 would result in generally higher emissions of benzene and DPM (except for Alternative 4 in some analysis years). Alternative 2 would have generally lower emissions of 1,3-butadiene than the Preferred Alternative and generally higher emissions than Alternative 4.

At the national level, emissions of all toxic air pollutants could increase because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. However, the increases in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 2, most nonattainment areas would experience net increases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix B).

4.2.1.3.3 Health Outcomes and Monetized Benefits

In the Base Grid Mix, in Analysis A, adverse health effects nationwide would be reduced under Alternative 2 compared to the No Action Alternative (*see* Tables 4.2.1-7-A1 and -A2). These health benefits would increase greatly from 2021 to 2060. In Analysis B, adverse health impacts would be reduced in 2021 through 2040 but increase in 2060 compared to the No Action Alternative (*see* Tables 4.2.1-7-B1 and -B2). In the Alternate Grid Mix, adverse health impacts would be reduced in all years in Analysis A and Analysis B. In Analysis A, these reductions would increase steadily from 2021 to 2060. In Analysis B, these reductions would increase through 2040. The reductions in 2060 would be less than in any other year.

As shown in Tables 4.2.1-8-A1 and -A2 and 4.2.1-8-B1 and -B2, the monetized health impacts under Alternative 2 would range from a maximum benefit of $5.6 billion to a maximum negative impact of $227 million, depending on grid mix, analysis, and year. In the Base Grid Mix case, in Analysis A, monetized benefits would increase steadily from 2021 through 2060. In Analysis B, monetized benefits would increase from 2021 through 2040; however, in 2060, there would be a negative monetary impact. In the Alternate Grid Mix case, monetized benefits would accrue in Analyses A and B in all analysis years.

4.2.1.4 Alternative 3: Preferred

4.2.1.4.1 Criteria Pollutants

Tables 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 show the changes in nationwide emissions of criteria pollutants under the Preferred Alternative compared to the No Action Alternative and the other action alternatives. Figures 4.2.1-3-A1 and -A2 and 4.2.1-3-B1 and -B2 show these changes in percentages for 2040. Figures 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 show criteria pollutant emissions under the Preferred Alternative by year. Under this alternative, emissions of all pollutants except CO decrease compared to the No Action Alternative (except for SO_2 in 2040 and 2060 in Analyses B1 and B2). CO emissions increase compared to the No Action Alternative (except in 2060 under Analysis B1) because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT. This alternative generally reduces emissions more than Alternative 2. Emissions under the Preferred Alternative are less than under Alternative 2 for NO_x, $PM_{2.5}$, SO_2, and VOCs, and greater than under Alternative 2 for CO (except under Analysis B1 in later years). Emissions under the Preferred

Alternative are greater than under Alternative 4 for CO, $PM_{2.5}$, and VOCs, and less than under Alternative 4 for NO_x and SO_2 (after 2025).

Under the Preferred Alternative, almost all nonattainment areas would experience reductions in emissions of SO_2 and VOCs. Most nonattainment areas would experience increases in emissions of CO in all years and $PM_{2.5}$ and NO_x in all years except 2060 in Analyses B1 and B2. The increases in CO and $PM_{2.5}$ emissions occur because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT. The increases in NO_x emissions are due to increases in the diesel vehicle share of total VMT. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.1.4.2 Toxic Air Pollutants

Tables 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 show the changes in nationwide emissions of toxic air pollutants under the Preferred Alternative compared to the No Action Alternative and the other action alternatives. Figures 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 show toxic pollutant emissions under the Preferred Alternative by year. Figures 4.2.1-6-A1 and -A2 and 4.2.1-6-B1 and -B2 shows these changes in percentage terms for 2040. Compared to the No Action Alternative, the Preferred Alternative would generally result in reduced emissions of benzene and DPM and increased emissions (except in Analysis B1 after 2040) of acetaldehyde, acrolein and 1,3-butadiene. Formaldehyde emissions under the Preferred Alternative increase or decrease compared to the No Action Alternative, depending on analysis and year. Emissions under the Preferred Alternative are greater than under Alternative 2 (except in Analysis B1 after 2025) for acetaldehyde and acrolein, but lower for benzene and DPM. Results are mixed for formaldehyde. Compared to Alternative 4, emissions under the Preferred Alternative would be generally lower for acetaldehyde (before 2040), acrolein, and DPM (except in 2021), and formaldehyde, but generally higher for benzene and 1,3-butadiene (except in 2021).

At the national level, emissions of most toxic air pollutants could increase because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. However, as for less-stringent alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under the Preferred Alternative, most nonattainment areas would experience net increases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix B).

4.2.1.4.3 Health Outcomes and Monetized Benefits

In all analyses, reductions in adverse health effects would occur nationwide under the Preferred Alternative compared to the No Action Alternative (*see* Tables 4.2.1-7-A1 and -A2 and 4.2.1-7-B1 and -B2). These health benefits generally increase from 2021 to 2060. These trends occur in both the Base Grid Mix and the Alternate Grid Mix.

As shown in Tables 4.2.1-8-A1 and -A2 and 4.2.1-8-B1 and -B2, the monetized health benefits under the Preferred Alternative would range from \$190 million to \$8.7 billion across all analyses. In the Base Grid Mix, these monetized benefits are greater than those in all other analyses. In the Alternate Grid Mix, the monetized benefits under the Preferred Alternative are generally greater than those under Alternative 2 but less than those under Alternative 4.

4.2.1.5 Alternative 4: 7 Percent per Year Increase in Fuel Economy

4.2.1.5.1 Criteria Pollutants

Tables 4.2.1-2-A1 and -A2 and 4.2.1-2-B1 and -B2 show the changes in nationwide emissions of criteria pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figures 4.2.1-3-A1 and -A2 and 4.2.1-3-B1 and -B2 show these changes in percentages for 2040. Under Alternative 4, nationwide emissions of CO (after 2021), VOCs, and $PM_{2.5}$ compared to the No Action Alternative would be reduced because of EPA emission standards and greater fuel economy, despite an increase in VMT. Emissions of NO_x and SO_2 decrease in 2021 before reaching a minimum between 2025 and 2040, and then increase compared to the No Action Alternative. The reductions and increases compared to the No Action Alternative are of a greater (and sometimes opposite) magnitude than the relative reductions or increases under Alternative 2 and the Preferred Alternative.

Under Alternative 4, all nonattainment areas would experience reductions in emissions of $PM_{2.5}$ and VOCs for all years. Most nonattainment areas would experience increases in NO_x emissions in all years. Most nonattainment areas would see decreases in CO and SO_2 emissions in all years (except CO in 2021 in Analyses A1 and A2). The increases in NO_x emissions in some nonattainment areas are due to the EPA emission standards and greater fuel economy being more than offset by growth in VMT. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.1.5.2 Toxic Air Pollutants

Tables 4.2.1-5-A1 and -A2 and 4.2.1-5-B1 and -B2 show the changes in nationwide emissions of toxic air pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figures 4.2.1-6-A1 and -A2 and 4.2.1-6-B1 and -B2 show these changes in percentages for 2040. Compared to the No Action Alternative, Alternative 4 would result in reduced emissions of benzene and 1,3-butadiene (except in 2021), and DPM (except in 2040 and 2060 in some analyses), and in increased emissions of acrolein and formaldehyde. Under Alternative 4, emissions of benzene and 1,3-butadiene (after 2021) are less than under all other action alternatives. Emissions of acrolein, DPM (after 2040), and formaldehyde are higher than under all other action alternatives.

At the national level, as with the less-stringent alternatives, emissions of most toxic air pollutants could increase because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. Under Alternative 4, nonattainment areas would experience net increases in emissions of most toxic air pollutants except for benzene in all analysis years and 1,3-butadiene after 2021 (*see* Appendix B).

4.2.1.5.3 Health Outcomes and Monetized Benefits

In the Base Grid Mix, in Analyses A1 and A2, reductions in adverse health effects nationwide would occur in all years under Alternative 4 compared to the No Action Alternative (*see* Tables 4.2.1-7-A1 and -A2). These health benefits increase greatly from 2021 to 2040, but decrease in 2060 (in Analysis A1, while continuing to increase in 2060 in Analysis A2). In Analysis B, adverse health effects under Alternative 4 compared to the No Action Alternative decrease in 2021 and 2025, but increase in 2060 (adverse health effects in 2040 increase in Analysis B1, but decrease in Analysis B2 compared to the No Action Alternative) (*see* Tables 4.2.1-7-B1 and -B2). In the Alternate Grid Mix, adverse health impacts of Alternative 4 would be reduced in all analyses.

As shown in Tables 4.2.1-8-A1 and -A2 and 4.2.1-8-B1 and -B2, the monetized health benefits under Alternative 4 range from a maximum benefit of $12 billion to a maximum negative impact of $2.7 billion across Analyses A and B. In the Base Grid Mix case, in Analysis A, monetized benefits would occur in all years. In Analysis B, monetized benefits would occur in 2021 and 2025, and monetized negative impacts would occur in 2040 and 2060. In the Alternate Grid Mix case, monetized benefits would occur in all years in Analyses A and B.

4.2.2 Cumulative Impacts

4.2.2.1 Results of the Analysis

As discussed in Section 4.1, 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 also continue to decline. However, as future trends show, vehicle travel is having a decreasing impact on emissions as a result of stricter EPA standards for vehicle emissions and the chemical composition of fuels, even with additional growth in VMT (Smith 2002). This general trend will continue, to a greater or lesser degree, with implementation of any of the alternative CAFE standards.

The analysis in this section shows that the action alternatives result in different levels of emissions from passenger cars and light trucks when measured against projected trends in the absence of agency action. 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 and figures throughout Section 4.2.2 present the results of the air quality cumulative impacts analysis. Following the comparative overview in this section, Sections 4.2.2.2 through 4.2.2.5 describe the results of the analysis of emissions for Alternatives 1 through 4 in greater detail.

4.2.2.1.1 Criteria Pollutants Overview

Tables 4.2.2-1-C1 and -C2 summarize the total upstream and downstream[49] emissions from passenger cars and light trucks by alternative for each of the criteria pollutants and analysis years. Figures 4.2.2-1-C1 and -C2 illustrate this information for 2040, the forecast year by which a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet standards as set forth under the Proposed Action.

Figures 4.2.2-2-C1 and -C2 summarize the changes over time in total national emissions of criteria pollutants from passenger cars and light trucks under the Preferred Alternative. These figures show mixed trends for the criteria pollutants. Emissions of NO_x, SO_2, and VOCs decline from 2021 to 2025 due to increasingly stringent EPA regulation of tailpipe emissions from vehicles and from reductions in upstream emissions from fuel production, but reach a minimum typically between 2025 and 2040, and increase from 2040 to 2060 due to continuing growth in VMT. Emissions of CO and $PM_{2.5}$ increase steadily from 2021 to 2060 because, for these pollutants, the reductions from EPA regulation of tailpipe emissions and reductions in upstream emissions from fuel production are more than offset by continuing growth in VMT.

[49] Downstream emissions do not include evaporative emissions from vehicle fuel systems due to modeling limitations.

Table 4.2.2-1-C1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C1

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,972,643	15,002,175	15,008,611	14,976,431
2025	15,008,505	15,067,547	15,081,718	14,819,971
2040	18,045,534	18,282,305	18,226,596	16,582,923
2060	24,167,562	24,914,947	24,833,759	22,349,229
Nitrogen oxides (NO_x)				
2021	1,255,518	1,248,863	1,246,865	1,246,643
2025	1,071,605	1,059,229	1,054,276	1,069,606
2040	963,690	929,417	918,999	968,719
2060	1,278,260	1,217,919	1,209,402	1,281,722
Particulate matter ($PM_{2.5}$)				
2021	54,081	53,273	53,020	52,142
2025	57,224	55,677	54,958	53,117
2040	77,415	72,983	70,854	64,556
2060	104,073	95,883	93,667	84,244
Sulfur dioxide (SO_2)				
2021	141,793	136,781	135,274	134,719
2025	145,194	136,331	133,833	152,508
2040	176,325	150,053	156,945	244,467
2060	234,964	178,306	190,508	313,042
Volatile organic compounds (VOCs)				
2021	1,289,873	1,278,104	1,274,379	1,259,736
2025	1,137,616	1,114,801	1,103,745	1,068,814
2040	910,137	844,123	807,107	685,662
2060	1,184,742	1,059,953	1,019,822	848,129

Table 4.2.2-1-C2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C2

Pollutant and Year	Alternative1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	14,657,379	14,682,880	14,684,965	14,661,610
2025	14,620,666	14,677,118	14,688,365	14,478,066
2040	16,607,692	16,845,377	16,876,576	15,457,857
2060	20,788,696	21,466,322	21,518,739	19,514,510
Nitrogen oxides ($NO_{x)}$				
2021	1,238,977	1,232,862	1,231,300	1,230,761
2025	1,052,633	1,040,540	1,035,836	1,048,650
2040	891,753	860,018	850,361	903,223
2060	1,105,686	1,053,758	1,048,823	1,123,271
Particulate matter ($PM_{2.5}$)				
2021	52,563	51,845	51,575	50,807
2025	55,420	53,974	53,169	51,548
2040	71,183	67,172	65,049	59,346
2060	89,552	82,592	80,551	72,439
Sulfur dioxide ($SO_{2)}$				
2021	136,436	131,818	130,217	128,983
2025	138,792	129,737	125,539	139,364
2040	157,963	132,542	126,605	197,350
2060	197,281	147,700	144,471	236,352
Volatile organic compounds (VOCs)				
2021	1,273,510	1,263,105	1,259,153	1,246,633
2025	1,118,000	1,096,929	1,085,078	1,054,968
2040	840,558	781,478	748,840	636,947
2060	1,020,744	915,236	883,100	733,171

Figure 4.2.2-1-C1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis C1

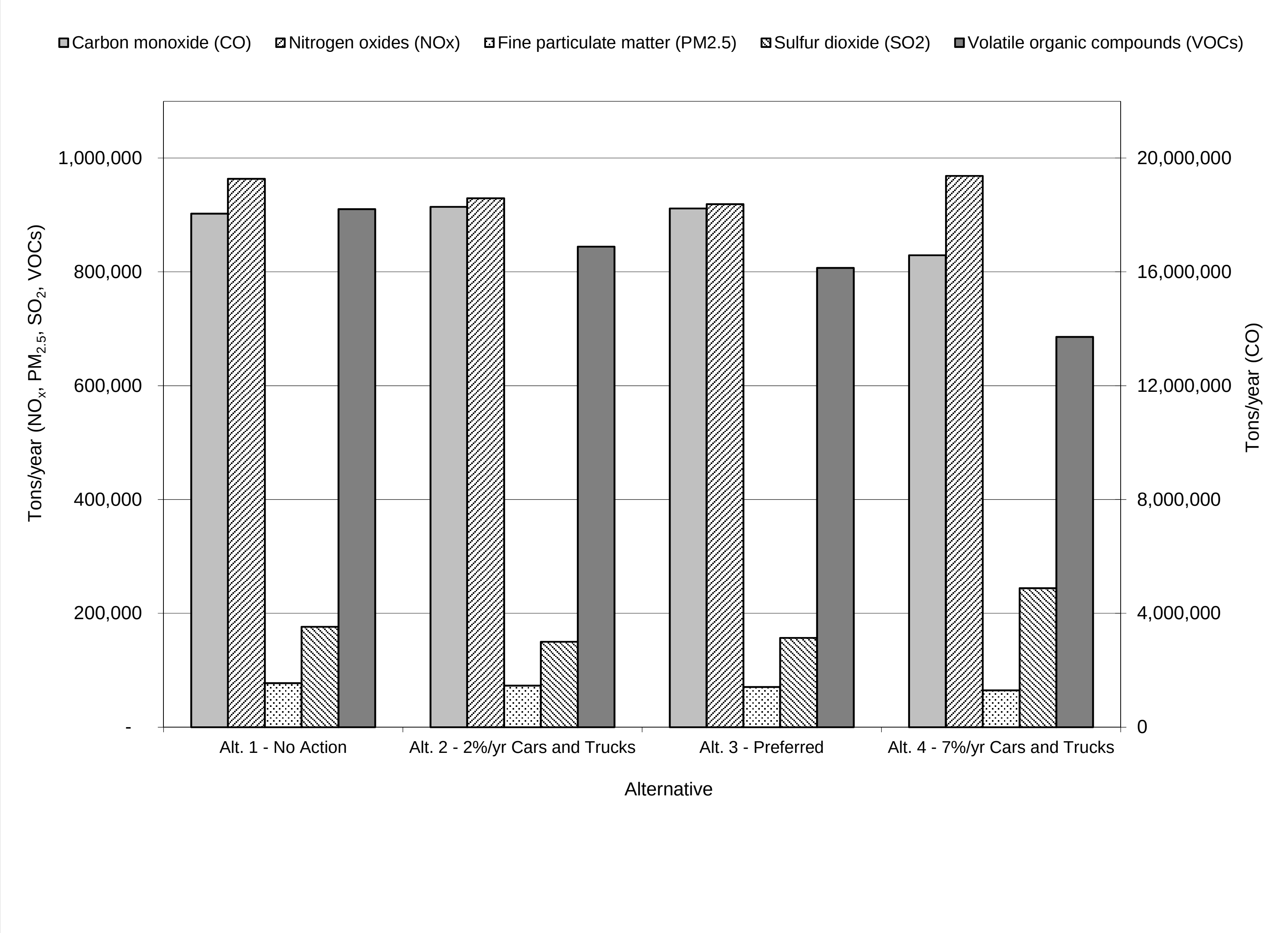


Figure 4.2.2-1-C2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis C2

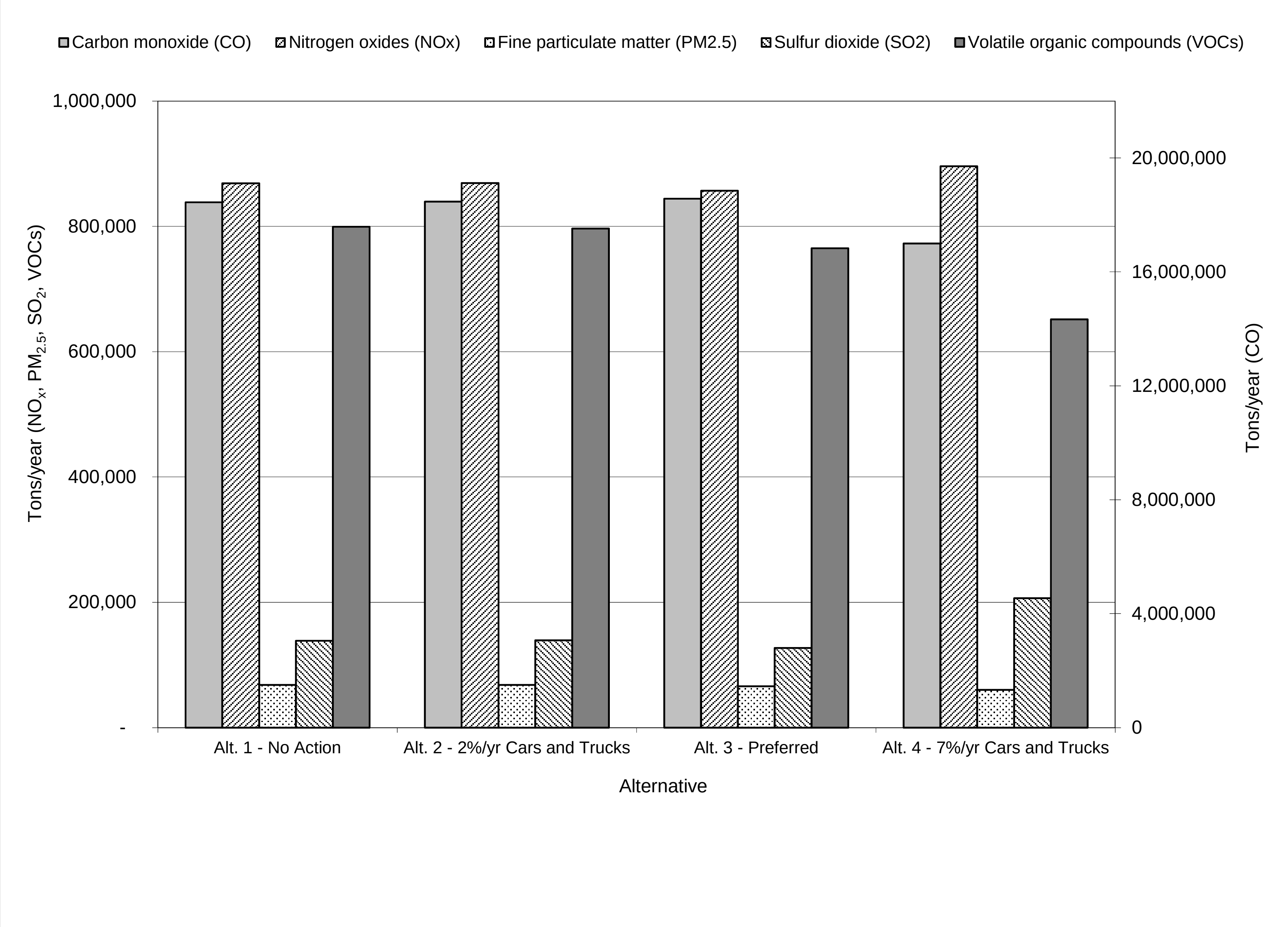


Figure 4.2.2-2-C1. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis C1

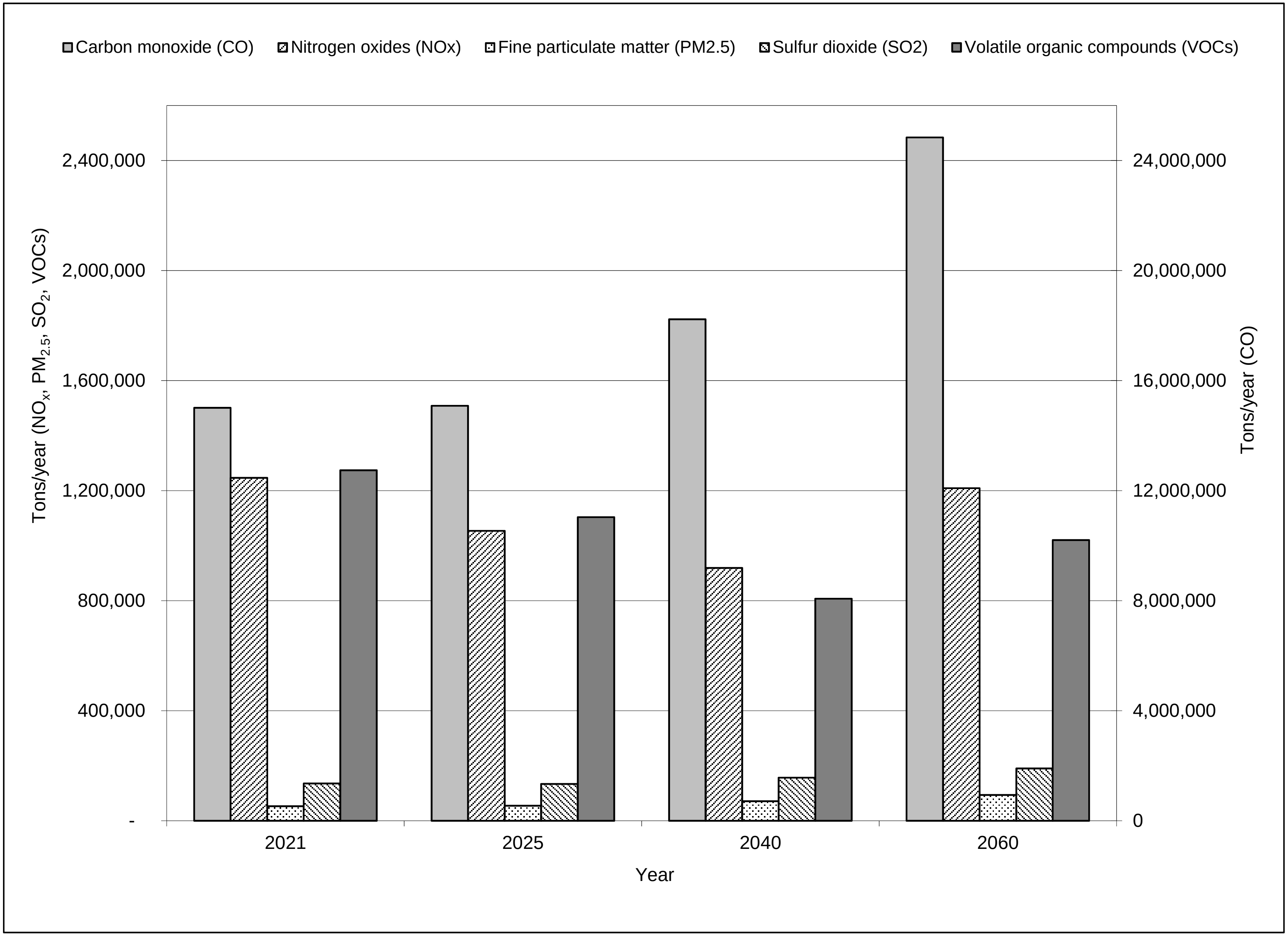
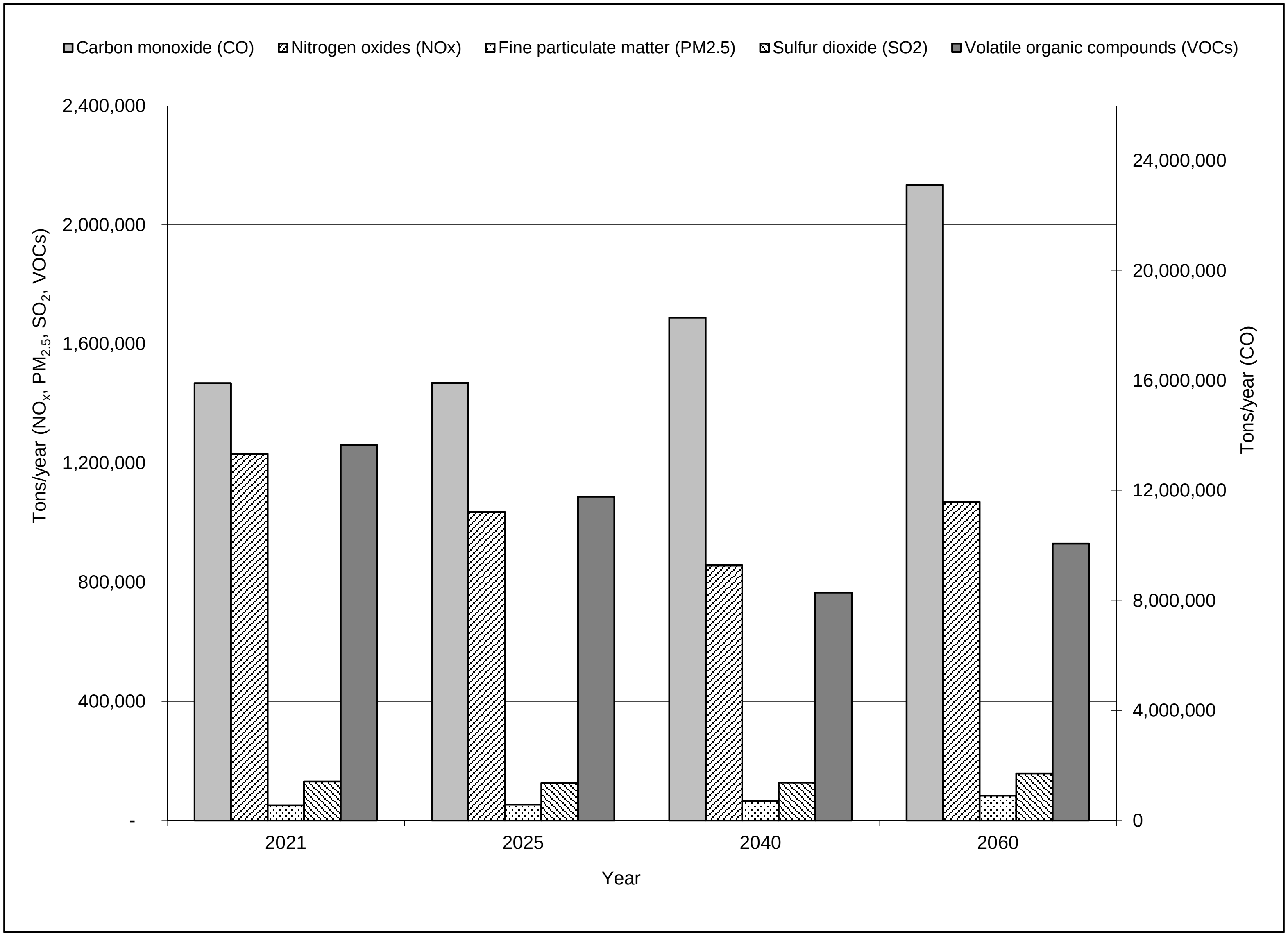


Figure 4.2.2-2-C2. Nationwide Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis C2



Total emissions are made up of four components, consisting of two sources of emissions (downstream and upstream) for each of the two vehicle classes (passenger cars and light trucks) covered by the proposed rule. To show the relationship among these four components for criteria pollutants, tables in Appendix A break down the total emissions of criteria pollutants by component.

Tables 4.2.2-2-C1 and-C2 list the net change in nationwide criteria pollutant emissions from passenger cars and light trucks for each of the criteria pollutants and analysis years under each action alternative compared to the No Action Alternative. Figures 4.2.2-3-C1 and -C2 show these changes in percentages for 2040. As a general trend, emissions of each pollutant decrease from Alternatives 2 through 4 as each successive alternative becomes more stringent. However, the magnitudes of the declines are not consistent across all pollutants, and there are some emission increases, 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. As a result of these interactions, emissions under different alternatives in some years are greater for less-stringent alternatives than for more-stringent alternatives. For example, NO_x and SO_2 emissions generally decrease from Alternative 1 through Alternative 3, but increase after 2025 under Alternative 4. Increases in NO_x emissions are due primarily to increases in the number of diesel-fueled vehicles, while increases in SO_2 emissions are due primarily to increases in the number of EVs. Conversely, CO emissions generally increase from Alternative 1 through the Preferred Alternative and decrease under Alternative 4. VOC and $PM_{2.5}$ emissions decrease steadily from Alternatives 1 through 4. The decreases in emissions are due to reductions in fuel consumption that outpace growth in VMT under the more-stringent alternatives.

Under Alternative 2 and the Preferred Alternative, the greatest relative reductions in emissions among the criteria pollutants occur for SO_2, for which emissions decrease by as much as 12 percent by 2060 compared to the No Action Alternative. Emissions of $PM_{2.5}$ and VOCs under Alternative 2 and the Preferred Alternative decrease by 10 percent or less compared to the No Action Alternative. Emissions of NO_x under Alternative 2 and the Preferred Alternative decrease by 4 percent or less, and emissions of CO increase by up to 4 percent compared to the No Action Alternative. Under Alternative 4, the greatest relative reductions in emissions among the criteria pollutants occur for VOCs, for which emissions decrease by as much as 27 percent by 2060. Emissions of $PM_{2.5}$ decrease by as much as 17 percent under Alternative 4 and CO emissions decrease by as much as 11 percent. Emissions of NO_x and SO_2 show increases after 2021 under Alternative 4 compared to the No Action Alternative.

Across the analyses, the differences in national emissions of criteria air pollutants among all the action alternatives (compared to the No Action Alternative) range from small (1 percent or less) to large (83 percent) in the same year. The small differences are not expected to lead to measurable changes in concentrations of criteria pollutants in the ambient air. The large differences in emissions could lead to differences in ambient pollutant concentrations.

Tables 4.2.2-3-C1 and -C2 summarize the criteria air pollutant analysis results by nonattainment area. Tables in Appendix B list the emissions changes for each nonattainment area. For CO, NO_x, and $PM_{2.5}$, most nonattainment areas would experience increases in emissions across all years under Alternative 2 and the Preferred Alternative (and Alternative 4 for NO_x), but decreases in SO_2, and VOCs. Under Alternative 4, most nonattainment areas would experience increases in emissions of NO_x across all years, and of CO in 2021 in Analysis C1. Under Alternative 4, most nonattainment areas would experience decreases in emissions of CO (after 2021), $PM_{2.5}$, SO_2, and VOCs.

Table 4.2.2-2-C1. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C1[a,b]

Pollutant and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	0	29,532	35,969	3,789
2025	0	59,042	73,214	-188,534
2040	0	236,772	181,063	-1,462,610
2060	0	747,385	666,197	-1,818,333
Nitrogen oxides (NO_x)				
2021	0	-6,655	-8,653	-8,874
2025	0	-12,376	-17,329	-2,000
2040	0	-34,273	-44,690	5,030
2060	0	-60,341	-68,858	3,462
Particulate matter ($PM_{2.5}$)				
2021	0	-808	-1,061	-1,938
2025	0	-1,546	-2,266	-4,107
2040	0	-4,432	-6,561	-12,859
2060	0	-8,189	-10,406	-19,828
Sulfur dioxide (SO_2)				
2021	0	-5,012	-6,519	-7,074
2025	0	-8,863	-11,360	7,315
2040	0	-26,272	-19,380	68,142
2060	0	-56,658	-44,456	78,078
Volatile organic compounds (VOCs)				
2021	0	-11,769	-15,494	-30,137
2025	0	-22,815	-33,871	-68,802
2040	0	-66,015	-103,030	-224,476
2060	0	-124,789	-164,920	-336,614

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

Table 4.2.2-2-C2. Nationwide Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C2[a,b]

Pollutant and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Carbon monoxide (CO)				
2021	0	25,501	27,586	4,231
2025	0	56,451	67,698	-142,600
2040	0	237,685	268,884	-1,149,835
2060	0	677,626	730,043	-1,274,187
Nitrogen oxides (NO_x)				
2021	0	-6,115	-7,677	-8,216
2025	0	-12,092	-16,797	-3,983
2040	0	-31,735	-41,392	11,470
2060	0	-51,928	-56,863	17,584
Particulate matter ($PM_{2.5}$)				
2021	0	-718	-988	-1,756
2025	0	-1,446	-2,250	-3,872
2040	0	-4,011	-6,134	-11,837
2060	0	-6,959	-9,000	-17,113
Sulfur dioxide (SO_2)				
2021	0	-4,617	-6,218	-7,453
2025	0	-9,055	-13,252	572
2040	0	-25,421	-31,358	39,387
2060	0	-49,581	-52,809	39,071
Volatile organic compounds (VOCs)				
2021	0	-10,405	-14,358	-26,877
2025	0	-21,071	-32,922	-63,032
2040	0	-59,080	-91,718	-203,611
2060	0	-105,507	-137,644	-287,573

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

Figure 4.2.2-3-C1 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis C1

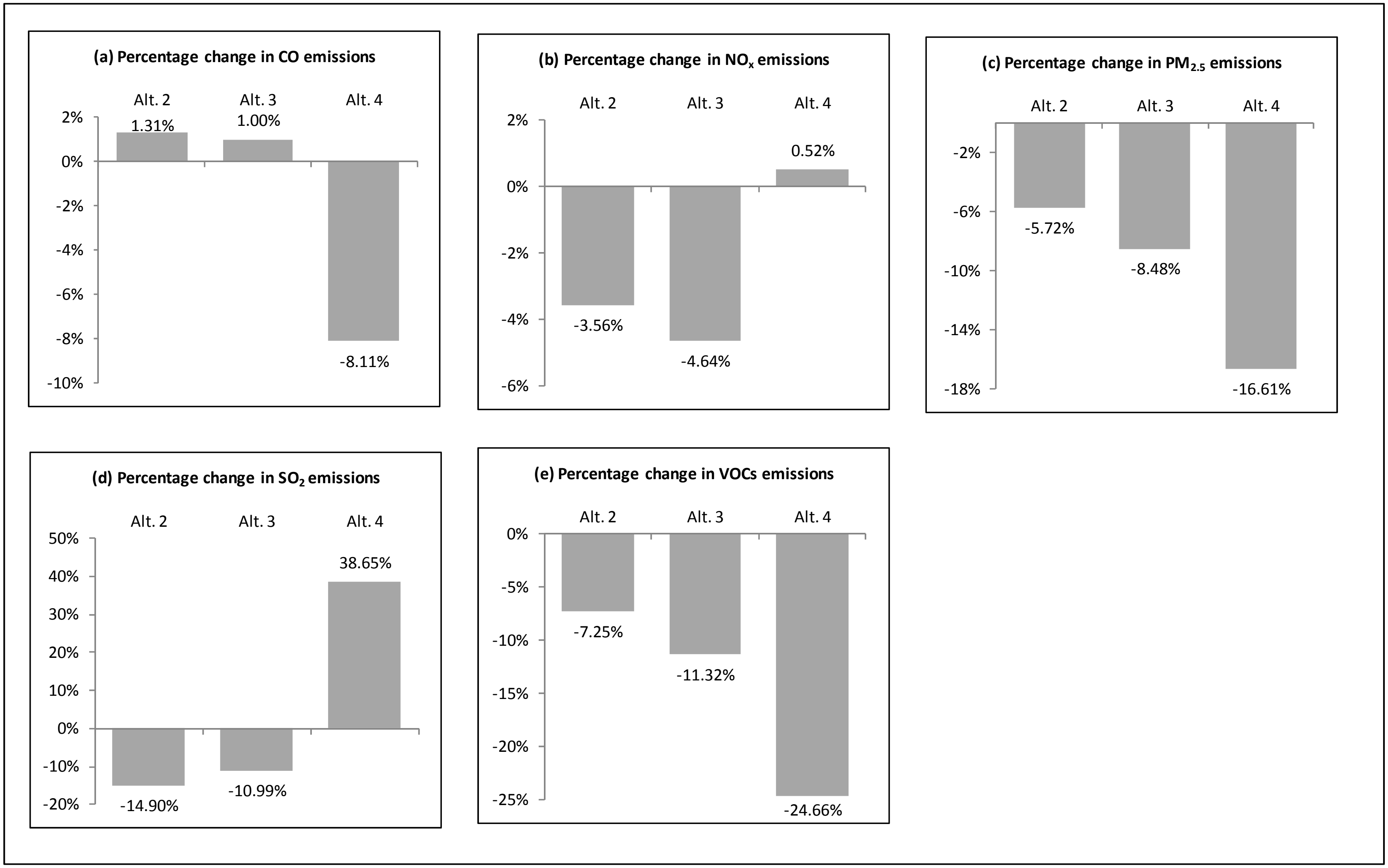


Figure 4.2.2-3-C2 (a)–(e). Nationwide Percentage Changes in Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis C2

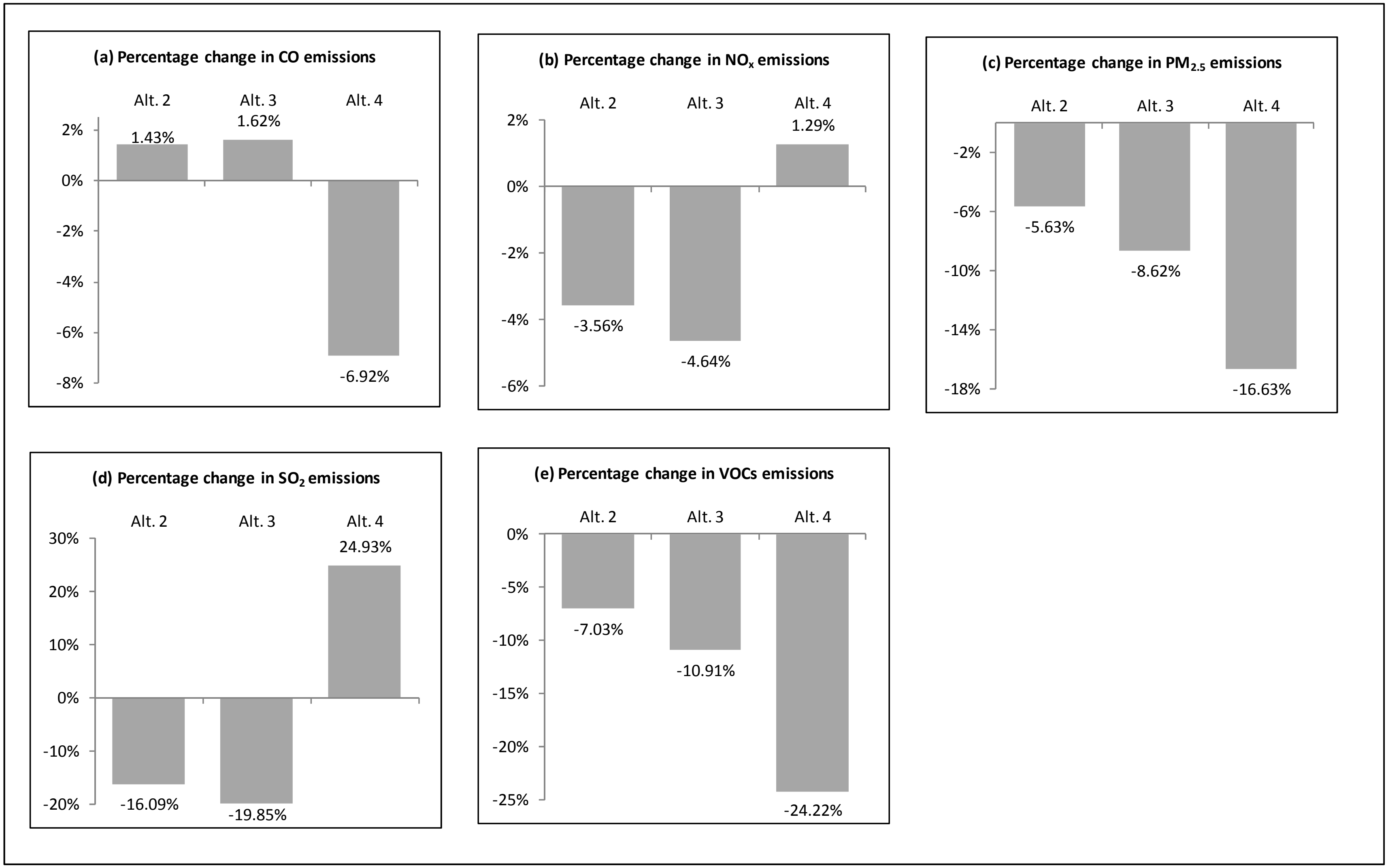


Table 4.2.2-3-C1. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis C1[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	36,250	2060	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-88,033	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	1,530	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-7,800	2060	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	49	2060	2	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-1,343	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Sulfur dioxide (SO_2)	Maximum Increase	11,124	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-5,799	2060	2	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	10	2060	2	Riverside County (Coachella Valley), CA (O_3)
	Maximum Decrease	-9,581	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.

Table 4.2.2-3-C2. Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis C2[a]

Criteria Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area (Pollutant(s))
Carbon monoxide (CO)	Maximum Increase	35,401	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-61,634	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Nitrogen oxides (NO_x)	Maximum Increase	2,467	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-7,317	2060	3	Houston-Galveston-Brazoria, TX (O_3)
Particulate matter ($PM_{2.5}$)	Maximum Increase	44	2060	2	Dallas-Fort Worth, TX (O_3)
	Maximum Decrease	-1,199	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Sulfur dioxide (SO_2)	Maximum Increase	6,192	2060	4	Beaumont-Port Arthur, TX (O_3)
	Maximum Decrease	-5,272	2060	3	Beaumont-Port Arthur, TX (O_3)
Volatile organic compounds (VOCs)	Maximum Increase	11	2060	2	Riverside County (Coachella Valley), CA (O_3)
	Maximum Decrease	-8,106	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)

a. Emissions changes are rounded to the nearest whole number.

4.2.2.1.2 Toxic Air Pollutants Overview

Tables 4.2.2-4-C1 and -C2 summarize the total upstream and downstream[26] emissions of toxic air pollutants from passenger cars and light trucks by alternative for each of the toxic air pollutants and analysis years. The trends for toxic air pollutant emissions across the alternatives are mixed due to increasingly stringent EPA regulation of tailpipe emissions from vehicles and from reductions in upstream emissions from fuel production. Tables 4.2.2-4-C1 and -C2 show that emissions of acetaldehyde, acrolein, and formaldehyde generally increase from Alternative 1 to Alternative 4. This trend is least pronounced for formaldehyde, for which emissions decrease under Alternative 2 and the Preferred Alternative for several combinations of analyses and years. Acetaldehyde emissions also decrease under Alternative 4 for certain analyses and years. Emissions of 1,3-butadiene under Alternative 2 and the Preferred Alternative increase progressively over time compared to the No Action Alternative, while emissions decrease under Alternative 4 after 2021. Benzene emissions decrease from Alternative 1 to Alternative 4 (except under Alternative 2 in 2060, when they increase compared to the No Action Alternative in Analysis C2). DPM emissions decrease from Alternative 1 to the Preferred Alternative compared to the No Action Alternative, and either increase or decrease under Alternative 4 depending on year and analysis. DPM emissions under all the action alternatives remain below the levels under the No Action Alternative in Analysis C1, but exceed the levels under the No Action Alternative in Analysis C2 for later analysis years under Alternative 4. These trends are accounted for by the extent of technologies assumed to be deployed under the different action alternatives to meet the different fuel economy requirements.

Table 4.2.2-4-C1. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C1

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Acetaldehyde				
2021	6,731	6,738	6,739	6,763
2025	6,258	6,273	6,277	6,331
2040	6,742	6,812	6,790	6,658
2060	9,019	9,262	9,232	9,010
Acrolein				
2021	317	317	316	322
2025	289	288	289	308
2040	309	311	311	390
2060	414	422	422	543
Benzene				
2021	31,252	31,219	31,205	31,100
2025	25,262	25,200	25,156	24,742
2040	17,856	17,737	17,516	14,759
2060	23,262	23,261	22,997	18,702

[26] Downstream emissions do not include evaporative emissions from vehicle fuel systems due to modeling limitations.

Table 4.2.2-4-C1. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C1 (continued)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
1,3-Butadiene				
2021	3,500	3,503	3,503	3,503
2025	2,998	3,004	3,005	2,989
2040	2,696	2,727	2,717	2,461
2060	3,578	3,680	3,665	3,257
Diesel particulate matter (DPM)				
2021	8,982	8,646	8,547	8,400
2025	9,119	8,466	8,177	8,274
2040	10,981	9,037	8,138	10,176
2060	14,630	10,743	9,808	13,438
Formaldehyde				
2021	7,505	7,493	7,492	7,592
2025	6,813	6,791	6,787	7,191
2040	7,150	7,116	7,073	8,803
2060	9,557	9,586	9,547	12,253

Table 4.2.2-4-C2. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	6,633	6,638	6,644	6,666
2025	6,133	6,146	6,160	6,216
2040	6,261	6,333	6,374	6,333
2060	7,815	8,038	8,104	8,044
Acrolein				
2021	314	314	314	319
2025	286	285	288	304
2040	291	293	300	385
2060	364	371	382	510
Benzene				
2021	30,938	30,908	30,891	30,808
2025	24,858	24,802	24,747	24,407
2040	16,488	16,405	16,226	13,640
2060	20,001	20,044	19,851	16,024

Table 4.2.2-4-C2. Nationwide Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C2 (continued)

Pollutant and Year	Alternative 1 No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
1,3-Butadiene				
2021	3,457	3,460	3,461	3,462
2025	2,943	2,948	2,951	2,940
2040	2,498	2,530	2,533	2,307
2060	3,090	3,183	3,190	2,850
Diesel particulate matter (DPM)				
2021	8,778	8,487	8,411	8,296
2025	8,895	8,301	8,068	8,199
2040	10,117	8,379	7,787	10,057
2060	12,636	9,360	8,897	12,694
Formaldehyde				
2021	7,434	7,425	7,436	7,523
2025	6,729	6,709	6,740	7,103
2040	6,717	6,697	6,822	8,705
2060	8,380	8,427	8,641	11,480

Figures 4.2.2-4-C1 and -C2 show the changes in toxic air pollutant emissions for each alternative for 2040, the forecast year by which a large proportion of passenger car and light-truck VMT would be accounted for by vehicles that meet standards as set forth under the Proposed Action.

Figures 4.2.2-5-C1 and -C2 summarize the changes over time in total national emissions of toxic air pollutants from passenger cars and light trucks under the Preferred Alternative. These figures indicate a consistent trend among the toxic air pollutants. Emissions decline from 2021 to 2025 due to increasingly stringent EPA regulation of emissions from vehicles and from reductions in upstream emissions from fuel production, but reach a minimum typically between 2025 and 2040, and increase from 2040 to 2060 due to continuing growth in VMT.

As with criteria pollutant emissions, total toxic pollutant emissions are made up of four components, consisting of two sources of emissions (downstream and upstream) for each of the two vehicle classes (passenger cars and light trucks) covered by the Proposed Action. To show the relationship among these four components for toxic air pollutants, tables in Appendix A break down the total emissions of toxic air pollutants by component.

Figure 4.2.2-4-C1. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis C1

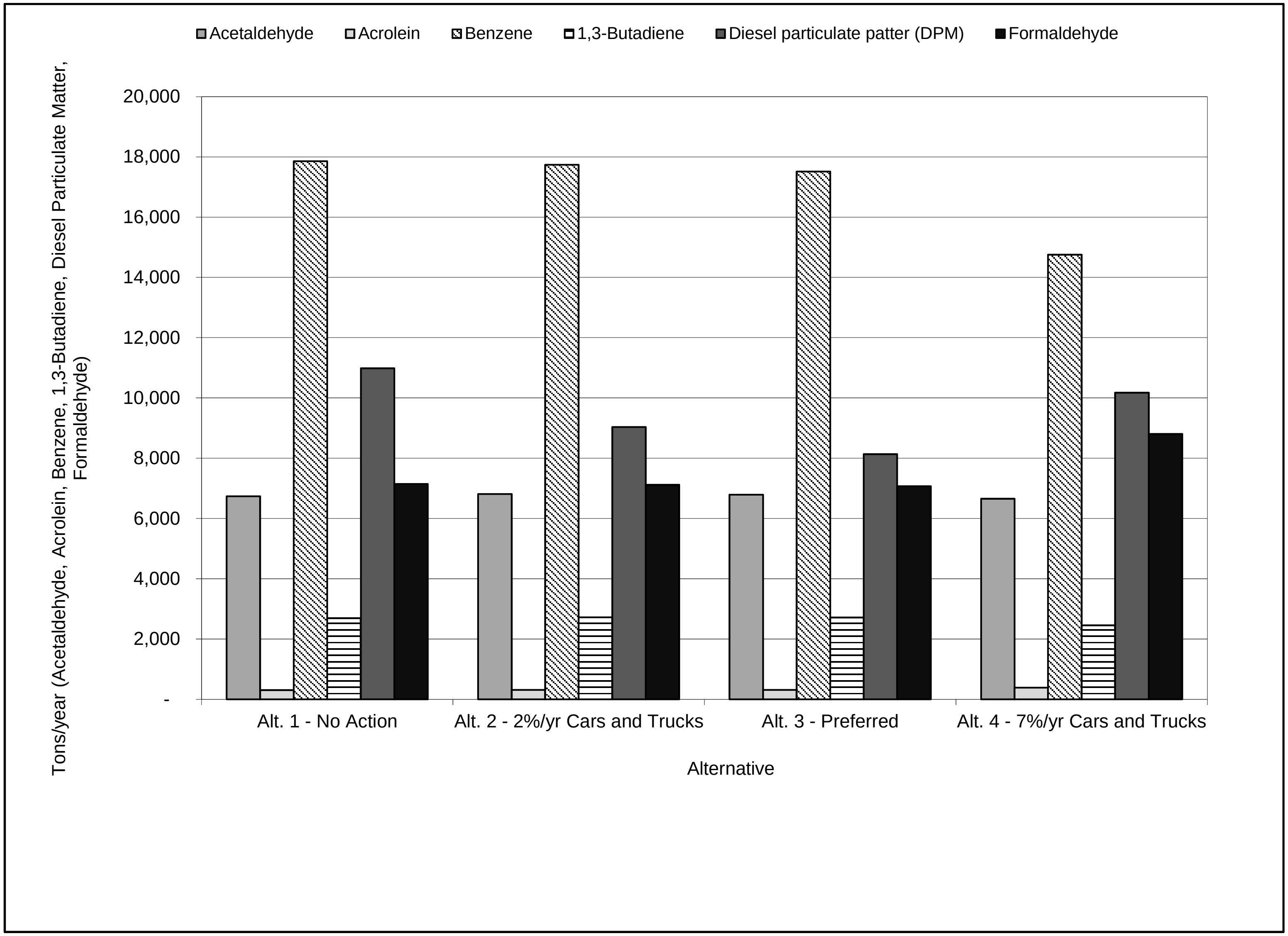


Figure 4.2.2-4-C2. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) for 2040 by Alternative, Analysis C2

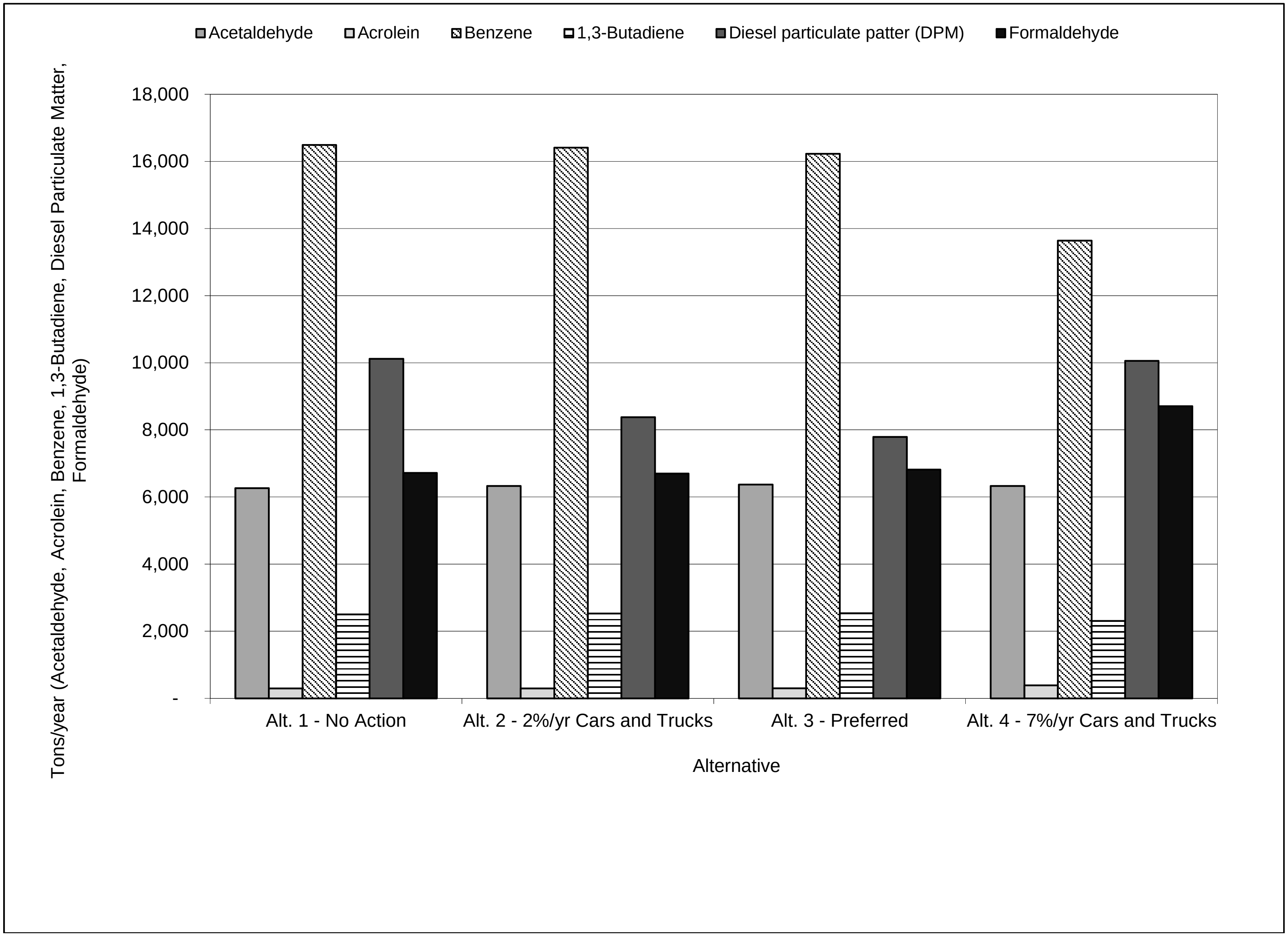


Figure 4.2.2-5-C1. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis C1

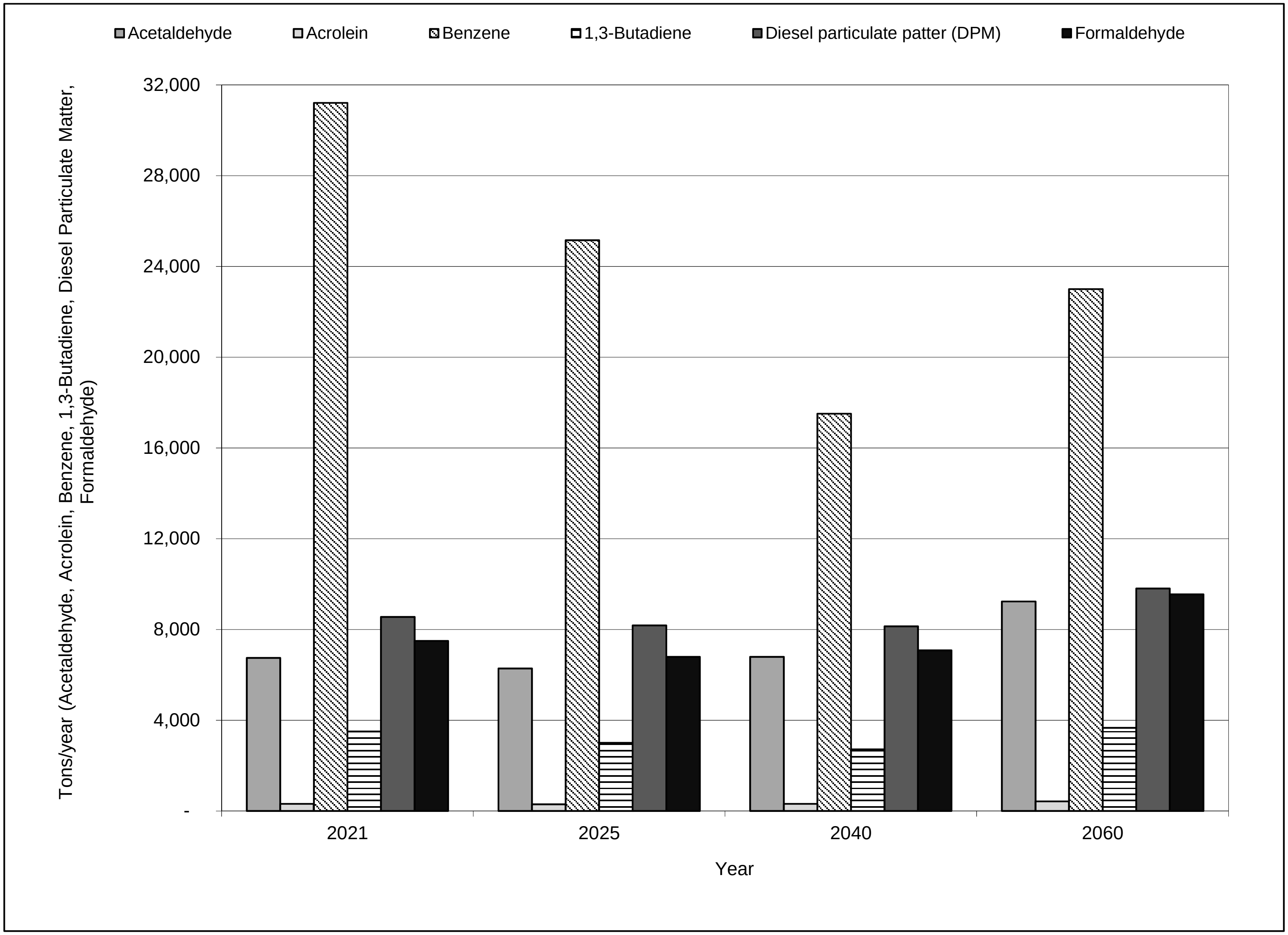
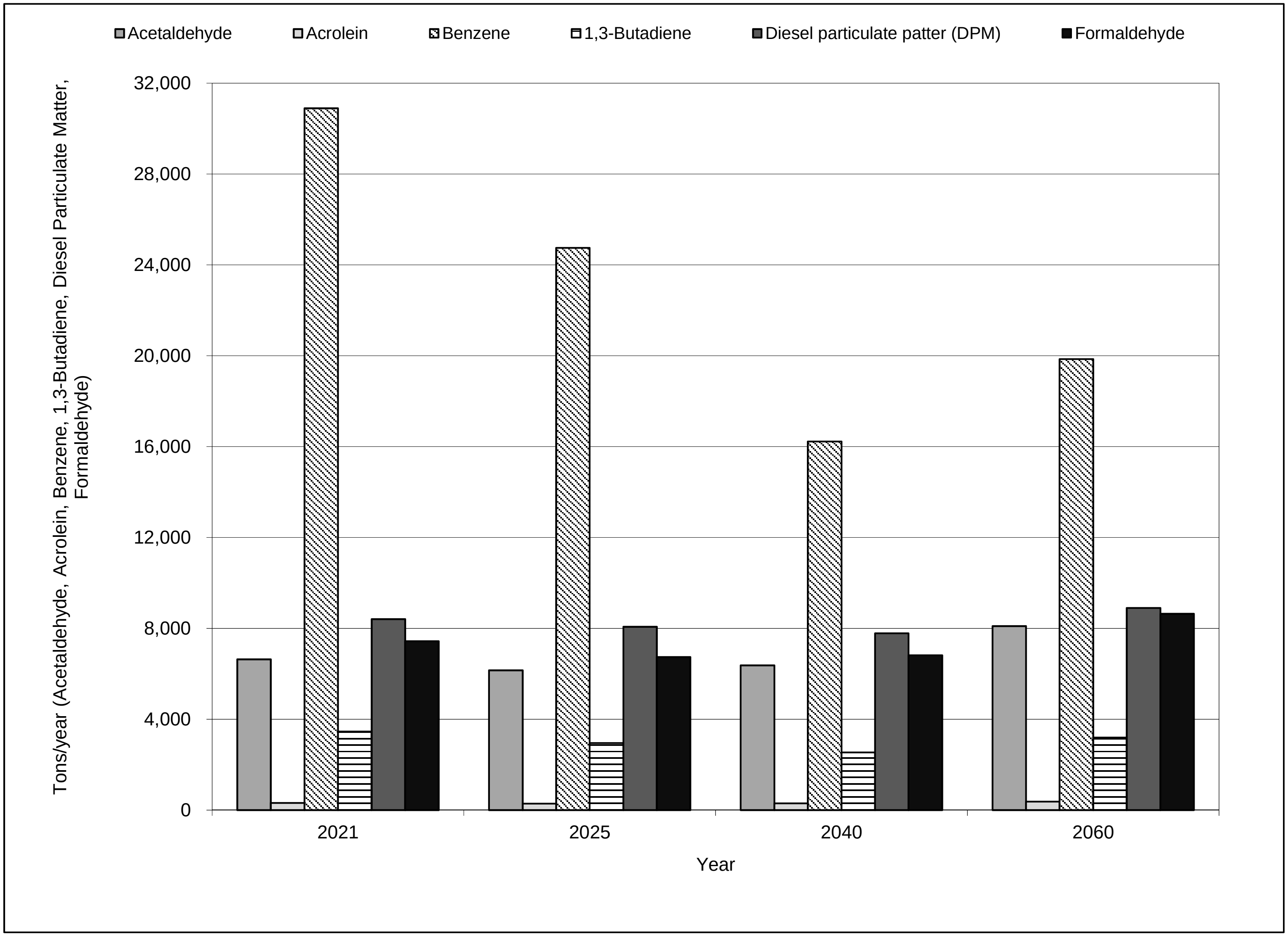


Figure 4.2.2-5-C2. Nationwide Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) under the Preferred Alternative by Year, Analysis C2



Tables 4.2.2-5-C1 and -C2 list the net change in nationwide emissions from passenger cars and light trucks for each of the toxic air pollutants and analysis years compared to the No Action Alternative. Figures 4.2.2-6-C1 and -C2 show these changes in percentages for 2040. Together, these tables and figures show that the magnitude of nationwide emission changes tends to increase from 2021 to 2060, and that emissions under Alternative 2 and the Preferred Alternative are similar to each other for most combinations of analysis, pollutant, and year. Emissions of benzene and DPM under the Preferred Alternative are generally less than under Alternative 2, but emissions of acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde under the Preferred Alternative are greater than or less than under Alternative 2 depending on the analysis, pollutant, and year. The magnitude of the emissions changes under Alternative 4 is generally greater than under Alternative 2 and the Preferred Alternative, except for DPM.

Table 4.2.2-5-C1. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C1[a,b]

Pollutant and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/year Cars and Trucks
Acetaldehyde				
2021	0	7	8	32
2025	0	15	18	72
2040	0	70	49	-83
2060	0	242	213	-9
Acrolein				
2021	0	0	0	5
2025	0	-1	0	19
2040	0	2	2	80
2060	0	8	8	129
Benzene				
2021	0	-32	-47	-151
2025	0	-62	-106	-520
2040	0	-119	-340	-3,097
2060	0	-1	-265	-4,560
1,3-Butadiene				
2021	0	3	3	4
2025	0	6	7	-9
2040	0	31	21	-235
2060	0	102	87	-321
Diesel particulate matter (DPM)				
2021	0	-336	-435	-582
2025	0	-653	-942	-845
2040	0	-1,945	-2,843	-805
2060	0	-3,887	-4,823	-1,193
Formaldehyde				
2021	0	-11	-13	87
2025	0	-22	-26	379
2040	0	-35	-77	1,653
2060	0	29	-10	2,697

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

Table 4.2.2-5-C2. Nationwide Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks (tons/year) by Alternative, Analysis C2[a,b]

	Alternative 1[c]	Alternative 2	Alternative 3	Alternative 4
Pollutant and Year	No Action	2%/year Cars and Trucks	Preferred	7%/year Cars and Trucks
Acetaldehyde				
2021	0	6	11	34
2025	0	13	27	83
2040	0	73	113	73
2060	0	223	290	230
Acrolein				
2021	0	1	1	5
2025	0	-1	2	18
2040	0	2	9	94
2060	0	7	18	146
Benzene				
2021	0	-30	-48	-130
2025	0	-57	-111	-451
2040	0	-83	-262	-2,848
2060	0	43	-150	-3,977
1,3-Butadiene				
2021	0	2	3	5
2025	0	6	8	-2
2040	0	32	35	-190
2060	0	93	100	-240
Diesel particulate matter (DPM)				
2021	0	-291	-366	-481
2025	0	-594	-827	-696
2040	0	-1,738	-2,330	-59
2060	0	-3,276	-3,739	58
Formaldehyde				
2021	0	-10	1	89
2025	0	-19	11	375
2040	0	-20	104	1,988
2060	0	47	261	3,100

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

Figure 4.2.2-6-C1 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis C1

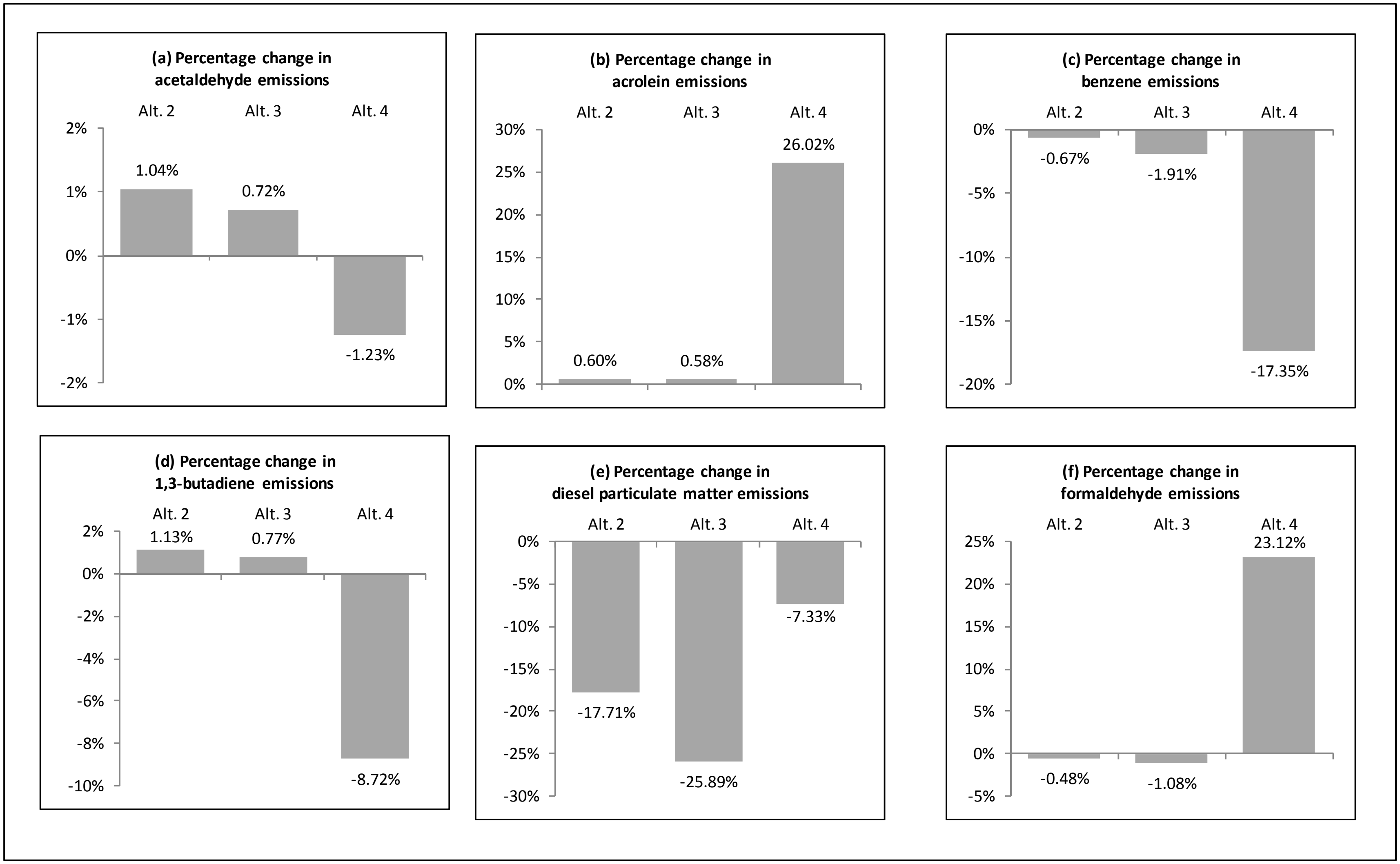
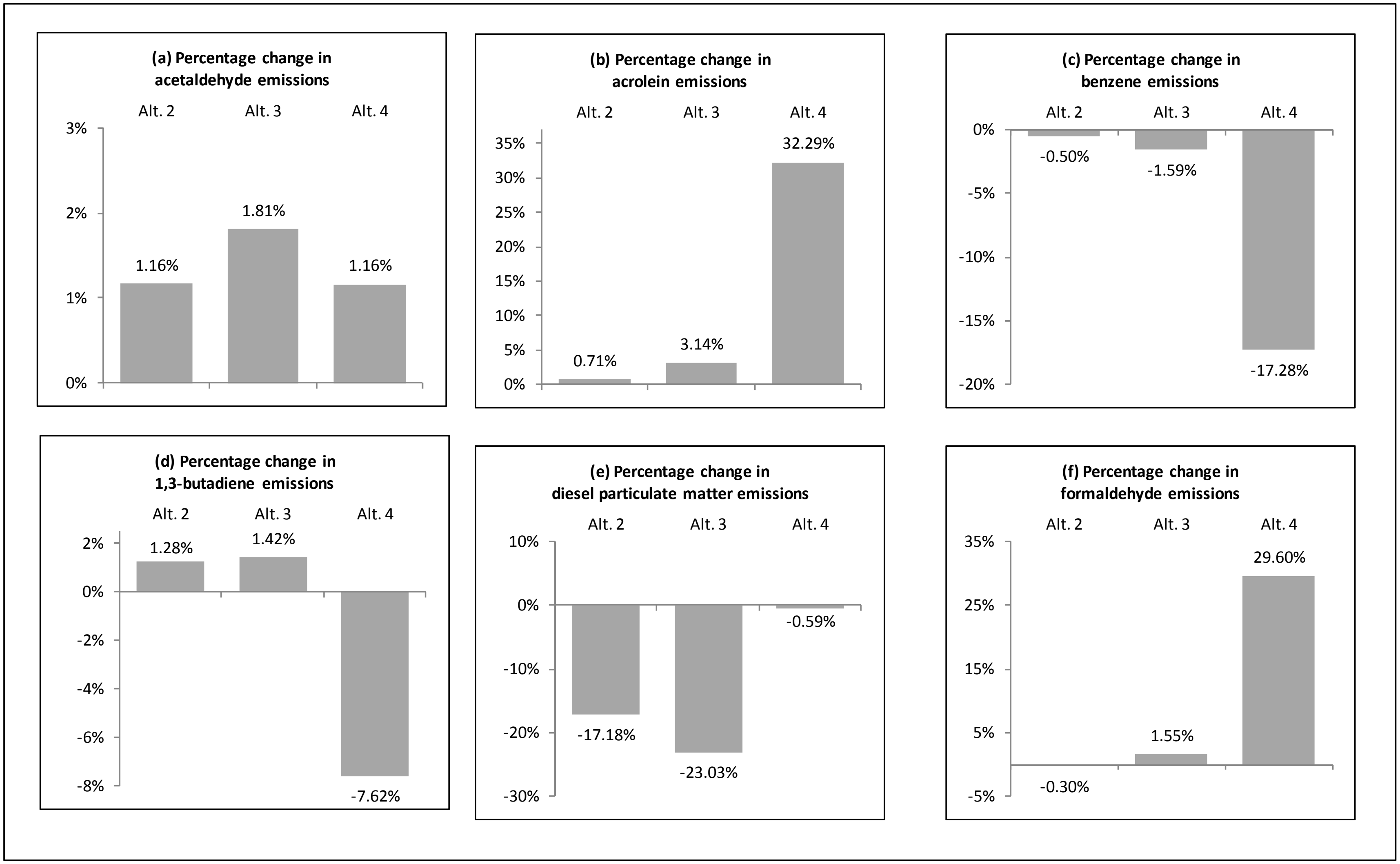


Figure 4.2.2-6-C2 (a)–(f). Nationwide Percentage Changes in Toxic Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Action Alternative in 2040 Compared to the No Action Alternative, Analysis C2



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.

Tables 4.2.2-6-C1 and -C2 summarize the air toxics analysis results by nonattainment area.[27] Tables in Appendix B list the estimated emission changes for each nonattainment area. For acetaldehyde, acrolein, DPM, and formaldehyde, most nonattainment areas experience increases in emissions across all years and action alternatives. For benzene and 1,3-butadiene the results are mixed; the number of nonattainment areas that would experience increases is less under the more-stringent alternatives, and the number that would experience decreases is greater under the more-stringent alternatives.

Table 4.2.2-6-C1. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis C1[a]

Hazardous Air Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area[b]
Acetaldehyde	Maximum Increase	12	2060	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-18	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Acrolein	Maximum Increase	6	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-1	2060	4	Beaumont-Port Arthur, TX (O_3)
Benzene	Maximum Increase	27	2060	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-186	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	5	2060	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-15	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	182	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (O_3, $PM_{2.5}$)
	Maximum Decrease	-528	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Formaldehyde	Maximum Increase	148	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-127	2060	3	Houston-Galveston-Brazoria, TX (O_3)

a. Emissions changes are rounded to the nearest whole number.

[27] EPA has not established NAAQS for airborne toxics. Therefore, none of these areas is designated as a nonattainment area because of emissions of airborne toxics. Toxic air pollutant emissions data for nonattainment areas are provided for information only.

Table 4.2.2-6-C2. Changes in Toxic Air Pollutant Emissions from U.S. Passenger Cars and Light Trucks, Maximum Changes by Nonattainment Area and Alternative, Analysis C2[a]

Hazardous Air Pollutant	Maximum Increase/Decrease	Change (tons/year)	Year	Alternative	Nonattainment Area
Acetaldehyde	Maximum Increase	15	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-11	2060	4	Beaumont-Port Arthur, TX (O_3)
Acrolein	Maximum Increase	7	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-1	2060	4	Beaumont-Port Arthur, TX (O_3)
Benzene	Maximum Increase	25	2060	2	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-162	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (CO, $PM_{2.5}$)
1,3-Butadiene	Maximum Increase	5	2060	3	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-11	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
Diesel particulate matter (DPM)	Maximum Increase	197	2060	4	New York-N. New Jersey-Long Island, NY-NJ-CT (CO, $PM_{2.5}$)
	Maximum Decrease	-424	2060	4	Houston-Galveston-Brazoria, TX (O_3)
Formaldehyde	Maximum Increase	164	2060	4	Los Angeles South Coast Air Basin, CA (CO, NO_x, O_3, PM_{10}, $PM_{2.5}$)
	Maximum Decrease	-102	2060	3	Houston-Galveston-Brazoria, TX (O_3)

a. Emissions changes are rounded to the nearest whole number.

4.2.2.1.3 Health Effects and Monetized Health Benefits Overview

In Analyses C1 and C2, adverse health effects would decrease nationwide under each of the action alternatives compared to the No Action Alternative (*see* Tables 4.2.2-7-C1 and -C2). As described in Section 4.1.2.7.2, the changes in PM mortality shown in these tables are measured in several ways; benefits are measured under the Pope methodology and the Laden methodology and at discount rates of 3 and 7 percent. While the number of PM mortalities varies between the two methods, under both methods the percent change in mortality across alternatives and years is equal. As with the health effect and monetized health benefits tables in Analyses A1, A2, B1, and B2, the results for Analyses C1 and C2 include projections for both the Base Grid Mix case and Alternate Grid Mix case. Tables 4.2.2-8-C1 and -C2 list the corresponding monetized health benefits under the action alternatives compared to the No Action Alternative.

In Analyses C1 and C2, the health benefits of each alternative tend to increase steadily from the near future (2021) to later years (2060). For all years, the benefits from under the Preferred Alternative are greater than those under Alternative 2. Under Alternative 4, the near-term (2021 and 2025) health benefits are generally greater than all other action alternatives, but the benefits in later years (2040 and 2060) are generally the least of all alternatives due to increases in VMT and the number of diesel-fueled vehicles and EVs.

Table 4.2.2-7-C1. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis C1[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-45/-45	-58/-59	-87/-96
2025	0	-87/-90	-120/-130	-110/-170
2040	0	-300/-310	-360/-420	-220/-540
2060	0	-580/-600	-620/-700	-450/-880
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-110/-120	-150/-150	-220/-250
2025	0	-220/-230	-310/-330	-270/-440
2040	0	-770/-800	-920/-1,100	-560/-1,400
2060	0	-1,500/-1,500	-1,600/-1,800	-1,200/-2,300
Chronic bronchitis				
2021	0	-30/-31	-40/-40	-59/-66
2025	0	-59/-60	-82/-87	-71/-110
2040	0	-190/-200	-230/-270	-140/-350
2060	0	-370/-380	-390/-440	-290/-570
Emergency room visits for asthma				
2021	0	-42/-43	-55/-56	-82/-91
2025	0	-81/-84	-110/-120	-98/-160
2040	0	-270/-280	-320/-370	-170/-440
2060	0	-520/-530	-550/-620	-360/-730
Work-loss days				
2021	0	-5,700/-5,800	-7,500/-7,500	-11,000/-12,000
2025	0	-11,000/-11,000	-15,000/-16,000	-13,000/-21,000
2040	0	-33,000/-34,000	-40,000/-46,000	-24,000/-60,000
2060	0	-64,000/-65,000	-68,000/-77,000	-50,000/-98,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.2-7-C2. Nationwide Changes in Health Outcomes from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks (cases/year) by Alternative, Analysis C2[a], Base Grid Mix and Alternate Grid Mix[b]

Outcome and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)
Mortality (ages 30 and older), Pope et al. (2002)				
2021	0	-40/-40	-55/-55	-82/-88
2025	0	-85/-85	-130/-130	-120/-170
2040	0	-280/-290	-390/-420	-300/-530
2060	0	-500/-510	-600/-630	-500/-800
Mortality (ages 30 and older), Laden et al. (2006)				
2021	0	-100/-100	-140/-140	-210/-230
2025	0	-220/-220	-330/-330	-320/-440
2040	0	-720/-730	-1,000/-1,100	-760/-1,400
2060	0	-1,300/-1,300	-1,500/-1,600	-1,300/-2,000
Chronic bronchitis				
2021	0	-28/-28	-37/-37	-56/-60
2025	0	-57/-57	-86/-87	-83/-110
2040	0	-180/-180	-250/-260	-190/-340
2060	0	-320/-320	-380/-400	-320/-510
Emergency room visits for asthma				
2021	0	-38/-38	-52/-52	-78/-84
2025	0	-79/-80	-120/-120	-110/-160
2040	0	-250/-250	-350/-370	-240/-440
2060	0	-450/-450	-530/-560	-420/-670
Work-loss days				
2021	0	-5,100/-5,200	-7,000/-7,000	-11,000/-11,000
2025	0	-10,000/-11,000	-16,000/-16,000	-15,000/-21,000
2040	0	-31,000/-31,000	-43,000/-46,000	-33,000/-59,000
2060	0	-55,000/-56,000	-65,000/-69,000	-55,000/-88,000

a. Negative changes indicate fewer health impacts; positive changes indicate additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.2-8-C1. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis C1[a], Base Grid Mix and Alternate Grid Mix[b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al.(2002)				
2021	$0	$330/330	$430/440	$640/710
2025	$0	$650/670	$910/960	$790/1,300
2040	$0	$2,400/2,500	$2,800/3,300	$1,700/4,200
2060	$0	$4,600/4,700	$4,900/5,500	$3,600/7,000
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$810/820	$1,100/1,100	$1,600/1,700
2025	$0	$1,600/1,600	$2,200/2,400	$1,900/3,100
2040	$0	$5,800/6,000	$6,900/8,100	$4,300/10,000
2060	$0	$11,000/11,000	$12,000/13,000	$8,800/17,000
7-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$290/300	$380/390	$570/640
2025	$0	$580/600	$810/860	$710/1,100
2040	$0	$2,200/2,200	$2,600/3,000	$1,600/3,900
2060	$0	$4,200/4,200	$4,400/5,000	$3,300/6,300
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$720/730	$940/950	$1,400/1,600
2025	$0	$1,400/1,500	$2,000/2,100	$1,700/2,800
2040	$0	$5,300/5,500	$6,300/7,400	$3,900/9,400
2060	$0	$10,000/10,000	$11,000/12,000	$8,000/15,000

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

Table 4.2.2-8-C2. Nationwide Monetized Health Benefits (U.S. million dollars/year, in 2011 dollars) from Criteria Pollutant Emissions from U.S. Passenger Cars and Light Trucks by Alternative, Analysis C2[a], Base Grid Mix and Alternate Grid Mix [b]

Rate and Year	Alternative 1[c] No Action	Alternative 2 2%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)	Alternative 3 Preferred (Base Grid Mix/ Alternate Grid Mix)	Alternative 4 7%/year Cars and Trucks (Base Grid Mix/ Alternate Grid Mix)
3-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al.(2002)				
2021	$0	$300/300	$400/410	$610/650
2025	$0	$630/640	$950/970	$930/1,300
2040	$0	$2,200/2,200	$3,100/3,300	$2,300/4,200
2060	$0	$3,900/4,000	$4,700/4,900	$3,900/6,300
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$730/730	$990/990	$1,500/1,600
2025	$0	$1,500/1,600	$2,300/2,400	$2,300/3,100
2040	$0	$5,400/5,500	$7,600/8,000	$5,700/10,000
2060	$0	$9,600/9,800	$11,000/12,000	$9,700/15,000
7-Percent Discount Rate				
Benefits-per-ton Assuming Premature Mortality Based on Pope et al. (2002)				
2021	$0	$270/270	$360/360	$540/580
2025	$0	$560/570	$850/870	$830/1,100
2040	$0	$2,000/2,000	$2,800/3,000	$2,100/3,800
2060	$0	$3,600/3,600	$4,300/4,500	$3,600/5,700
Benefits-per-ton Assuming Premature Mortality Based on Laden et al. (2006)				
2021	$0	$650/650	$880/890	$1,300/1,400
2025	$0	$1,400/1,400	$2,100/2,100	$2,000/2,800
2040	$0	$4,900/5,000	$6,900/7,300	$5,200/9,300
2060	$0	$8,800/8,900	$10,000/11,000	$8,800/14,000

a. Positive changes indicate greater benefits and fewer health impacts; negative changes indicate fewer benefits and additional health impacts. Values have been rounded.
b. The two entries for each alternative and year illustrate different upstream emissions assumptions. *See* Section 4.1.2.1 for details.
c. 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.

The monetized benefits of these health impacts follow similar trends to the changes in health outcomes. In Analyses C1 and C2, monetized benefits increase steadily from 2021 to 2060. Under Alternative 4, the near-term (2021) monetary benefits are generally greater than under all other action alternatives, but the benefits in later years (2040 and 2060) are generally the least of all alternatives. In total, the monetized health benefits in Analysis C1 range between $290 million and $17 billion, depending on the analysis, alternative, year, discount rate, and study. The monetized health benefits in Analysis C2 range between $270 million and $15 billion, depending on the same factors.

Sections 4.2.2.2 through 4.2.2.5 describe the results of the analysis of emissions for Alternatives 1 through 4 in greater detail. The magnitude of emissions change from one action alternative to the next generally increases between Alternative 2 and Alternative 4 consistent with the greater overall improvements in fuel economy.

The Base Grid Mix in this EIS is based on NEMS AEO 2012 Early Release version fuel mix projections for 2020. The Alternate Grid Mix (results are in Appendix H) is based on the fuel mix projections of the cleaner “GHG Price Economy-wide” emissions side case in the AEO 2011 for 2035.

4.2.2.2 Alternative 1: No Action

4.2.2.2.1 Criteria Pollutants

Under the No Action Alternative there would be no change after 2016 in the forecast for new vehicle passenger car and light-truck fuel economy. Current trends in the levels of criteria pollutant emissions from vehicles would continue under the No Action Alternative, with emissions of NO_x and VOCs continuing to decline due to the EPA emission standards (*see* Section 4.1), despite a growth in total VMT from 2021 to 2040, but increasing from 2040 to 2060 due to growth in total VMT during that period overwhelming the initial declines (*see* Tables 4.2.2-1-C1 and -C2 and Figures 4.2.2-1-C1 and -C2). Emissions of CO, $PM_{2.5}$ and SO_2 are predicted to increase from 2021 to 2060 because declines due to the EPA emission standards and fuel economy improvements are more than offset by growth in VMT beginning before 2021. The No Action Alternative would not change these trends and therefore would not result in any change in criteria pollutant emissions nationally or in nonattainment areas beyond changes projected to result from future trends in emissions and VMT (*see* Tables 4.2.2-1-C1 and -C2).

Emissions of CO under the No Action Alternative are generally less than emissions under Alternative 2 and Alternative 3, but generally greater than emissions under Alternative 4. Emissions of NO_x and SO_2 under the No Action Alternative are generally greater than emissions under Alternative 2 and Alternative 3 but less than emissions under Alternative 4. Emissions of $PM_{2.5}$ and VOCs under the No Action Alternative are greater than emissions under all action alternatives. For both Analyses C1 and C2, changes in emissions are greatest in 2060 under Alternative 4, in which emissions range up to 55 percent greater or 28 percent less than under the No Action Alternative.

4.2.2.2.2 Toxic Air Pollutants

EPA regulates toxic air pollutants from motor vehicles through vehicle emission standards and fuel quality standards, as discussed in Section 4.1.1.3.1. As with the criteria pollutants, current trends in the levels of toxic air pollutant emissions from vehicles would continue under the No Action Alternative. Emissions of all pollutants (except DPM) would continue to decline in early years due to the EPA emission standards (*see* Section 4.2.1.1), despite a growth in total VMT from 2021 or 2040, but would increase from 2040 to 2060 due to growth in total VMT during that period outpacing the initial declines (*see* Tables 4.2.2-4-C1 and -C2). DPM emissions would increase across all years. The No Action Alternative would not change the current CAFE standards and therefore would not result in any change in toxic air pollutant emissions throughout the United States (*see* Tables 4.2.2-5-C1 and -C2) beyond projected trends shown in Tables 4.2.2-4-C1 and -C2.

Emissions under the No Action Alternative are generally less than those under each of the action alternatives for acetaldehyde (except under Alternative 4 after 2025 in Analysis C1), acrolein (except under Alternative 2 in 2025), and 1,3-butadiene (except under Alternative 4 after 2021), but greater for benzene and DPM (except under Alternative 4 after 2040 in Analysis C2). Results are mixed for formaldehyde. Changes in emissions between the No Action Alternative and the action alternatives are greatest in 2060, in which emissions of formaldehyde under the action alternatives range up to 40 percent greater and 30 percent less than under the No Action Alternative.

4.2.2.2.3 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 of most criteria pollutants continuing to increase from 2021 to 2060 due to a growth in total VMT, which more than offsets reductions due to the EPA vehicle emission standards (*see* Section 4.2.1). The human health-related impacts expected under current trends would continue (*see* Tables 4.2.2-7-C1 and -C2 and 4.2.2-8-C1 and -C2). The No Action Alternative would not result in any other increase or decrease in human health impacts throughout the United States beyond projected trends shown for the No Action Alternative in Tables 4.2.2-7-C1 and -C2 and 4.2.2-8-C1 and -C2.

4.2.2.3 Alternative 2: 2 Percent per Year Increase in Fuel Economy

4.2.2.3.1 Criteria Pollutants

Tables 4.2.2-2-C1 and -C2 show the changes in nationwide emissions of criteria pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-3-C1 and -C2 show these changes in percentages for 2040. Under Alternative 2, nationwide emissions of $PM_{2.5}$, 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 generally are less than those under the other action alternatives. Emissions of CO under Alternative 2 increase compared to the No Action Alternative in all years because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT due to the rebound effect.

Under Alternative 2, all nonattainment areas would experience reductions in emissions of SO_2 and VOCs (except in Analysis C2 in 2060) compared to the No Action Alternative. Most nonattainment areas would experience slight increases in $PM_{2.5}$, NO_x, and CO emissions (except in Analysis C2 in 2060, when most nonattainment areas would see decreases). These increases are due to the rebound effect, which more than offsets emission reductions from decreased fuel usage. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.2.3.2 Toxic Air Pollutants

Tables 4.2.2-5-C1 and -C2 show the changes in nationwide emissions of toxic air pollutants under Alternative 2 compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-6-C1 and -C2 show these changes in percentages for 2040. Compared to the No Action Alternative, Alternative 2 would result in reduced emissions of benzene (before 2060 in Analysis C2), DPM, and formaldehyde (before 2060), increased emissions of acetaldehyde, acrolein, and 1,3-butadiene, for all analysis years. Compared to Alternative 2, emissions under the other action alternatives would be generally higher for acrolein (except under the Preferred Alternative in Analysis C2), and generally lower for benzene. Compared to Alternative 2, emissions under the other action alternatives would be higher or lower for acetaldehyde, 1,3-butadiene, DPM, and formaldehyde, depending on the analysis year and alternative.

At the national level, emissions of most toxic air pollutants could increase because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. However, the increases in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under Alternative 2, most nonattainment areas would experience net increases in emissions of most toxic air pollutants in all of the analysis years (*see* Appendix B).

4.2.2.3.3 Health Outcomes and Monetized Benefits

Under Alternative 2, there would be a reduction in adverse health outcomes in all years compared to the No Action Alternative (*see* Tables 4.2.2-7-C1 and -C2). These health benefits would increase with each future year. The health benefits under Alternative 2 would be less than the health benefits under the Preferred Alternative in both generation mixes. In the Base Grid Mix case, the health benefits under Alternative 2 would be less than the health benefits of Alternative 4 in 2021 and 2025, and greater than the health benefits under Alternative 4 in 2060. In the Alternate Grid Mix case, the health benefits under Alternative 2 would be less than those under Alternative 4.

As shown in Tables 4.2.2-8-C1 and -C2, the monetized health benefits under Alternative 2 would range from $270 million to $11 billion.

4.2.2.4 Alternative 3: Preferred

4.2.2.4.1 Criteria Pollutants

Tables 4.2.2-2-C1 and -C2 show the changes in nationwide emissions of criteria pollutants under the Preferred Alternative compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-3-C1 and -C2 show these changes in percentages for 2040. Figure 4.2.2-2-C1 and -C2 show criteria pollutant emissions under the Preferred Alternative by year. Under this alternative, emissions of all pollutants except CO are reduced compared to the No Action Alternative. CO emissions are increased compared to the No Action Alternative because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT. The Preferred Alternative generally reduces emissions by a greater amount than Alternative 2 (except for SO_2 in Analysis C1 after 2025 and CO, for which emissions increase under Alternative 2 and the Preferred Alternative), but by less than the more-stringent Alternative 4 (except for NO_x and SO_2, for which emissions increase under Alternative 4 after 2025).

Under the Preferred Alternative, all nonattainment areas would experience reductions in emissions of SO_2 and VOCs for all years (except in 2060 in Analysis C2). Most nonattainment areas would experience slight increases in emissions of NO_x, CO, and $PM_{2.5}$ in all years (except for CO and $PM_{2.5}$ in 2060 in Analysis C2). The increases in emissions of CO (and NO_x and $PM_{2.5}$, in some cases) occur because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT. The increases in $PM_{2.5}$ and NO_x emissions are due to increases in the diesel vehicle share of total VMT. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.2.4.2 Toxic Air Pollutants

Tables 4.2.2-5-C1 and -C2 show the changes in nationwide emissions of toxic air pollutants under the Preferred Alternative compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-6-C1 and -C2 show these changes in percentages for 2040. Figures 4.2.2-5-C1 and -C2 show toxic pollutant emissions under the Preferred Alternative by year. Compared to the No Action Alternative, the Preferred Alternative would result in reduced emissions of benzene and DPM and increased emissions of acetaldehyde, acrolein, and 1,3-butadiene for all analysis years. Results are mixed for formaldehyde, which increase in Analysis C2 and decrease in Analysis C1 compared to the No Action Alternative. For most pollutants, emissions under the Preferred Alternative are greater than under Alternative 2, except for benzene and DPM for all analyses and years, and acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde in Analysis C1 after 2025. Compared to Alternative 4, emissions under the Preferred Alternative would be lower for acetaldehyde (in 2021 and 2025), acrolein, DPM (after 2021), and formaldehyde; and higher for benzene, acetaldehyde (in 2040 and 2060), and 1,3-butadiene (after 2021).

At the national level, emissions of most toxic air pollutants could increase under the Preferred Alternative because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. However, as with the less-stringent alternatives, the reductions in upstream emissions would not be uniformly distributed to individual nonattainment areas. Under the Preferred Alternative, most nonattainment areas would experience net increases in emissions of all toxic air pollutants in all analysis years (*see* Appendix B), with the exception of benzene and 1,3-butadiene emissions in some analyses and years.

4.2.2.4.3 Health Outcomes and Monetized Benefits

Under the Preferred Alternative, there is a reduction in adverse health outcomes in all years compared to the No Action Alternative (*see* Tables 4.2.2-7-C1 and -C2). These health benefits increase with each future year. The health benefits under the Preferred Alternative are greater than the health benefits under Alternative 2. In the Base Grid Mix case, the health benefits under the Preferred Alternative would be greater than the health benefits under Alternative 4 (except in 2021). In the Alternate Grid Mix case, the health benefits under the Preferred Alternative would be less than those under Alternative 4.

As shown in Tables 4.2.2-8-C1 and -C2, the monetized health benefits under the Preferred Alternative would range from \$360 million to \$13 billion.

4.2.2.5 Alternative 4: 7 Percent per Year Increase in Fuel Economy

4.2.2.5.1 Criteria Pollutants

Tables 4.2.2-2-C1 and -C2 show the changes in nationwide emissions of criteria pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-3-C1 and -C2 show these changes in percentages for 2040. Under Alternative 4, nationwide emissions of all criteria pollutants compared to the No Action Alternative would be reduced (except NO_x and SO_2 in later years, which would increase compared to the No Action Alternative) because of EPA emission standards and greater fuel economy, despite an increase in VMT. These reductions and increases would be greater than under any other action alternative, with the exception of NO_x (in 2021 and 2025) and SO_2 (in 2025, 2040, and 2060).

Under Alternative 4, all nonattainment areas would experience reductions in emissions of $PM_{2.5}$ and VOCs for all years. Most nonattainment areas would experience reductions in SO_2 and CO emissions for all years (except for CO in 2021). Most nonattainment areas would experience increases in NO_x emissions after 2021, while a few nonattainment areas would see larger decreases in these years (in Analysis C1). The increases in CO and NO_x emissions in some nonattainment areas occur because declines due to the EPA emission standards and greater fuel economy are more than offset by growth in VMT. In nonattainment areas that would experience increases in SO_2 emissions, the increases are due to increases in the diesel and EV shares of total VMT. Tables in Appendix B list the emission changes for each nonattainment area.

4.2.2.5.2 Toxic Air Pollutants

Tables 4.2.2-5-C1 and -C2 show the changes in nationwide emissions of toxic air pollutants under Alternative 4 compared to the No Action Alternative and the other action alternatives. Figures 4.2.2-6-C1 and -C2 show these changes in percentages for 2040. Compared to the No Action Alternative, Alternative 4 would result in reduced emissions of benzene, 1,3-butadiene (except in 2021), and DPM (except in 2060 in Analysis C2), and in increased emissions of acetaldehyde (except after 2025 in Analysis C1), acrolein, and formaldehyde. Compared to the other action alternatives, Alternative 4 would result in reduced emissions of benzene and 1,3-butadiene (after 2021), and increased emissions of acrolein and formaldehyde. Results are mixed for acetaldehyde and DPM, depending on analysis and year.

At the national level, as for less-stringent alternatives, emissions of most toxic air pollutants could increase because the increases in vehicle emissions due to the rebound effect more than offset reductions in upstream emissions of toxic air pollutants due to improved fuel economy and the resulting decline in the volume of fuel refined and distributed. Under Alternative 4, most nonattainment areas would experience net increases in emissions of all toxic air pollutants in all analysis years, except for benzene, which would decrease in all nonattainment areas for all analysis years, and 1,3-butadiene and acetaldehyde, which would either increase or decrease in most nonattainment areas depending on analysis and year (*see* Appendix B).

4.2.2.5.3 Health Outcomes and Monetized Benefits

Under Alternative 4, there is a reduction in adverse health outcomes in all years compared to the No Action Alternative (*see* Tables 4.2.2-7-C1 and -C2). These health benefits increase with each future year. In the Base Grid Mix case, the health benefits under Alternative 4 would be either greater than the health benefits under Alternative 2 and less than the health benefits under the Preferred Alternative (except in 2021). In the Alternate Grid Mix case, the health benefits would be greater than the those under Alternative 2 and the Preferred Alternative.

As shown in Tables 4.2.2-8-C1 and -C2, the monetized health benefits under Alternative 4 range from $540 million to $17 billion.

CHAPTER 5 GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE

This section describes how the Proposed Action would affect the anticipated pace and extent of future changes in global climate. Although CEQ released draft guidance on consideration of the effects of climate change and greenhouse gas (GHG) emissions under NEPA in February 2010, the draft guidance has not been finalized, and there is currently no applicable final guidance or regulation from CEQ, DOT, or NHTSA for addressing climate change in an EIS. One of the key matters about which Federal agencies must use their own judgment is when they determine how to describe the potential differences between direct and indirect climate change-related impacts of a proposed action and the cumulative impacts associated with a proposed action.

In this EIS, the discussion of climate change direct and indirect impacts focuses on impacts associated with reductions in GHG emissions due to NHTSA's Proposed Action (assumed to remain in place after 2025 at the level of the MY 2025 standards as set forth by the agency). The Proposed Action would affect fuel consumption and emissions attributable to light-duty vehicles into the future. Results in this Chapter are shown through 2100, the end of the analytical period for this section. The discussion of consequences of the Proposed Action focuses on GHG emissions and their effects on the climate system (i.e., atmospheric CO_2 concentrations, temperature, sea level, and precipitation).

The cumulative impacts analysis addresses the effects of the Proposed Action together with those of other past, present, and reasonably foreseeable future actions, including projected increases in fuel economy. These reasonably foreseeable future actions, beyond those resulting directly or indirectly from the Proposed Action, would have additional effects on fuel consumption and emissions attributable to light-duty vehicles through 2100. Climate modeling for the cumulative impacts analysis applies different assumptions about the effect of broader global GHG policies on emissions outside the U.S. light-duty vehicle fleet. The analysis of cumulative impacts also extends the discussion of consequences to include not only the immediate effects of GHG emissions on the climate system (i.e., 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).

This chapter is organized as follows:

- Section 5.1 introduces key topics on GHGs and climate change.
- Section 5.2 describes the affected environment in terms of current and anticipated trends in GHG emissions and climate.
- Section 5.3 outlines the methodology NHTSA used to evaluate climate effects.
- Section 5.4 describes the direct, indirect, and cumulative environmental impacts of the Proposed Action and alternatives that NHTSA considered.
- Section 5.5 qualitatively describes the cumulative impacts of climate change on key natural and human resources.
- Section 5.6 qualitatively describes the cumulative non-climate effects of CO_2.

5.1 Introduction

This EIS draws primarily on panel-reviewed synthesis and assessment reports from the Intergovernmental Panel on Climate Change (IPCC), the U.S. Climate Change Science Program, the National Research Council, the Arctic Council, and the U.S. Global Change Research Program. It also cites EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act* (EPA 2009e) [1], which heavily relied on those major international or national scientific assessment reports. NHTSA similarly relies on assessment 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. These sources have been vetted by both the climate change research community and by the U.S. Government and are the foundation for the discussion of climate change in this EIS.

This EIS also draws on peer-reviewed panel reports and literature that has been published since the release of the IPCC, the U.S. Climate Change Science Program, and the U.S. Global Change Research Program panel-reviewed reports, to provide the most current review of climate change science. Because the recent peer-reviewed literature has not been assessed or synthesized by an expert panel, these sources supplement, but do not supersede, the findings of the panel-reviewed reports. In virtually every case, the recent literature corroborates the findings of the panel reports.

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 decisionmakers, is consistent with NHTSA's approach in its EISs for the MY 2012–2016 CAFE standards and the MY 2014–2018 HD vehicle standards.

5.1.1 Uncertainty within the IPCC Framework

As with all other environmental impacts, assessing climate change impacts involves uncertainty. Given the global importance of climate change and the need to communicate uncertainty to a variety of decisionmakers, IPCC has focused considerable attention on developing a systematic approach to characterize and communicate this information. In this EIS, NHTSA uses the system developed by IPCC to describe uncertainty associated with various impacts.

The IPCC reports communicate uncertainty and confidence bounds using commonly understood, but carefully defined, words in italics, such as *likely* and *very likely*, to represent likelihood of occurrence. The *IPCC Fourth Assessment Report Summary for Policymakers* (IPCC 2007d) and the *IPCC Fourth Assessment Synthesis Report* (IPCC 2007e) briefly explain this convention.[2] 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 Chapter 5 when discussing qualitative environmental impacts on specific resources. The reader should refer to the

[1] *Available at*: <http://epa.gov/climatechange/Downloads/endangerment/Endangerment_TSD.pdf> (Accessed: July 2, 2012).
[2] The IPCC is currently updating its findings and plans to release a Fifth Assessment Report in 2014.

referenced IPCC documents to gain a full understanding of the meaning of those uncertainty terms in the context of the IPCC findings.[3]

As addressed in the *IPCC Fourth Assessment Synthesis Report*, uncertainties can be classified in several 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. Confidence terminology (Table 5.1.1-1) is expressed as degree of confidence in being correct. Likelihood terminology is expressed in probability of an outcome. Table 5.1.1-2 identifies the terms that the IPCC uses to define the likelihood of an occurrence or outcome (where the outcome or result can be estimated probabilistically).

Table 5.1.1-1. Standard Terms Used to Define Levels of Confidence

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

Table 5.1.1-2. Standard Terms Used to Define the Likelihood of An Occurrence of a Climate-related Event

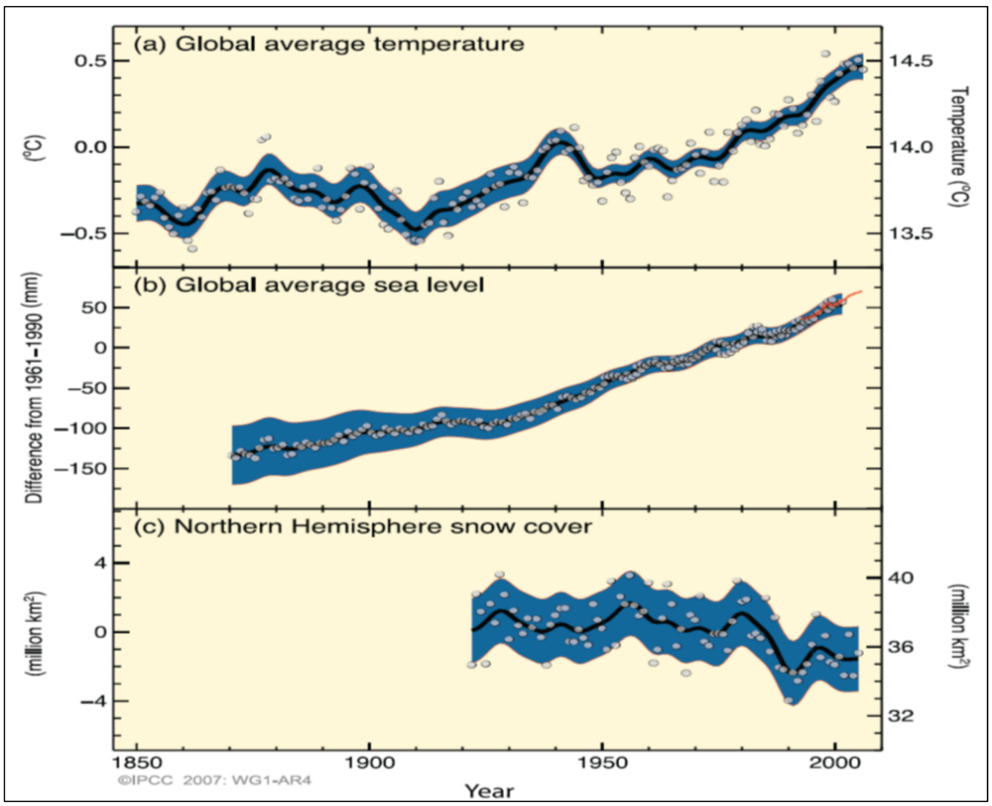
Likelihood Terminology	Likelihood of the Occurrence/Outcome
Virtually certain	Greater than 99% probability
Extremely likely	Greater than 95% probability
Very likely	Greater than 90% probability
Likely	Greater than 66% probability
More likely than not	Greater than 50% probability
About as likely as not	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] NHTSA notes that these terms could have different meanings 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 2.3.6.

5.1.2 Climate Change and its Causes

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. Over the twentieth century, Earth's global average surface temperature rose by approximately 0.74 °C (1.3 °F) (EPA 2009e, IPCC 2007d, NRC 2010c); global average sea level has been gradually rising, increasing approximately 0.17 meters (6.7 inches) during the twentieth century (IPCC 2007d); in the Atlantic Ocean, the maximum rate of change over the last 50 years has been more than 2 millimeters (0.08 inch) per year observed in a band running east-northeast from the U.S. east coast (EPA 2009e, IPCC 2007a); Arctic sea-ice cover has been decreasing at a rate of approximately 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 been decreasing (EPA 2009e, IPCC 2007d) (*see* Figure 5.1.2-1).

Figure 5.1.2-1. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover[a]

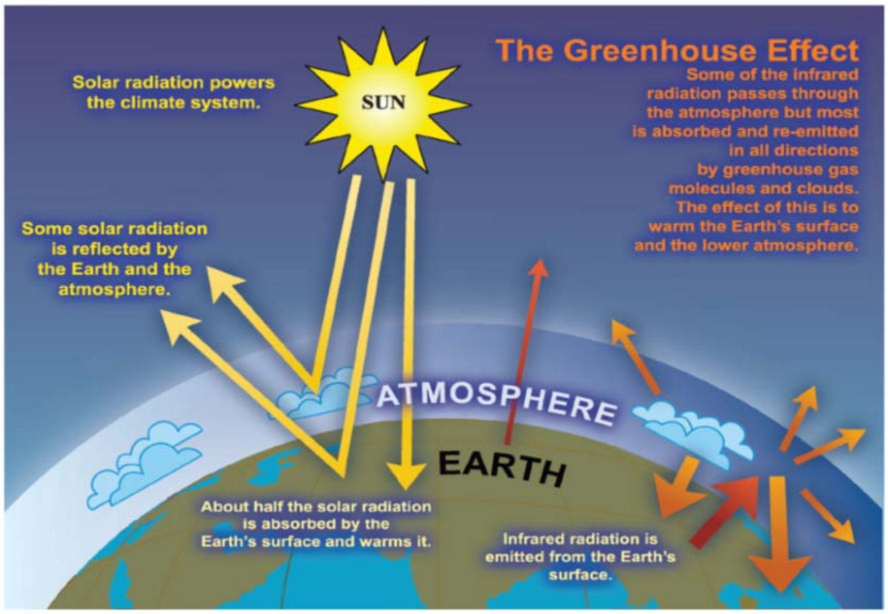


a. Source: IPCC 2007d.

Earth absorbs heat energy from the sun and returns most of this heat to space as terrestrial infrared radiation. GHGs trap heat in the lower atmosphere (the atmosphere extending from Earth's surface to approximately 9 to 14 miles above the surface), absorb heat energy emitted by Earth's surface and lower atmosphere, and re-radiate 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 5.1.2-2). 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 5.2 are largely a result of GHG emissions from human activities. Both EPA and 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 2009e, IPCC 2007d).

Figure 5.1.2-2. The Greenhouse Effect[a]



a. Source: IPCC 2007a, p. 115.

Most GHGs, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone, occur naturally. Human activities such as the combustion of fossil fuel for transportation and electric power 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 produced mainly for use in industrial processes and emitted to the atmosphere (e.g., as a result of leaks in refrigeration and air-conditioning systems).

5.1.3 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, forest management, agricultural production, and waste management. Emissions of CO_2, CH_4, and N_2O from human activities comprise approximately 99 percent of annual anthropogenic GHG emissions addressed by national inventory reports (WRI 2012a).[4] Atmospheric concentrations of CO_2, CH_4, and N_2O had, by 2007, increased approximately 38, 149, and 23 percent, respectively, since the beginning of the Industrial Revolution in the mid 1700s (EPA 2009e citing

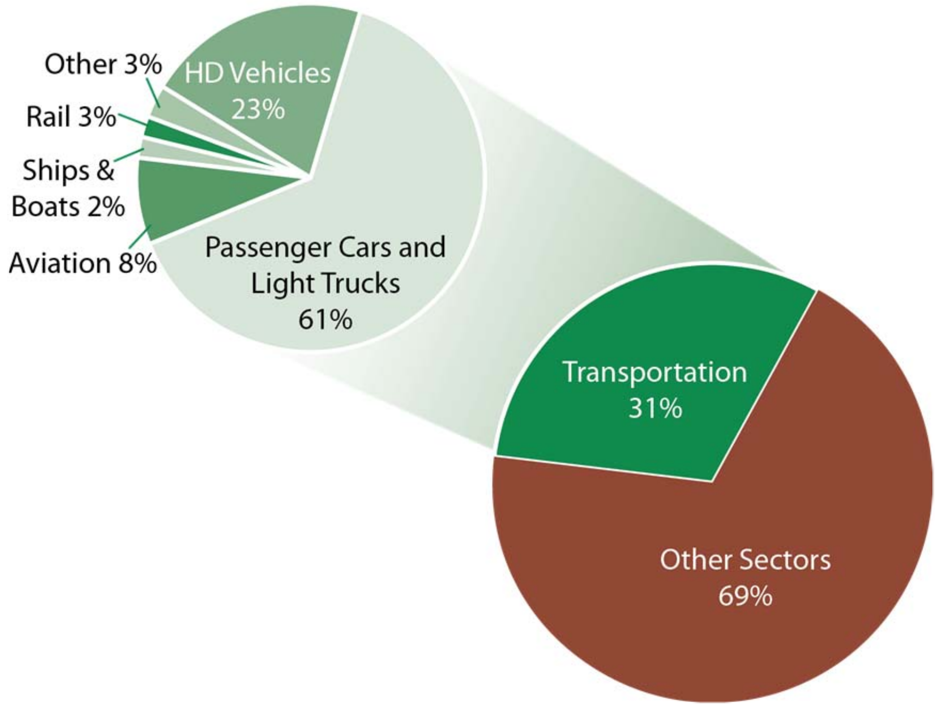
[4] Each GHG has a different level of radiative forcing (the ability to trap heat). To compare their relative contributions, gases are converted to carbon dioxide equivalent (CO_2e) using their unique global warming potential (GWP).

NOAA 2009 and IPCC 2007a, GCRP 2009). Global atmospheric CO_2 concentration has increased from approximately 280 parts per million (ppm) in pre-industrial times to approximately 391 ppm in 2011 (NOAA 2012). 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 natural 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. According to World Resources Institute's Climate Analysis Indicators Tool (CAIT), emissions from the United States account for approximately 17.4 percent of total global CO_2 emissions (WRI 2012a).[5] EPA's National Greenhouse Gas Inventory for 1990–2010 indicates that, in 2010, the U.S. transportation sector contributed about 30.6 percent of total U.S. CO_2 emissions, with passenger cars and light trucks accounting for 61.5 percent of total U.S. CO_2 emissions from transportation (EPA 2012a). Therefore, approximately 18.8 percent of total U.S. CO_2 emissions are from passenger cars and light trucks, and these vehicles in the United States account for 3.3 percent of total global CO_2 emissions (based on comprehensive global CO_2 emissions data available for 2005).[6] Figure 5.1.3-1 shows the proportion of U.S. emissions attributable to the transportation sector and the contribution of each mode of transportation to U.S. emissions.

[5] The estimate for global emissions from WRI is for 2005, the most recent year with available data for all GHGs.
[6] Percentages exclude land-use change and forestry and exclude international bunker fuels (i.e., international marine and aviation travel).

Figure 5.1.3-1. Contribution of Transportation to U.S. CO_2 Emissions and Proportion Attributable by Mode, 2010[a,b]



a. HD = heavy-duty.
b. Source: EPA 2012a.

5.1.4 Evidence of Climate Change

Observations and studies reporting trends from around the world demonstrate that Earth is undergoing climatic change much more quickly than would be expected from natural variations. As stated in a recent National Research Council (NRC) report, "There is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and these changes are in large part caused by human activities" (NRC 2010c). The global average surface temperature is rising, with decades from 1970 to 2009 being progressively warmer than prior decades, with the warmest temperatures observed during 2000 to 2009 (Arndt et al. 2010). Nine of the 10 warmest years on record have occurred since 2001 (NCDC 2011). A number of trends observed over the twentieth century further support the evidence of climate-induced changes. For example, cold-dependent habitats are shifting to higher altitudes and latitudes, and growing seasons are becoming longer (EPA 2009e, GCRP 2009, IPCC 2007d, Montoya and Raffaelli 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 2009e, IPCC 2007d). Oceans are becoming more acidic as a result of increasing absorption of CO_2, driven by higher atmospheric concentrations of CO_2 (EPA 2009e, NRC 2010a, NRC 2010b, GCRP 2009, National Science and Technology Council 2008). 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).

The weight of evidence that climate change is already occurring supports the projections of incremental environmental changes in the future. As discussed later in this chapter, although NHTSA has quantified the impacts of the alternatives on several climate parameters, it is very difficult to quantitatively translate these changes to damages on specific resources. Nonetheless, it is clear from current trends that these resources are likely to be affected to some degree by climate change. This section provides a qualitative analysis of these trends that is useful for the decisionmaker in consideration of the projected impacts of the Proposed Action. As discussed below, each of the action alternatives would, to a greater or lesser extent, result in decreased GHG emissions as compared to the No Action Alternative. The more the alternatives would reduce GHG emissions, the more they would be expected to also reduce the direct and indirect risks associated with these phenomena. Additional evidence of climate change is discussed throughout this section.

5.1.5 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 2009e, IPCC 2007d). The effects of the CO_2 emissions that have accumulated in the atmosphere prior to 2100 will persist well beyond 2100. If current trends continue, this elevation in atmospheric CO_2 concentrations will persist for many centuries, with the potential of temperature anomalies continuing much longer (Archer et al. 2009a, Archer and Brovkin 2008, Eby et al. 2009, Montenegro et al. 2007). In addition, global GHG emissions since 2000 have been increasing at a growth rate greater than the most fossil fuel-intensive emission scenario (A1Fi) in the IPCC Special Report on Emissions Scenarios (Raupach et al 2007).

By 2100, the IPCC projects an average increase in surface temperature of 1.8 °C (3.2 °F) to 4.0 °C (7.2 °F) compared to 1980 through 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 science. At the national, regional, and local levels, there can be significant differences in warming compared to the global average. This is due to the influence of smaller-scale factors, such as topography and changes in land-use, on local-scale climates (GCRP 2009). Elevated global average temperatures could persist even if atmospheric CO_2 concentrations decline. Because of the heat capacity of the oceans, centuries are required to realize all the warming from a given level of CO_2 concentrations. Therefore, while reductions in or stabilization of 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 could persist for centuries.

In addition, the IPCC projects that this temperature increase will impact sea level, causing a rise of 0.18 meter (0.6 foot) 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. 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 NRC suggests a more modest increase in sea level of 0.5 to 1.0 meter (1.6 to 3.3 feet) by 2100 (NRC 2010a). Delaying reductions in anthropogenic GHG emissions will increase the concentration at which CO_2 stabilizes in Earth's atmosphere, increasing the risk of greater warming and greater sea-level rise (Allen et al. 2009, Lowe et al. 2009, Mignone et al. 2008, Vaughan et al. 2009).

In addition to increases in global average temperature and sea level, climate change is expected to have many environmental, human health, and economic consequences. For a more in-depth analysis of the future impacts of climate change on various sectors, *see* Section 5.5 of this EIS.

5.1.6 Black Carbon and Other Aerosols

Aerosols are solid or liquid particles suspended in Earth's atmosphere. The chemical composition of aerosols varies enormously and can include sulfates, nitrates, dust, black carbon, and other chemical species (CCSP 2009a). Aerosols are either emitted directly from a source (e.g., power plants, forest fires, and volcanoes) into Earth's atmosphere or are chemically created in the atmosphere from gases (CCSP 2009a). The U.S. passenger car and light-truck fleet is not a large source of black carbon emissions, and there is no evidence to suggest that the alternatives differ significantly in terms of their effect on black carbon and aerosol emissions. However, given their important influence on climate, this section provides an overview of these emissions and their climatic interactions.

Depending on meteorological conditions and other factors, aerosols typically remain in Earth's atmosphere from a few days to more than a week (CCSP 2009a). Their relatively short lifetimes can create regional areas of high aerosol concentrations nearby and some distance downwind from emission source(s) (CCSP 2009a). Therefore, unlike GHGs, any climatic impact of aerosols may be evaluated at the regional scale.

An aerosol's effect on climate depends on its composition. Some aerosols, like sulfates, reflect incoming sunlight back to space causing a cooling effect; other aerosols, like black carbon, absorb incoming sunlight causing a warming effect (CCSP 2009a; IPCC 2007a). In addition, some aerosols attract moisture/water vapor and can affect the lifetime and reflectivity of clouds. Overall, IPCC (2007a) estimates that aerosols cool the Earth's atmosphere due to the reflection of incoming sunlight and their interaction with clouds, though these estimates have large uncertainties. These estimates do not include considerations of the effect of black carbon (*see* section 5.1.6.3). The overall effect of aerosols on precipitation is not known at the global scale, and this topic continues to be an active area of research (IPCC 2007a).

Among the aerosols, black carbon has recently attracted much attention because of its strong effect on the Earth's energy balance. 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).[7] A recent report from the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) suggests that the reduction of black carbon emissions could reduce global mean warming rates over the next few decades, while reductions of CO_2 emissions are required for reducing global mean warming over the long term (UNEP and WMO 2011).

There is no single accepted methodology for summarizing in a simple way the range of effects that black carbon emissions have on the climate or representing these effects and impacts in terms of CO_2e, and significant scientific uncertainties remain regarding black carbon's total climate effect.[8] 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, it is not feasible to quantify black carbon climate impacts in an analysis of the proposed standards. Therefore, a qualitative description of the climatic effects and general characteristics of black carbon follows.

5.1.6.1 Emissions

Globally, 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. They also have less stringent air emission control standards and technologies. The United States contributes approximately 7 to 8 percent of the world's black carbon emissions. The transportation sector is the single largest contributor in the United States, accounting for approximately 52 percent of U.S. black carbon emissions, followed by wildfires and agriculture/prescribed burns (Battye et al. 2002, Bond et al. 2004; EPA 2012c).[9] Approximately 93 percent of mobile source black carbon emissions in the

[7] 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.

[8] The range of uncertainty in the current magnitude of black carbon's climate-forcing effect is evidenced by the wide ranges presented in the IPCC Fourth Assessment Report (2007a) and the more recent study by Ramanathan and Carmichael (2008).

[9] Bond et al. (2004) estimated global black carbon emissions (in $PM_{2.5}$) to be 8,000 gigagrams. Battye et al. (2002) calculated total U.S. black carbon emissions at 433 gigagrams; the EPA 2001 National Emissions Inventory (NEI) database provides fine particle ($PM_{2.5}$) emissions that were then proportioned to black carbon for U.S. on-road diesel vehicles (65 to 89 gigagrams) and on-road gasoline vehicles (16 to 35 gigagrams). U.S. passenger cars and light trucks represent most (97 percent) of on-road gasoline consumed in the United States (EPA 2012a), and therefore are estimated to contribute 4 to 8 percent to the total U.S. black carbon emissions. (Diesel consumption from the fleet is small; therefore, black carbon emissions from diesel consumed by the fleet is likely insignificant.)

United States are from diesel sources (EPA 2012c). Because the U.S. passenger car and light-truck fleet is largely gasoline powered (not diesel), these vehicles are not a significant source of black carbon emissions. There is considerable uncertainty surrounding black carbon emission estimates; Ramanathan and Carmichael (2008) estimate 50 percent uncertainty in global estimates, while the uncertainty in regional emission estimates can range from a factor of 2 to 5.

5.1.6.2 Climatic Interactions

Although black carbon has been an air pollutant of concern for years due to its direct human health effects, climate change experts have become concerned with it because of its influence on climate change (EPA 2009e, NRC 2010c, EPA 2012c). Recent studies suggest black carbon is a major contributor to anthropogenic warming as it 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[10] 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 clouds (IPCC 2007d, EPA 2009e, Ramanathan and Carmichael 2008, Kopp and Mauzerall 2010, NRC 2010c, EPA 2012c). The following paragraphs discuss these interactions.

Black carbon absorbs solar radiation and re-emits this energy into the surrounding air, thereby warming it. 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. This causes 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), which would normally reflect sunlight at a high rate, the particles have a lesser effect at Earth's surface. Regardless of the characteristics of the underlying surface, black carbon particles cause warming in the atmosphere above Earth's surface.

When black carbon deposits onto snow and ice, it reduces the albedo as it absorbs incoming solar radiation and contributes to enhanced melting (EPA 2009e, Ramanathan and Carmichael 2008, Flanner et al. 2007, EPA 2012c). For example, in places where black carbon emissions are high (e.g., 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 2007d). The Arctic has also experienced accelerated spring melting and a longer 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). Another recent study modeled black carbon and dust deposition and found that they cause significant warming over large areas of the Arctic Ocean and sub-Arctic seas during the fall and winter months (Goldenson 2012).

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 droplets, which can extend the life of the cloud and increase cloud cover (Ramanathan and Carmichael 2008). In addition, reducing precipitation can extend the atmospheric lives of aerosols. Although initially hydrophobic (i.e., the aerosol does not attract moisture/water vapor), black carbon becomes hygroscopic (i.e., the aerosol attracts

[10] Surfaces on Earth (including land, oceans, and clouds, etc.) reflect solar radiation back to space. This reflective characteristic, known as albedo, indicates the proportion of incoming solar radiation the surface reflects. High albedo has a cooling effect, because the surface reflects rather than absorbs most solar radiation.

moisture/water vapor) as it ages in the atmosphere, thus acting as a cloud condensation nucleus. This increases the number of droplets in clouds, thereby increasing the cloud albedo (Kopp and Mauzerall 2010). Conversely, black carbon radiatively warms the surrounding air as it absorbs solar radiation, which leads to evaporation of cloud droplets by lowering the relative humidity and reducing cloud cover (Ramanathan and Carmichael 2008). An important issue, which can vary by region, is which aerosols – non-black carbon or black carbon – dominate in cloud effects (Ramanathan and Carmichael 2008). The observed weakening of the summertime Indian monsoon has been attributed, in part, to black carbon atmospheric absorption (Ramanathan and Carmichael 2008, Meehl et al. 2008).

5.1.6.3 Net Radiative Effect

A recent study suggests that black carbon has more than half of the positive radiative forcing effect of CO_2 and has 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 more than 0.9 watts per square meter, which is more than twice that estimated by the IPCC (2007a). However, there is great uncertainty associated with these estimates. The different treatment of black carbon across global-scale modeling studies and the variation in regional concentrations 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). In addition, Spracklen et al. (2011) suggests black carbon acting to promote the development of cloud droplets plays a significant role in increasing the radiative cooling caused by clouds, emphasizing the importance of including this mechanism when considering the particle's net effect on climate.

5.1.6.4 Comparison to Properties of Greenhouse Gases

Black carbon has a much shorter atmospheric lifespan than GHGs. The U.S. Climate Change Science Program (CCSP 2009a) estimates the life of black carbon in the atmosphere as being approximately 1 to 2 weeks, generally depending on meteorological conditions. This is quite short compared to the atmospheric life of CO_2 in the atmosphere.[11] This short life suggests black carbon's effects are greatest near the emission source; however, the nearby air molecules heated by black carbon's absorption of solar radiation 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 (i.e., about a week) effect on radiative forcing.

As with the warming associated with GHGs, the physical environment reacts to the climatic impacts of black carbon. For example, black carbon can contribute to the warming of permafrost in the Arctic region. As permafrost warms it releases large amounts of methane into the atmosphere, leading to additional warming (EPA 2009e). As another example, the warming associated with black carbon can contribute to earlier melting of sea ice in the Arctic, exposing open oceans earlier in the year. The open oceans absorb solar radiation that would have been reflected by sea ice, leading to enhanced regional warming (EPA 2009e). *See* section 5.5.8 for more discussion of these and other interactions.

[11] "About 50% of a CO_2 increase will be removed from the atmosphere within 30 years, and a further 30% will be removed within a few centuries. The remaining 20% may stay in the atmosphere for many thousands of years" (IPCC 2007a).

5.2 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 include descriptions of conditions globally and in the United States. Many themes in the discussions regarding conditions in the United States reappear in the global discussions.

5.2.1 Greenhouse Gas Emissions (Historic and Current)

5.2.1.1 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, fossil fuels are still the primary source of energy for the world and the predominant source of GHG emissions.

As noted earlier, levels of atmospheric CO_2 have been rising rapidly. For approximately 10,000 years before the Industrial Revolution, atmospheric CO_2 levels were 280 ppm (plus or minus 20 ppm). Since the Industrial Revolution, CO_2 levels have risen to approximately 390 ppm in 2011 (NOAA 2012). In addition, the concentrations of CH_4 and N_2O in the atmosphere increased 149 and 23 percent, respectively, by 2007 (EPA 2009e, NOAA 2009, Peterson and Baringer 2009).

In 2005, gross global GHG emissions were estimated to be 44,117 $MMTCO_2e$, a 20.3 percent increase since 1990[12] (WRI 2012a). In general, global GHG emissions have increased regularly, although annual increases vary according to a variety of factors (e.g., weather, energy prices, and economics).

The primary GHGs emitted are CO_2, CH_4, N_2O, and the fluorinated gases HFCs, PFCs, and SF_6. In 2005, CO_2 emissions comprised 77 percent of global emissions on a GWP-weighted basis, followed by CH_4 (15 percent) and N_2O (7 percent). Collectively, fluorinated gases represented 1 percent of global emissions covered by national inventories (WRI 2012a).

GHGs are emitted from a wide variety of sectors, including energy, industrial processes, waste, agriculture, and forestry. The energy sector is the largest contributor of global GHG emissions, accounting for 64 percent of global emissions in 2005. The next highest contributors to emissions are agriculture (14 percent) and land-use change and forestry (12 percent) (WRI 2012a).

[12] All GHG estimates cited in Section 5.2.1.1 include contributions from land-use change and forestry, as well as bunker fuels. The most recent emission estimates for all gases from WRI CAIT are for 2005.

Transportation CO_2 emissions comprise roughly 12 percent of total global GHG emissions (included in the 64 percent cited above for the energy sector [WRI 2012a]). Emissions from transportation are primarily due to the combustion of petroleum-based fuels to power vehicles. Global transportation CO_2 emissions have increased by 35 percent from 1990 to 2005 (WRI 2012a).

5.2.1.2 U.S. Emissions

GHG emissions for the United States in 2010[13] were estimated at 6,821.7 million metric tons of CO_2e ($MMTCO_2e$) (EPA 2012a). U.S. emissions comprise approximately 16 percent of global GHGs emitted[14] (WRI 2012a). Annual U.S. emissions, which have increased 9 percent since 1990, are heavily influenced by "general economic conditions, energy prices, weather, and the availability of non-fossil alternatives" (EPA 2012a).

Similar to the global trend, CO_2 is by far the primary GHG emitted in the United States, representing 83.7 percent of U.S. GHG emissions in 2010 (EPA 2012a). CH_4 accounts for 9.8 percent of total GHGs on a GWP-weighted basis, followed by N_2O (4.5 percent) and the high-GWP gases (2.1 percent) (EPA 2012a).

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 79 percent of total U.S. emissions (EPA 2012a). The CO_2 emissions due to combustion of fossil fuels are from fuels consumed in the electric power (42 percent of fossil-fuel emissions), transportation (32 percent), industry (14 percent), residential (6 percent), and commercial (4 percent) sectors, with the remaining emissions, from U.S. territories, accounting for 1 percent of the total (EPA 2012a). When U.S. CO_2 emissions are apportioned by end use, transportation is still the single leading source of U.S. emissions from fossil fuels, causing approximately one-third of total CO_2 emissions from fossil fuels (EPA 2012a).[15]

Passenger cars and light trucks, which include sport utility vehicles, pickup trucks, and minivans, account for more than half of U.S. transportation CO_2 emissions, and CO_2 emissions from these vehicles have increased by 13 percent since 1990 (EPA 2012a). This increase was driven by two factors: (1) an increase in use of passenger cars and light trucks and (2) relatively little improvement in their average fuel economy. Population growth and expansion, economic growth, and low fuel prices led to more vehicle miles traveled (VMT) over this period, while the rising popularity of sport utility vehicles and other light trucks kept the average combined fuel economy of new passenger cars and light trucks relatively constant (EPA 2012a). Although emissions from these vehicles typically increase each year, emissions from 2008 to 2010 declined due to a decrease in economic activity associated with the recent recession (EPA 2012a).

5.2.2 Climate Change Effects (Historic and Current)

In its 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 2007d). The IPCC concludes that, "At continental, regional and ocean basin scales, numerous long-term changes

[13] Most recent year for which an official EPA estimate is available (EPA 2012a).
[14] Based on global and U.S. estimates for 2005, the most recent year for which a global estimate is available. Excluding carbon sinks from forestry and agriculture.
[15] Apportioning by end use allocates emissions associated with electricity generation to the sectors (residential, commercial, industrial, and transportation) where it is used.

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 2007d).

This section provides an overview of observed historical and current climate change and ocean salinity effects and impacts at the global, regional, and national scales. Much of the material that follows is drawn from the following studies, including the citations therein: *Summary for Policymakers* (IPCC 2007d), *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* (EPA 2009e), *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 2010c). The impacts associated with these observed trends are further discussed in Section 5.5.

Sections 5.2.2.1 through 5.2.2.3 address increased temperatures, sea-level rise, and changes in precipitation patterns, respectively. Section 5.4 of this EIS provides a quantitative analysis of the effects of the regulatory alternatives on each of these three climate attributes. Sections 5.2.2.4 through 5.2.2.6 address increased incidence of severe weather, changes in ice cover and extent, and ocean acidification, which represent phenomena for which the effects of the alternatives cannot be quantified with current methods. They are described to provide a more complete discussion of historic and current climate change trends and impacts. As discussed below, although the incremental effects of the alternatives are not quantified for these impacts, the more the alternatives reduce GHG emissions, the more they reduce the direct and indirect risks associated with these phenomena.

5.2.2.1 Increased Temperatures

The IPCC states that scientific evidence shows that the increase in GHGs (primarily, CO_2, CH_4, and N_2O) since 1750 has led to an increase in global radiative forcing of 2.30 watts per square meter (plus or minus 0.23 watts per square meter) (EPA 2009e, IPCC 2007a). 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 2007d).

Average temperatures. This increase in radiative forcing results in higher temperatures, which are being observed. The global average surface temperature has been increasing over the past century. In the past 100 years, the global mean surface temperature has risen by 0.74 plus or minus 0.18 °C (1.3 plus or minus 0.32 °F) (IPCC 2007a). Temperatures are rising at an increasing rate. The average rate of increase over the past century was 0.07 plus or minus 0.02 °C (0.13 plus or minus 0.04 °F) per decade. Over the past 50 years, temperatures have been rising at nearly twice that average rate, or 0.13 plus or minus 0.03 °C (0.23 plus or minus 0.05 °F) per decade (IPCC 2007a). Over the past 30 years, the average global temperature has risen even faster, for an average of 0.29 °F per decade (EPA 2009e citing NOAA 2009). The average Arctic temperature has increased at almost twice the global average rate in the past 100 years. Temperature increases are more pronounced over land; air temperatures over land are warming at about twice the rate as over oceans (IPCC 2007a).

Recent measurements (1995–2006) suggest the Earth has been at its warmest in more than a century of direct observations (IPCC 2007a), with the average temperature for the contiguous United States rising at a rate near 0.58 °F per decade in the past few decades (1979–2008) (EPA 2009e citing NOAA 2009). Similar to the global trend, the U.S. average temperature is now 1.25°F warmer than at the beginning of the twentieth century, with an average warming of 0.13 °F per decade from 1895 through 2008; this rate of warming is increasing (EPA 2009e citing NOAA 2009). Global ocean temperatures have also continued to warm. For example, in summer 2009 ocean-surface temperatures were 0.58 °C (1.04 °F) above the average global temperature recorded for the twentieth century (Hoegh-Guldberg and Bruno 2010), and the global ocean surface temperature for January 2010 was the second warmest January on record.

Surface temperatures are not rising uniformly around the globe. For example, an area over the southeastern United States has been termed the "warming hole" because temperature observations during the twentieth century suggest a cooling trend there (Portmann et al. 2009). 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).

Extreme temperatures. Across regions of the world including the United States, extreme temperatures have changed significantly over the past 50 years (1951–2003). Hot days, hot nights, and heat waves have become more frequent; cold days, cold nights, and frost have become less frequent (EPA 2009e, IPCC 2007a, GCRP 2009, NRC 2010a). Since 1950, the frequency of heat waves experienced in the United States has increased, although in many regions the heat waves recorded in the 1930s remain the most severe on record. 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).

Weather balloons and satellites have recorded increases in temperatures since 1958 and 1979, respectively (Arndt et al. 2010). 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 northern latitudes, the growing season increased an average of approximately 2 weeks during the second half of the twentieth century (EPA 2009e citing IPCC 2007b), and plant flowering and animal spring migrations are occurring earlier (EPA 2009e, IPCC 2007b, NRC 2010a, NRC 2010c). Permafrost top layer temperatures have generally increased since the 1980s (approximately 3 °C [5 °F] in the Arctic), while the maximum area covered by seasonal frozen ground has decreased since 1900 by approximately 7 percent in the Northern Hemisphere, with a decrease in spring of up to 15 percent (EPA 2009e citing Lemke et al. 2007; NRC 2010a).

5.2.2.2 Sea-level Rise

Contributions to 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. From 1961 to 2003, thermal expansion on average contributed approximately 25 percent to observed sea-level rise, while melting ice contributed less than 50 percent. The full magnitude of sea-level rise was not fully explained by observations (EPA 2009e). Between 1993 and 2003, during which observing systems improved, thermal expansion and melting ice were roughly equal in their effect on sea-level rise (EPA 2009e).

Between 1961 and 2003, global ocean temperature warmed by approximately 0.18 °F from the surface to a depth of 700 meters (0.43 mile) (EPA 2009e, IPCC 2007a). This warming contributed an average of 0.4 plus or minus 0.1 millimeter (0.016 plus or minus 0.0039 inch) per year to sea-level rise (EPA 2009e, IPCC 2007a), 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 *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 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 three times faster than that for mountain glaciers and ice caps (Rignot et al. 2011). For the period 1993 to 2007, Cazenave and Llovel (2010) suggest that approximately 30 percent of the observed rate of sea-level rise was due to thermal expansion, and approximately 55 percent was due to melting of land ice, thus suggesting that thermal expansion contributes less to sea-level rise than some studies previously stated (e.g. EPA 2009e). Dynamical ice loss (i.e., where a supporting ice shelf situated along the boundary between the glacier and ocean collapses, thereby allowing for the downgradient flow of ice streams within the glacier to reach the ocean) explains most of the Antarctic net mass loss and about half of the Greenland net mass loss; the other half occurred because melting has exceeded snowfall accumulation (IPCC 2007d).

Observed global sea-level rise. Global average sea level rose at an average rate of 1.8 plus or minus 0.5 millimeters (0.07 plus or minus 0.019 inch) per year from 1961 to 2003, with the rate increasing to approximately 3.1 plus or minus 0.7 millimeters (0.12 plus or minus 0.027 inch) per year from 1993 to 2003 (EPA 2009e, IPCC 2007a). Recent reports indicate that since the beginning of satellite measurements in the early 1990s, sea level has actually risen at a slightly greater rate of 3.4 millimeters (0.13 inch) per year (Rahmstorf 2010 citing Cazanave and Llovel 2010). Total twentieth century rise is estimated at 170 plus or minus 50 millimeter (6.7 plus or minus 2 inches) (EPA 2009e, IPCC 2007a). However, since the publication of the IPCC Fourth Assessment Report, 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 a recently recognized source of instrument bias (Domingues et al. 2008). The study found the improved estimates demonstrate clear agreement with the decadal variability of the climate models that included volcanic forcing.[16] Furthermore, this study estimated the globally averaged sea-level trend from 1961 to 2003 to be a rise of 1.5 plus or minus 0.4 millimeters (0.063 plus or minus 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 accounting for thermal expansion in the upper ocean and deep ocean, variations in the Antarctic and Greenland ice sheets, glaciers and ice caps, and terrestrial storage. Although there is variation of the rate of sea-level rise among these studies, the estimates agree within the stated ranges of uncertainty.

Observed regional sea-level rise. 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 2009e, IPCC 2007a).

Nationally, 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 (the faster pace being due to relatively rapid 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 2009e).

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

[16] Volcanic eruptions can emit large numbers of particles and gases 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 have been observed to remain in the stratosphere for more than a year.

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 2009e citing Nicholls et al. 2007).[17]

5.2.2.3 Changes in Precipitation Patterns

As the climate warms, evaporation from land and oceans will increase and more moisture can be held in the atmosphere (GCRP 2009). Depending on atmospheric conditions, this translates to some areas experiencing increases in precipitation events, while other areas are left more susceptible to droughts. 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 of changes in climate including increased moisture content in the atmosphere, heavy precipitation events have increased in frequency over most land areas (National Science and Technology Council 2008).

Global, regional, and national precipitation trends. 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 (IPCC 2007a).

Over the contiguous United States, total annual precipitation increased approximately 6 percent from 1901 to 2005 on average. The greatest increases were noted in the northern Midwest and the South, and there were notable decreases in Hawaii and the Southwest (EPA 2010c). 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 with extreme 1-day precipitation events have been observed from 1990 to 2010 (EPA 2010c).

Global, regional, and national trends in droughts. Longer, more intense droughts caused by higher temperatures and decreased precipitation have been observed in some regions 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 2009e, IPCC 2007a, NRC 2010c). 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).

Most regions in the United States experienced decreases in drought severity and duration over the twentieth century, although there are exceptions to this trend, such as the severe drought in the Southwest from 1999 to 2008 (EPA 2009e citing IPCC 2007a, National Science and Technology Council 2008) and recent severe drought in the Southeast (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 2010c).

National streamflow trends. Melting snow and ice, increased evaporation, and changes in precipitation patterns all affect surface water. Stream flow decreased approximately 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.

[17] "The shoreline erosion in Louisiana is also impacted by human alterations and loss of sediment supply" (EPA 2009e).

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-caused climate change was responsible for up to 60 percent of the observed changes in river flows, winter air temperature, and snowpack in the western United States. Analytical and modeling results for eight river basins indicate that northwestern and north-central regions of the western United States are becoming wetter, while the southwestern and south-central regions are becoming drier (Bureau of Reclamation 2011a).

National trends in snow cover. An empirical analysis of available data indicated that temperature and precipitation impact mountain snowpack in concert with the nature of the impact strongly dependent on factors such as latitude and elevation (Stewart 2009). At high elevations that remain below freezing in winter, precipitation increases have resulted in increased snowpack, while warmer temperatures at mid-elevations have decreased snowpack and led to earlier snowmelt, even with precipitation increases (Kundzewicz et al. 2007). 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 2010c). For North America as a whole, EPA (2010c) 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.

In addition to trends detected in total snow coverage across the entire winter and early spring season, some investigators have found trends for specific months. Total snow-cover area in the United States increased in the November-to-January season from 1915 to 2004 (National Science and Technology Council 2008).[18] 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).

5.2.2.4 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. Developing long-term trends of tropical cyclones can be problematic, because the accuracy and completeness of the tropical cyclone record is continuously being improved (WMO 2006). However, there is observational evidence of an increase in intense tropical cyclone activity correlated with increases of tropical sea-surface temperatures in the North Atlantic since about 1970 (EPA 2009e). Six of the 10 most active hurricane seasons have occurred since the mid 1990s, mirroring the variations in sea surface temperatures of the tropical Atlantic (EPA 2010c). There is also evidence of an increase in extreme wave height characteristics over the past two decades, associated with more frequent and more intense hurricanes (CCSP 2008a). However, concerns about data quality and multi-decadal variability persist (EPA 2009e). 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). The major factors influencing the increase in cost associated with hurricane-related losses that have been sustained from 1980 to 2003 are population growth and

[18] Snowfall tends to increase as temperature approaches the freezing point because the air can hold more moisture, but above the freezing point, there is a shorter time of freezing conditions reducing the snowfall pack amount.

demographic shifts, rather than changes in climate (NOAA 2003). Recently, there is a growing confidence in the model projections that climate change may increase hurricane strength, but it is still unclear how the overall frequency of occurrence might change (NRC 2010c).

Evidence is also insufficient to determine whether there are trends in large-scale phenomena such as the Meridional Overturning Circulation,[19] or in small-scale phenomena such as tornadoes, hail, lightning, and dust storms (IPCC 2007d).

5.2.2.5 Changes in Ice Cover and Permafrost

Changes in air and ocean temperatures, precipitation onto the ice mass, and water salinity are affecting glaciers, sea-ice cover, 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 loss of mass from 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 2009e citing NSIDC 2009). Warming in the Arctic has proceeded at about twice the rate as elsewhere, leading to decreases in summer sea-ice extent, glacier and ice sheet mass loss, coastal erosion, and permafrost thawing (AMAP 2011).[20] Some Arctic ice that previously was thick enough to last through summer has now thinned enough to melt completely in summer. In 2007, sea-ice extent was approximately 23 percent less than the previous all-time minimum observed in 2005 (EPA 2009e, National Science and Technology Council 2008). Average sea-ice thickness in the central Arctic *very likely* decreased by approximately 3 feet from 1987 to 1997 (EPA 2009e, National Science and Technology Council 2008). 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). 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 2009e, National Science and Technology Council 2008).

5.2.2.6 Acidification of Oceans

Increasing CO_2 concentrations have forced additional uptake by the oceans, which lowers the pH of the water. When CO_2 dissolves in seawater, the hydrogen ion concentration of the water increases; this is measured as a decline in pH. Compared to the pre-industrial period, the pH of the world's oceans has dropped 0.1 unit (IPCC 2007a). 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 5.6, although research on the ultimate impacts of ocean acidification is limited, available observational, laboratory, and theoretical studies indicate that acidification is likely to interfere with the calcification of coral reefs and therefore inhibit the growth and survival of coral reef ecosystems (EPA 2009e, NRC 2010a, NRC 2010c, GCRP 2009, IPCC 2007e).

[19] 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.
[20] Permafrost thawing releases CO_2 and CH_4 into the atmosphere (*see* Section 5.5.2).

5.3 Analysis Methodology

The methodology NHTSA used to characterize the effects of the alternatives on climate has three key elements, as follows:

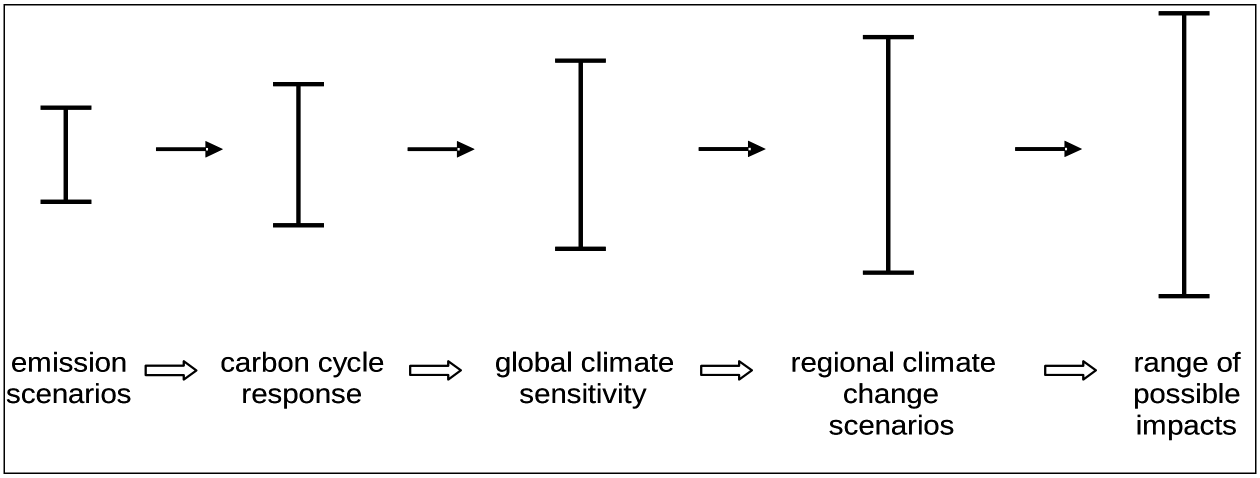
- Analyzing the effects of each alternative on GHG emissions. Many analyses of policies and regulations express their goals, and measure their effectiveness, in terms of GHG emission reductions.
- Estimating the monetized damages associated with GHG emissions and reductions attributable to each alternative. Economists have estimated the incremental effect of GHG emissions, and monetized those effects, to express the "social cost of carbon" (SCC), in terms of dollars per ton of CO_2 equivalent. By multiplying GHG emission reductions by this SCC, NHTSA derived a monetized estimate of the benefits of emission reductions.
- Analyzing how GHG emissions and reductions under each alternative affect the climate system (climate effects). Climate models characterize the relationship between GHG emissions and various climatic parameters in the atmosphere/ocean system, including temperature, precipitation, and sea level. In this element, NHTSA translated the changes in GHG emissions associated with each alternative to changes in temperature, precipitation, and sea level in relation to a reference case (business as usual) scenario.

In this EIS, effects on GHG emissions and the climate system are expressed in terms of emissions; CO_2 concentrations, temperature, precipitation, and sea level for each of the action alternatives. Comparisons between the No Action Alternative and each action alternative 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 5.3-1). As indicated in Figure 5.3-1, the emission estimates used in this EIS have narrower bands of uncertainty than the global climate effects, which are less uncertain than regional climate change effects. The effects on climate are, in turn, less uncertain than the impacts of climate change on affected resources (such as terrestrial and coastal ecosystems, human health, and other resources discussed in Section 5.5). 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 5.3-1. Cascade of Uncertainty in Climate Change Simulations[a]



a. Source: Moss and Schneider 2000.

Scientific understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decisionmaking, evaluating reasonably foreseeable impacts on the human environment involves many assumptions and uncertainties. This EIS uses methods and data to analyze climate impacts 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. The information cited throughout this section that is extracted from the most recent EPA, IPCC, and U.S. Global Change Research Program reports on climate change has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The tools used to perform the climate change impacts analysis in this EIS, including the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) and the objEcts version of the Global Change Assessment Model (GCAM), are widely available and generally accepted in the scientific community.[21]

The U.S. Climate Change Science Program Synthesis and Assessment Product 3.1 (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 will 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.

5.3.1 Methodology for Modeling Greenhouse Gas Emissions

The emission estimates in this EIS include GHG emissions resulting from light-duty vehicle fuel combustion (tailpipe emissions) as well as upstream emissions from the production and distribution of fuel.[22] GHG emissions were estimated by the DOT Volpe National Transportation Systems Center using the following models: the CAFE Compliance and Effects model (referred to as the Volpe model), described in Section 2.3.1, to calculate tailpipe emissions, and the Greenhouse Gases and Regulated Emissions in Transportation (GREET) model, developed by the U.S. Department of Energy (DOE) Argonne National Laboratory, to estimate emissions associated with production, transportation, and storage of gasoline and diesel from crude oil as well as emissions associated with the generation of electricity. The

[21] GCAM is used as the basis for the Representative Concentration Pathway (RCP) 4.5 scenario (Thomson et al. 2011).

[22] Section 2.4.1.2 provides more information on the upstream emission factors applied to account for upstream fuel and electricity generation.

Volpe model uses emission factors ([amount of pollutant emitted per unit of source activity, e.g., grams per VMT]) derived from EPA's Motor Vehicle Emissions Simulator (MOVES).

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 2017–2060 vehicles were estimated using the methodology described in Section 2.3. For the climate analysis, GHG emission trajectories are projected through year 2100. NHTSA estimated GHG emissions for the light-duty vehicle fleet for 2061–2100 by applying the projected rate of change in U.S. transportation fuel consumption over this period from GCAM.[23] For 2061 through 2100, the GCAMReference and GCAM6.0 scenarios project 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 2060 does not change significantly. Therefore, emissions remain relatively constant from 2060 through 2100. The assumptions and methods used to develop the GHG emission estimates for this EIS are broadly consistent with those used in the MY 2012–2016 CAFE Final EIS (NHTSA 2010b) and the MY 2014–2018 HD Final EIS (NHTSA 2011b).

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 and electricity (upstream emissions). The Volpe model also estimated the following non-GHGs: SO_2, NO_x, CO, and VOCs.

Fuel savings from more stringent CAFE standards would result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[24] There is a direct relationship among fuel efficiency, fuel consumption, and CO_2 emissions. Fuel efficiency describes how much fuel a vehicle requires to perform a certain amount of work (for example, how many miles it can travel or how many tons it can carry per mile traveled). A vehicle is more fuel-efficient if it can perform more work while consuming less fuel. Lower fuel consumption reduces CO_2 emissions directly because the primary source of vehicle-related CO_2 emissions is the combustion of carbon-based fuel in internal-combustion engines; 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, NHTSA 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.[25] Specifically, NHTSA estimated CO_2 emissions from fuel combustion as the

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[23] 2060 is the last year for which the CAFE Compliance and Effects (Volpe) model provides estimates of fleet CO_2 emissions for this analysis.

[24] For this rulemaking, NHTSA estimated emissions of vehicular CO_2, CH_4, and N_2O emissions, but did not estimate vehicular emissions of HFCs, which are not regulated under NHTSA's action. HFCs are released to the atmosphere only through air-conditioning system leakage and are not directly related to fuel efficiency. NHTSA's authority under EISA extends only to the regulation of vehicle fuel efficiency. For the reader's reference, CH_4 and N_2O account for 1.5 percent of the tailpipe GHG emissions from passenger vehicles and light trucks, and CO_2 emissions account for the remaining 98.5 percent. Of the total (including non-tailpipe) GHG emissions from passenger vehicles, tailpipe CO_2 represents approximately 94.7 percent, tailpipe CH_4 and N_2O represent approximately 1.5 percent, and HFCs represent approximately 3.9 percent. (Values are calculated from EPA 2012a.) HFC emissions could increase slightly with increases in VMT due to the rebound effect; however, any increases would likely be mitigated by EPA regulation of vehicle air conditioning.

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

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. Volpe estimated the global reductions in CO_2 emissions during each phase of fuel and electricity production and distribution (i.e., upstream emissions) using CO_2 emissions rates obtained from the GREET 1 2011 model using the previous assumptions about how fuel savings are reflected in reductions in activity during each phase of fuel production and distribution.[26] 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.

5.3.2 Social Cost of Carbon

This section describes the methodology used to estimate the monetized damages associated with GHG 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 SCC developed by the Interagency Working Group on Social Cost of Carbon; this approach is consistent with the analysis of GHG impacts in EPA's Preliminary Regulatory Impact Analysis (Preliminary RIA) for the MY 2017–2025 rulemaking.

The SCC is an estimate of the monetized damages associated with an incremental increase in annual carbon dioxide 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 in order to estimate the monetized benefits associated with GHG reductions under each alternative. The following description parallels the discussion about GHG benefits in EPA's Preliminary RIA and provides details of this analysis.

The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. The SCC estimates used in this analysis were developed through an interagency process that included DOT/NHTSA, EPA, and other Executive Branch entities, and concluded in February 2010. These SCC estimates were used previously in the benefits analysis for the NHTSA/EPA joint rulemakings to establish MY 2012–2016 CAFE standards and MY 2014–2018 HD vehicle standards.[27] The SCC Technical Support Document (TSD) provides a complete discussion of the methods used to develop these SCC estimates.[28]

The interagency group selected four SCC values for use in regulatory analyses; NHTSA has updated these values to 2010 dollars for this analysis. Values for emissions occurring in 2012 are approximately $5,

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[26] Some modifications were made to the estimation of upstream emissions, consistent with EPA assumptions in the joint light-duty vehicle CAFE and GHG emissions rulemaking for MYs 2017–2025. Chapter 4 of EPA's Preliminary RIA provides more information regarding these modifications.

[27] For a discussion about the application of the SCC, *see* the NPRM.

[28] EPA 2010d. *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).

\$23, \$37, and \$69 per metric ton of CO_2-equivalent (CO_2e).[29] 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 there is no consensus 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, and the use of a probability density function for equilibrium climate sensitivity in all three models. Treating climate sensitivity probabilistically allows the estimation of SCC at higher temperature outcomes, which 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 ensure that the estimates are internally consistent with other modeling assumptions. Table 5.3.2-1 lists 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 analysis covers a shorter period.

Table 5.3.2-1 lists global SCC estimates, in constant 2010 dollars per metric ton of GHGs (in CO_2e) emitted. The first three columns of SCC estimates are the average SCCs across all three of the integrated assessment models used in the interagency group SCC analysis. The final column indicates the 95th percentile of the SCC at a 3 percent discount rate across the three models. Annual versions of these values are used in the subsequent calculations in this section.

Many serious challenges arise when attempting to assess the incremental economic impacts of GHG emissions. A recent report from the National Academies (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about: (1) future emissions of GHGs, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harm associated with climate change will raise serious questions of science, economics, and ethics, and should be viewed as provisional.

The interagency group noted several limitations to the SCC analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of

[29] The SCC estimates were converted from 2007 dollars to 2010 dollars using a Gross Domestic Product (GDP) price deflator (approximately 1.045) obtained from the Bureau of Economic Analysis, National Income, and Product Accounts (NIPA) Table 1.1.9, Implicit Price Deflators for Gross Domestic Product (using the annual, rather than quarterly, GDP for the United States) (BEA 2012).

Table 5.3.2-1. Social Cost of Carbon, 2012–2050 (in 2010 dollars per metric ton)

Year	Discount Rate and Statistic[a]			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2012	$5	$23	$38	$71
2015	$6	$25	$40	$76
2020	$7	$27	$44	$84
2025	$9	$31	$48	$94
2030	$10	$34	$52	$104
2035	$12	$38	$57	$115
2040	$13	$41	$61	$125
2045	$15	$44	$64	$134
2050	$16	$47	$68	$142

a. The dollar mounts in these columns are rounded for presentation purposes.

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 the Federal Government uses for regulatory analysis will continue to evolve with improvements in modeling. Additional details on these limitations are discussed in the SCC TSD.

Although CO_2 is the GHG emitted by human activities into the atmosphere that has the greatest global climate effect, other GHGs, including CH_4, N_2O, HFCs, PFCs, and SF_6, also contribute to climate change. However, because these gases differ in atmospheric lifetimes, their relative damages are not constant over time. Transforming gases into CO_2 equivalents using GWP, NHTSA multiplied the carbon equivalents by the SCC to incorporate the social costs of non-CO_2 gases.

5.3.3 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 precipitation
4. Changes in sea level

The change in GHG emissions is a direct effect of the improvements in fuel economy associated with the alternatives; the four effects on climate change can be considered 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 Volpe model (tailpipe) and the associated estimated changes in upstream emissions using GREET.[30] NHTSA also performed a sensitivity analysis to examine variations 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 impacts.

Section 5.3.3.1 through 5.3.3.3 describe MAGICC, the climate sensitivity analysis, and the baseline emissions scenario used to represent the No Action Alternative in this analysis.

5.3.3.1 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 emission scenarios that were not run with the more complex atmospheric-ocean general circulation models (AOGCMs).[31]
- 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 also plans to use MAGICC 5.3.v2 for the Final RIA.
- NHTSA used MAGICC to assess direct and indirect impacts of climate change in the Final EIS for the MY 2012–2016 CAFE standards released in February 2010 (NHTSA 2010b) and again for the MY 2014–2018 HD Final EIS released in June 2011 (NHTSA 2011b).

5.3.3.2 Global Emission Scenarios

As described above, MAGICC uses long-term emission scenarios that represent different assumptions about key drivers of GHG emissions. The reference scenario used in this EIS is the GCAMReference scenario (formerly MiniCAM), which does not assume comprehensive global actions to mitigate GHG emissions. NHTSA selected the GCAMReference scenario for its incorporation of a comprehensive suite of greenhouse and pollutant gas emissions, including carbonaceous aerosols and a global context of emissions with a full suite of GHGs and ozone precursors.

[30] Some SO_2 emissions are associated with the charging of EVs. However, total power plant emissions are limited by "caps" under the EPA Acid Rain Program and the Cross-State Air Pollution Rule and Clean Air Interstate Rule, and will also be reduced through emissions standards such as the recent Mercury and Air Toxics Standards rule. As a result of these rules and advances in technology, emissions from the power-generation sector are expected to decline over time (the grid is expected to become cleaner, as exemplified by the Alternate Grid Mix described in Chapter 4). Any economic activity or trend that leads to an increase in electrical demand – including increases in EV sales and use – would be accommodated by the power industry in planning for compliance with applicable emissions limitations.

[31] For a discussion of AOGCMs, *see* Chapter 8 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.

In 2003, the U.S. Climate Change Science Program released the *Strategic Plan for the U.S. Climate Change Science Program* (CCSP 2003), which called for the preparation of 21 synthesis and assessment products (SAPs) addressing a variety of topics on climate change science, GHG mitigation, and adapting to the impacts of climate change. These scenarios used updated economic and technology data along with improved scenario development tools that incorporated knowledge gained over the 10 years since the IPCC *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) was released. The strategy recognized that it would be important to have a consistent set of emission scenarios so that the whole series of SAPs would have the same foundation. Therefore, one of the earliest products in the series – SAP 2.1, *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application* (Clarke et al. 2007) – developed 15 global emission scenarios, corresponding to five different emission trajectories from each of three groups using different models (IGSM, MiniCAM , and MERGE).[32] MiniCAM was later renamed GCAM, which is the updated successor to MiniCAM based on improvements in the modeling, and which is the scenario used in this EIS.

Each climate modeling group independently produced a unique emission 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.

As explained in more detail below, while the direct and indirect impacts analysis uses the GCAMReference scenario, the cumulative impacts analysis uses the GCAM6.0 scenario to represent a Reference Case global emission scenario, because this scenario assumes significant global actions to address climate change. Sections 5.3.3.2.1 through 5.3.3.2.3 describe the differences among these scenarios and provide the rationale for use in each analysis.

5.3.3.2.1 Scenario Used for the Direct and Indirect Impacts Analysis

The results of the direct and indirect impacts analysis rely primarily on the GCAMReference scenario to represent a reference case emissions scenario. The GCAMReference scenario provides a global context for emissions of a full suite of GHGs and ozone precursors. NHTSA chose the GCAMReference scenario to present the results of the direct and indirect effects analysis 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, a partnership between Pacific Northwest National Laboratory and the University of Maryland. The GCAMReference scenario is

[32] IGSM is the Massachusetts Institute of Technology 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.

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.[33]

- 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.
- SAP 2.1 is more than a decade newer than the IPCC SRES, and therefore takes into account 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 Regulatory Impact Analysis for the joint NHTSA and EPA *Final Rule on Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*.[34]

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.[35] For example, CO_2 emissions from passenger cars and light trucks in the United States in 2020 under the No Action Alternative in Analysis A are estimated to be between 1,300 $MMTCO_2$ and 1,329 $MMTCO_2$; the emissions in 2020 under the Preferred Alternative in Analysis A are estimated to be between 1,262 $MMTCO_2$ and 1,292 $MMTCO_2$. The difference of between 29 and 30 $MMTCO_2$ represents the reduction in emissions projected to result from adopting the Preferred Alternative under Analysis A. Global emissions for the GCAMReference scenario in 2020 are estimated to be 38,017 $MMTCO_2$, and are assumed to incorporate emissions from passenger cars and light trucks in the United States under the No Action Alternative. Global emissions under the Preferred Alternative are therefore estimated to be between 29 $MMTCO_2$ and 30 $MMTCO_2$ less than this reference level, or approximately 37,987 to 37,988 $MMTCO_2$ in 2020.

There are some inconsistencies between the overall assumptions that SAP 2.1 and the Joint Global Change Research Institute used to develop the global emissions scenario and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand.[36] However, these inconsistencies affect the characterization of each alternative in equal proportion, so

[33] 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.”

[34] *See* Final Regulatory Impact Analysis, Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, August 2011, *Available at:* <http://www.nhtsa.gov/fuel-economy> (Accessed*:* May 29, 2012).

[35] The GCAMReference is well established in the scientific community as a reference baseline. While it would be possible to adjust this baseline based on recent rulemakings for MY 2012–2016 CAFE standards and MY 2014–2018 HD vehicle standards, NHTSA has not done so because this would suggest that the agency should also speculate about how other recent domestic and global actions might have affected this baseline. Adjusting this baseline in such a manner would undermine the integrity of a well-established reference point and would have little effect on the magnitude of the impacts attributed to the rule in terms of the climate parameters.

[36] Many of the economic assumptions used in the Volpe model reflect the assumptions and methodologies described in Chapter 2.

the relative estimates provide a reasonable approximation of the differences in environmental impacts among the alternatives.

5.3.3.2.2 Scenarios Used for the Cumulative Impacts Analysis

The cumulative impacts analysis relies primarily on the GCAM6.0 scenario to represent a reference case global emissions scenario that assumes significant global actions to address climate change. NHTSA chose the GCAM6.0 scenario to represent reasonably foreseeable actions. This reference case global emissions scenario serves as a baseline against which the climate benefits of the various alternatives in this EIS can be measured. For the analysis in this EIS, each action alternative for cumulative impacts was simulated by calculating the difference between annual GHG emissions under that alternative and emissions under the No Action Alternative and subtracting this change in the GCAM6.0 scenario to generate modified global-scale emissions scenarios, which show the effect of the various alternatives on the global emissions path.

NHTSA used the GCAM6.0 scenario as the primary global emission scenario for evaluating climate effects in the cumulative impacts analysis, but also used the Representative Concentration Pathway (RCP)4.5 scenario[37] and the GCAMReference emission scenario to evaluate the sensitivity of the results to a reasonable range of alternative emission scenarios.

The GCAM6.0 scenario is the GCAM representation of the radiative forcing target (6.0 watts per square meter) of the (RCP) scenarios developed by the MiniCAM model of the Joint Global Change Research Institute. The GCAM6.0 scenario assumes a moderate level of global GHG reductions. It is based on a set of assumptions about drivers such as population, technology, socioeconomic changes, and global climate policies that correspond to stabilization, by 2100, of total radiative forcing and associated CO_2 concentrations at roughly 678 parts per million by volume (ppm).[38] More specifically, GCAM6.0 is a scenario that incorporates declines in overall energy use, including fossil fuel use, as compared to the reference case. In addition, GCAM6.0 includes increases in renewable energy and nuclear energy. The proportion of total energy use supplied by electricity also increases over time due to fuel switching in end-use sectors. CO_2 capture and storage also plays an important role that allows for continued use of fossil fuels for electricity generation and cement manufacture while limiting CO_2 emissions. Although GCAM6.0 does not explicitly include specific climate change mitigation policies, it does represent a plausible future pathway of global emissions in response to significant global action to mitigate climate change.

Using the GCAM6.0 scenario as described above, total emissions from passenger cars and light trucks in the United States from 2017–2020 under the No Action Alternative are estimated to be between 1,300 $MMTCO_2$ and 1,329 $MMTCO_2$; emissions from 2017–2020 under the Preferred Alternative are estimated

[37] The RCP4.5 scenario is another, more aggressive, stabilization scenario that illustrates the climate system response to stabilizing the anthropogenic components of radiative forcing at 4.5 watts per square meter in 2100. The RCP4.5 scenario "assumes that climate policies, in this instance the introduction of a set of global greenhouse gas emissions prices, are invoked to achieve the goal of limiting emissions, concentrations and radiative forcing" (Thomson et al. 2011). This scenario is a "stabilization scenario" – i.e., one that stabilizes the atmospheric concentration of CO_2 – with a pathway that minimizes cost. In other words, the RCP4.5 scenario "assumes that all nations of the world undertake emissions mitigation simultaneously and effectively, and share a common global price that all emissions to the atmosphere must pay with emissions of different gases priced according to their hundred-year global warming potentials" (Thomson et al. 2011). Although RCP4.5 does not explicitly include specific climate change mitigation policies, it represents a plausible future pathway of global emissions in response to more significant global action to mitigate climate change than the GCAM6.0 scenario.

[38] Based on 3 °C (5.4 °F) climate sensitivity.

to be between 1,257 $MMTCO_2$ and 1,279 $MMTCO_2$. The difference of between 22 $MMTCO_2$ and 29 $MMTCO_2$ (rounded) represents the reduction in emissions projected to result from adopting the Preferred Alternative. Global CO_2 emissions for the GCAM6.0 scenario from 2017–2020 are estimated to be between 37,522 $MMTCO_2$ and 37,522 $MMTCO_2$ and are assumed to incorporate the level of emissions from passenger cars and light trucks in the United States under the No Action Alternative. Global emissions under the Preferred Alternative are therefore estimated to be between 22 $MMTCO_2$ and 29 $MMTCO_2$ less than this reference level, or between 37,500 $MMTCO_2$ and 37,486 $MMTCO_2$ from 2017–2020 under the cumulative impacts analysis.

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

NHTSA chose the GCAM6.0 scenario as the primary global emissions scenario for evaluating climate effects for this chapter because regional, national, and international initiatives and programs now in the planning stages and underway indicate that some reduction in the growth rate of global GHG emissions is reasonably foreseeable in the future. The initiatives and programs discussed below are those NHTSA has determined are relevant to its consideration of past, present, or reasonably foreseeable actions to reduce GHG emissions. NHTSA used this scenario to assess the impacts of the action alternatives when reasonably foreseeable reductions in global GHG emissions are taken into account. Although it is not possible to quantify the precise GHG reductions associated with these actions, policies, or programs when taken together, collectively they illustrate an existing and continuing trend of U.S. and global awareness, emphasis, and efforts toward significant GHG reductions. NHTSA has not attempted to quantify the precise benefits associated with these programs. Rather, they imply that future commitments for reductions are probable. Therefore, a scenario that accounts for moderate reductions in the rate of global GHG emissions, such as the GCAM6.0 scenario, can be considered reasonably foreseeable under NEPA.

United States: Regional Actions

- **Regional Greenhouse Gas Initiative (RGGI).** Beginning January 1, 2009, RGGI was the first mandatory, market-based effort in the United States to reduce GHG emissions (RGGI 2009). Nine northeastern and Mid-Atlantic States (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont[39]) have agreed to cap annual emissions from power plants in the region at 188 $MMTCO_2$ for 2009 through 2011, and 165 $MMTCO_2$ for 2012 through 2014 (RGGI 2012). Beginning in 2015, this cap will be reduced 2.5 percent each year through 2019, for a total of a 10 percent emission reduction from the 2015 cap from the power sector by 2018 (RGGI 2012). Therefore, the cap comprises two phases: the first is a stabilization phase from 2009 through 2014, and the second is a reduction phase from 2015 through 2018.
- **Western Climate Initiative (WCI).** The WCI is a regional, multi-sector, GHG reduction initiative that includes California and several Canadian provinces.[40] It has committed to reducing regional emissions 15 percent below 2005 levels by 2020. This program is the most comprehensive carbon-reduction strategy designed to date in North America. Participants set regional GHG targets and implement emission trading policies to reduce GHGs from the region. California, British Columbia,

[39] In 2011, New Jersey's governor withdrew the state from RGGI. As of April 12, 2012, New Jersey state legislators have been attempting to override the governor's order and reinstate the state's participation in the program.
[40] During 2011, six states formerly involved in the WCI (New Mexico, Arizona, Washington, Oregon, Montana, and Utah) withdrew from the initiative (Environmental Leader 2012a).

and Quebec have moved forward with the first of two phases of the cap-and-trade system, which began January 1, 2012. Ontario and Manitoba are committed to implementing programs soon, but have not yet begun implementation. In its first phase, the WCI cap-and-trade program covers emissions of seven GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3) from the following sectors of the economy: electricity generation, including imported electricity; industrial and commercial fossil-fuel combustion; industrial process emissions; fossil-fuel consumption for transportation; and residential fuel use. Together, these sectors cover two-thirds of all emissions in the WCI region. Affected entities and facilities will be required to surrender enough allowances to cover emissions that occur within each compliance period (currently 3 years). The second phase begins January 1, 2015, when the program expands to include any transportation fuels, and residential, commercial, and industrial fuels not otherwise covered during the first phase (WCI 2012). When fully implemented in 2015, the program will cover nearly 90 percent of GHG emissions in the WCI region.

United States: Federal Actions

- **Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units.** In March 2012, EPA proposed a new standard for allowable carbon emissions from new power plants. If finalized as proposed, the rule will apply to new fossil-fuel-fired electric utility generation units larger than 25 megawatts (electric utility generating units). Any electric utility generating units constructed or permitted to be constructed within 12 months of the date of the proposed rule (before March 27, 2013) would be exempt from the rule, as would any units in non-continental areas, such as Hawaii and U.S. non-state territories. From March 27, 2013, onward, emissions from new electric generating utilities would be capped at 1,000 pounds (453.6 kilograms) of CO_2 per megawatt-hour of electricity generated. New power plants would be able to use technologies such as carbon capture and storage to meet this standard. EPA and DOE have indicated that, even in the absence of the rule, most new facilities constructed in the next decade and beyond will meet the proposed standard due to the economics of coal and natural gas (EPA 2012f).
- **NHTSA and EPA Joint Rule on GHG Emissions and Fuel Economy Standards for Light-Duty Vehicles.** In April 2010, NHTSA and EPA issued a joint Final Rule establishing a new National Program to improve the fuel efficiency and reduce GHG emissions of MYs 2012–2016 passenger cars and light trucks. NHTSA issued CAFE standards under the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA), and EPA issued GHG emissions standards under the Clean Air Act (CAA). These rules require a combined average fleetwide fuel economy of 34.1 mpg and 250 grams per mile of CO_2 for MY 2016 light-duty vehicles. Vehicles covered by these standards are responsible for almost 60 percent of all U.S. transportation-related GHG emissions. The program is projected to reduce GHG emissions from the U.S. light-duty vehicle fleet by 19 percent by 2030 (NHTSA 2010b citing EPA 2009).

- **NHTSA and EPA Joint Rule on GHG Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles, MYs 2014–2018**. On August 9, 2011, NHTSA and EPA announced joint rules to establish fuel efficiency and GHG standards for medium- and heavy-duty engines and vehicles. The rules together comprise a coordinated and comprehensive heavy-duty vehicle National Program and result in substantial improvements in fuel efficiency and reductions in GHG emissions from heavy-duty vehicles. The agencies' standards apply to highway vehicles and engines that are not regulated by the passenger car, light-duty truck, and medium-duty passenger vehicle CAFE and GHG standards. NHTSA set mandatory standards for heavy-duty vehicles and engines beginning in MY 2016 and voluntary standards beginning in MYs 2014–2015. EPA set mandatory standards for heavy-duty vehicles and engines beginning in MY 2014. The agencies estimate that the combined standards will reduce CO_2 emissions by approximately 270 million metric tons and save 530 million barrels of oil over the life of vehicles sold during MYs 2014–2018.[41] In addition, MY 2019 and later vehicles will also yield additional GHG benefits because these standards will remain in place after 2018.
- **EPA Prevention of Significant Deterioration (PSD) and Title V Greenhouse Gas Tailoring Rule.** In May 2010, EPA issued a rule to address GHG emissions from stationary sources under CAA permitting programs. Under the first step to phase in this rule, which went into effect January 2, 2011, only those sources already subject to the PSD program due to their non-GHG emissions (which includes newly constructed facilities or those that are modified to significantly increase non-GHG emissions) are subject to PSD and Title V permitting requirements. During the first step, such facilities that have emissions increases of at least 75,000 tons per year of GHGs (based on CO_2e), and also significantly increase emissions of at least one non-GHG pollutant, will need to implement Best Available Control Technology (BACT). Also during this step, no sources are subject to permitting requirements based solely on their GHG emissions. The second step, which began July 1, 2011, covers all new facilities with the potential to emit at least 100,000 tons per year of CO_2e and modifications to existing facilities that result in emissions of at least 100,000 tons per year and that increase GHG emissions by at least 75,000 tons per year of CO_2e. Title V requirements will apply to facilities that emit at least 100,000 tons of CO_2e per year. On February 24, 2012, EPA proposed keeping GHG permitting at its current levels for the third step in the interest of reducing the burden on state permitting authorities. At the same time, EPA proposed two new approaches to streamline GHG permitting: (1) increase flexibilities and usefulness of plant-wide applicability limits, allowing companies to respond quickly under changing plant conditions, and (2) create the regulatory authority for EPA to issue permits for GHGs in circumstances for which EPA is the PSD permitting authority, giving plants a way to stay under the requirements for major source permitting for GHGs as long as the facility minimizes its GHG emissions (EPA 2012e).
- **Renewable Fuel Standard 2 (RFS2).** Section 211(o) of the CAA requires that a renewable fuel standard be determined annually that is applicable to refiners, importers, and certain blenders of gasoline. On the basis of this standard, each regulated party determines the volume of renewable fuel that it must ensure is consumed as motor vehicle fuel. RFS2, which went into effect July 1, 2010, will increase the volume of renewable fuel required to be blended into gasoline from the baseline of 9 billion gallons in 2008 to 36 billion gallons by 2022.[42] EPA estimates that the greater

[41] Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles Final Rules, 76 FR 57106 (Sept. 15, 2011).
[42] Final Rule: Regulations of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program. 75 FR 14670 (Mar. 26, 2010).

volume of biofuel mandated by RFS2 will reduce life-cycle GHG emissions by an annual average of 150 million tons of CO_2e.[43] The final renewable fuel standard for 2012 is 9.23 percent.[44,45]

- **United States GHG Emissions Target in Association with the Copenhagen Accord.** Building on the pledge made at the December 2009 United Nations climate change conference in Copenhagen (COP-15), President Obama submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a GHG target for the United States in the range of 17 percent below 2005 levels by 2020. At the December 2011 United Nations climate change conference in Durban, South Africa (COP-17), the United States reiterated this commitment (U.S. Department of State 2011). Among other initiatives, recent federal actions that are expected to reduce GHG emissions include a $90-billion investment in clean energy through the American Recovery and Reinvestment Act of 2009, more stringent energy efficiency standards for commercial and residential appliances, and development of wind energy on the Outer Continental Shelf.

International Actions

- **United Nations Framework Convention on Climate Change – The Kyoto Protocol, and the annual Conference of the Parties (COP).** The UNFCCC is an international treaty signed by many countries around the world (including the United States[46]), which entered into force on March 21, 1994, and sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change (UNFCCC 2002).

  The Kyoto Protocol is an international agreement linked to the UNFCCC. The major feature of the Kyoto Protocol is its binding targets for 36 industrialized countries and the European Community for reducing GHG emissions, which covers more than half of the world's GHG emissions. These reductions amount to approximately 5 percent of 1990 emissions over the 5-year period 2008 through 2012 (UNFCCC 2005). The December 2011 COP-17 held in Durban, South Africa, resulted in an agreement to extend the soon-to-expire Kyoto Protocol. The "Second Commitment Period" requires Parties to reduce emissions by at least 25 percent to 40 percent below 1990 levels by 2020 (WRI 2012b).

  At COP-15 (held in 2009) all major developed and developing countries agreed to pledge specific emission reductions. At COP-16, in December 2010, a draft accord pledged to limit global temperature increase to less than 2 °C (3.6 °F) above pre-industrial global average temperature. At COP-17, the Parties established the "Working Group on the Durban Platform for Enhanced Action" to develop a protocol for mitigating emissions from rapidly developing countries no later than 2015, and to take effect in 2020 (UNFCCC 2011). The parties also made a long-term commitment to mobilize $100 billion per year to the Green Climate Fund by 2020, which will operate under the oversight of the COP to support climate change-related projects around the world. Plans for

[43] Id.

[44] EPA. 2011j. EPA Finalizes 2012 Renewable Fuel Standards. Released December 27, 2011. *Available at*: <http://yosemite.epa.gov/opa/admpress.nsf/0/A7CE72844710BE0A85257973006A20F3> (Accessed: April 26, 2012).

[45] Actual carbon savings might be less than anticipated because EIA projects that these volumes will not likely be achieved in 2023.

[46] Although a signatory to the Kyoto Protocol, the United States has neither ratified nor withdrawn from the protocol. Treaties are nonbinding on the United States unless ratified by the Senate by a two-thirds majority, and the Kyoto Protocol has not been submitted to the Senate for ratification. On July 25, 1997, before the Kyoto Protocol was finalized, the Senate passed (by a 95 to 0 vote) the Byrd-Hagel Resolution, which stated the Senate position that the United States should not be a signatory to any treaty that did not include binding targets and timetables for developing nations as well as industrialized nations or "would result in serious harm to the economy of the United States." *See* S. Res. 98, 105th Cong. (1997).

financing the commitment have not been developed (IISD 2011). As of April 12, 2012, 141 countries have agreed to the Copenhagen Accord, accounting for the vast majority of global emissions (UNFCCC 2010). However, the pledges are not legally binding, and much remains to be negotiated.[47]

- **The European Union Greenhouse Gas Emission Trading System (ETS).** In January 2005, the European Union ETS commenced operation as the largest multi-country, multi-sector GHG emission trading system worldwide (European Union 2010). The aim of the ETS is to help European Union member states achieve compliance with their commitments under the Kyoto Protocol (European Union 2005). This trading system does not entail new environmental targets; instead, it allows for less expensive compliance with existing targets under the Kyoto Protocol. The scheme is based on Directive 2003/87/EC, which entered into force on October 25, 2003 (European Union 2010) and covers more than 11,500 energy-intensive installations across the European Union. This represents almost half of Europe's emissions of CO_2. These installations include combustion plants, oil refineries, coke ovens, and iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp, and paper (European Union 2005).
- **Fuel Economy Standards in Asia.** Both Japan and China have taken actions to reduce fuel use, and CO_2 emissions, and criteria pollutant emissions from vehicles. Japan has invested heavily in research and development programs to advance fuel-saving technologies, has implemented fiscal incentives such as high fuel taxes and differential vehicle fees, and has mandated fuel economy standards based on vehicle weight class (utilizing country-specific testing procedures [Japan 10-15/JC08]). Similarly, China has implemented increasingly restrictive fuel economy standards. These country-wide standards are modeled after European Union standards (using the New European Driving Cycle testing methods). China has also implemented research and development programs, differential vehicle fees, and technology mandates (UN 2011).

5.3.3.3 Reference Case Modeling Runs

The modeling runs and sensitivity analysis model relative changes in atmospheric concentrations, global mean surface temperature, precipitation, and sea-level rise that could result under each alternative. The modeling runs are based on the reductions in emissions estimated to result from each of the action alternatives for both the direct and indirect and cumulative impacts analyses. They assume a climate sensitivity of 3 °C (5.4 °F) for a doubling of CO_2 concentrations in the atmosphere.[48] 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 global emissions scenario.
2. Global emissions for each action alternative were assumed to be 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 global emissions scenario minus the emission reductions

[47] During the June 2010 G8 Summit in Canada, the G8 Nations officially reiterated their support of the Copenhagen Accord and urged countries that had not already signed on to associate themselves with the accord and its goals. The G8 summit officially recognized a goal that global temperature should not increase by more than 2 °C (3.6 °F). A statement was made supporting a fair but binding post-2012 agreement for all countries to reduce their GHG emissions.
[48] In other words, global mean temperature is assumed to increase 3 °C (5.4 °F) with a doubling of CO_2 concentrations in the atmosphere compared to pre-industrial concentrations. This concept is more fully explained in the section below.

from that alternative).[49] 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.
4. NHTSA used the increase in global mean surface temperature to estimate the increase in global average precipitation for each alternative using the global emission scenario.

5.3.3.4 Sensitivity Analysis

NHTSA performed a sensitivity analysis to examine the effect of various equilibrium climate sensitivities on the results. Equilibrium climate sensitivity[50] 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 compared to pre-industrial atmospheric concentrations (280 ppm CO_2) (EPA 2009e citing NRC 2001). Sensitivity analyses examine the relationship among the alternatives, likely climate sensitivities, and scenarios of global emissions paths and the associated direct and indirect impacts for each combination. These relationships can be used to infer the effect of the emissions associated with the alternatives on direct and indirect climate impacts.

In the past 8 years, confidence in climate sensitivity projections has increased significantly (EPA 2009e citing Meehl et al. 2007). According to the 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 2009e, 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 performed the sensitivity analysis around two of the alternatives – the No Action Alternative and the Preferred Alternative – because this was deemed sufficient to assess the effect of various climate sensitivities on the results.

The approach uses the four steps listed below to estimate the sensitivity of the results to alternative estimates of the climate sensitivity:

1. NHTSA used the GCAMReference scenario for the direct and indirect impacts analysis and the GCAM6.0 scenario for the cumulative impacts analysis to represent emissions from the No Action Alternative.
2. Starting with the respective GCAM 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

[49] Some SO_2 emissions are associated with the charging of EVs. However, total power plant emissions are limited by "caps" under the EPA Acid Rain Program and the Cross-State Air Pollution Rule and Clean Air Interstate Rule, and will also be reduced through emissions standards such as the recent Mercury and Air Toxics Standards rule. As a result of these rules and advances in technology, emissions from the power-generation sector are expected to decline over time (the grid is expected to become cleaner, as exemplified by the Alternate Grid Mix described in Chapter 4). Any economic activity or trend that leads to an increase in electrical demand – including increases in EV sales and use – would be accommodated by the power industry in planning for compliance with applicable emissions limitations.

[50] In this EIS, the term "climate sensitivity" refers to "equilibrium climate sensitivity."

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 to 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).[51]
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 5.4 presents the results of the model runs for the alternatives. For the direct and indirect impacts analysis, the sensitivity analysis was performed against the GCAMReference scenario (785 ppm in 2100). For the cumulative impacts analysis, the sensitivity analysis also assesses the sensitivity around different global emissions scenarios. NHTSA assumed multiple global emissions scenarios including GCAM6.0 (678 ppm in 2100); RCP4.5 (522 ppm in 2100); and GCAMReference scenario (785 ppm in 2100). Section 5.4.2.3.5 presents the results of the cumulative impacts sensitivity analysis for these different global emission scenarios.

5.3.4 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, hydrosphere, land, cryosphere,[52] 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 2009e 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 2009e citing NRC 2002).

NHTSA's assessment of tipping points is based on an analysis of climate change science synthesis reports – including *Technical Support Document for EPA's Endangerment Finding for GHGs* (EPA 2009e), 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

[51] *See* Box 10.2, Figure 2 in IPCC 2007a.
[52] The cryosphere describes the portion of Earth's surface that is frozen water, such as snow, permafrost, floating ice, and glaciers.

and abrupt climate change in Section 5.5.8 of this EIS.[53] The analysis applies equally to the direct and indirect impacts discussion and the cumulative impacts discussion given that tipping points are best viewed in the perspective of long-term, large-scale global trends.

[53] *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"); *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997b) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

5.4 Environmental Consequences

This section describes projected impacts on climate under the Proposed Action and alternatives considered. Using the methodologies described in Section 5.3, NHTSA modeled the effects of the Proposed Action on atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise.

To calculate the incremental benefits of the Proposed Action, NHTSA examined the direct and indirect impacts for the analytical methodologies described in Chapter 2 and summarized here.

- In Analyses A1 and A2, the agency assumes that the average fleetwide fuel economy for light-duty vehicles would not exceed the minimum level necessary to comply with CAFE standards. Therefore, Analyses A1 and A2 measure the impacts of the action alternatives under which average fleetwide fuel economy in each model year does not exceed the level of the CAFE standards for that model year, compared to a No Action Alternative under which average fleetwide fuel economy after MY 2016 will never exceed the level of the agencies' MY 2016 standards established by final rule in April 2010. Tables and figures in this Final EIS that depict results for Analysis A1 (these have "A1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM Worldwide-based fleet projection. Tables and figures that depict results for Analysis A2 (these have "A2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC Automotive-based fleet projection.
- In Analyses B1 and B2, the agency assumes continued improvements in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Therefore, Analyses B1 and B2 measure the impacts of the action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing improvements in new vehicle fuel economy after MY 2025, compared to a No Action Alternative that assumes the average fleetwide fuel economy level of light-duty vehicles would continue to increase beyond the level necessary to meet the MY 2016 standards, even in the absence of agency action. Tables and figures in this Final EIS that depict results for Analysis B1 (these have "B1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis B2 (these have "B2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection.
- In Analyses C1 and C2, the agency compares action alternatives assuming overcompliance by certain manufacturers through MY 2025 and ongoing fuel economy improvements after MY 2025 with a No Action Alternative under which there are no continued improvements in fuel economy after MY 2016 (i.e., the average fleetwide fuel economy for light-duty vehicles would not exceed the latest existing standard). In this way, the cumulative impacts analysis combines the No Action Alternative from Analyses A1 and A2 with the action alternatives from Analyses B1 and B2. Tables and figures in this Final EIS that depict results for Analysis C1 (these have "C1" after the table or figure number) show estimated impacts derived from a MY 2008 baseline fleet, fleet sales projections to MY 2025 from AEO 2011, and a CSM-based fleet projection. Tables and figures that depict results for Analysis C2 (these have "C2" after the table or figure number) show estimated impacts derived from a MY 2010 baseline fleet, fleet sales projections to MY 2025 from the AEO 2012 Early Release, and an LMC-based fleet projection. For more explanation of NHTSA's methodology regarding the cumulative impacts analysis, *see* Section 2.5.

The analysis of direct and indirect impacts in Section 5.4.1 (Analyses A1, A2, B1, and B2) is based on a scenario under which there are no other major global actions to reduce GHGs. That section presents the projected results of the alternatives compared to the current climate trajectory, independent of other actions.

The analysis of cumulative impacts in Section 5.4.2 (Analyses C1 and C2) measure the impact of fuel economy improvements that result directly or indirectly from the Proposed Action and alternatives in addition to reasonably foreseeable improvements in fuel economy caused by other actors – that is, fuel economy improvements that would result from actions taken by manufacturers without agency action. For assessing climate impacts, the analysis in Section 5.4.2 is also broader in that it addresses the effects of the proposed standards in concert with the effects of other past, present, and reasonably foreseeable future actions affecting the current climate trajectory.

Appendix A provides the air quality and climate impacts of the Proposed Action and alternatives for passenger cars and light trucks separately.

5.4.1 Direct and Indirect Impacts

This section describes the environmental consequences of the Proposed Action alternatives on GHG emissions and climate effects.

5.4.1.1 Greenhouse Gas Emissions

Using the methodology described in Section 5.3, NHTSA estimated projected emission reductions under the Proposed Action and alternatives for 2017 through 2100. The emission reductions in the following discussion represent the differences in total annual emissions in future years of U.S. passenger cars and light trucks in use under the No Action Alternative and each action alternative (Alternatives 2 through 4). The projected change in fuel production and use under each alternative determines the resulting impacts on total energy use and petroleum consumption, which in turn determine the reduction in CO_2 emissions under 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 expected under the action alternatives. However, in assessing the direct and indirect impacts and cumulative impacts on climate change indicators, as described in Sections 5.4.1.3 and 5.4.2.3, NHTSA incorporates reductions of all GHGs.

Tables 5.4.1-1-A1 and -A2 and Figures 5.4.1-1-A1 and -A2 show total U.S. passenger car and light-truck CO_2 emissions under the No Action Alternative and emission reductions that would result from each of the action alternatives from 2017 through 2100 for Analyses A1 and A2. U.S. passenger car and light-truck emissions for this period range from a low of 100,000 $MMTCO_2$ under Alternative 4 up to 155,400 $MMTCO_2$ under the No Action Alternative. Compared to the No Action Alternative, projected emission reductions from 2017 through 2100 under the action alternatives range from 16,700 to 43,000 $MMTCO_2$.

Table 5.4.1-1-A1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative,[a] Analysis A1

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	155,400		
2 - 2%/year Cars and Trucks	135,700	19,700	13%
3 - Preferred	124,100	31,300	20%
4 - 7%/year Cars and Trucks	112,400	43,000	28%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Table 5.4.1-1-A2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative,[a] Analysis A2

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	138,800		
2 - 2%/year Cars and Trucks	122,100	16,700	12%
3 - Preferred	111,200	27,500	20%
4 - 7%/year Cars and Trucks	100,000	38,800	28%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Figure 5.4.1-1-A1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative, Analysis A1

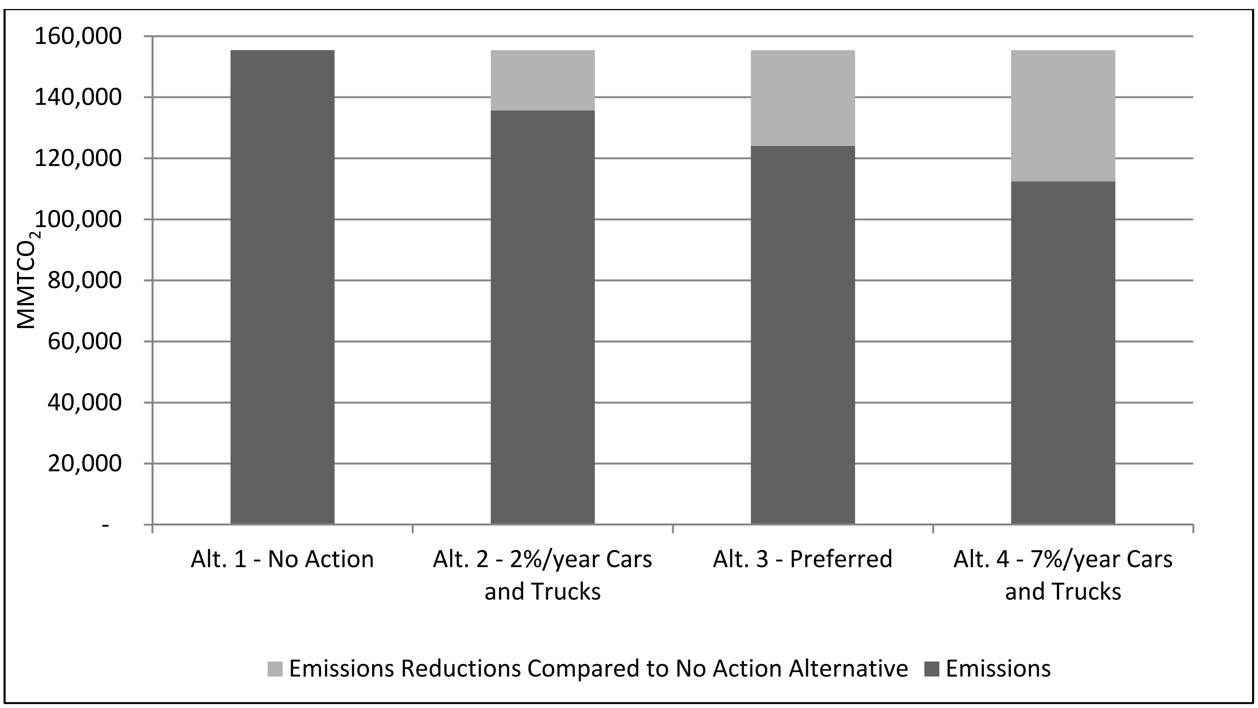
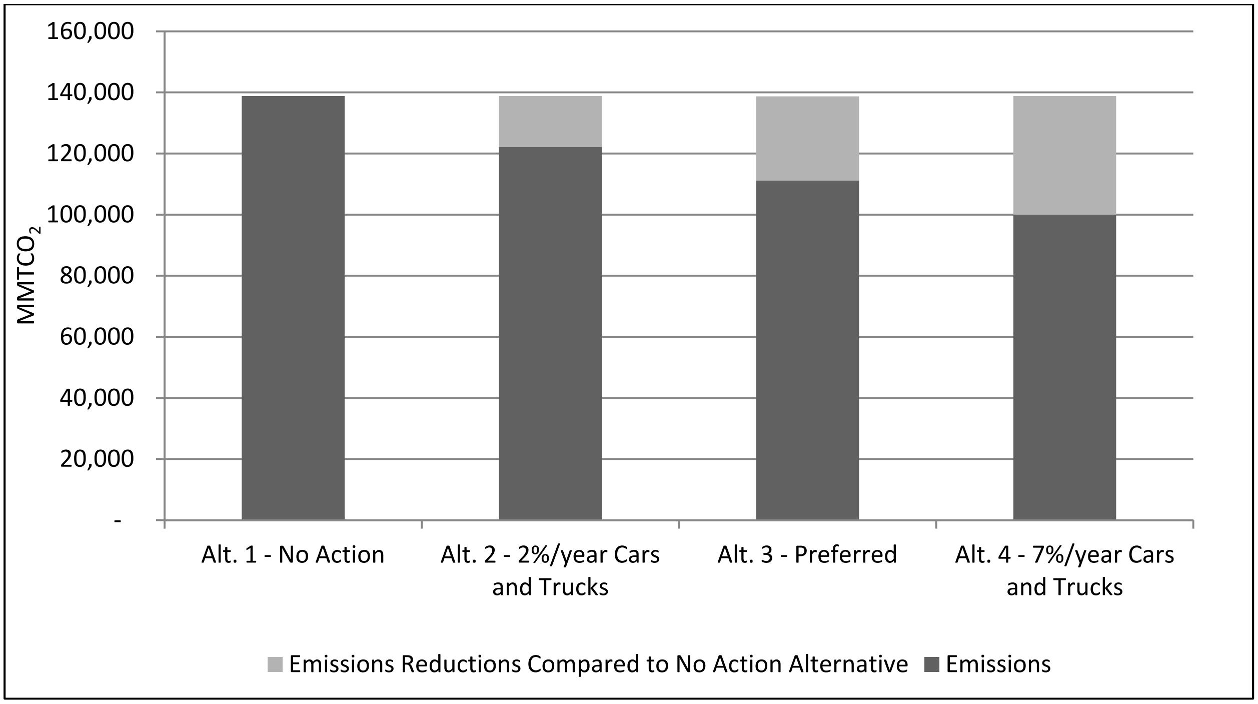


Figure 5.4.1-1-A2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative, Analysis A2



In Analyses A1 and A2, compared to total global emissions of 5,099,256 $MMTCO_2$ over this period (projected by the GCAMReference scenario), the Proposed Action is expected to reduce global CO_2 emissions by approximately 0.33 to 0.84 percent from their projected levels under the No Action Alternative.

Tables 5.4.1-1-B1 and -B2 and Figures 5.4.1-1-B1 and -B2 show total U.S. light-duty vehicle CO_2 emissions under the No Action Alternative and emission reductions that would result from each of the action alternatives from 2017 through 2100 for Analyses B1 and B2. U.S. light-duty vehicle emissions for this period range from a low of 91,600 $MMTCO_2$ under Alternative 4 up to 124,100 $MMTCO_2$ under the No Action Alternative. Compared to the No Action Alternative, projections of emission reductions from 2017 through 2100 under the action alternatives range from 2,500 to 22,000 $MMTCO_2$.

Table 5.4.1-1-B1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative,[a] Analysis B1

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	124,100		
2 - 2%/year Cars and Trucks	121,400	2,800	2%
3 - Preferred	111,800	12,300	10%
4 - 7%/year Cars and Trucks	102,100	22,000	18%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Table 5.4.1-1-B2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative,[a] Analysis B2

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	111,400		
2 - 2%/year Cars and Trucks	108,900	2,500	2%
3 - Preferred	100,200	11,300	10%
4 - 7%/year Cars and Trucks	91,600	19,800	18%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Figure 5.4.1-1-B1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative, Analysis B1

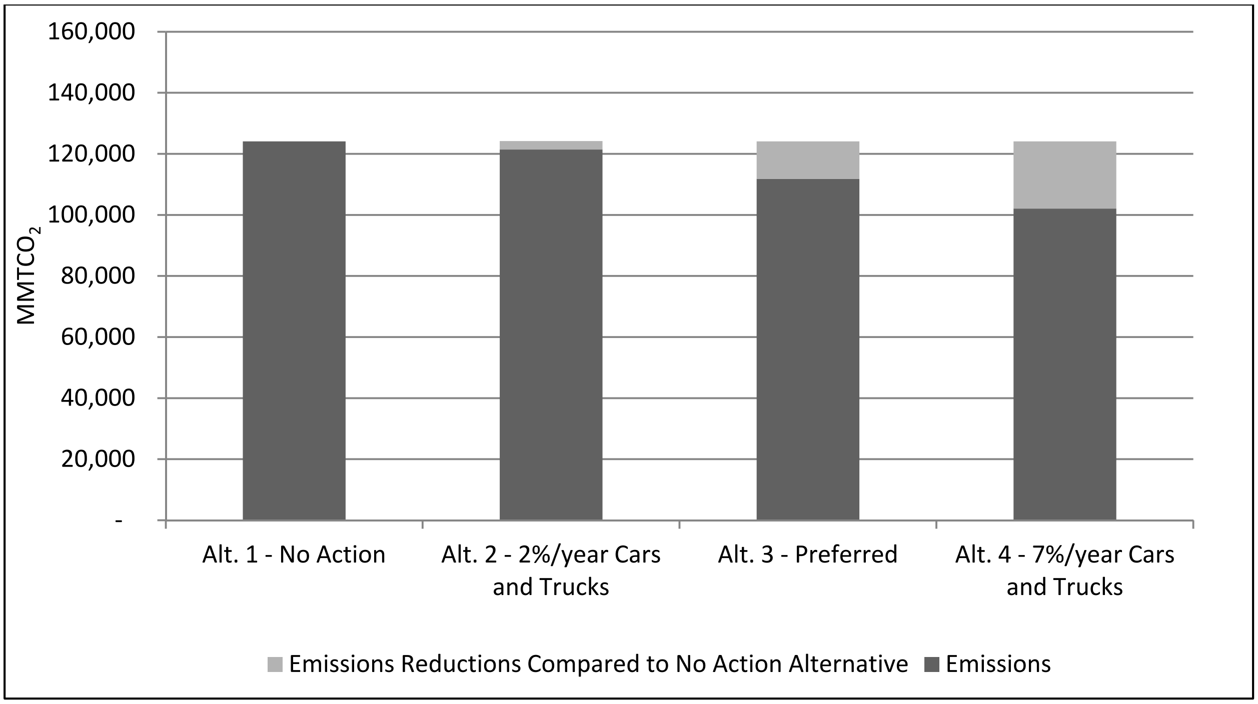
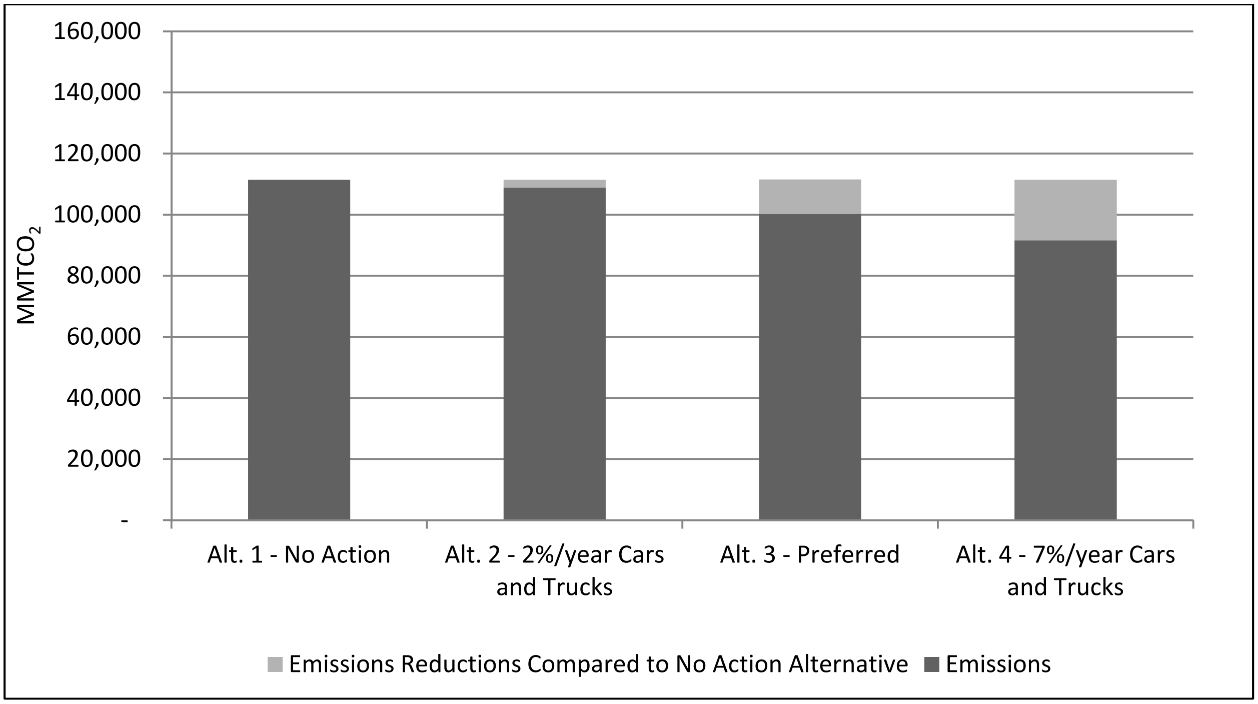


Figure 5.4.1-1-B2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks from 2017 through 2100 by Alternative, Analysis B2



In Analyses B1 and B2, compared to total global emissions of 5,099,256 $MMTCO_2$ over this period (projected by the GCAMReference scenario), this rulemaking is expected to reduce global CO_2 emissions by about 0.05 to 0.43 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 emissions from passenger cars and light trucks in the context of emissions projections from the transportation sector and expected or stated goals from existing programs designed to reduce CO_2 emissions. Passenger cars and light trucks currently account for a significant amount of CO_2 emissions in the United States. In Analyses A1 and A2, the action alternatives reduce total CO_2 emissions from U.S. light-duty vehicles by a range of 12 to 28 percent in the period from 2017 through 2100 compared to the No Action Alternative. In Analyses B1 and B2, the action alternatives reduce total CO_2 emissions from U.S. light-duty vehicles by a range of 2 to 18 percent in the period from 2017 through 2100 compared to the No Action Alternative. Compared to total U.S. CO_2 emissions from all sources 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 a range of 3.2 to 8.3 percent under Analyses A1 and A2 and a range of 0.1 to 3.6 percent under Analyses B1 and B2 in that year. Figures 5.4.1-2-A1 and -A2 and 5.4.1-2-B1 and -B2 show projected annual emissions from U.S. passenger cars and light trucks under the alternatives.

Figure 5.4.1-2-A1. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A1

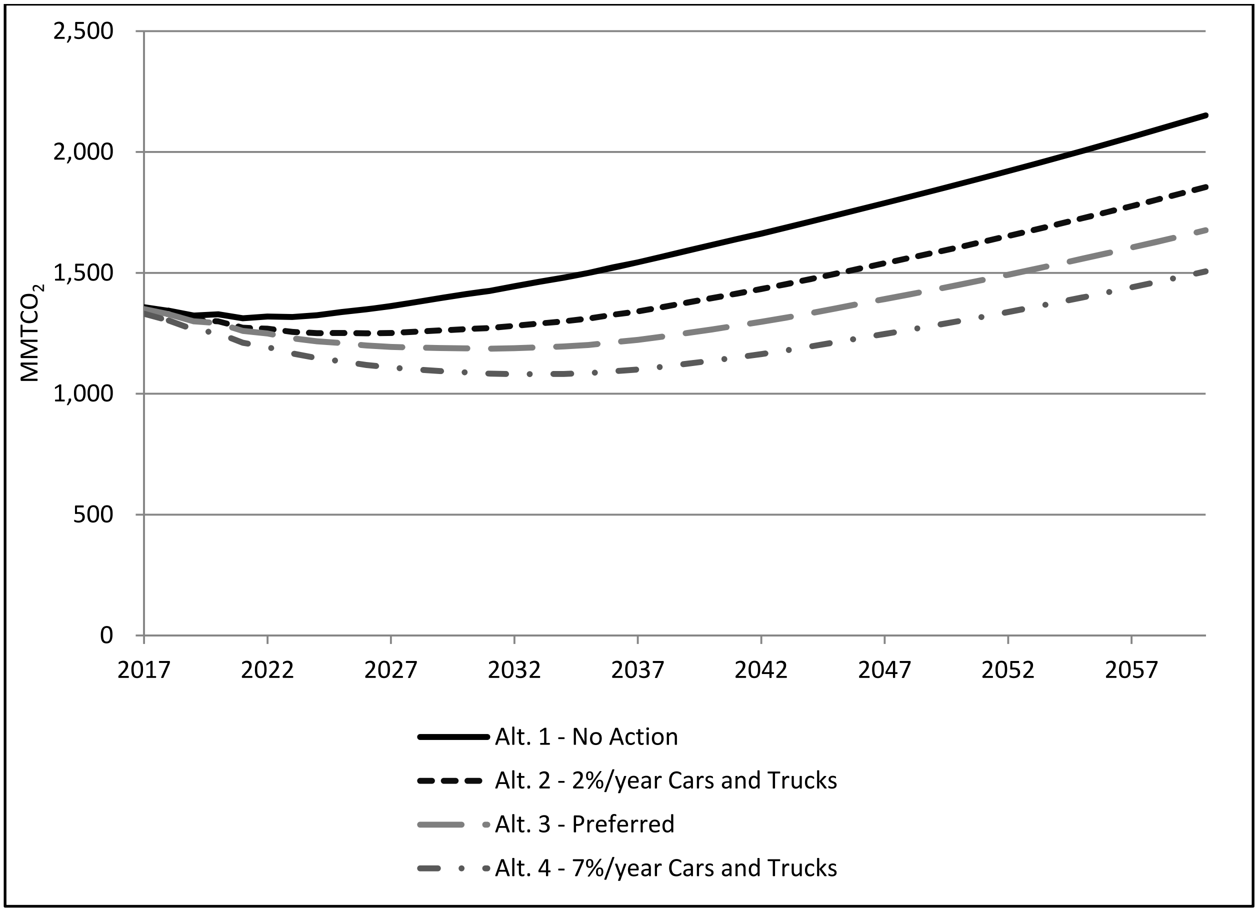


Figure 5.4.1-2-A2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A2

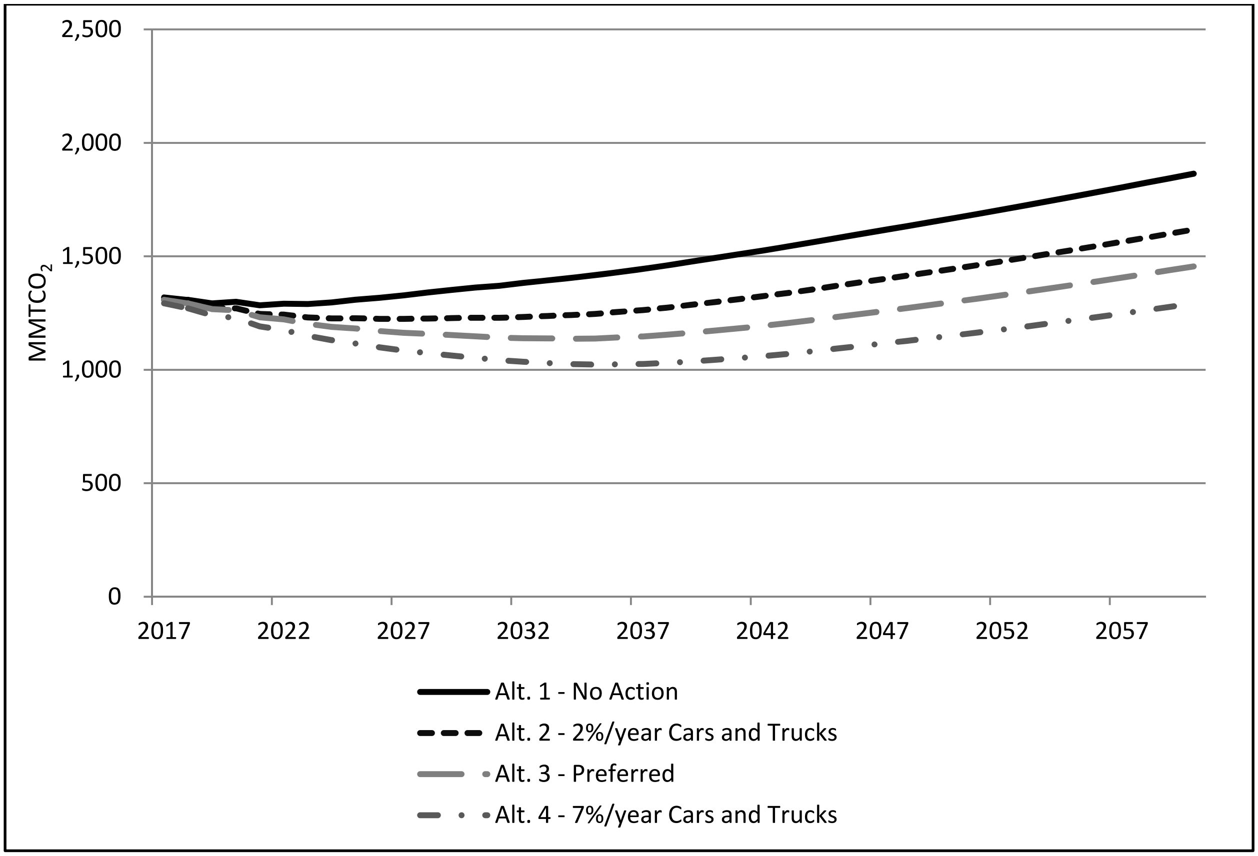


Figure 5.4.1-2-B1. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B1

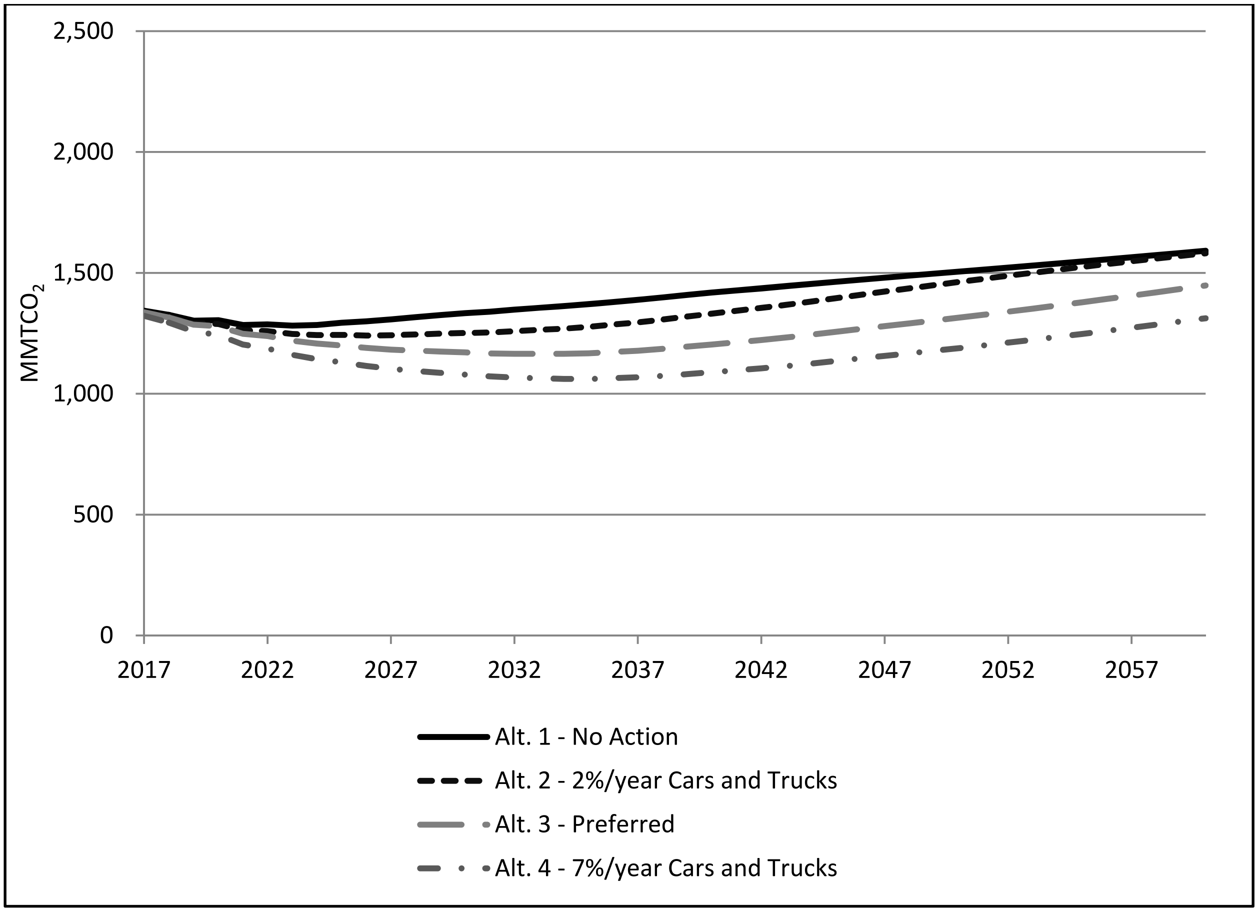
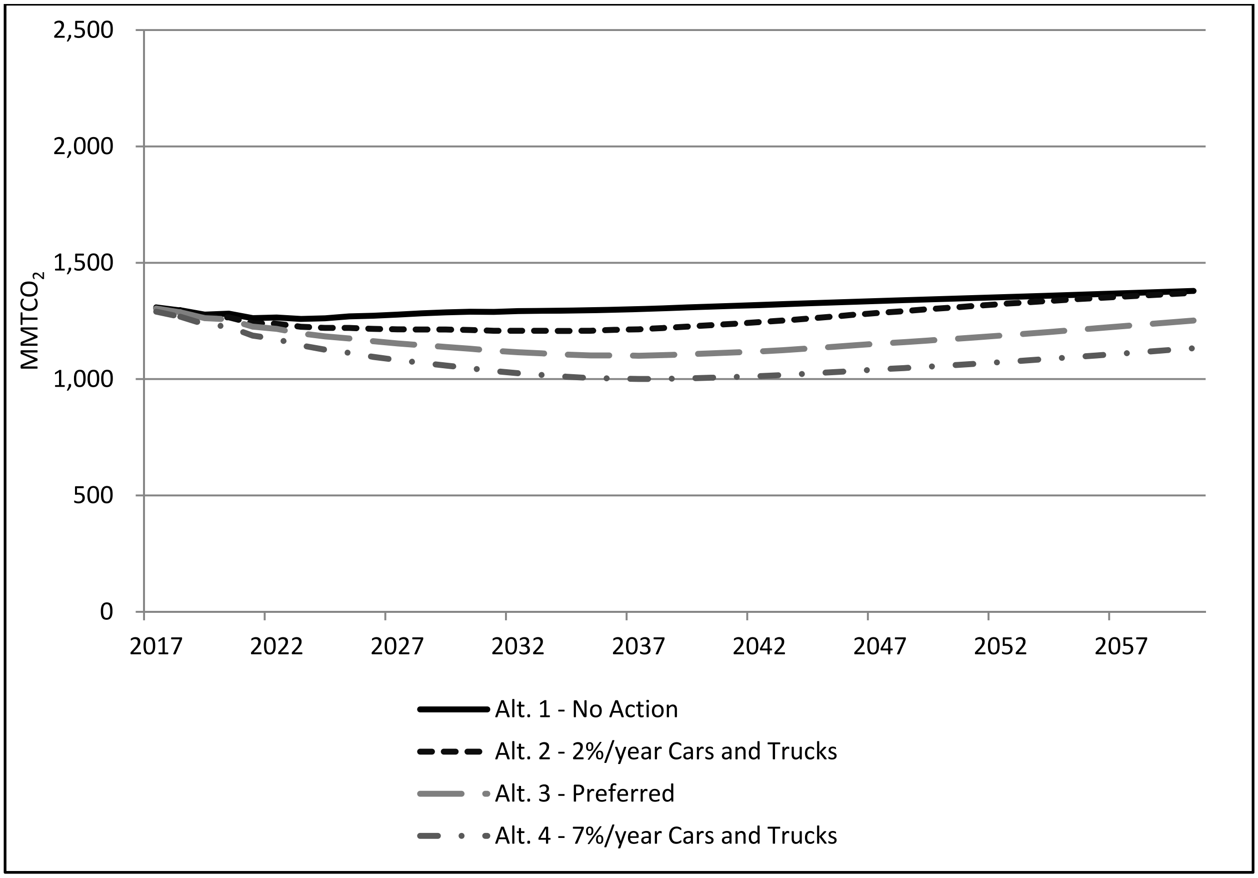


Figure 5.4.1-2-B2. Projected Annual CO_2 Emissions ($MMTCO_2$) from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B2



Tables 5.4.1-2-A1 and -A2 and 5.4.1-2-B1 and -B2 show that under the No Action Alternative, total CO_2, CH_4, and N_2O emissions from passenger cars and light trucks in the United States are projected to substantially increase between 2017 and 2100 in Analyses A1 and A2, while undergoing little to moderate growth in Analyses B1 and B2. Growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in a growth in VMT. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks.

Table 5.4.1-2-A1. Emissions of Greenhouse Gases ($MMTCO_2e$ per year)[a] from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A1[b]

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Greenhouse Gas and Year	**No Action**	**2%/Year Cars and Trucks**	**Preferred**	**7%/Year Cars and Trucks**
Carbon dioxide (CO_2)				
2020	1,329	1,300	1,292	1,251
2040	1,615	1,396	1,266	1,137
2060	2,152	1,855	1,676	1,506
2080	2,137	1,842	1,665	1,495
2100	1,987	1,713	1,548	1,391
Methane (CH_4)				
2020	4.90	4.82	4.79	4.68
2040	6.36	5.70	5.31	5.48
2060	8.50	7.62	7.08	7.49
2080	8.44	7.56	7.03	7.44
2100	7.85	7.03	6.54	6.92
Nitrous oxide (N_2O)				
2020	7.10	7.10	7.09	7.07
2040	7.51	7.53	7.52	6.57
2060	10.08	10.16	10.18	8.78
2080	10.01	10.09	10.11	8.72
2100	9.31	9.38	9.40	8.11

a. $MMTCO_2e$ = million metric tons carbon dioxide equivalent.
b. Emissions from 2016-2100 were scaled using the rate of change for the U.S. transportation GHG fuel consumption from the GCAMReference scenario. These assumptions project a slight decline over this time period.

Table 5.4.1-2-A2. Emissions of Greenhouse Gases ($MMTCO_2e$ per year)[a] from U.S. Passenger Cars and Light Trucks by Alternative, Analysis A2[b]

Greenhouse Gas and Year	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/Year Cars and Trucks	Preferred	7%/Year Cars and Trucks
Carbon dioxide (CO_2)				
2020	1,300	1,271	1,262	1,228
2040	1,493	1,299	1,173	1,044
2060	1,864	1,618	1,456	1,292
2080	1,851	1,607	1,445	1,283
2100	1,722	1,494	1,344	1,193
Methane (CH_4)				
2020	4.77	4.69	4.66	4.57
2040	5.83	5.27	4.95	5.12
2060	7.31	6.61	6.21	6.58
2080	7.25	6.56	6.17	6.54
2100	6.75	6.10	5.74	6.08
Nitrous oxide (N_2O)				
2020	6.93	6.93	6.93	6.90
2040	6.83	6.84	6.80	5.99
2060	8.59	8.64	8.62	7.50
2080	8.53	8.58	8.56	7.45
2100	7.93	7.98	7.96	6.93

a. $MMTCO_2e$ = million metric tons carbon dioxide equivalent.

b. Emissions from 2016–2100 were scaled using the rate of change for the U.S. transportation GHG fuel consumption from the GCAMReference scenario. These assumptions project a slight decline over this time period.

Table 5.4.1-2-B1. Emissions of Greenhouse Gases (MMTCO$_2$e per year)[a] from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B1[b]

Greenhouse Gas and Year	Alternative 1 No Action	Alternative 2 2%/Year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/Year Cars and Trucks
Carbon dioxide (CO_2)				
2020	1,305	1,289	1,279	1,243
2040	1,418	1,331	1,204	1,089
2060	1,591	1,581	1,448	1,312
2080	1,580	1,570	1,438	1,303
2100	1,470	1,460	1,337	1,212
Methane (CH_4)				
2020	4.83	4.78	4.75	4.67
2040	5.78	5.51	5.11	5.43
2060	6.87	6.83	6.40	7.07
2080	6.82	6.78	6.36	7.02
2100	6.34	6.30	5.91	6.53
Nitrous oxide (N_2O)				
2020	7.10	7.10	7.09	7.06
2040	7.52	7.53	7.52	6.55
2060	10.21	10.21	10.20	8.75
2080	10.14	10.14	10.13	8.68
2100	9.43	9.43	9.42	8.08

a. MMTCO$_2$e = million metric tons carbon dioxide equivalent.
b. Emissions from 2016-2100 were scaled using the rate of change for the U.S. transportation GHG fuel consumption from the GCAMReference scenario. These assumptions project a slight decline over this time period.

Table 5.4.1-2-B2. Emissions of Greenhouse Gases ($MMTCO_2e$ per year)[a] from U.S. Passenger Cars and Light Trucks by Alternative, Analysis B2[b]

Greenhouse Gas and Year	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	No Action	2%/Year Cars and Trucks	Preferred	7%/Year Cars and Trucks
Carbon dioxide (CO_2)				
2020	1,281	1,265	1,257	1,225
2040	1,312	1,232	1,110	1,006
2060	1,379	1,370	1,252	1,133
2080	1,369	1,361	1,243	1,125
2100	1,274	1,266	1,156	1,046
Methane (CH_4)				
2020	4.71	4.67	4.65	4.57
2040	5.31	5.07	4.77	5.22
2060	5.92	5.90	5.63	6.45
2080	5.88	5.85	5.59	6.40
2100	5.47	5.45	5.20	5.95
Nitrous oxide (N_2O)				
2020	6.93	6.93	6.93	6.89
2040	6.84	6.85	6.79	5.87
2060	8.71	8.71	8.65	7.34
2080	8.65	8.65	8.59	7.29
2100	8.04	8.05	7.99	6.78

a. $MMTCO_2e$ = million metric tons carbon dioxide equivalent.
b. Growth or decline in emissions between 2060 and 2100 were scaled against GCAMReference transportation sector assumptions. These assumptions project overall decline in emissions over the time period.

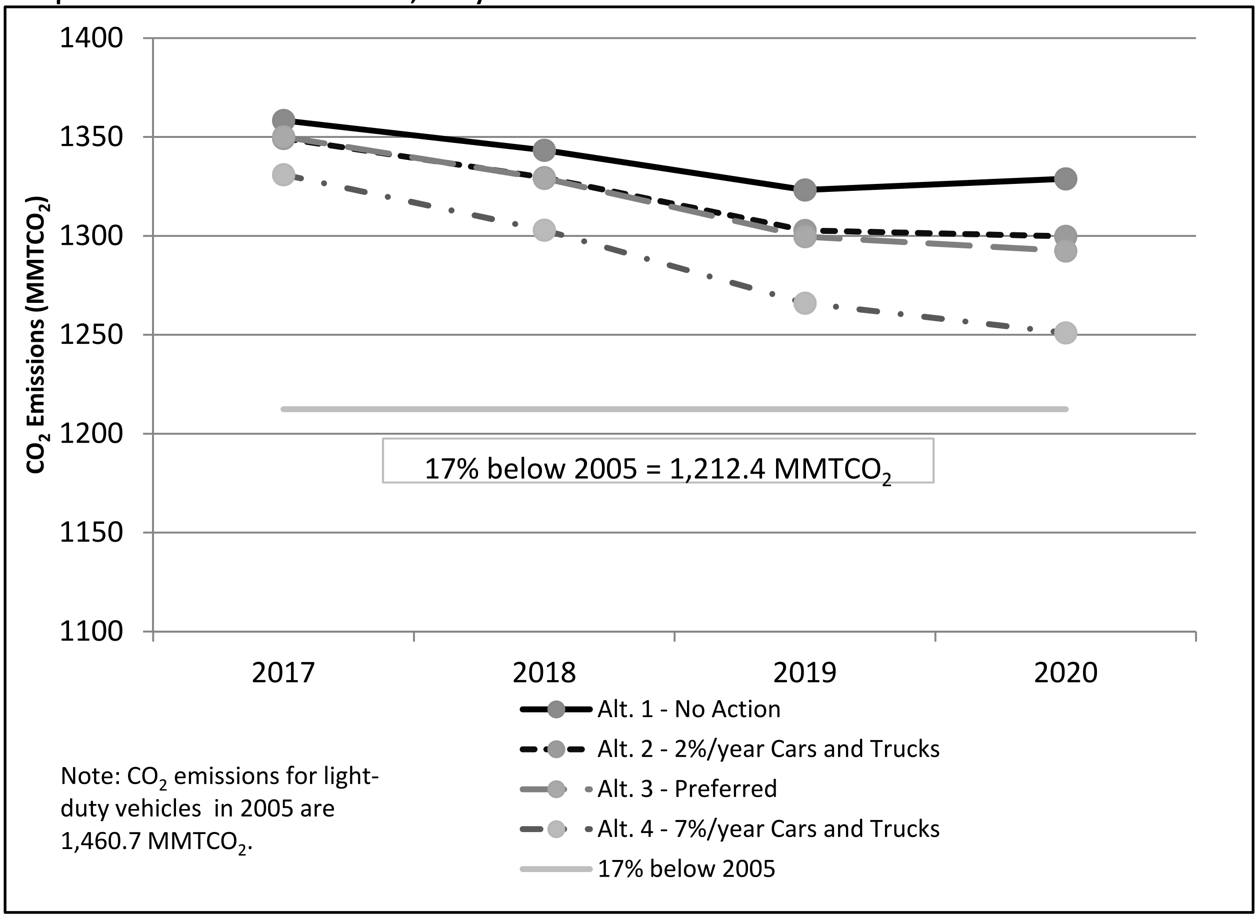
The preceding tables also illustrate that, in all analyses, each action alternative would reduce passenger car and light-truck emissions of CO_2 from their projected levels under the No Action Alternative. Similarly, under each of the action alternatives, CH_4 emissions in future years are projected to decline from their projected levels under the No Action Alternative (except under Alternative 4 in Analyses B1 and B2 after 2060). Progressively larger reductions in CO_2 emissions from their levels under the No Action Alternative are projected under Alternatives 2 through 4, because the action alternatives require progressively larger increases in fuel economy.

5.4.1.1.1 Comparison to the U.S. Target under the Copenhagen Accord

These results can be viewed in light of GHG emissions reduction targets. In 2010, President Obama submitted to the 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. 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 U.S. passenger car and light-truck sector in 2020 would decrease in the range of 11.0 to 15.9 percent below 2005 levels in Analyses A1 and A2 and 11.8 to 16.1

percent below 2005 levels in Analyses B1 and B2.[1] Figures 5.4.1-3-A1 and -A2 and 5.4.1-3-B1 and -B2 show that NHTSA estimates the proposed standards would reduce CO_2 emissions significantly from future levels estimated to occur in the absence of the proposed fuel economy standards. However, assuming the same percentage decrease in emissions would need to be achieved from all sectors in order to reach the President's target, these reductions in emissions alone would not reduce total passenger car and light-truck emissions to the goal of 17 percent below their 2005 levels by 2020.

Figure 5.4.1-3-A1. Projected Annual CO2 Emissions from U.S. Passenger Cars and Light Trucks by Alternative Compared to 17% below 2005 Levels, Analysis A1



[1] A 17 percent reduction would mean a reduction of 248.3 $MMTCO_2$ from 2005 levels, or a reduction ranging between 68.8 and 116.5 $MMTCO_2$ from the No Action Alternative in 2020.

Figure 5.4.1-3-A2. Projected Annual CO_2 Emissions from U.S. Passenger Cars and Light Trucks by Alternative Compared to 17% below 2005 Levels, Analysis A2

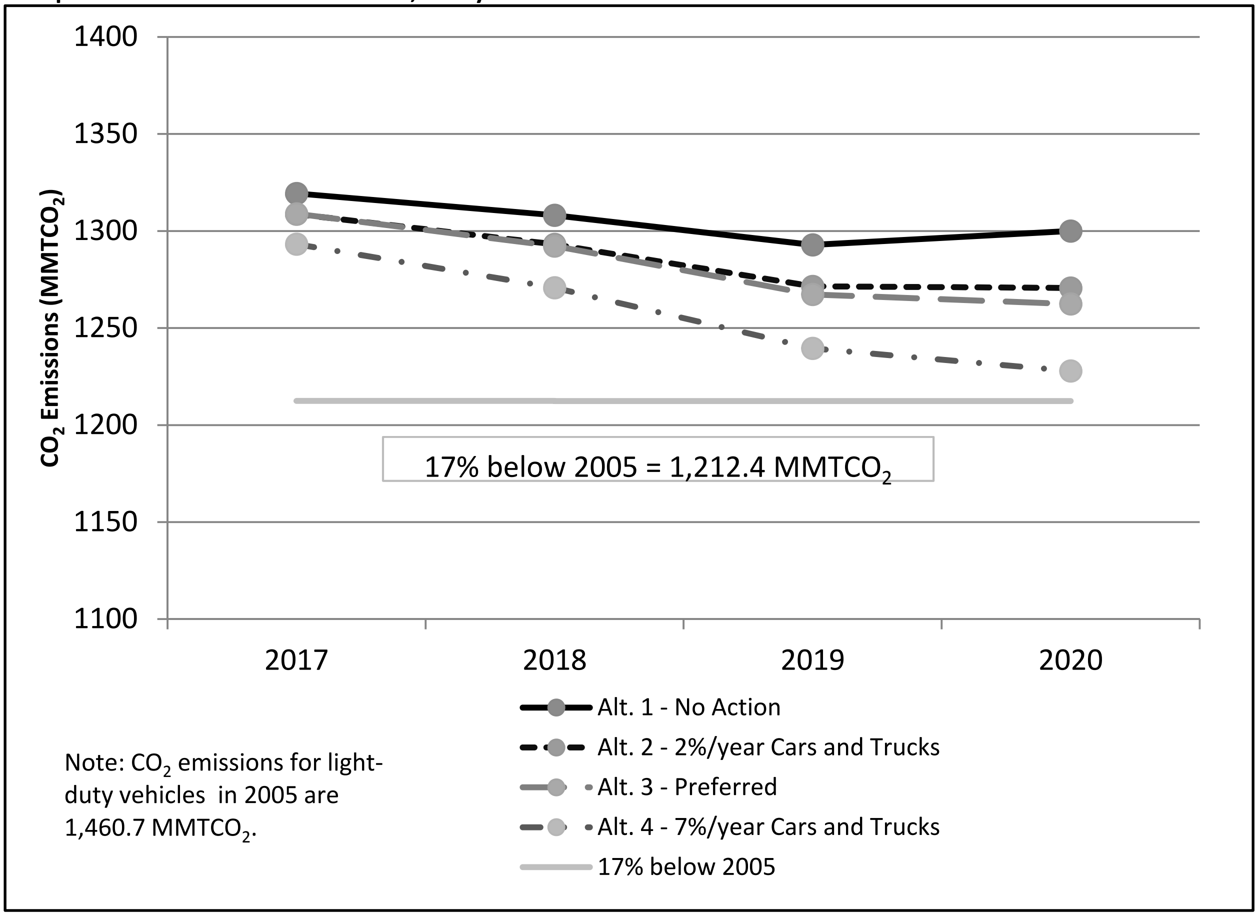


Figure 5.4.1-3-B1. Projected Annual CO_2 Emissions from U.S. Passenger Cars and Light Trucks by Alternative Compared to 17% below 2005 Levels, Analysis B1

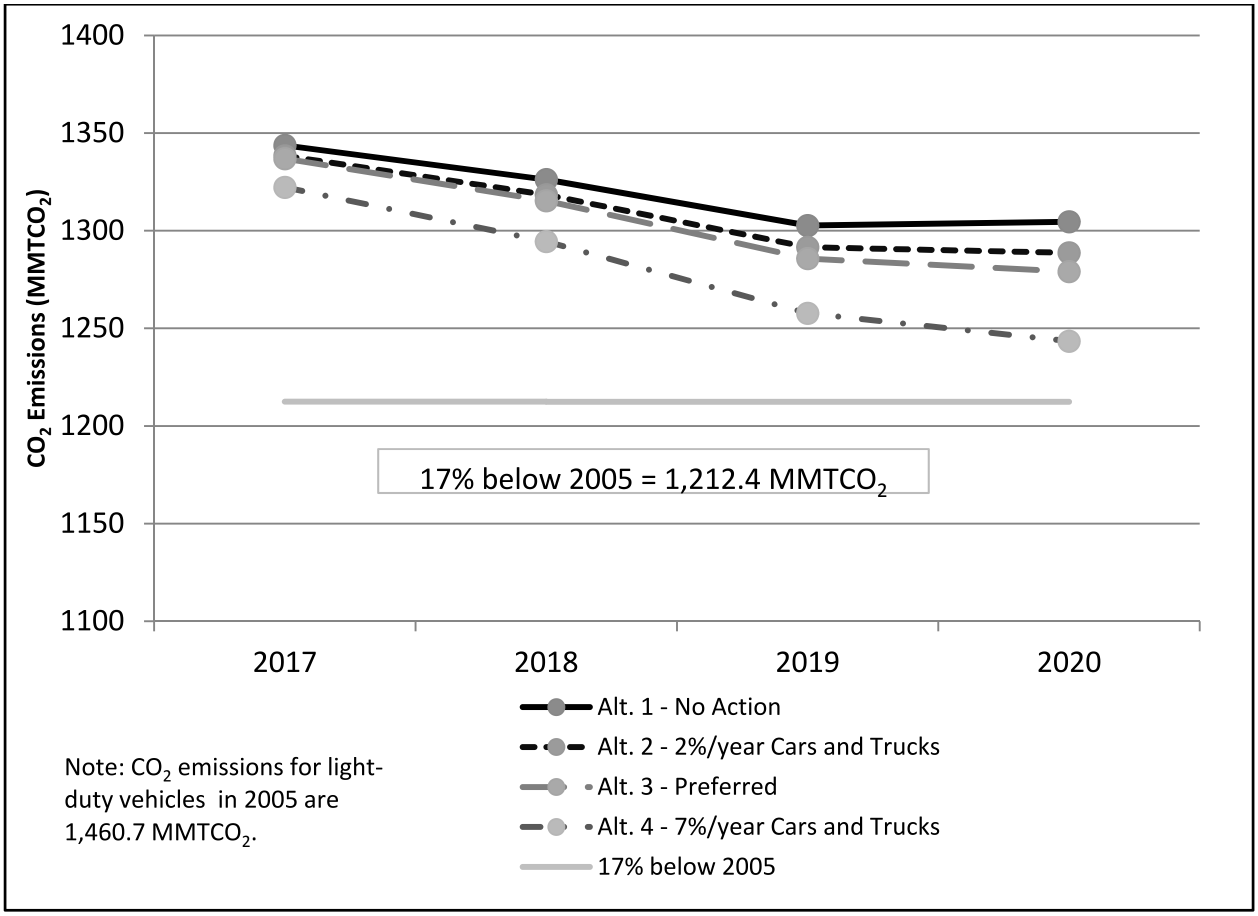
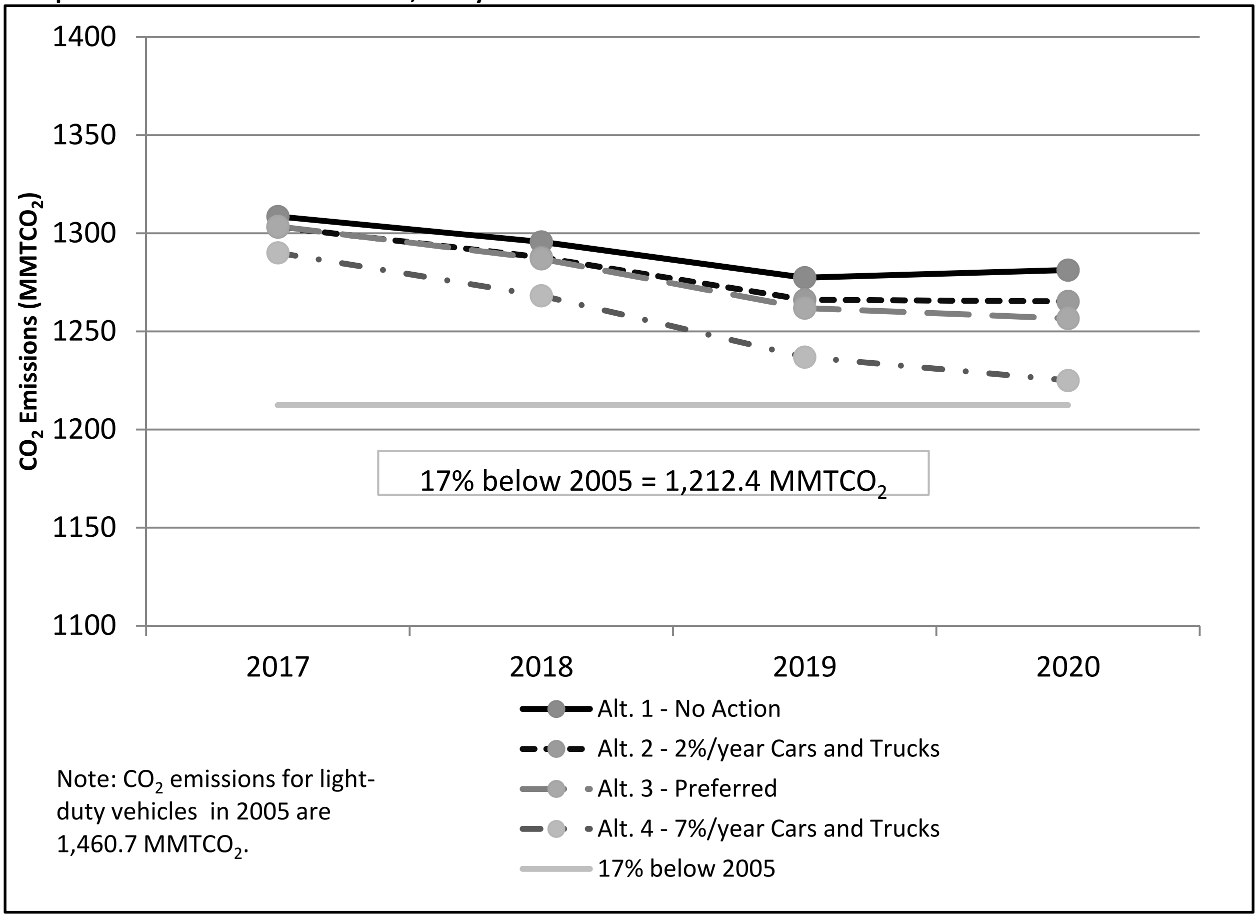


Figure 5.4.1-3-B2. Projected Annual CO_2 Emissions from U.S. Passenger Cars and Light Trucks by Alternative Compared to 17% below 2005 Levels, Analysis B2



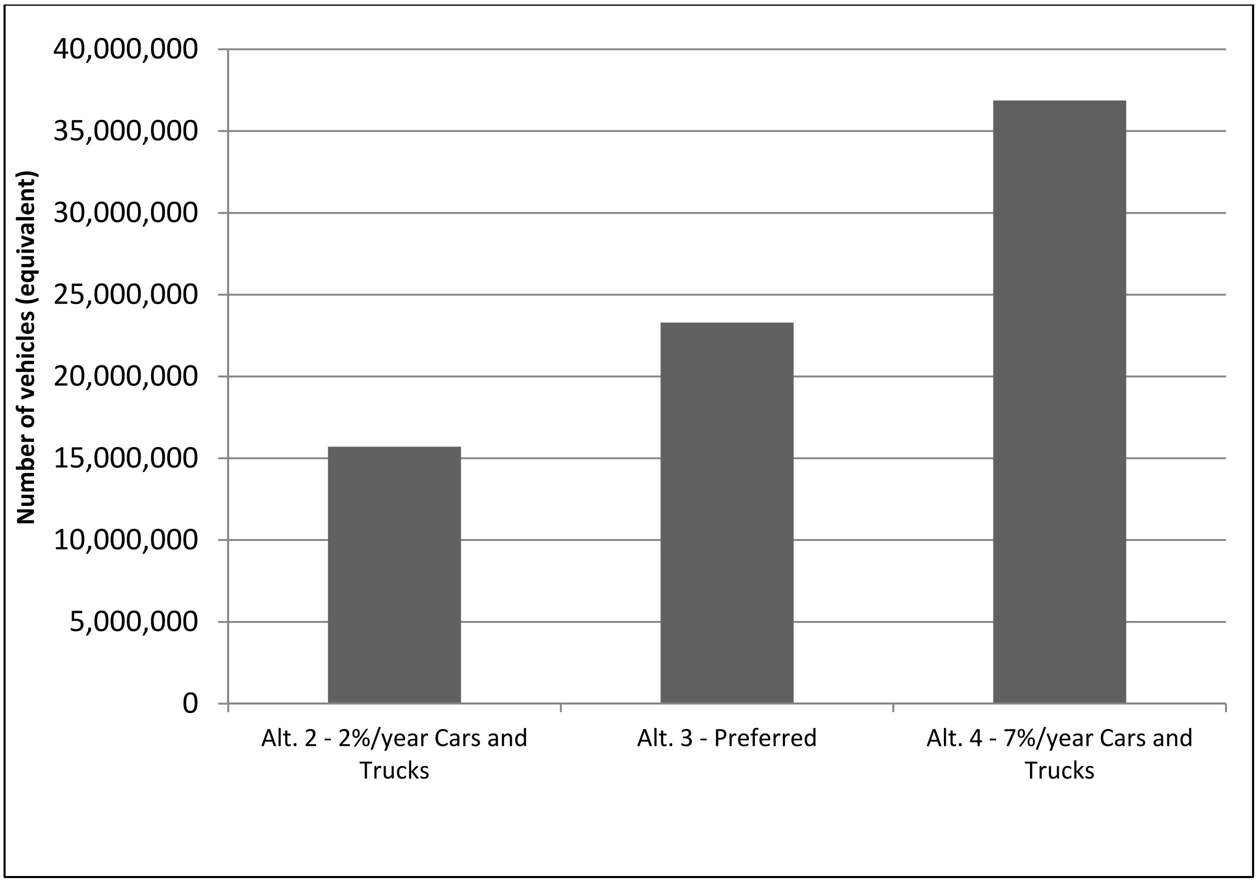
The President's target outlined above does not specify that every emitting sector of the economy must contribute equally proportional emission reductions. Significantly, the action of setting fuel economy standards does not directly regulate total emissions from passenger cars and light trucks. NHTSA's authority to promulgate new fuel economy standards does not allow the agency to regulate other factors affecting emissions, including driving habits; therefore, NHTSA cannot, for example, control VMT. Under all of the alternatives, growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use (annual VMT per vehicle) due to economic improvement and a variety of other factors, is projected to result in growth in light-duty vehicle VMT.

This projected growth in travel between 2017 and 2060 more than offsets the effect of improvements in fuel economy for all but Alternative 3 in Analysis B2, and Alternative 4 in Analyses A2, B1, and B2. Under the other alternatives, there would be increases in total fuel consumption by passenger cars and light trucks in the United States between 2017 and 2060 and over the long term. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from passenger cars and light trucks. However, NHTSA anticipates reduced annual fuel consumption and CO_2 emissions from present levels over the short term under all alternatives.

5.4.1.1.2 Comparison to Annual Emissions from Passenger Cars and Light Trucks

As an illustration of the fuel savings projected under the action alternatives, Figures 5.4.1-4-A1 and -A2 express the CO_2 reductions under each action alternative in 2025 as the equivalent number of passenger cars and light trucks that would produce those emissions in that year in Analyses A1 and A2. The emission reductions under the action alternatives are equivalent to the annual emissions of between 14.8 million light-duty vehicles (Alternative 2) and 36.9 million light-duty vehicles (Alternative 4) in 2025, compared to the annual emissions that would occur under the No Action Alternative. Emission reductions in 2025 under the Preferred Alternative are equivalent to annual emissions from between 22.9 million and 23.3 million passenger cars and light trucks.

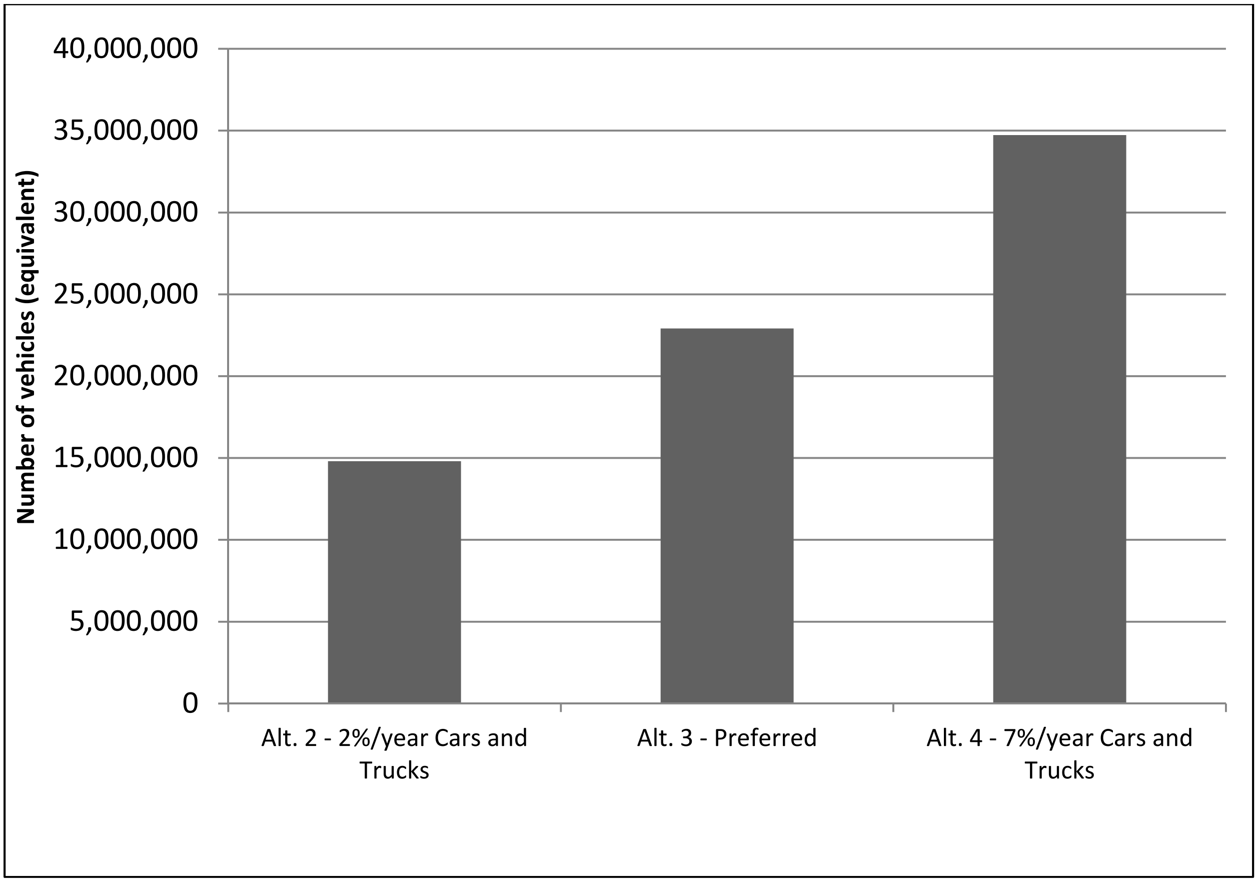
Figure 5.4.1-4-A1. Number of U.S. Passenger Cars and Light Trucks Equivalent to CO_2 Reductions in 2025 Compared to the No Action Alternative, Analysis A1



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 that meet the increasingly stringent fuel economy standards required under each alternative.[2]

[2] The light-duty vehicle equivalency is based on an average per-vehicle emissions estimate, which includes both tailpipe CO_2 emissions and associated upstream emissions from fuel production and distribution. The average light-duty vehicle accounts for between 5.53 and 5.56 metric tons of CO_2 in 2025 in Analyses A1 and A2 based on Volpe and GREET model analysis.

Figure 5.4.1-4-A2. Number of U.S. Passenger Cars and Light Trucks Equivalent to CO_2 Reductions in 2025 Compared to the No Action Alternative, Analysis A2



Figures 5.4.1-4-B1 and -B2 show the CO_2 reductions projected to result under each action alternative in 2025 as the equivalent number of passenger cars and light trucks that would produce those emissions in that year in Analyses B1 and B2. The emission reductions under the action alternatives are equivalent to the annual emissions of between 9.2 million light-duty vehicles (Alternative 2) and 30.6 million light-duty vehicles (Alternative 4) in 2025, compared to the annual emissions that would occur under the No Action Alternative. Emission reductions in 2025 under the Preferred Alternative are equivalent to the annual emissions of 17.5 million light-duty 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 that meet the increasingly stringent fuel economy standards required under each alternative.[3]

[3] The light-duty vehicle equivalency is based on an average per-vehicle emissions estimate, which includes both tailpipe CO_2 emissions and associated upstream emissions from fuel production and distribution. The average light-duty vehicle accounts for between 5.34 and 5.39 metric tons of CO_2 in 2025 in Analyses B1 and B2 based on Volpe and GREET model analysis.

Figure 5.4.1-4-B1. Number of U.S. Passenger Cars and Light Trucks Equivalent to CO_2 Reductions in 2025 Compared to the No Action Alternative, Analysis B1

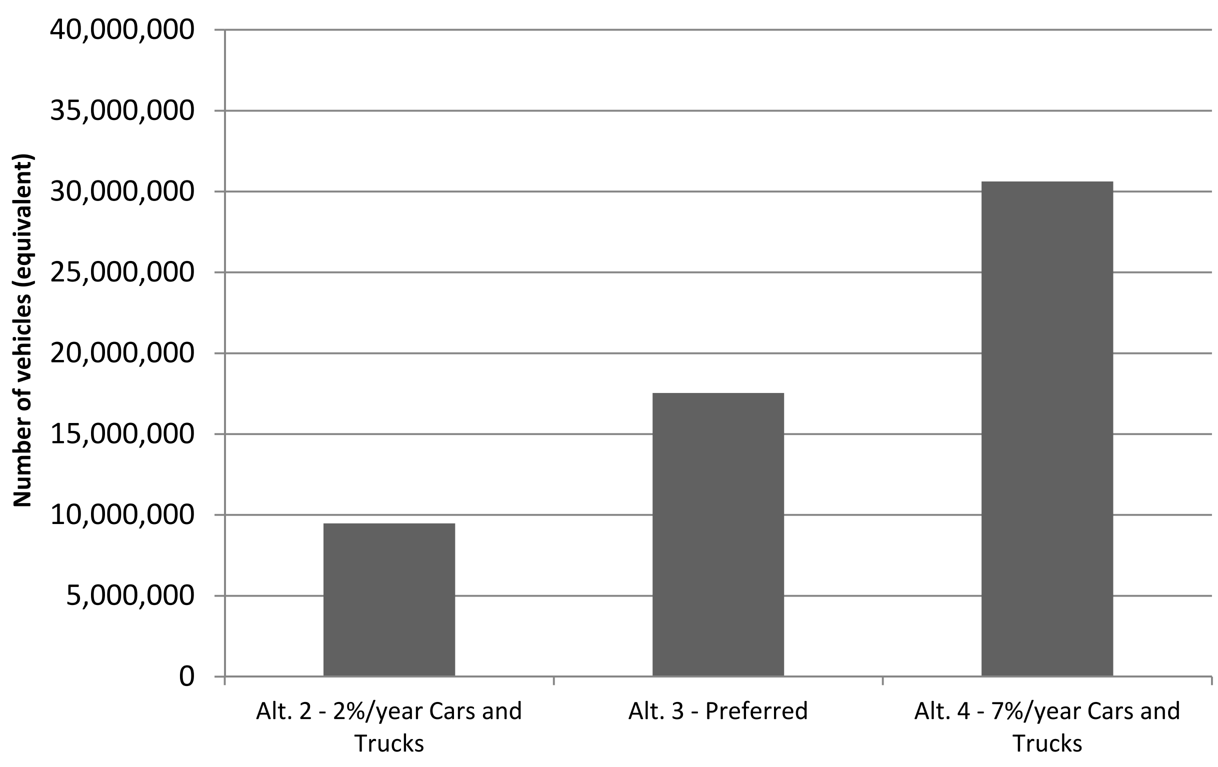
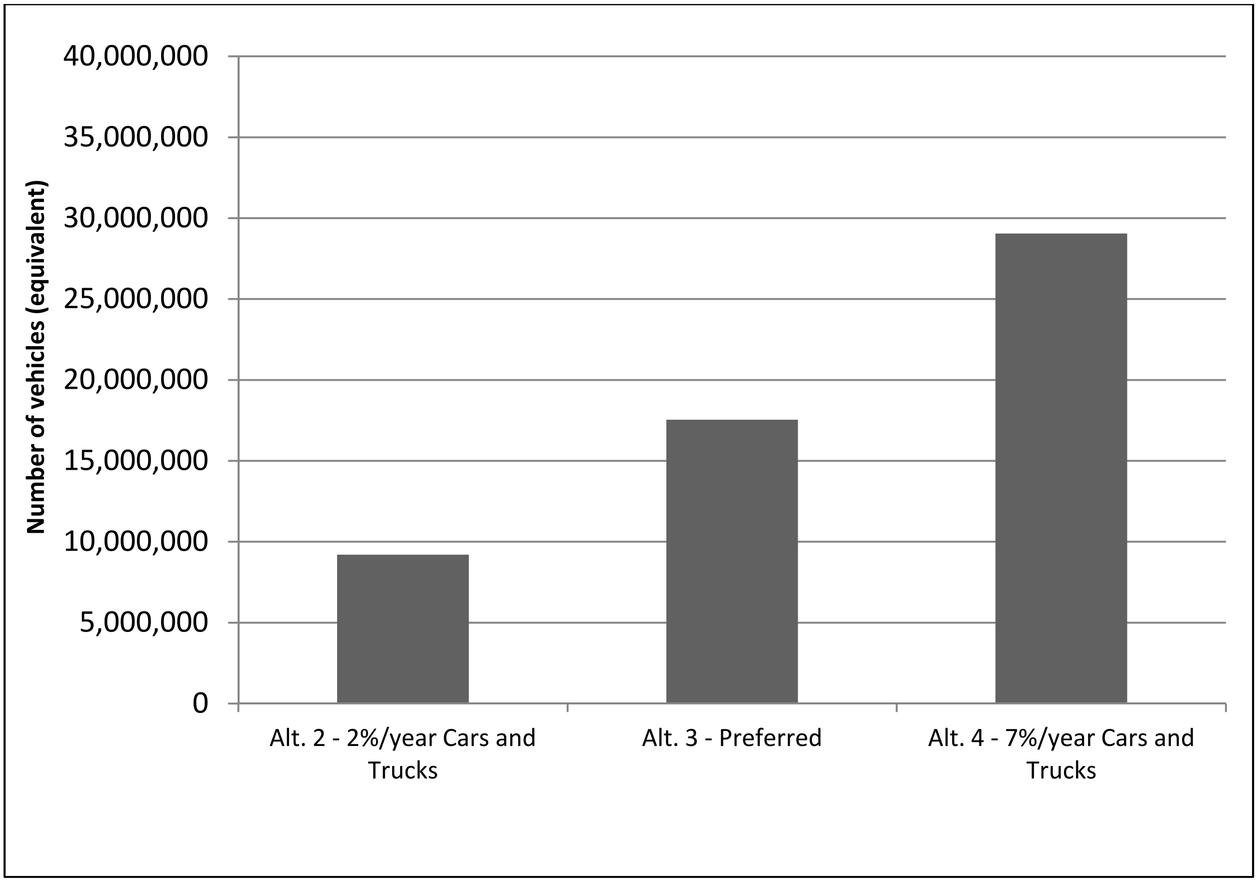


Figure 5.4.1-4-B2. Number of U.S. Passenger Cars and Light Trucks Equivalent to CO_2 Reductions in 2025 Compared to the No Action Alternative, Analysis B2



5.4.1.1.3 Comparison to Regional GHG Reduction Programs in North America

These emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. The WCI currently includes the State of California and several Canadian provinces as participants (WCI 2012). In 2010, WCI released its "Design for the Regional WCI Program," in which WCI explains its commitment to, and strategy for, reducing annual GHG emissions in the WCI region by 15 percent (compared to the 2005 baseline) by 2020 (WCI 2012); this is equivalent to a reduction of approximately 95 $MMTCO_2e$ per year (British Columbia 2009, CARB 2011, Quebec 2011). Total emissions reductions between 2020 and 2025 would be approximately 570 $MMTCO_2e$.[4] WCI anticipates that the 15 percent reduction in emissions will be possible through incentivizing the adoption of cleaner energy sources, incentivizing the creation of green jobs, and by implementing a cap and trade system that accounts for two-thirds of the emissions reductions. The first phase of WCI's cap-and-trade program began January 1, 2012; its second phase begins January 1, 2015 (WCI 2012). When fully implemented in 2015, the program will cover nearly 90 percent of GHG emissions in the WCI region.

[4] WCI has not yet released a new estimate of emissions reductions (after the withdrawal of some member states). NHTSA estimated projected reductions for 2020–2025 using the 2005 baseline emissions data for California, British Columbia, and Quebec, and reducing these by 15 percent.

Elsewhere in the United States, the nine RGGI member states in the northeast and mid-Atlantic regions have set a goal to reduce annual CO_2 emissions from power plants in the Northeast by 10 percent by 2018, or by about 12 $MMTCO_2e$ per year (RGGI 2012). Projected total emission reductions between 2006 and 2024 under the initiative were originally estimated at 268 $MMTCO_2$ when this program began in 2006 (RGGI 2006).[5] This estimate represented a 23 percent reduction compared to the 2024 business-as-usual baseline (as estimated in 2006) and a 10 percent reduction compared to the actual 2006 baseline emissions (RGGI 2006). With the withdrawal of New Jersey from the initiative in 2011, the projected emission reductions from 2006 to 2024 are now roughly 228 $MMTCO_2e$.[6] In comparison, the Proposed Action is projected to reduce cumulative CO_2 emissions by 374 to 962 $MMTCO_2$ in Analyses A1 and A2 and 214 to 765 $MMTCO_2$ in Analyses B1 and B2 between 2017 and 2025 (depending on the alternative), with emissions levels representing between a 4 and 18 percent reduction from the baseline emissions for U.S. passenger cars and light trucks in 2025 (considering all analyses).

Note that comparisons between the Proposed Action and other programs are not straightforward, given the difference in the periods over which reductions are estimated and differences in the emissions reference case. In general, the longer the period, the greater the potential emission reductions. Emissions are generally trending upward, so reductions in relation to a static baseline (e.g., annual emissions as of 2005 or 2006) will be greater than if they were expressed in relation to a business-as-usual baseline (as is the case for the CAFE standards analysis). Table 5.4.1-3 summarizes the emission reductions for the Proposed Action and WCI and RGGI programs.

Table 5.4.1-3. Comparison of GHG Emissions Impacts between 2017–2025 CAFE Standards and Regional Initiatives

Program	Cumulative Emission Reduction Period	Baseline from Which Reductions are Estimated	Range of reductions ($MMTCO_2e$)[a]
MY 2017–2025 CAFE Standards, Analyses A1 and A2	2017–2025	Business as usual baseline	374 to 962
MY 2017–2025 CAFE Standards, Analyses B1 and B2	2017–2025	Business as usual baseline	214 to 765
Western Climate Initiative (WCI)	2020–2025	Annual emissions in 2005	570
Regional GHG Initiative (RGGI)	2006–2024	Annual emissions in 2006	228

a. $MMTCO_2e$ = million metric tons of carbon dioxide equivalent.

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 Action are projected to *increase* over the long term under most alternatives due to increases in vehicle ownership and use. Second, these projections are

[5] Emission 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 created by projects outside 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 allowing reductions elsewhere.

[6] RGGI has not yet released a new estimate (after the withdrawal of New Jersey from the initiative). NHTSA estimated projected reductions using the 2006 baseline emissions data for each of the nine remaining RGGI states.

estimates only, and the scope of these climate programs differs from the scope of the Proposed Action in terms of geography, sector, and purpose.

In this case, the comparison of emission reductions from the alternative fuel economy 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 on a scale similar to many of the most progressive and ambitious GHG emissions reduction programs underway in the United States.

5.4.1.2 Social Cost of Carbon

Tables 5.4.1-4-A1 and -A2 and 5.4.1-4-B1 and -B2 list the benefits of the Proposed Action in terms of reduced monetized damages. NHTSA derived the net present value of the benefits reported these tables by: (1) utilizing the estimates of the SCC per ton reported previously in Section 5.3.2, (2) applying each future year's SCC estimate (per ton) to the projected reduction in GHG emissions during that year under each action alternative, presented in Section 5.4.1, (3) discounting the resulting figure to its present value, and (4) summing those estimates for each year from 2017 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 future benefits. These estimates show increasing benefits with decreasing discount rates and with higher GHG damage estimates. The estimated net present value for a given action alternative varies by approximately an order of magnitude across the discount rates. The estimated net present value computed using a single discount rate differs by roughly a factor of three across alternatives.

Table 5.4.1-4-A1. Reduced Monetized Damages of Climate Change for each Regulatory Alternative, Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis A1

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$17,025	$91,485	$156,553	$278,470
3 - Preferred	$26,491	$142,711	$244,340	$434,354
4 - 7%/year Cars and Trucks	$38,038	$203,847	$348,641	$620,552

Table 5.4.1-4-A2. Reduced Monetized Damages of Climate Change for each Regulatory Alternative, Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis A2

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$15,338	$82,171	$140,529	$250,147
3 - Preferred	$24,701	$132,690	$227,051	$403,894
4 - 7%/year Cars and Trucks	$35,706	$191,187	$326,931	$582,026

Table 5.4.1-4-B1. Reduced Monetized Damages of Climate Change for each Regulatory Alternative, Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis B1

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$7,224	$37,837	$64,403	$115,266
3 - Preferred	$16,661	$88,773	$151,648	$270,285
4 - 7%/year Cars and Trucks	$26,944	$143,117	$244,326	$435,803

Table 5.4.1-4-B2. Reduced Monetized Damages of Climate Change for each Regulatory Alternative, Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis B2

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$6,763	$35,339	$60,122	$107,666
3 - Preferred	$15,849	$84,274	$143,902	$256,604
4 - 7%/year Cars and Trucks	$25,123	$133,301	$227,516	$405,924

5.4.1.3 Direct and Indirect Impacts on Climate Change Indicators

Sections 5.4.1.3.1 through 5.4.1.3.4 describe the direct and indirect impacts of the alternatives on four relevant climate change indicators: atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise. Section 5.4.1.3.5 presents the sensitivity analysis.

5.4.1.3.1 Atmospheric CO_2 Concentrations

MAGICC 5.3.v2 is a simple climate model well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 5.4.1-5.[7] As the table shows, the results of the model runs developed for this analysis agree relatively well with IPCC estimates for both CO_2 concentrations and surface temperature.

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

Table 5.4.1-5. Comparison of MAGICC Modeling Results and Reported IPCC Results[a,b]

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

a. IPCC 2007a.
b. The IPCC values represent the average of the 5 to 95 percent range of the rise of sea level from 1980 through 1989 and 2090 through 2099.

A comparison of sea-level rise from MAGICC 5.3.v2 and the IPCC Fourth Assessment Report is presented in the release documentation for MAGICC 5.3.v2 (Wigley 2008). In Table 3 of the documentation, Wigley presents the results for six SRES scenarios, which show that the comparable values for sea-level rise from MAGICC 5.3.v2 (total sea-level rise minus estimates for contributions from non-melt sources such as permafrost warming) are within 0.01 centimeter (0.004 inch) in 2095.

As discussed in Section 5.3.3, NHTSA used the GCAMReference scenario to represent the No Action Alternative in the MAGICC modeling runs. Tables 5.4.1-6-A1 and -A2 and 5.4.1-6-B1 and -B2, and Figures 5.4.1-5-A1 and -A2 and 5.4.1-5-B1 and -B2 through 5.4.1-8-A1 and -A2 and 5.4.1-8-B1 and -B2 present the results of MAGICC simulations for the No Action Alternative and the three action alternatives in terms of CO_2 concentrations and increases in global mean surface temperature in 2040, 2060, and 2100.

Table 5.4.1-6-A1. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAMReference) by Alternative,[a,b] Analysis A1

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	478.8	563.7	784.9	1.191	1.833	3.064	11.21	18.79	37.40
2 - 2%/year Cars and Trucks	478.5	563.0	783.0	1.190	1.830	3.058	11.20	18.78	37.34
3 - Preferred	478.3	562.5	781.9	1.189	1.828	3.054	11.20	18.77	37.30
4 - 7%/year Cars and Trucks	478.1	562.0	780.7	1.188	1.825	3.049	11.20	18.75	37.26
Reductions under Alternative Vehicle Standards									
2 - 2%/year Cars and Trucks	0.3	0.8	1.9	0.001	0.003	0.006	0.01	0.01	0.06
3 - Preferred	0.4	1.2	3.0	0.002	0.005	0.010	0.01	0.02	0.10
4 - 7%/year Cars and Trucks	0.7	1.7	4.1	0.003	0.008	0.015	0.01	0.04	0.14

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to the year 1990.

Table 5.4.1-6-A2. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAMReference) by Alternative,[a,b] Analysis A2

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	478.8	563.7	784.9	1.191	1.833	3.064	11.21	18.79	37.40
2 - 2%/year Cars and Trucks	478.5	563.0	783.3	1.190	1.830	3.058	11.21	18.78	37.35
3 - Preferred	478.4	562.6	782.3	1.189	1.828	3.055	11.20	18.77	37.31
4 - 7%/year Cars and Trucks	478.2	562.1	781.2	1.188	1.826	3.050	11.20	18.75	37.27
Reductions under Alternative Vehicle Standards									
2 - 2%/year Cars and Trucks	0.3	0.7	1.6	0.001	0.003	0.006	0.00	0.01	0.05
3 - Preferred	0.4	1.1	2.6	0.002	0.004	0.009	0.01	0.02	0.09
4 - 7%/year Cars and Trucks	0.6	1.6	3.7	0.003	0.007	0.014	0.01	0.04	0.13

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to the year 1990.

Table 5.4.1-6-B1. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAMReference) by Alternative,[a,b] Analysis B1

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	478.8	563.7	784.9	1.191	1.833	3.064	11.21	18.79	37.40
2 - 2%/year Cars and Trucks	478.6	563.5	784.6	1.190	1.832	3.063	11.21	18.79	37.39
3 - Preferred	478.5	563.1	783.7	1.190	1.830	3.060	11.20	18.78	37.35
4 - 7%/year Cars and Trucks	478.3	562.7	782.8	1.189	1.828	3.056	11.20	18.76	37.32
Reductions under Alternative Vehicle Standards									
2 - 2%/year Cars and Trucks	0.1	0.2	0.2	0.001	0.001	0.001	0.00	0.00	0.01
3 - Preferred	0.3	0.6	1.1	0.001	0.003	0.004	0.01	0.01	0.05
4 - 7%/year Cars and Trucks	0.5	1.1	2.1	0.002	0.005	0.008	0.01	0.03	0.08

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to 1990.

Table 5.4.1-6-B2. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAMReference) by Alternative,[a,b] Analysis B2

Totals by Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	478.8	563.7	784.9	1.191	1.833	3.064	11.21	18.79	37.40
2 - 2%/year Cars and Trucks	478.7	563.5	784.7	1.190	1.832	3.063	11.21	18.79	37.39
3 - Preferred	478.5	563.1	783.8	1.190	1.830	3.060	11.20	18.78	37.36
4 - 7%/year Cars and Trucks	478.3	562.8	783.0	1.189	1.828	3.057	11.20	18.77	37.33
Reductions under Alternative Vehicle Standards									
2 - 2%/year Cars and Trucks	0.1	0.2	0.2	0.001	0.001	0.001	0.00	0.00	0.01
3 - Preferred	0.3	0.6	1.0	0.001	0.002	0.004	0.01	0.01	0.04
4 - 7%/year Cars and Trucks	0.5	1.0	1.9	0.002	0.004	0.007	0.01	0.02	0.07

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to 1990

In Analyses A1 and A2, estimated CO_2 concentrations for 2100 range from 780.7 ppm under Alternative 4 to 784.9 ppm under the No Action Alternative. For Analyses B1 and B2, CO_2 concentrations range from 782.8 ppm under Alternative 4 to 784.9 ppm under the No Action Alternative in 2100. For 2040 and 2060, the corresponding range is even tighter. Because CO_2 concentrations are the key determinant of other climate effects (which in turn act as drivers on the resource impacts discussed in Section 5.5), this leads to small differences in these effects. Even though these effects are small, they occur on a global scale and are long-lasting.

Figure 5.4.1-5-A1. Atmospheric CO_2 Concentrations by Alternative, Analysis A1

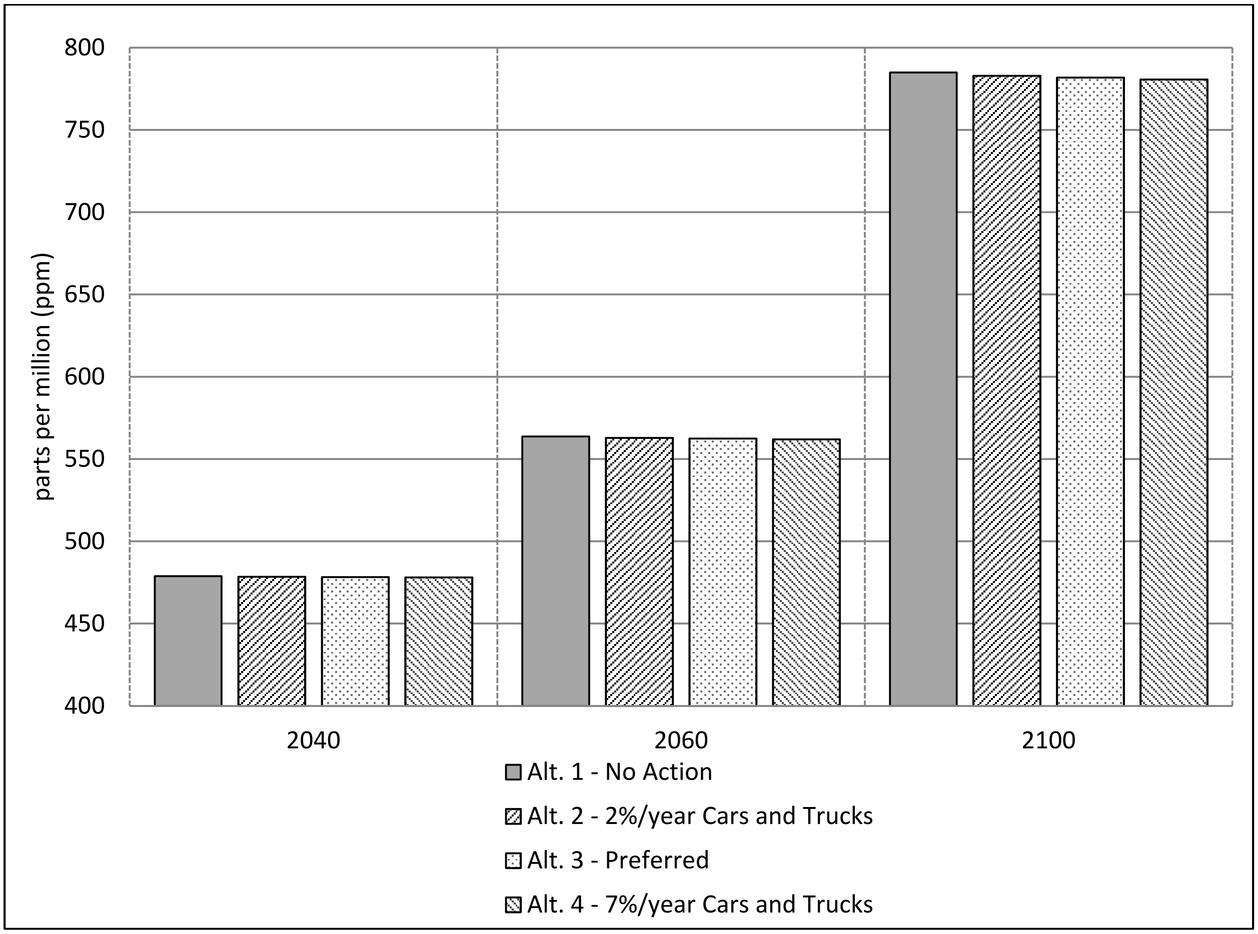


Figure 5.4.1-5-A2. Atmospheric CO_2 Concentrations by Alternative, Analysis A2

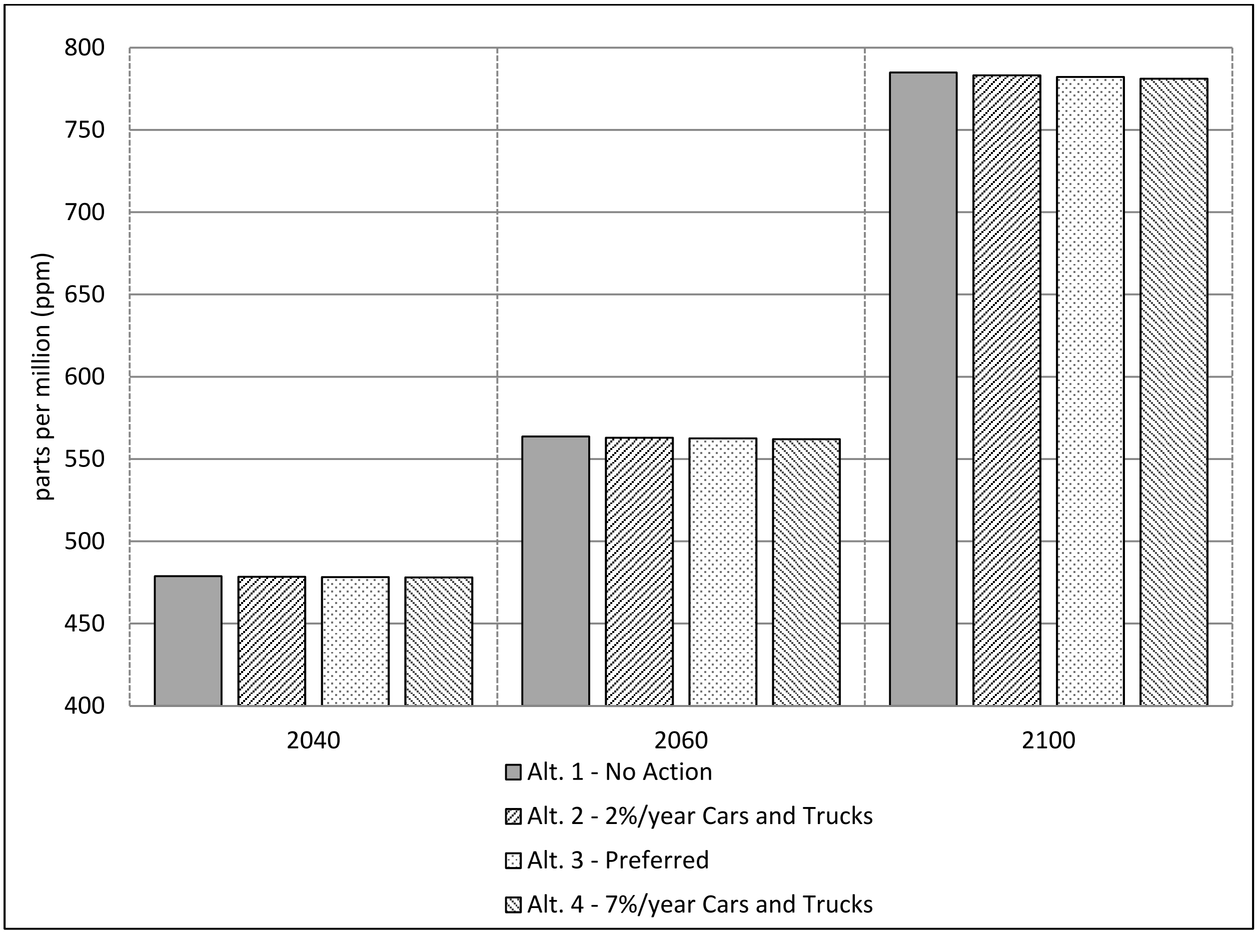


Figure 5.4.1-5-B1. Atmospheric CO_2 Concentrations by Alternative, Analysis B1

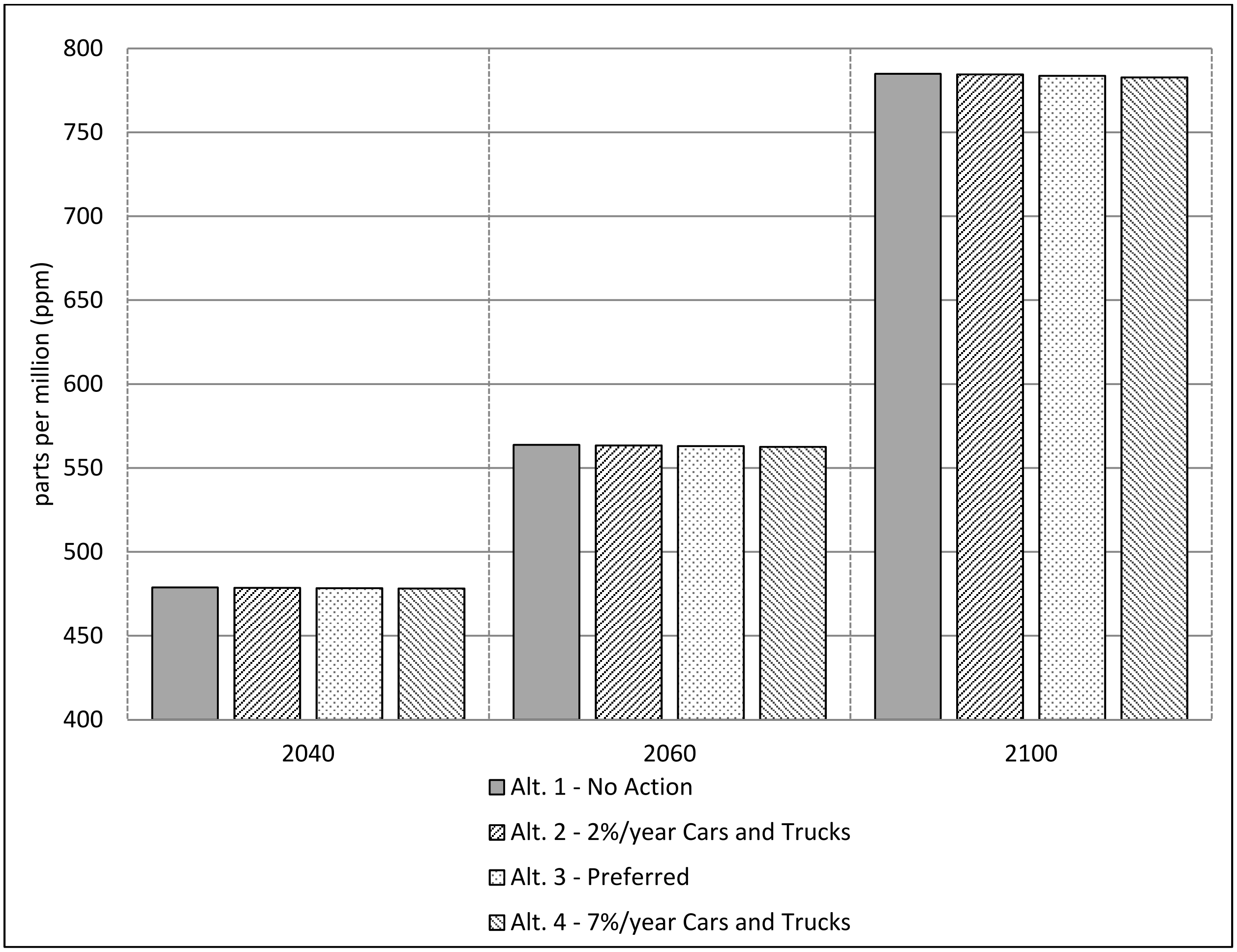


Figure 5.4.1-5-B2. Atmospheric CO_2 Concentrations by Alternative, Analysis B2

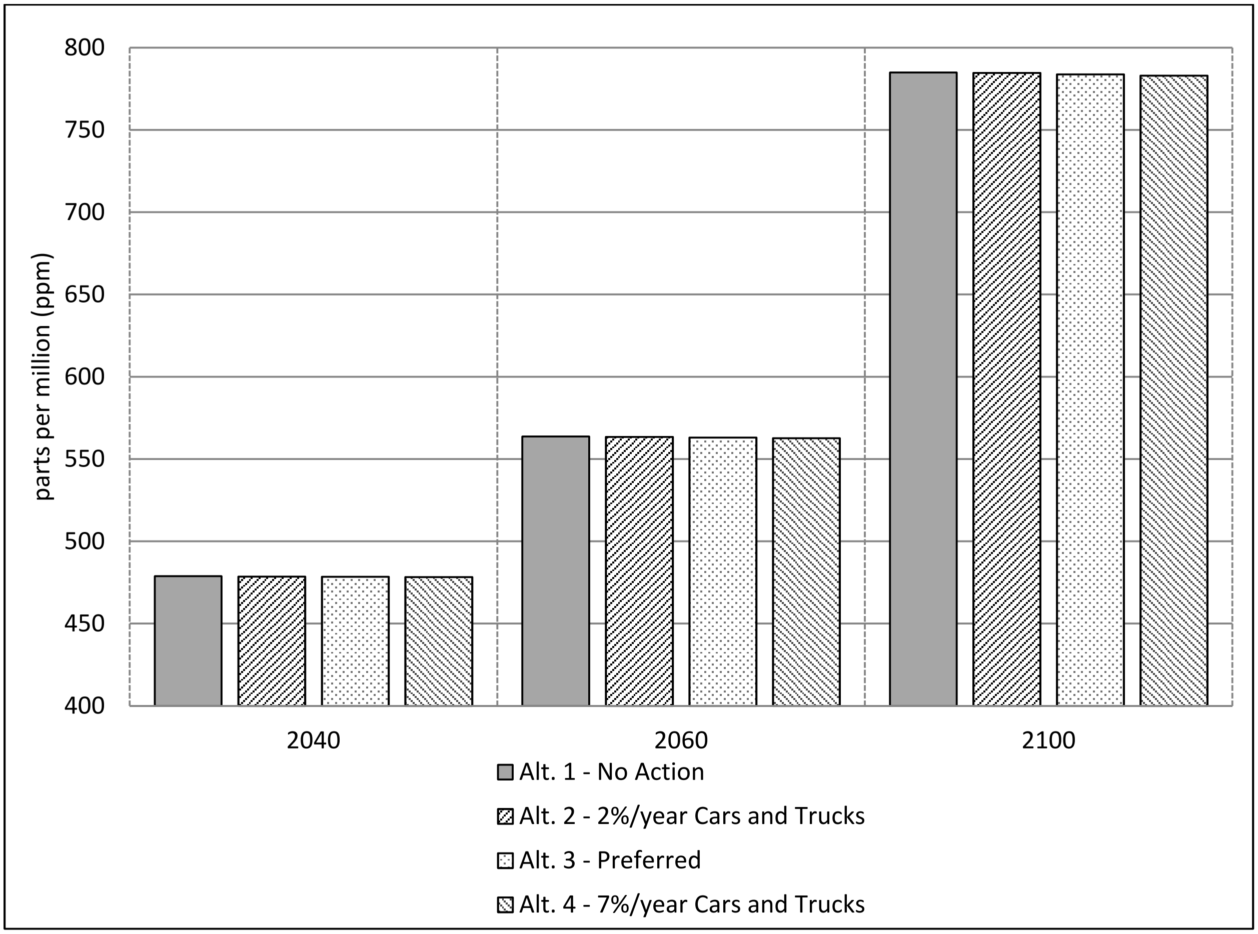


Figure 5.4.1-6-A1. Reduction in Atmospheric CO_2 Concentrations Compared to the No Action Alternative, Analysis A1

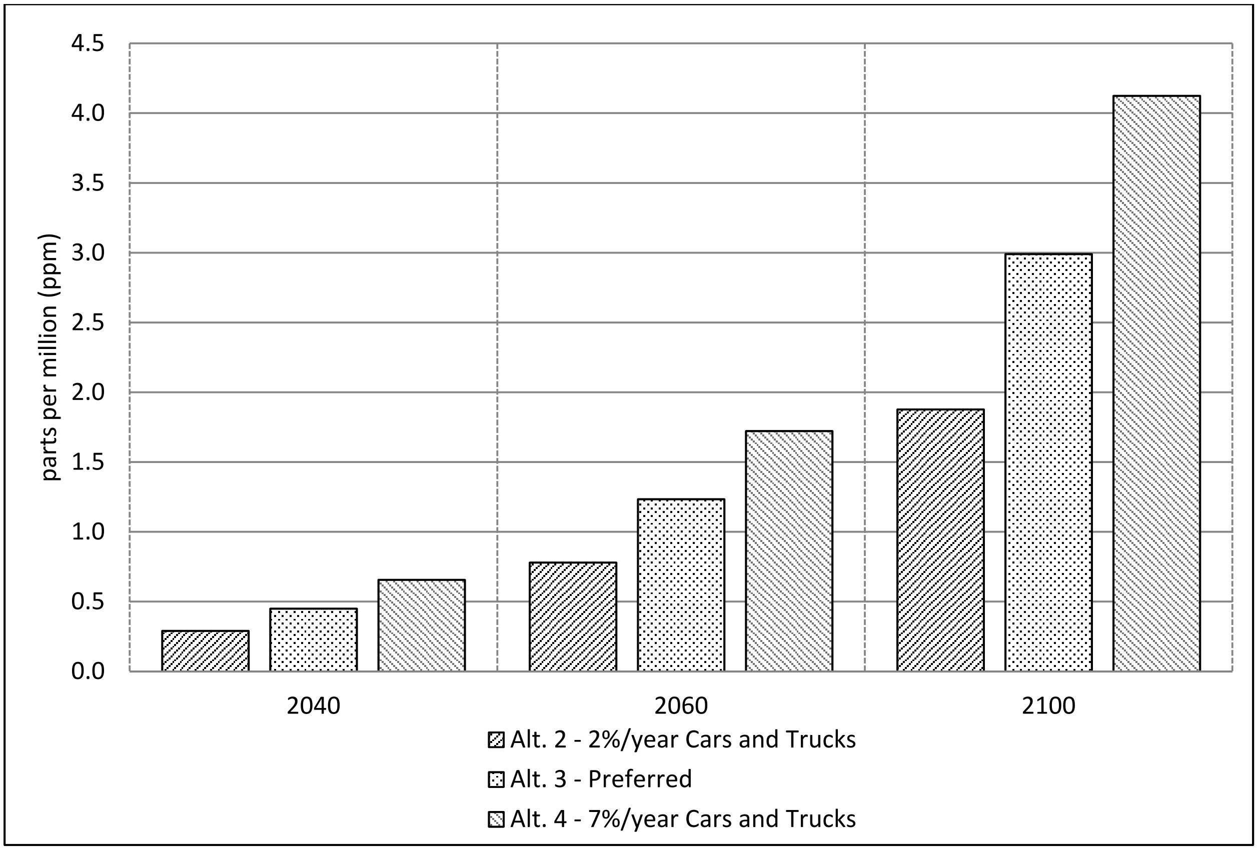


Figure 5.4.1-6-A2. Reduction in Atmospheric CO_2 Concentrations Compared to the No Action Alternative, Analysis A2

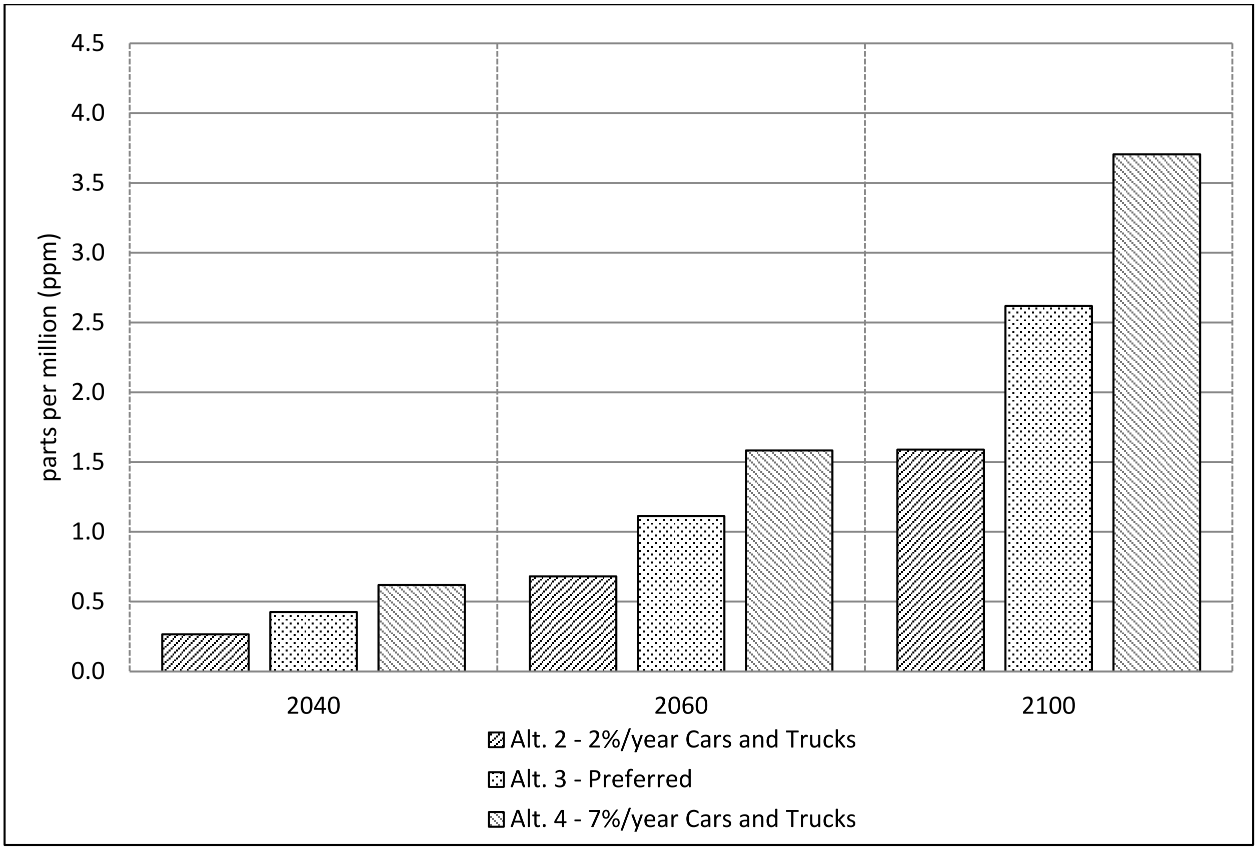


Figure 5.4.1-6-B1. Atmospheric Reduction in CO_2 Concentrations Compared to the No Action Alternative, Analysis B1

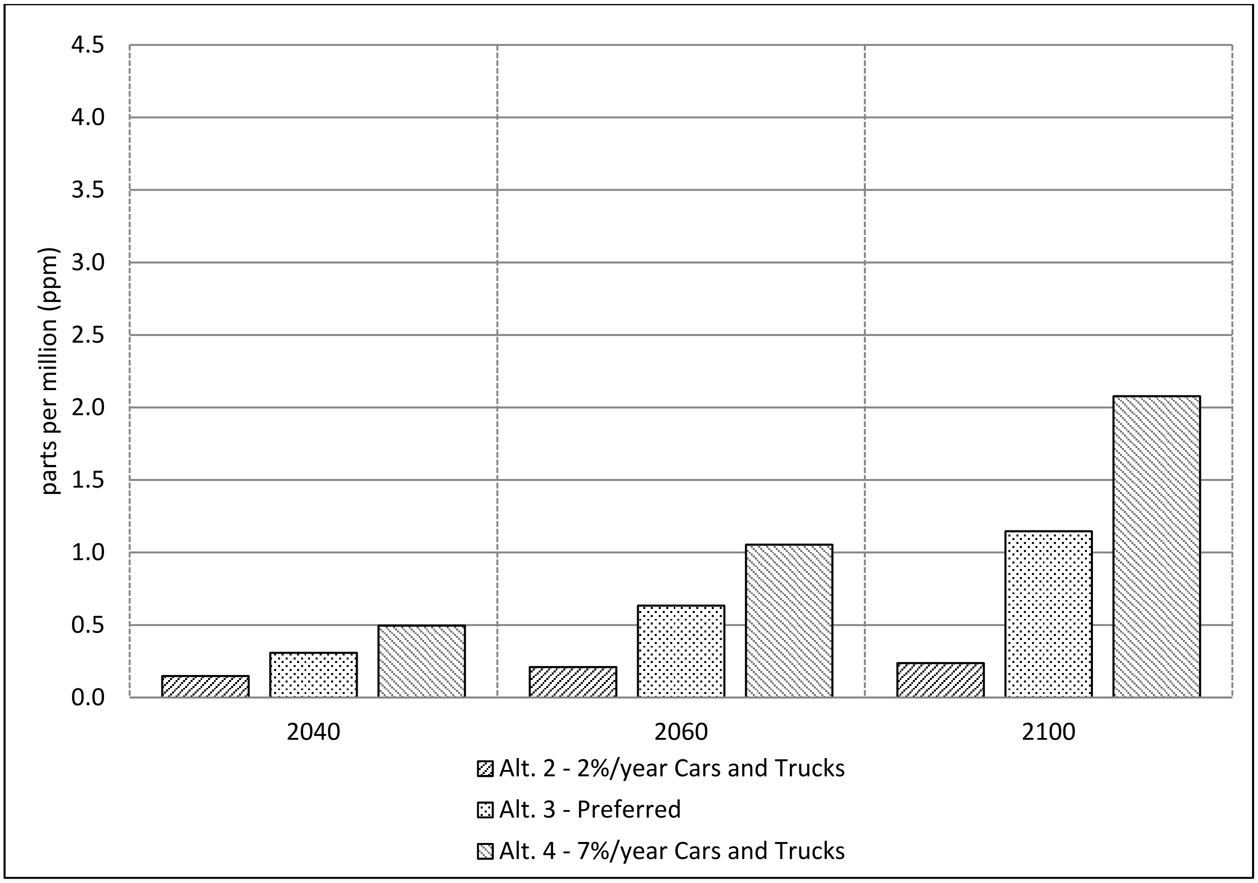


Figure 5.4.1-6-B2. Atmospheric Reduction in CO_2 Concentrations Compared to the No Action Alternative, Analysis B2

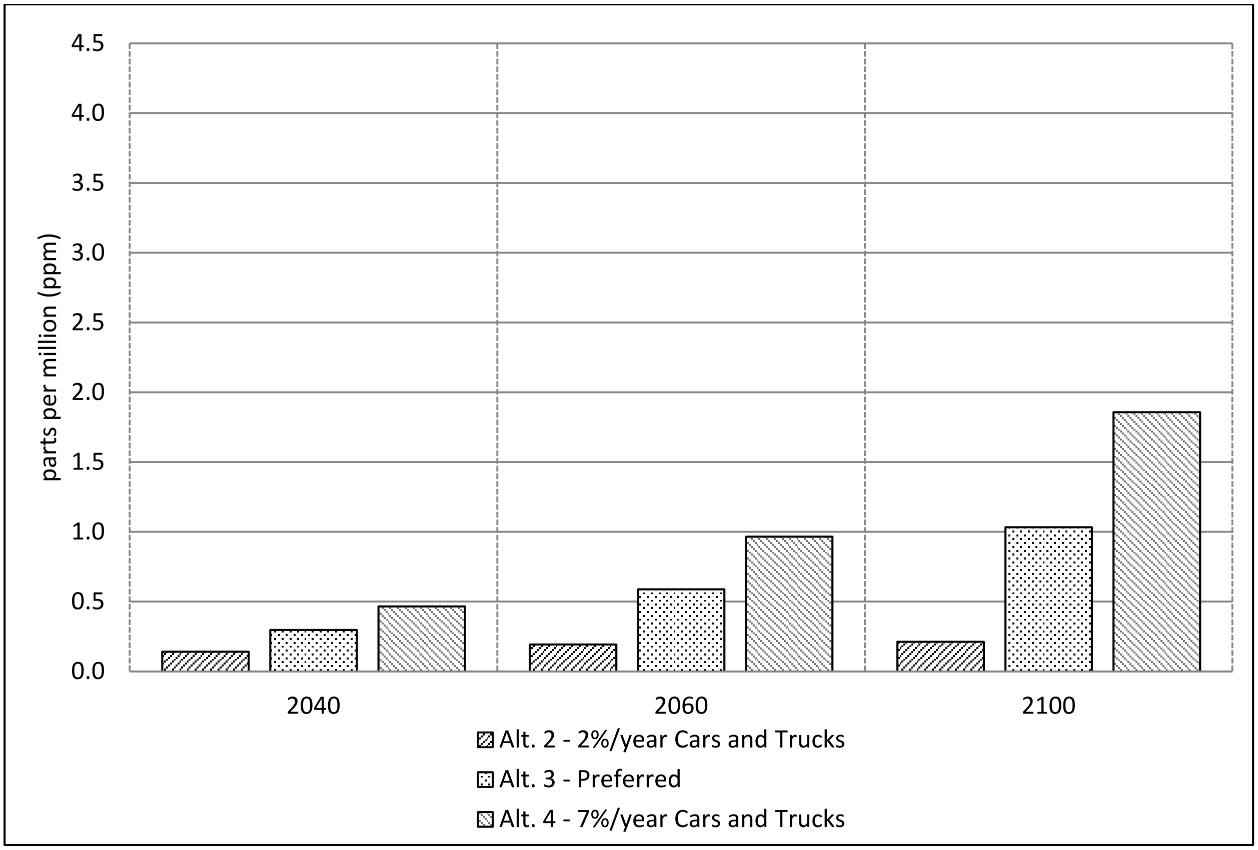


Figure 5.4.1-7-A1. Global Mean Surface Temperature Increase by Alternative, Analysis A1

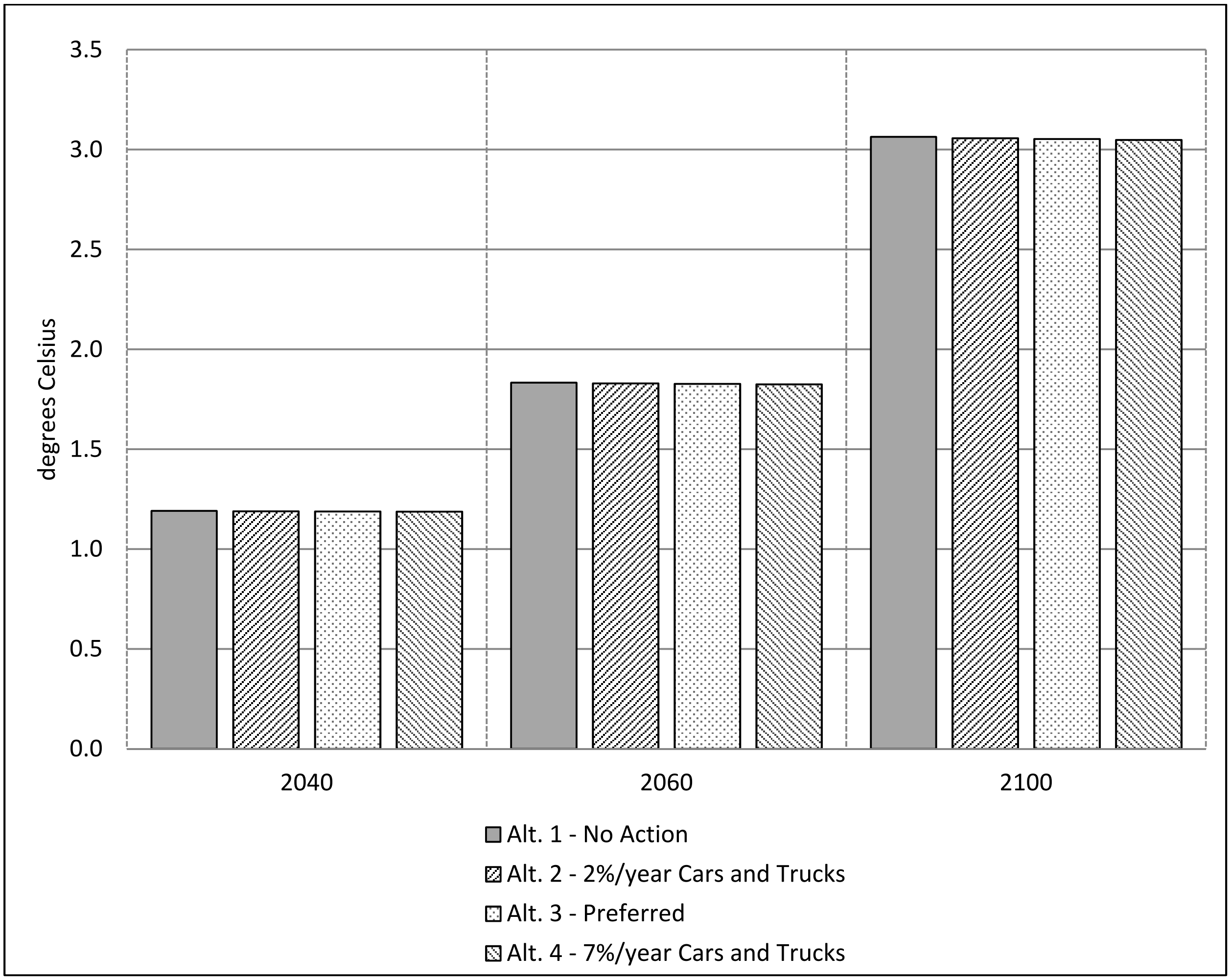


Figure 5.4.1-7-A2. Global Mean Surface Temperature Increase by Alternative, Analysis A2

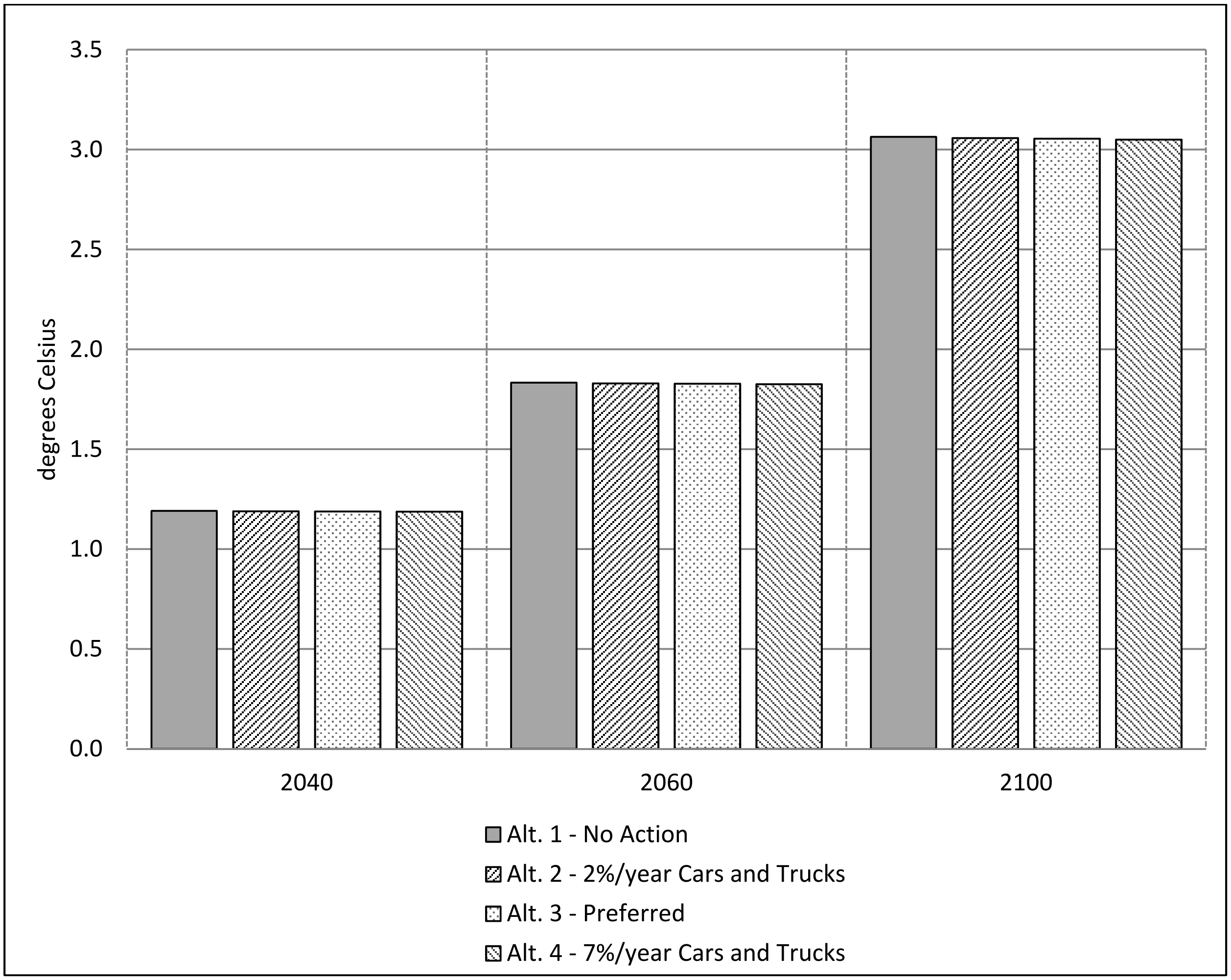


Figure 5.4.1-7-B1. Global Mean Surface Temperature Increase by Alternative, Analysis B1

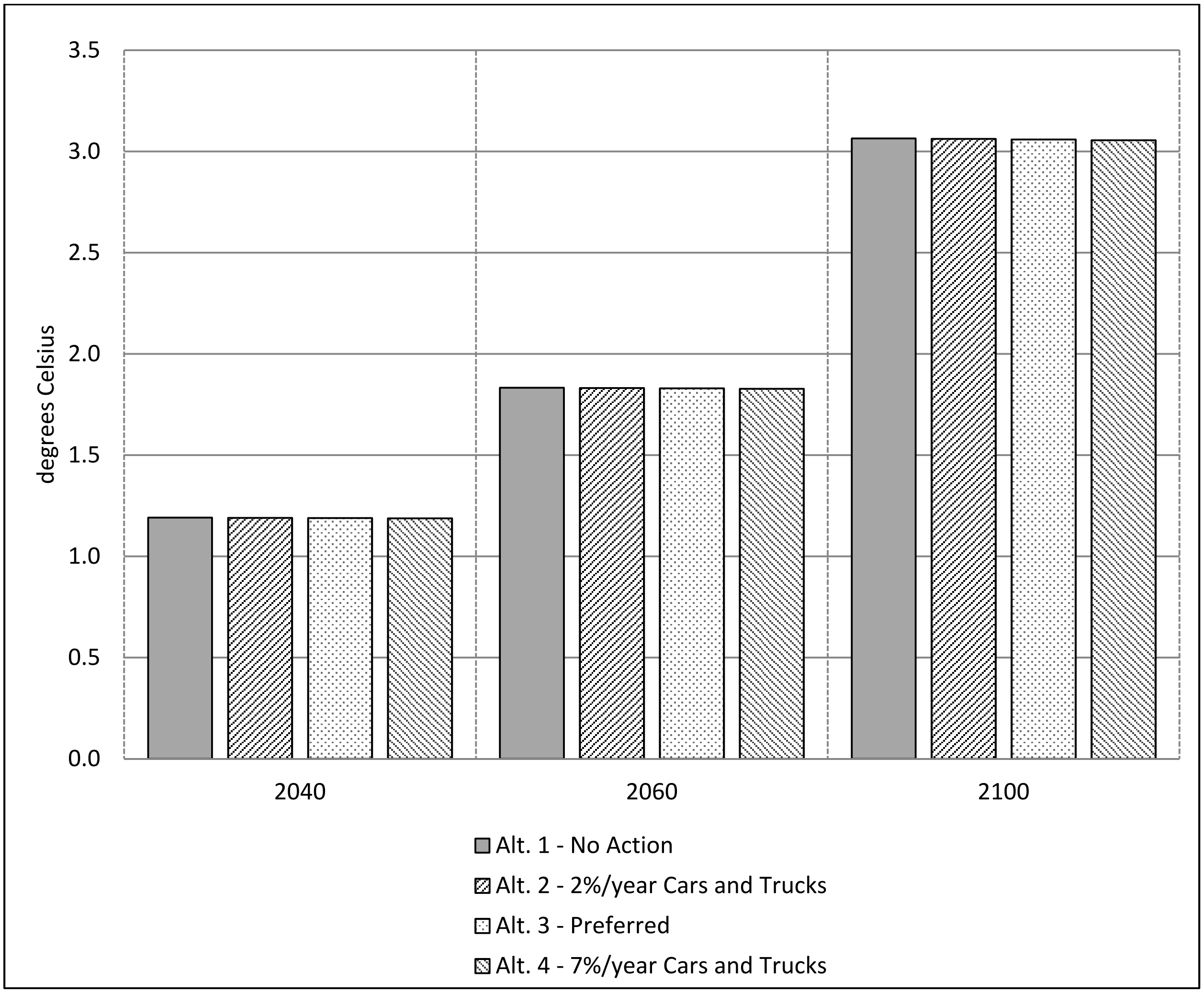


Figure 5.4.1-7-B2. Global Mean Surface Temperature Increase by Alternative, Analysis B2

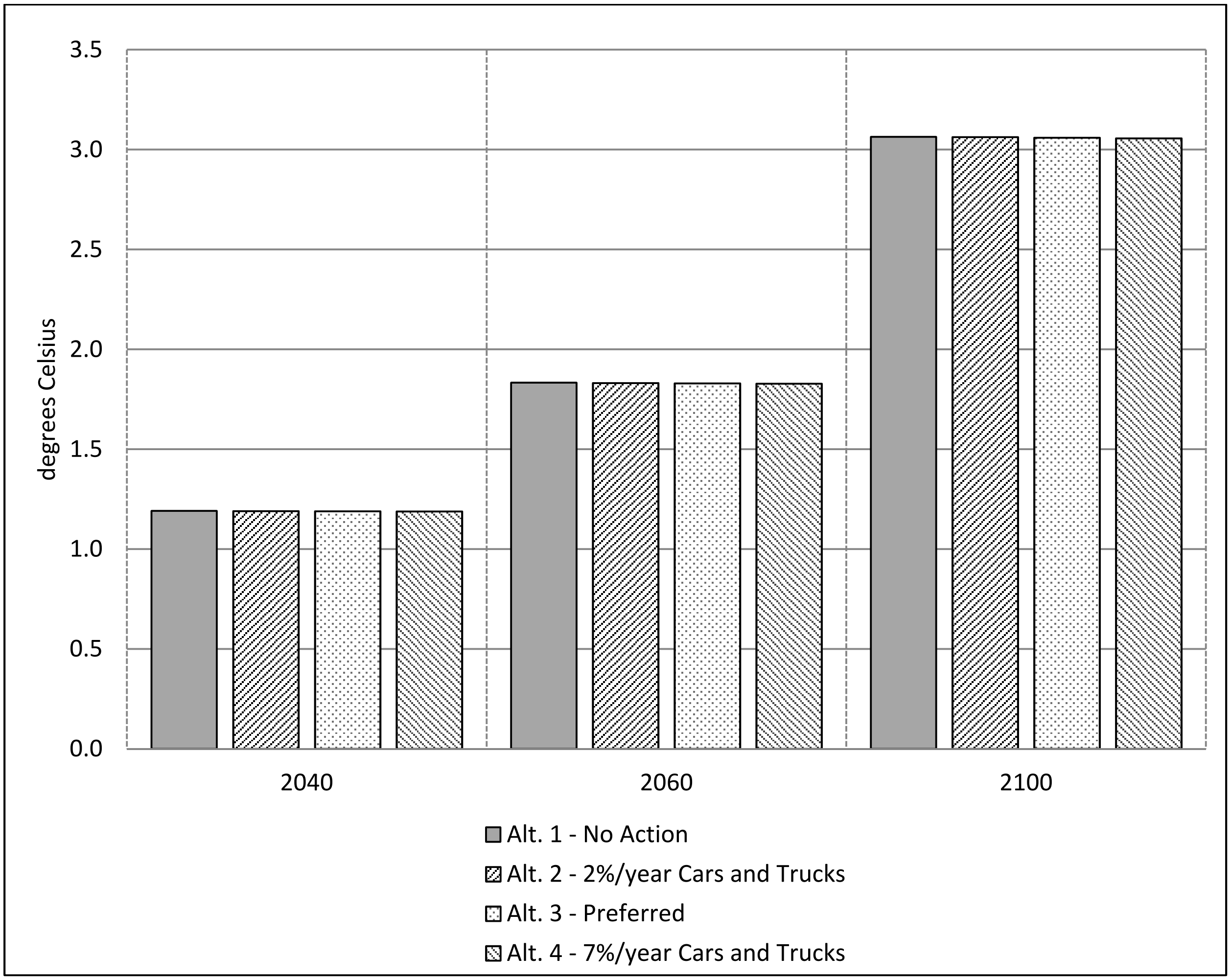


Figure 5.4.1-8-A1. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis A1

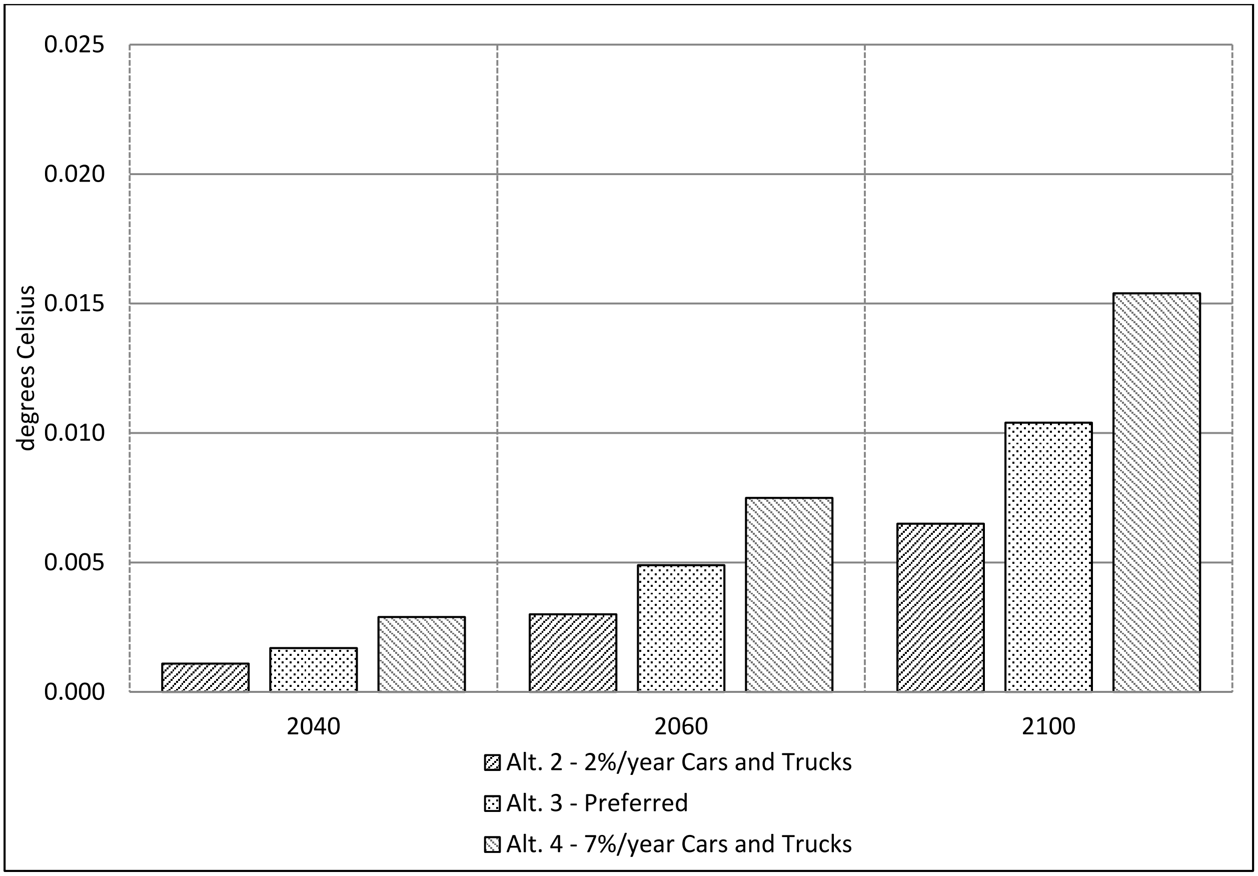


Figure 5.4.1-8-A2. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis A2

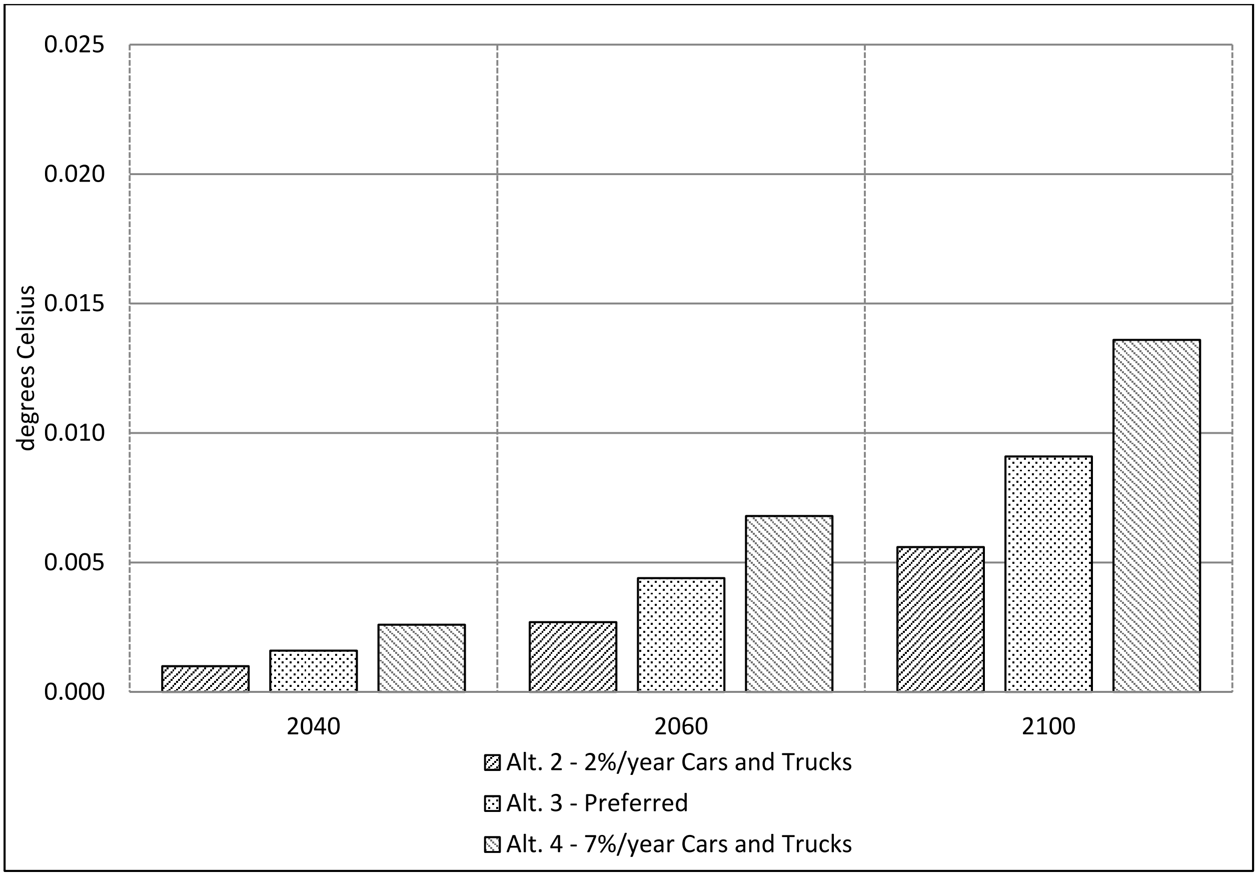


Figure 5.4.1-8-B1. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis B1

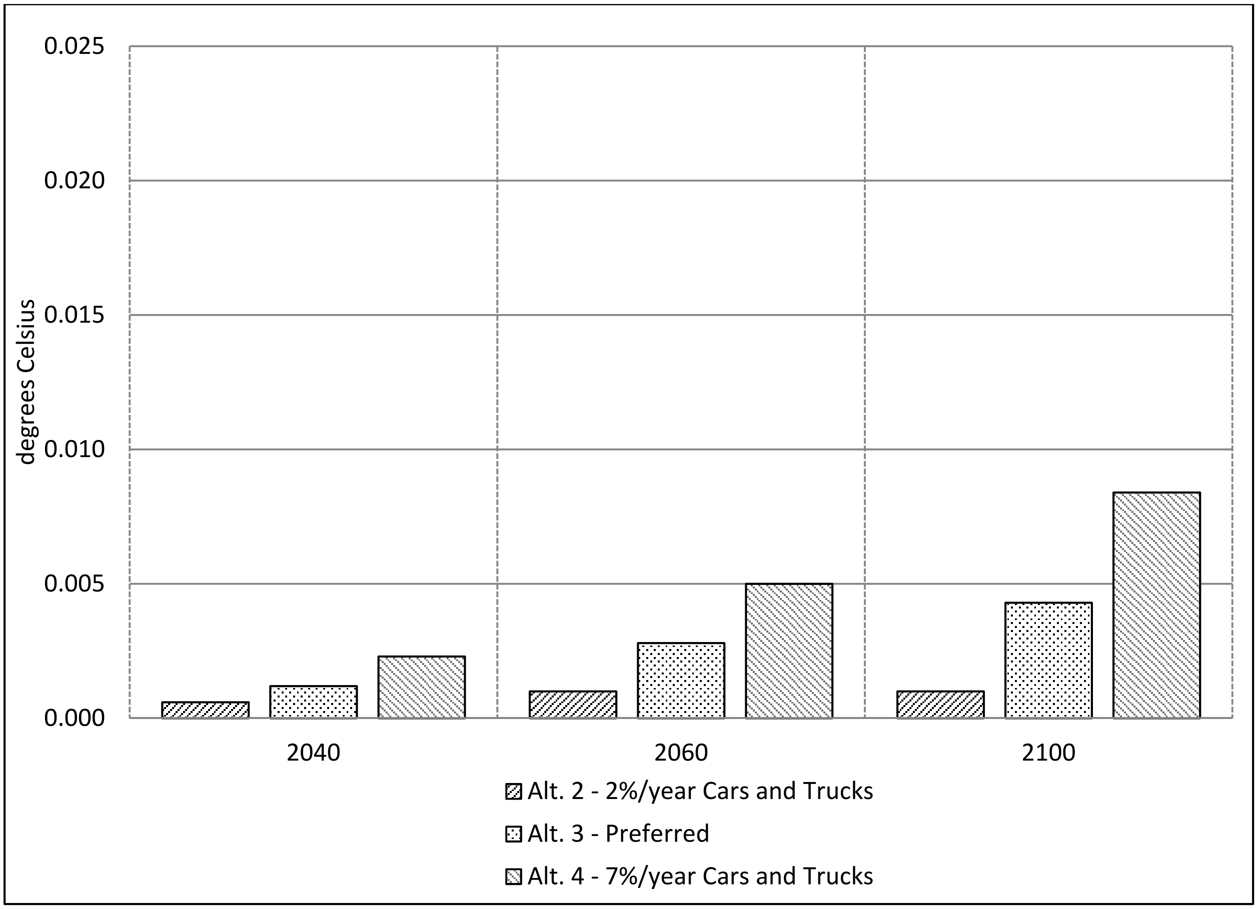
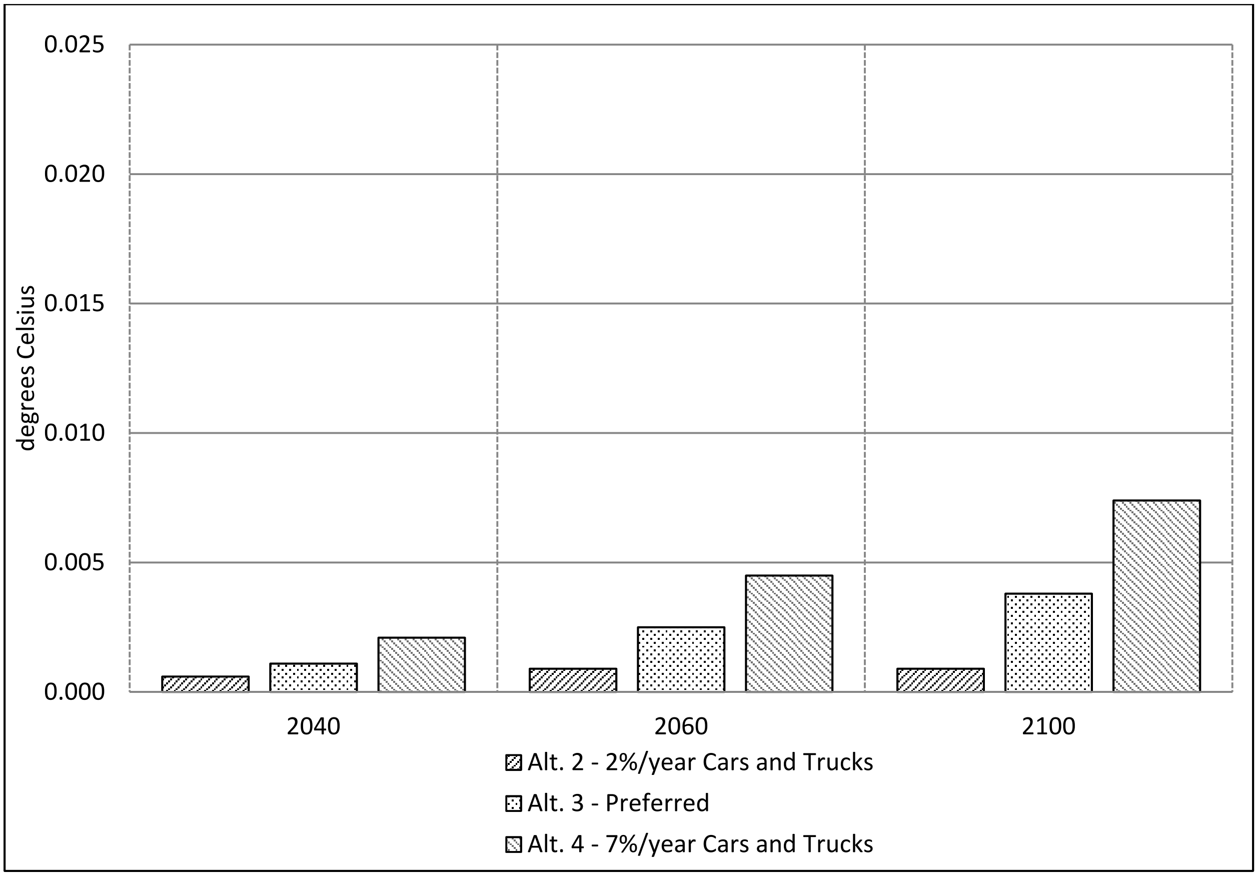


Figure 5.4.1-8-B2. Reduction in Global Mean Surface Temperature Compared to the No Action Alternative, Analysis B2



As Figures 5.4.1-5-A1 and -A2 and 5.4.1-5-B1 and -B2 through 5.4.1-8-A1 and -A2 and 5.4.1-8-B1 and -B2 show, the reduction in the increases in projected CO_2 concentrations under each action alternative compared to the No Action Alternative amounts to a small fraction of the projected total increases in CO_2 concentrations. However, the relative impact of the action alternatives is demonstrated by the reduction in increases of CO_2 concentrations under the range of action alternatives. As shown in Figures 5.4.1-6-A1 and -A2 and 5.4.1-6-B1 and -B2, in Analyses A1 and A2, the reduction in the level of increase in CO_2 concentrations by 2100 under Alternative 4 is more than twice that of Alternative 2, and in Analyses B1 and B2 the reduction in the level of increase in CO_2 concentrations by 2100 under Alternative 4 is almost nine times that of Alternative 2.

5.4.1.3.2 Temperature

Tables 5.4.1-6-A1 and -A2 and 5.4.1-6- B1 and -B2 list MAGICC simulations of mean global surface air temperature increases. Under the No Action Alternative in all analyses,[8] global surface air temperature is projected to increase from 1990 levels by 1.19 °C (2.14 °F) by 2040, 1.83 °C (3.29 °F) by 2060, and

[8] As discussed above and in Section 5.3.3, NHTSA used the GCAMReference scenario to represent the No Action Alternative in the MAGICC modeling runs. Therefore, the No Action Alternative in the tables in this section is identical. *See* Section 5.3.3.2.1 for a description of how benefits for each action alternative were calculated in this section.

3.06 °C (5.51 °F) by 2100.[9] The differences among the reductions in baseline temperature increases projected to result from the various action alternatives are small compared to total projected changes. For example, in 2100 the reduction in temperature increase compared to the No Action Alternative ranges from 0.006 °C (0.011 °F) under Alternative 2 to 0.015 °C (0.027 °F) under Alternative 4 in Analyses A1 and A2 and from 0.001 °C (0.002 °F) under Alternative 2 to 0.008 °C (0.014 °F) under Alternative 4 in Analyses B1 and B2. Figures 5.4.1-8-A1 and -A2 and 5.4.1-8-B1 and -B2 also illustrate that reductions in the growth of projected global mean surface temperature under each action alternative compared to the No Action Alternative are anticipated to be small compared to total projected changes. However, the *relative* impacts of the action alternatives compared to one another can be seen by comparing the reductions in the increases in global mean surface temperature projected to occur under Alternatives 2 and 4. As shown in Figures 5.4.1-8-A1 and -A2 and 5.4.1-8-B1 and -B2, the reduction in the projected growth in global temperature under Alternative 4 is more than twice as large as that under Alternative 2 in Analyses A1 and A2 and more than eight times as large as that under Alternative 2 in Analyses B1 and B2.

Table 5.4.1-7 summarizes the regional changes in warming and seasonal temperatures presented in the IPCC Fourth Assessment Report. At this time, quantifying the changes in regional climate as a result of the action alternatives is not possible due to the limitations of existing climate models, but the action alternatives would be expected to reduce the regional impacts in proportion to reductions in global mean surface temperature.

Table 5.4.1-7. Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report[a]

Land Area	Sub-region	Mean Warming	Other Effects on Temperature
Africa	Mediterranean area and northern Sahara	*Likely* larger than global mean throughout continent and in all seasons	
	Southern Africa and western margins	*Likely* larger than global mean throughout continent and in all seasons	
	East Africa	*Likely* larger than global mean throughout continent and in all seasons	
Mediterranean and Europe	Northern Europe	*Likely* to increase more than the global mean with largest warming in winter	
	Southern and Central Europe	*Likely* to increase more than the global mean with largest warming in winter	Maximum summer temperatures *likely* to increase more than the average
	Mediterranean area	*Likely* to increase more than the global mean with largest warming in winter	

[9] Because the actual increase in global mean surface temperature lags the commitment to warming, the impact on global mean surface temperature increase is less than the impact on the long-term commitment to warming. The actual increase in surface temperature lags the commitment due primarily to the time required to heat the ocean to the level committed by the concentrations of the GHGs.

Table 5.4.1-7. Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report[a] (continued)

Land Area	Sub-region	Mean Warming	Other Effects on Temperature
Asia	Central Asia	*Likely* to be well above the global mean	
	Tibetan Plateau	*Likely* to be well above the global mean	
	Northern Asia	*Likely* to be well above the global mean	
	Eastern Asia	*Likely* to be above the global mean	*Very likely* that heat waves/hot spells in summer will be longer, more intense, and more frequent *Very likely* fewer very cold days
	South Asia	*Likely* to be above the global mean	*Very likely* fewer very cold days
	Southeast Asia	*Likely* to be similar to the global mean	
North America	Northern regions/Northern North America	*Likely* to exceed the global mean warming	Warming is *likely* to be greatest in winter. Minimum winter temperatures are *likely* to increase more than the average
	Southwest		Warming is *likely* to be greatest in summer Maximum summer temperatures are *likely* to increase more than the average
Central and South America	Southern South America	*Likely* to be similar to the global mean warming	
	Central America	*Likely* to be larger than global mean warming	
Australia and New Zealand	Southern Australia	*Likely* comparable to the global mean but less than in the rest of Australia	Increased frequency of extreme high daily temperatures and decreased frequency of cold extremes are *very likely*
	Southwestern Australia	*Likely* comparable to the global mean	
	Rest of Australia	*Likely* comparable to the global mean	
	New Zealand, South Island	*Likely* less than the global mean	
	Rest of New Zealand	*Likely* comparable to the global mean	

Table 5.4.1-7. Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment Report[a] (continued)

Land Area	Sub-region	Mean Warming	Other Effects on Temperature
Polar Regions	Arctic	*Very likely* to warm during this century more than the global mean	Warming greatest in winter and smallest in summer
	Antarctic	*Likely* to warm	
Small Islands		*Likely* to be smaller than the global annual mean	

a. Source: Christensen et al. 2007.

5.4.1.3.3 Precipitation

In some areas, the increase in energy available to the hydrologic cycle might increase precipitation. Increases in precipitation result from higher temperatures causing more water evaporation, which causes more water vapor to be available for precipitation (EPA 2009e). Increased evaporation leads to increased precipitation in areas where surface water is sufficient, such as over oceans and lakes. In drier areas, increased evaporation can actually accelerate surface drying, which can lead to droughts (EPA 2009e). Overall, according to the IPCC (Meehl et al. 2007), global mean precipitation is expected to increase under all climate scenarios. However, spatial and seasonal variations will be considerable. Generally, precipitation increases are *very likely* to occur in high latitudes, and decreases are *likely* to occur in the sub-tropics (EPA 2009e).

As noted in Section 5.3.3, MAGICC does not directly simulate changes in precipitation, and NHTSA has not undertaken precipitation modeling with a full Atmospheric-Ocean General Circulation Model. However, the IPCC (Meehl et al. 2007) summary of precipitation represents the most thoroughly reviewed, credible means of producing an assessment of this highly uncertain factor. NHTSA expects that the Proposed Action and alternatives would reduce anticipated changes in precipitation (i.e., in a reference case with no GHG emission reduction policies) in proportion to the effects of the alternatives on temperature.

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (Meehl et al. 2007) is given as the scaled change in precipitation (expressed as a percentage change from 1980 to 1999 averages) divided by the increase in global mean surface warming for the same period (per °C), as shown in Table 5.4.1-8. The IPCC provides scaling factors in the year ranges of 2011 to 2030, 2046 to 2065, 2080 to 2099, and 2180 to 2199. NHTSA used the scaling factors for the GCAMReference scenario in this analysis because MAGICC does not directly estimate changes in global mean precipitation.[10]

[10] Although MAGICC does not estimate changes in precipitation, SCENGEN (Scenario Generator) does. SCENGEN is an added component to MAGICC 5.3v2; it scales regional results of AOGCM models based on global mean surface temperature change and regional aerosol emissions from MAGICC.

Table 5.4.1-8. Global Mean Precipitation Increase (scaled, percent per °C)[a]

Scenario	2011–2030	2046–2065	2080–2099	2180–2199
A2 (high)	1.38	1.33	1.45	Not applicable
A1B (medium)	1.45	1.51	1.63	1.68
B1 (low)	1.62	1.65	1.88	1.89

a. Source: Meehl et al. 2007.

Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. The action alternatives are projected to reduce temperature increases and predicted increases in precipitation slightly compared to the No Action Alternative, as shown in Tables 5.4.1-9-A1 and -A2 and 5.4.1-9-B1 and -B2 (based on the A1B [medium] scenario).

Table 5.4.1-9-A1. Global Mean Precipitation (percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, by Alternative,[a] Analysis A1

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario by Alternative[b]			
Alternative 1 - No Action	0.600	1.675	2.760
Alternative 2 - 2%/year Cars and Trucks	0.599	1.673	2.755
Alternative 3 - Preferred	0.599	1.671	2.751
Alternative 4 - 7%/year Cars and Trucks	0.599	1.669	2.747
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[c]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.003	0.006
Alternative 3 - Preferred	0.000	0.004	0.009
Alternative 4 - 7%/year Cars and Trucks	0.000	0.006	0.014
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.87%	2.53%	4.50%
Alternative 2 - 2%/year Cars and Trucks	0.87%	2.53%	4.49%
Alternative 3 - Preferred	0.87%	2.52%	4.48%
Alternative 4 - 7%/year Cars and Trucks	0.87%	2.52%	4.48%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.00%	0.01%
Alternative 3 - Preferred	0.00%	0.01%	0.02%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.02%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. These numbers differ slightly from those in Table 5.4.1-6-A1, because the increases in temperature in Table 5.4.1-6-A1 relate to the global mean surface temperature in 1990, and those in this table represent increases compared to average temperature in the interval 1980 through 1999.
c. Precipitation changes reported as 0.000 are more than zero but less than 0.001.

Table 5.4.1-9-A2. Global Mean Precipitation (percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, by Alternative,[a] Analysis A2

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario by Alternative[b]			
Alternative 1 - No Action	0.600	1.675	2.760
Alternative 2 - 2%/year Cars and Trucks	0.599	1.673	2.755
Alternative 3 - Preferred	0.599	1.671	2.752
Alternative 4 - 7%/year Cars and Trucks	0.599	1.669	2.748
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[c]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.002	0.005
Alternative 3 - Preferred	0.000	0.004	0.008
Alternative 4 - 7%/year Cars and Trucks	0.000	0.006	0.012
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.87%	2.53%	4.50%
Alternative 2 - 2%/year Cars and Trucks	0.87%	2.53%	4.49%
Alternative 3 - Preferred	0.87%	2.52%	4.49%
Alternative 4 - 7%/year Cars and Trucks	0.87%	2.52%	4.48%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.00%	0.01%
Alternative 3 - Preferred	0.00%	0.01%	0.01%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.02%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. These numbers differ slightly from those in Table 5.4.1-6-A2, because the increases in temperature in Table 5.4.1-6-A2 relate to the global mean surface temperature in 1990, and those in this table represent increases compared to average temperature in the interval 1980 through 1999.
c. Precipitation changes reported as 0.000 are more than zero but less than 0.001.

Table 5.4.1-9-B1. Global Mean Precipitation (percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, by Alternative,[a] Analysis B1

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario by Alternative[b]			
Alternative 1 - No Action	0.600	1.675	2.760
Alternative 2 - 2%/year Cars and Trucks	0.599	1.674	2.759
Alternative 3 - Preferred	0.599	1.673	2.756
Alternative 4 - 7%/year Cars and Trucks	0.599	1.671	2.753
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[c]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.001	0.001
Alternative 3 - Preferred	0.000	0.002	0.004
Alternative 4 - 7%/year Cars and Trucks	0.000	0.004	0.008
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.87%	2.53%	4.50%
Alternative 2 - 2%/year Cars and Trucks	0.87%	2.53%	4.50%
Alternative 3 - Preferred	0.87%	2.53%	4.49%
Alternative 4 - 7%/year Cars and Trucks	0.87%	2.52%	4.49%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.00%	0.00%
Alternative 3 - Preferred	0.00%	0.00%	0.01%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.01%

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

b. These numbers differ slightly from those in Table 5.4.1-6-B1, because the increases in temperature in Table 5.4.1-6-B1 relate to the global mean surface temperature in 1990, and those in this table represent increases compared to average temperature in the interval 1980 through 1999.

c. Precipitation changes reported as 0.000 are more than zero but less than 0.001.

Table 5.4.1-9-B2. Global Mean Precipitation (percent Increase) Based on GCAMReference Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, by Alternative,[a] Analysis B2

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAMReference Scenario by Alternative[b]			
Alternative 1 - No Action	0.600	1.675	2.760
Alternative 2 - 2%/year Cars and Trucks	0.599	1.674	2.760
Alternative 3 - Preferred	0.599	1.673	2.757
Alternative 4 - 7%/year Cars and Trucks	0.599	1.671	2.754
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[c]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.001	0.001
Alternative 3 - Preferred	0.000	0.002	0.004
Alternative 4 - 7%/year Cars and Trucks	0.000	0.004	0.007
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.87%	2.53%	4.50%
Alternative 2 - 2%/year Cars and Trucks	0.87%	2.53%	4.50%
Alternative 3 - Preferred	0.87%	2.53%	4.49%
Alternative 4 - 7%/year Cars and Trucks	0.87%	2.52%	4.49%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.00%	0.00%
Alternative 3 - Preferred	0.00%	0.00%	0.01%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.01%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. These numbers differ slightly from those in Table 5.4.1-6-B2, because the increases in temperature in Table 5.4.1-6-B2 relate to the global mean surface temperature in 1990, and those in this table represent increases compared to average temperature in the interval 1980 through 1999.
c. Precipitation changes reported as 0.000 are more than zero but less than 0.001.

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation.[11] Regional variations and changes in the intensity of precipitation cannot be further quantified, primarily due to the lack of available AOGCMs required to estimate these changes. These models typically are used to provide results among scenarios with very large changes in emissions, such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles (such as those resulting from the action alternatives considered here) would produce results that would be difficult to resolve among scenarios. Also, the multiple AOGCMs produce results regionally consistent in some cases but inconsistent in others.

[11] As described in Meehl et al. 2007, the "intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity is projected to increase but periods between rainfall events would be longer. The mid-continental areas tend to dry during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than the mean in most tropical and mid- and high-latitude areas."

Table 5.4.1-10 summarizes, in qualitative terms, the regional changes in precipitation from the IPCC Fourth Assessment Report. Quantifying the changes in regional climate under the action alternatives is not possible at this time, but the action alternatives would be expected to reduce the relative precipitation changes in proportion to the reduction in global mean surface temperature.

Table 5.4.1-10. Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report[a]

Land Area	Sub-region	Precipitation	Snow Season and Snow Depth
Africa	Mediterranean area and northern Sahara	*Very likely* to decrease	
	Southern Africa and western margins	Winter rainfall *likely* to decrease in southern parts	
	East Africa	*Likely* to be an increase in annual mean rainfall	
Mediterranean and Europe	Northern Europe	*Very likely* to increase and extremes are *likely* to increase	*Likely* to decrease.
	Southern and Central Europe		*Likely* to decrease.
	Mediterranean area	*Very likely* to decrease and precipitation days are *very likely* to decrease	*Likely* to decrease.
Asia	Central Asia	Precipitation in summer is *likely* to decrease	
	Tibetan Plateau	Precipitation in boreal winter is *very likely* to increase	
	Northern Asia	Precipitation in boreal winter is *very likely* to increase Precipitation in summer is *likely* to increase	
	Eastern Asia	Precipitation in boreal winter is *likely* to increase Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	South Asia	Precipitation in summer is *likely* to increase *Very likely* to be an increase in the frequency of intense precipitation Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	
	Southeast Asia	Precipitation in boreal winter is *likely* to increase in southern parts Precipitation in summer is *likely* to increase in most parts Extreme rainfall and winds associated with tropical cyclones are *likely* to increase	

Table 5.4.1-10. Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment Report[a] (continued)

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

a. Source: Christensen et al. 2007

5.4.1.3.4 Sea-level Rise

IPCC identifies four primary components of sea-level rise: (1) thermal expansion of ocean water, (2) melting of glaciers and ice caps, (3) loss of land-based ice in Antarctica, and (4) loss of land-based ice in Greenland (IPCC 2007d). Ice-sheet discharge is an additional factor that could influence sea level over the long term. Ocean circulation, changes in atmospheric pressure, and geological processes can also influence sea-level rise at a regional scale (EPA 2009e). MAGICC calculates the oceanic thermal expansion component of global mean sea-level rise using a nonlinear temperature- and pressure-dependent expansion coefficient (Wigley 2008). It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets, and excludes non-melt sources, which the IPCC Fourth Assessment Report also excluded. Neither MAGICC 5.3.v2 nor the IPCC Fourth Assessment Report includes more recent information suggesting that ice flow from Greenland and Antarctica will be accelerated by projected temperature increases.

The IPCC Fourth Assessment Report projects a sea-level rise of 18 to 59 centimeters (0.6 to 1.9 feet) by 2090 to 2099 in relation to 1980 to 1999 (EPA 2009e). More recent studies find that the contribution of melting from large ice sheets and mountain glaciers to global sea-level rise could be more substantial than modeled by the IPCC (Grinsted et al. 2010 citing Hansen 2007, Meier et al. 2007). Further, IPCC results for sea-level projections might underestimate sea-level rise due to changes in global precipitation (Wentz et al. 2007, Zhang et al. 2007). A number of recent assessments estimate global sea-level rise over the twenty-first century and account for the additional melting from large ice sheets and mountain glaciers. These studies tend to suggest the IPCC estimates of sea-level rise are conservative. For example, Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 millimeters per year per degree Celsius of warming, and a projected sea-level rise of 0.5 to 1.4 meters (1.6 to 4.6 feet) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise over 1 meter [3.3 feet] by 2100 for strong warming scenarios cannot be ruled out." Another study, Rignot et al. (2011), estimates that current rates of ice melt and thermal expansion alone could raise global mean sea level by approximately 0.3 meter (1 foot) above current averages by 2050. *See* Section 5.5.1.3 for more information on sea-level rise.

Tables 5.4.1-6-A1 and -A2 and 5.4.1-6-B1 and -B2 list the impacts of the action alternatives on sea-level rise under the GCAMReference scenario. Analyses A1 and A2 show a sea-level rise in 2100 ranging from 37.40 centimeters (14.72 inches) under the No Action Alternative to 37.27 centimeters (14.67 inches) under Alternative 4. This represents a maximum reduction of 0.14 centimeter (0.06 inch) by 2100 under Alternative 4 compared to the No Action Alternative. Analysis B shows a sea-level rise in 2100 ranging from 37.40 centimeters (14.72 inches) under the No Action Alternative to 37.33 centimeters (14.70 inches) under Alternative 4. This represents a maximum reduction of 0.08 centimeter (0.03 inch) by 2100 under Alternative 4 compared to the No Action Alternative.

In summary, the impacts of the Proposed Action and alternatives on global mean surface temperature, precipitation, or sea-level rise are small compared to the expected changes associated with the emissions trajectories in the GCAMReference scenario. This is due primarily to the global and multi-sectoral nature of the climate problem. Although these effects are small, they occur on a global scale and are long-lasting. The combined impact of these emission reductions with emission reductions from other sources can have large health, societal, and environmental benefits.

5.4.1.3.5 Climate Sensitivity Variations

Using the methodology described in Section 5.3.3.4, NHTSA examined the sensitivity of projected climate effects to key technical or scientific assumptions used in the analysis. This examination included modeling the impact of various climate sensitivities on the climate effects under the No Action Alternative and the Preferred Alternative using the GCAMReference scenario. Tables 5.4.1-11-A1 and -A2 and 5.4.1-11-B1 and -B2 list the results from the sensitivity analysis, which included climate sensitivities of 1.5, 2.0, 2.5, 3.0, 4.5, and 6.0 °C (2.7, 3.6, 4.5, 5.4, 8.1, and 10.8 °F) for a doubling of CO_2 compared to pre-industrial atmospheric concentrations (280 ppm CO_2) (*see* Section 5.3.3.4).

Table 5.4.1-11-A1. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives,[a,b] Analysis A1

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.353	553.491	754.830	0.721	1.087	1.754	22.74
	2.0	475.859	556.833	764.551	0.899	1.365	2.232	28.20
	2.5	477.180	559.819	773.549	1.054	1.611	2.663	33.02
	3.0	478.345	562.497	781.878	1.189	1.828	3.054	37.30
	4.5	481.133	569.069	803.374	1.509	2.351	4.024	47.69
	6.0	483.168	574.017	820.582	1.739	2.734	4.765	55.45
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.446	1.213	2.859	0.001	0.003	0.006	0.06
	2.0	0.448	1.221	2.905	0.001	0.004	0.008	0.07
	2.5	0.448	1.228	2.950	0.002	0.004	0.009	0.08
	3.0	0.450	1.234	2.991	0.002	0.005	0.010	0.10
	4.5	0.451	1.248	3.093	0.002	0.006	0.013	0.12
	6.0	0.452	1.260	3.175	0.002	0.007	0.015	0.14

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise are relative to levels in 1990.

Table 5.4.1-11-A2. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives,[a,b] Analysis A2

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.376	553.609	755.187	0.721	1.087	1.755	22.75
	2.0	475.883	556.952	764.913	0.899	1.366	2.233	28.21
	2.5	477.203	559.938	773.916	1.054	1.611	2.665	33.03
	3.0	478.369	562.617	782.250	1.189	1.828	3.055	37.31
	4.5	481.157	569.190	803.758	1.509	2.351	4.025	47.71
	6.0	483.192	574.139	820.975	1.739	2.735	4.767	55.47
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.423	1.095	2.502	0.001	0.003	0.006	0.05
	2.0	0.424	1.102	2.543	0.001	0.004	0.007	0.06
	2.5	0.425	1.109	2.583	0.001	0.004	0.008	0.07
	3.0	0.426	1.114	2.619	0.002	0.004	0.009	0.09
	4.5	0.427	1.127	2.709	0.002	0.005	0.012	0.10
	6.0	0.428	1.138	2.782	0.002	0.006	0.013	0.12

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.

b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).

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

Table 5.4.1-11-B1. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives,[a,b] Analysis B1

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.493	554.082	756.603	0.722	1.088	1.758	22.77
	2.0	475.999	557.427	766.349	0.900	1.367	2.237	28.24
	2.5	477.320	560.416	775.371	1.054	1.613	2.669	33.07
	3.0	478.486	563.097	783.722	1.190	1.830	3.060	37.35
	4.5	481.274	569.674	805.274	1.509	2.353	4.031	47.76
	6.0	483.310	574.626	822.525	1.739	2.737	4.774	55.53
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.306	0.622	1.086	0.001	0.002	0.003	0.03
	2.0	0.308	0.627	1.107	0.001	0.002	0.003	0.03
	2.5	0.308	0.631	1.128	0.001	0.002	0.004	0.03
	3.0	0.309	0.634	1.147	0.001	0.003	0.004	0.05
	4.5	0.310	0.643	1.193	0.001	0.003	0.006	0.05
	6.0	0.310	0.651	1.232	0.002	0.004	0.006	0.06

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise are relative to levels in 1990.

Table 5.4.1-11-B2. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives,[a,b] Analysis B2

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.505	554.126	756.710	0.722	1.088	1.758	22.78
	2.0	476.011	557.472	766.458	0.900	1.367	2.237	28.24
	2.5	477.332	560.461	775.482	1.054	1.613	2.669	33.07
	3.0	478.498	563.142	783.835	1.190	1.830	3.060	37.36
	4.5	481.286	569.719	805.391	1.510	2.353	4.032	47.76
	6.0	483.322	574.672	822.646	1.740	2.737	4.774	55.53
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.294	0.578	0.979	0.001	0.002	0.002	0.02
	2.0	0.296	0.582	0.998	0.001	0.002	0.003	0.03
	2.5	0.296	0.586	1.017	0.001	0.002	0.003	0.03
	3.0	0.297	0.589	1.034	0.001	0.002	0.004	0.04
	4.5	0.298	0.598	1.076	0.001	0.003	0.005	0.05
	6.0	0.298	0.605	1.111	0.002	0.003	0.006	0.06

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise are relative to levels in 1990.

As the tables show, varying climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) can affect not only estimated warming, but also estimated sea-level rise and CO_2 concentration. This complex set of interactions occurs because sea level is influenced by temperature, while atmospheric CO_2 concentrations are affected by temperature-dependent effects of ocean carbon storage (specifically, higher temperatures result in lower aqueous solubility of CO_2). Therefore, as Tables 5.4.1-11-A1 and -A2 and 5.4.1-11-B1 and -B2 show, projected future atmospheric CO_2 concentrations differ with varying climate sensitivities even under the same alternative, despite the fact that CO_2 emissions are fixed under each alternative.

Simulated atmospheric CO_2 concentrations in 2040, 2060, and 2100 are a function of changes in climate sensitivity. The small changes in concentration are due primarily to small changes in the aqueous solubility of CO_2 in ocean water: slightly warmer air and sea surface temperatures lead to less CO_2 being dissolved in the ocean and slightly higher atmospheric concentrations.

The response of simulated global mean surface temperatures to variation in the climate sensitivity parameter varies among the years 2040, 2060, and 2100, as shown in Tables 5.4.1-11-A1 and -A2 and 5.4.1-11-B1 and -B2. In 2040, the impact of assumed variation in climate sensitivity is low, due primarily to the limited rate at which the global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact of variation in climate sensitivity is magnified by the larger change in emissions. In Analyses A1 and A2, the reduction in 2100 global mean surface temperature from the No Action Alternative to the Preferred Alternative ranges from 0.006 °C (0.011 °F) for the 1.5 °C (2.7 °F) climate sensitivity to 0.015 °C (0.027 °F) for the 6.0 °C (10.8 °F) climate sensitivity. In Analyses B1 and B2, the reduction in 2100 global mean surface temperature from the No Action Alternative to the Preferred Alternative ranges from 0.002 °C (0.004 °F) for the 1.5 °C (2.7 °F) climate sensitivity to 0.006 °C (0.011 °F) for the 6.0 °C (10.8 °F) climate sensitivity.

The sensitivity of the simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Tables 5.4.1-11-A1 and -A2 and 5.4.1-11-B1 and -B2. Scenarios with lower climate sensitivities show generally smaller increases in sea-level rise; at the same time, the reduction in the increase in sea-level rise is lower under the Preferred Alternative than under the No Action Alternative. Conversely, scenarios with higher climate sensitivities have higher projected sea-level rise; again, however, the reduction in the increase of sea-level rise is greater under the Preferred Alternative than under the No Action Alternative. The range in reduction of sea-level rise under the Preferred Alternative compared to the No Action Alternative is 0.05 to 0.14 centimeter (0.020 to 0.055 inch) in Analyses A1 and A2 and 0.02 to 0.06 centimeter (0.008 to 0.024 inch) in Analyses B1 and B2, depending on the assumed climate sensitivity.

5.4.2 Cumulative Impacts

The cumulative impacts climate analysis is broader than the corresponding direct and indirect impacts analysis in Section 5.4.1 because this section addresses the effects of the Proposed Action together with those of other past, present, and reasonably foreseeable future actions.

5.4.2.1 Greenhouse Gas Emissions

NHTSA estimated the emissions resulting from the Proposed Action using the methodologies described in Section 5.3. GHG emissions from MY 2061–2100 passenger cars and light trucks were then scaled using GCAM assumptions regarding the projected growth of U.S. transportation fuel consumption (*see* Section 5.3.1).

Cumulative emission reductions under each action alternative increase with the increasing stringency of the alternatives, with Alternative 2 having the lowest cumulative emission reductions and Alternative 4 having the highest. Tables 5.4.2-1-C1 and -C2 and Figures 5.4.2-1-C1 and -C2 show total GHG emissions and emission reductions projected to result from new U.S. passenger cars and light trucks from 2017–2100 under each action alternative. Between 2017 and 2100, projections of cumulative emission reductions due to the Proposed Action and other reasonably foreseeable future actions range from 29,800 to 53,300 $MMTCO_2$. Compared to cumulative global emissions of 4,190,614 $MMTCO_2$ over this period (projected by the GCAM6.0 scenario), the incremental impact of this rulemaking is expected to reduce global CO_2 emissions by about 0.7 to 1.3 percent from their projected levels under the No Action Alternative.

Table 5.4.2-1-C1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from 2017 through 2100 by Alternative, Analysis C1[a]

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	155,400		
2 - 2%/year Cars and Trucks	121,400	34,000	22%
3 - Preferred	111,800	43,600	28%
4 - 7%/year Cars and Trucks	102,100	53,300	34%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Table 5.4.2-1-C2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from 2017 through 2100 by Alternative, Analysis C2[a]

Alternative	Total Emissions	Emission Reductions Compared to the No Action Alternative	Percent Emission Reductions Compared to No Action Alternative Emissions
1 - No Action	138,800		
2 - 2%/year Cars and Trucks	108,900	29,800	21%
3 - Preferred	100,200	38,600	28%
4 - 7%/year Cars and Trucks	91,600	47,200	34%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact differences between the values.

Figure 5.4.2-1-C1. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from 2017 through 2100 by Alternative, Analysis C1

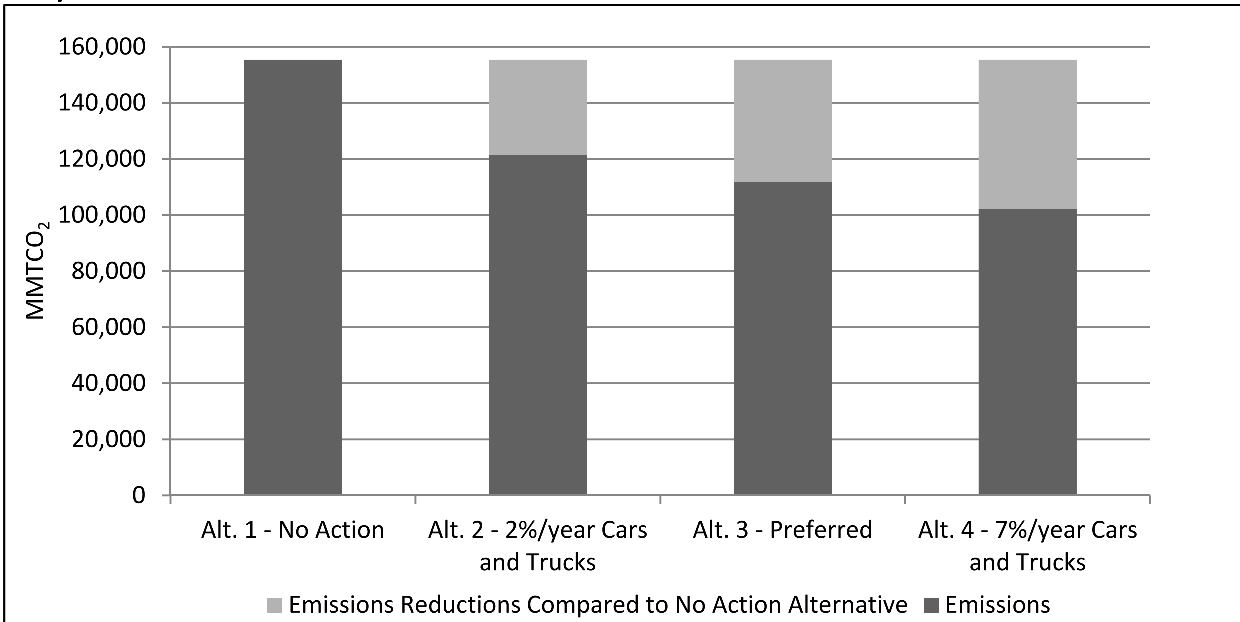
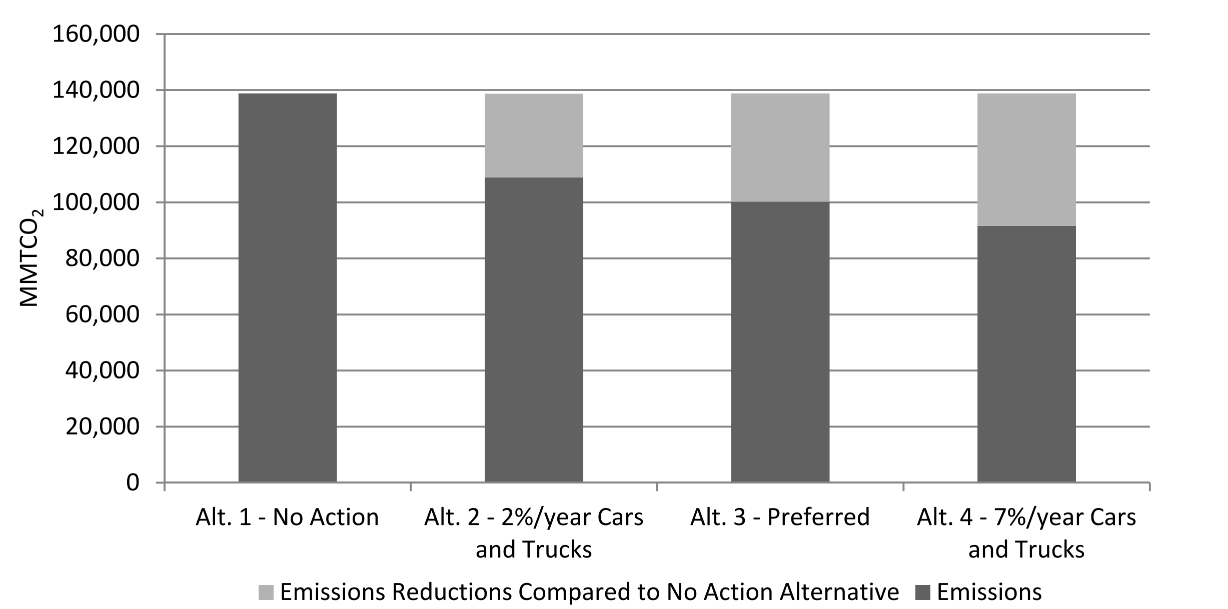


Figure 5.4.2-1-C2. CO_2 Emissions and Emission Reductions ($MMTCO_2$) from 2017 through 2100 by Alternative, Analysis C2



To illustrate the relative impact of these reductions, it can be helpful to consider the magnitude of U.S. emissions from passenger cars and light trucks and to compare them to total U.S. emissions from all sources. Light-duty vehicles in the United States currently account for approximately 18.8 percent of U.S. CO_2 emissions. With the action alternatives reducing U.S. passenger car and light-truck CO_2 emissions by 21 to 34 percent over the period 2017–2100 under the cumulative impacts analysis presented in this chapter, the Proposed Action would contribute to reducing total U.S. CO_2 emissions compared to the No Action Alternative. Compared to total U.S. CO_2 emissions from all sources in 2100 projected by the GCAM6.0 scenario of 4,401 $MMTCO_2$ (Clarke et al. 2007), the action alternatives and reasonably foreseeable future increases in fuel economy would reduce total U.S. CO_2 emissions by a range of 10.4 to 17.6 percent in 2100. Figures 5.4.2-2-C1 and -C2 show projected annual emissions from U.S. passenger cars and light trucks for MYs 2017–2025 taken together with reasonably foreseeable future actions.

Figure 5.4.2-2-C1. Annual CO_2 Emissions from U.S. Passenger Cars and Light Trucks under the Proposed Action ($MMTCO_2$), Analysis C1

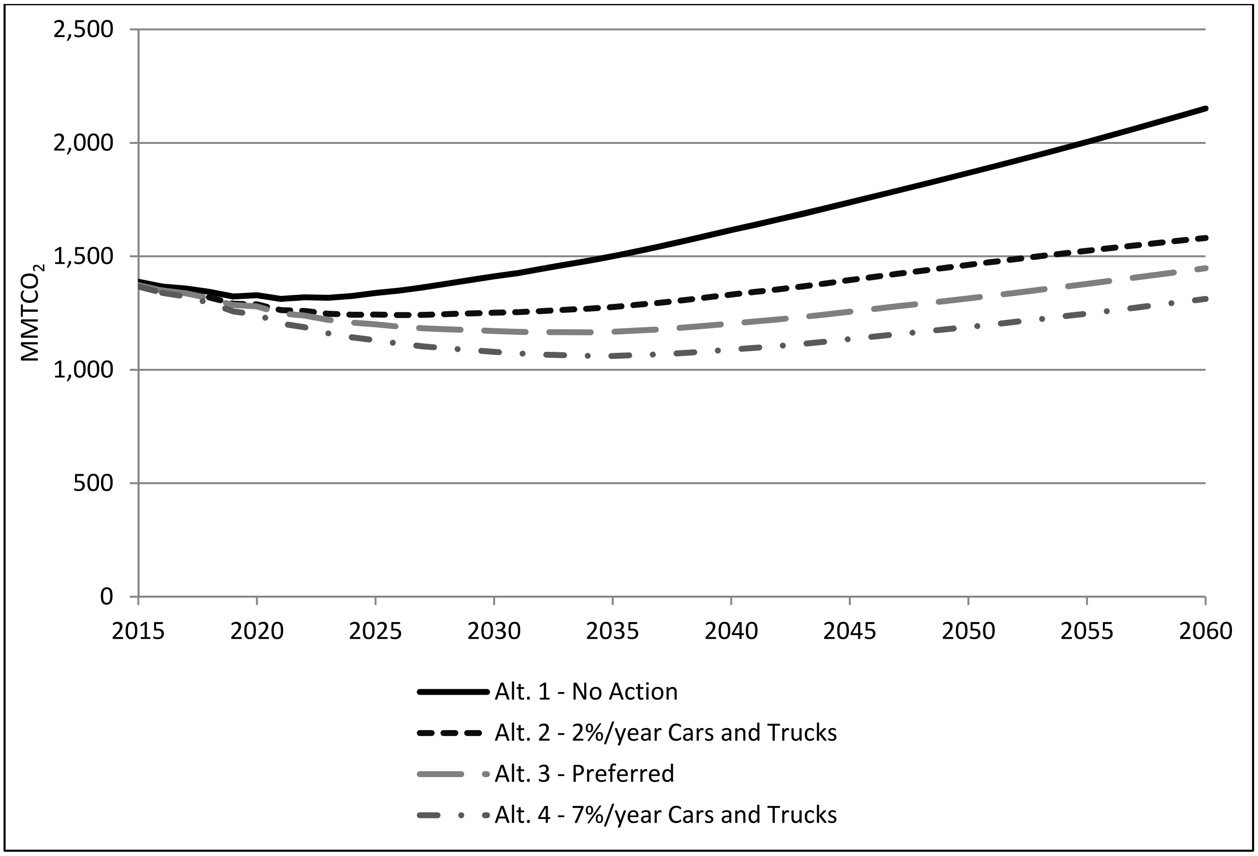
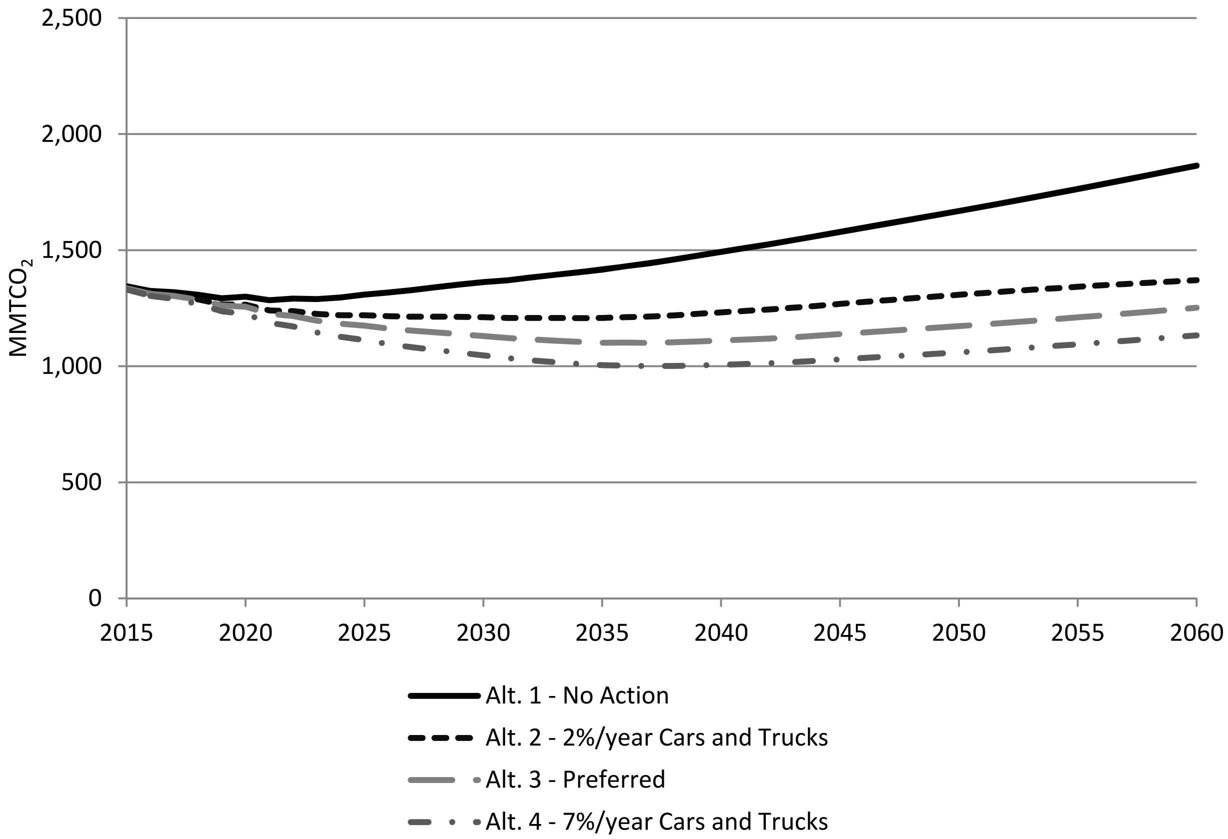


Figure 5.4.2-2-C2. Annual CO_2 Emissions from U.S. Passenger Cars and Light Trucks under the Proposed Action ($MMTCO_2$), Analysis C2



As described in Section 5.4.1.1, these emission reductions can also be compared to existing programs designed to reduce GHG emissions in the United States. By comparison, the proposed standards are expected to reduce cumulative CO_2 emissions by a range of 426 to 1,022 $MMTCO_2$ between 2017 and 2025 (depending on alternative), with emission levels representing a 7 to 18 percent reduction from the baseline emissions of U.S. passenger cars and light trucks in 2025.

Tables 5.4.2-2-C1 and -C2 show projected emissions of CO_2, CH_4, and N_2O to 2100 under the alternatives. CO_2 emissions account for almost all – 99 percent – of GWP-weighted emissions. As shown in these tables, CO_2 emissions from the light-duty vehicle fleet in the United States are projected to increase substantially from their levels in 2017 under the No Action Alternative, which assumes increases in both the number of light-duty vehicles and in VMT per vehicle. The tables also show that each action alternative would reduce total light-duty vehicle CO_2 emissions in future years significantly from their projected levels under the No Action Alternative. Progressively larger reductions in CO_2 emissions from the levels under the No Action Alternative are projected to occur during each future year through 2060, due to decreased fuel consumption as the fleet turns over.

Table 5.4.2-2-C1. Emissions of Greenhouse Gases ($MMTCO_2e$ per year),[a] Analysis C1

GHG and Year	Alternative 1 No Action	Alternative 2 2%/Year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/Year Cars and Trucks
Carbon Dioxide (CO_2)				
2020	1,329	1,289	1,279	1,243
2040	1,615	1,331	1,204	1,089
2060	2,152	1,581	1,448	1,312
2080	2,137	1,570	1,438	1,303
2100	1,987	1,460	1,337	1,212
Methane (CH_4)				
2020	4.90	4.78	4.75	4.67
2040	6.36	5.51	5.11	5.43
2060	8.50	6.83	6.40	7.07
2080	8.44	6.78	6.36	7.02
2100	7.85	6.30	5.91	6.53
Nitrous oxide (N_2O)				
2020	7.10	7.10	7.09	7.06
2040	7.51	7.53	7.52	6.55
2060	10.08	10.21	10.20	8.75
2080	10.01	10.14	10.13	8.68
2100	9.31	9.43	9.42	8.08

a. $MMTCO_2e$ = million metric tons carbon dioxide equivalent.

Table 5.4.2-2-C2. Emissions of Greenhouse Gases ($MMTCO_2e$ per year),[a] Analysis C2

GHG and Year	Alternative 1 No Action	Alternative 2 2%/Year Cars and Trucks	Alternative 3 Preferred	Alternative 4 7%/Year Cars and Trucks
Carbon Dioxide (CO_2)				
2020	1,300	1,265	1,257	1,225
2040	1,493	1,232	1,110	1,006
2060	1,864	1,370	1,252	1,133
2080	1,851	1,361	1,243	1,125
2100	1,722	1,266	1,156	1,046
Methane (CH_4)				
2020	4.77	4.67	4.65	4.57
2040	5.83	5.07	4.77	5.22
2060	7.31	5.90	5.63	6.45
2080	7.25	5.85	5.59	6.40
2100	6.75	5.45	5.20	5.95
Nitrous oxide (N_2O)				
2020	6.93	6.93	6.93	6.89
2040	6.83	6.85	6.79	5.87
2060	8.59	8.71	8.65	7.34
2080	8.53	8.65	8.59	7.29
2100	7.93	8.05	7.99	6.78

a. $MMTCO_2e$ = million metric tons carbon dioxide equivalent.

For the cumulative impacts analysis, under each alternative analyzed, growth in the number of passenger cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in growth of light-duty vehicle travel. This growth in VMT more than offsets the effect of improvements in fuel economy under Alternative 2 and the Preferred Alternative, resulting in projected increases above present levels in total fuel consumption by light-duty vehicles in the United States over the long term. Because CO_2 emissions are a direct consequence of total fuel consumption, the same result is projected for total CO_2 emissions from light-duty vehicles.

However, NHTSA anticipates reduced annual fuel consumption and CO_2 emissions from present levels over the short term under these alternatives. Under Alternative 4, increases in fuel economy are expected to result in fuel consumption and CO_2 emission levels through and beyond 2060 that are lower than present annual CO_2 emission levels.

Emissions of CO_2 (the primary gas that drives climate effects) from the U.S. light-duty vehicle fleet represented approximately 3.3 percent of total global emissions of CO_2 in 2005 (EPA 2012a, WRI 2012a).[12] Although substantial, this source is still a small percentage of global emissions. The proportion of global CO_2 emissions attributable to light-duty vehicles is expected to decline in the future,

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

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

5.4.2.2 Social Cost of Carbon

The SCC is an estimate of the monetized climate-related damages associated with an incremental increase in annual GHG emissions. *See* Section 5.3.3 for a description of the methodology used to estimate the monetized damages associated with GHG emissions and the reductions in those damages that would be attributable to each alternative, including the No Action Alternative.

Tables 5.4.2-3-C1 and -C2 list the cumulative impacts of the action alternatives in terms of reduced monetized damages. By applying each future year's SCC estimate to the estimated reductions in GHG emissions during that year for each scenario, discounting the resulting figure to its present value, and summing those estimates for each year from 2017 to 2050, NHTSA derived the net present value of the benefits in 2012 (Tables 5.4.2-3-C1 and C2). For internal consistency, the annual benefits are discounted to net present value terms using the same discount rate as each SCC estimate (i.e., 5 percent, 3 percent, and 2.5 percent), rather than the 3 percent and 7 percent discount rates applied to other future benefits.[13] Consistent with the SCC tables in Section 5.4.1.2 (Tables 5.4.1-4-A1 and -A2 and 5.4.1-4-B1, and -B2), these estimates show increasing benefits with decreasing discount rates (and higher damage estimates). The estimated net present value for a given alternative varies by approximately an order of magnitude across the discount rates. The estimated net present value computed using a single discount rate differs by roughly a factor of three across alternatives.

Table 5.4.2-3-C1. Reduced Monetized Damages of Climate Change for each Action Alternative Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis C1

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$21,964	$118,777	$203,514	$361,471
3 - Preferred	$31,400	$169,714	$290,758	$516,489
4 - 7%/year Cars and Trucks	$41,681	$224,058	$383,436	$682,007

[13] Other benefits or costs of proposed regulations unrelated to CO_2 emissions could be discounted at rates that differ from those used to develop the SCC estimates.

Table 5.4.2-3-C2. Reduced Monetized Damages of Climate Change for each Action Alternative Net Present Value in 2012 of GHG Emission Reductions between 2017 and 2050 (in millions of 2010 dollars), Analysis C2

Alternative	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate (95th Percentile Damages)
2 - 2%/year Cars and Trucks	$20,048	$108,384	$185,700	$329,845
3 - Preferred	$29,134	$157,319	$269,480	$478,783
4 - 7%/year Cars and Trucks	$38,408	$206,346	$353,094	$628,103

5.4.2.3 Cumulative Impacts on Climate Change Indicators

Using the methodology described in Chapter 2 and Section 5.3.3.2.2, Sections 5.4.2.3.1 through 5.4.2.3.4 describe the cumulative impacts of the alternatives on climate change in terms of atmospheric CO_2 concentrations, temperature, precipitation, and sea-level rise. Section 5.4.2.3.5 presents a sensitivity analysis of the results. The impacts of the Proposed Action, in combination with other reasonably foreseeable future actions, on global mean surface temperature, sea-level rise, and precipitation are relatively small in the context of the expected changes associated with the emissions trajectories in the GCAM scenarios.[14] Although relatively small, primarily due to the global and multi-sectoral nature of the climate problem, the impacts occur on a global scale and are long-lasting.

5.4.2.3.1 Atmospheric CO_2 Concentrations

MAGICC 5.3.v2 is a simple climate model well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emissions scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series.

The GCAM6.0 scenario, described in Section 5.3.3.2, was used to represent the No Action Alternative in the MAGICC runs for the cumulative impacts section of this EIS. Tables 5.4.2-4-C1 and -C2 and Figures 5.4.2-3-C1 and -C2 through 5.4.2-6-C1 and -C2 show the mid-range results of MAGICC model simulations for the No Action Alternative and the three action alternatives for CO_2 concentrations and increase in global mean surface temperature in 2040, 2060, and 2100. As Figures 5.4.2-3-C1 and -C2 and 5.4.2-4-C1 and -C2 show, the action alternatives produce a reduction in the increase in projected CO_2 concentration and temperature, but the reduction is a small fraction of the total increase in CO_2 concentrations and global mean surface temperature.

As shown in Tables 5.4.2-4-C1 and -C2, Figures 5.4.2-3-C1 and -C2, and Figures 5.4.2-4-C1 and -C2, the band of estimated CO_2 concentrations as of 2100 is fairly narrow, from a range of 672.9 ppm under Alternative 4 to 677.8 ppm under the No Action Alternative. For 2040 and 2060, the corresponding ranges are similar. Because CO_2 concentrations are the key driver of all other climate effects, the small changes in CO_2 leads to small differences in climate effects.

[14] These conclusions are not meant to express the view that impacts on global mean surface temperature, precipitation, or sea-level rise are not areas of concern for policymakers. Under NEPA, the agency is obligated to discuss "the environmental impact[s] of *the proposed action.*" 42 U.S.C. § 4332(2)(C)(i) (emphasis added).

Table 5.4.2-4-C1. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAM6.0) by Alternative, Analysis C1[a,b]

Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	471.7	543.4	677.8	1.114	1.666	2.564	10.84	17.73	33.42
2 - 2%/year Cars and Trucks	471.4	542.2	674.7	1.113	1.661	2.551	10.83	17.71	33.32
3 - Preferred	471.2	541.8	673.8	1.112	1.659	2.548	10.83	17.70	33.29
4 - 7%/year Cars and Trucks	471.0	541.4	672.9	1.111	1.657	2.543	10.83	17.68	33.25
Reductions Under Alternatives									
2 - 2%/year Cars and Trucks	0.3	1.1	3.2	0.001	0.004	0.012	0.01	0.02	0.10
3 - Preferred	0.5	1.6	4.0	0.002	0.006	0.016	0.01	0.03	0.13
4 - 7%/year Cars and Trucks	0.7	2.0	4.9	0.003	0.009	0.020	0.01	0.05	0.17

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to 1990.

Table 5.4.2-4-C2. CO_2 Concentrations, Global Mean Surface Temperature Increase, and Sea-level Rise Using MAGICC (GCAM6.0) by Alternative, Analysis C2[a,b]

Alternative	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-Level Rise (cm)[c]		
	2040	2060	2100	2040	2060	2100	2040	2060	2100
1 - No Action	471.7	543.4	677.8	1.114	1.666	2.564	10.84	17.73	33.42
2 - 2%/year Cars and Trucks	471.4	542.4	675.1	1.113	1.662	2.553	10.84	17.71	33.33
3 - Preferred	471.2	542.0	674.3	1.112	1.660	2.550	10.83	17.70	33.30
4 - 7%/year Cars and Trucks	471.1	541.6	673.5	1.111	1.658	2.546	10.83	17.69	33.27
Reductions Under Alternatives									
2 - 2%/year Cars and Trucks	0.3	1.0	2.8	0.001	0.004	0.011	0.00	0.02	0.09
3 - Preferred	0.5	1.4	3.5	0.002	0.006	0.014	0.01	0.03	0.12
4 - 7%/year Cars and Trucks	0.6	1.8	4.3	0.003	0.008	0.018	0.01	0.04	0.15

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise relate to 1990.

Figure 5.4.2-3-C1. Atmospheric CO_2 Concentrations (ppm) by Alternative, Analysis C1

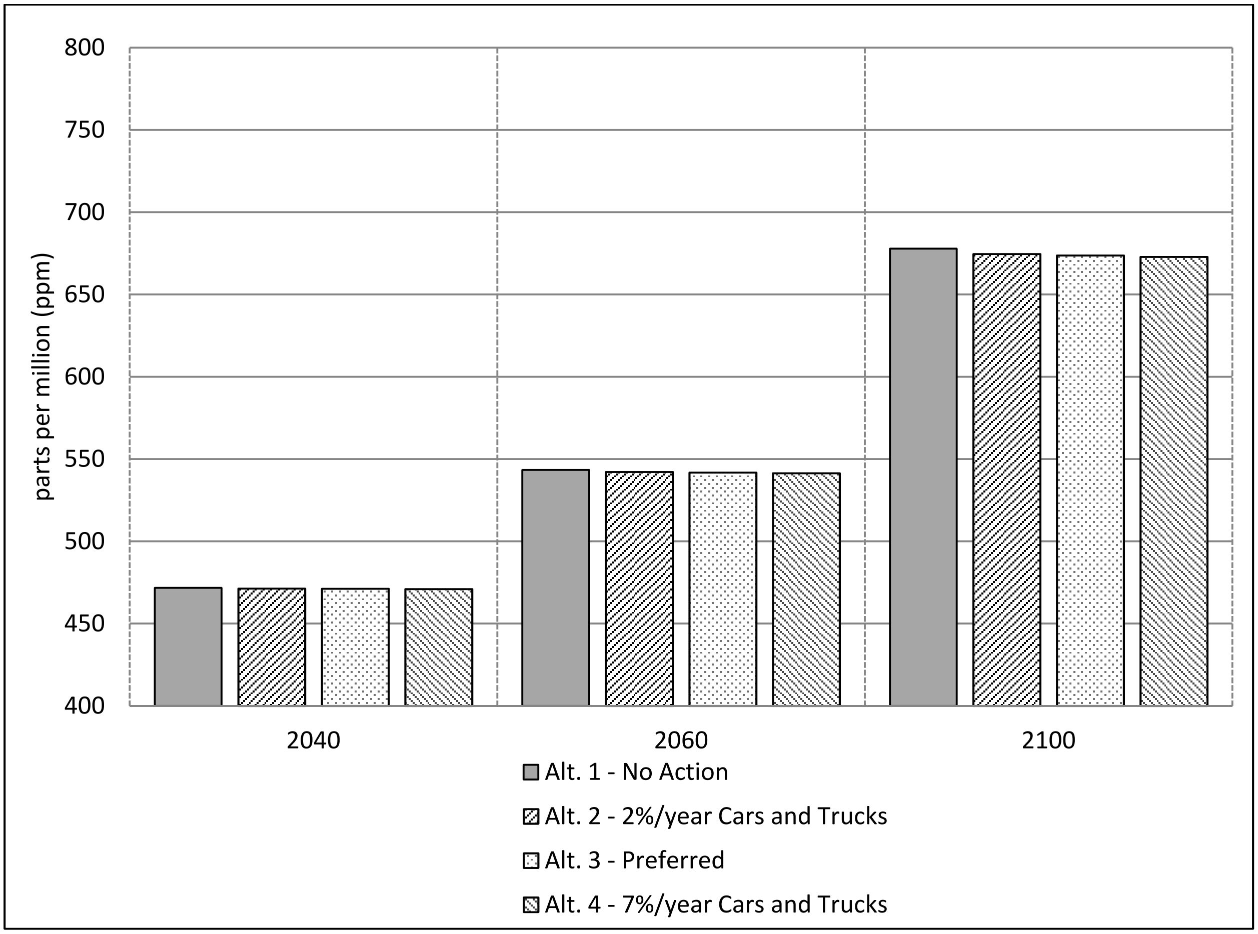


Figure 5.4.2-3-C2. Atmospheric CO_2 Concentrations (ppm) by Alternative, Analysis C2

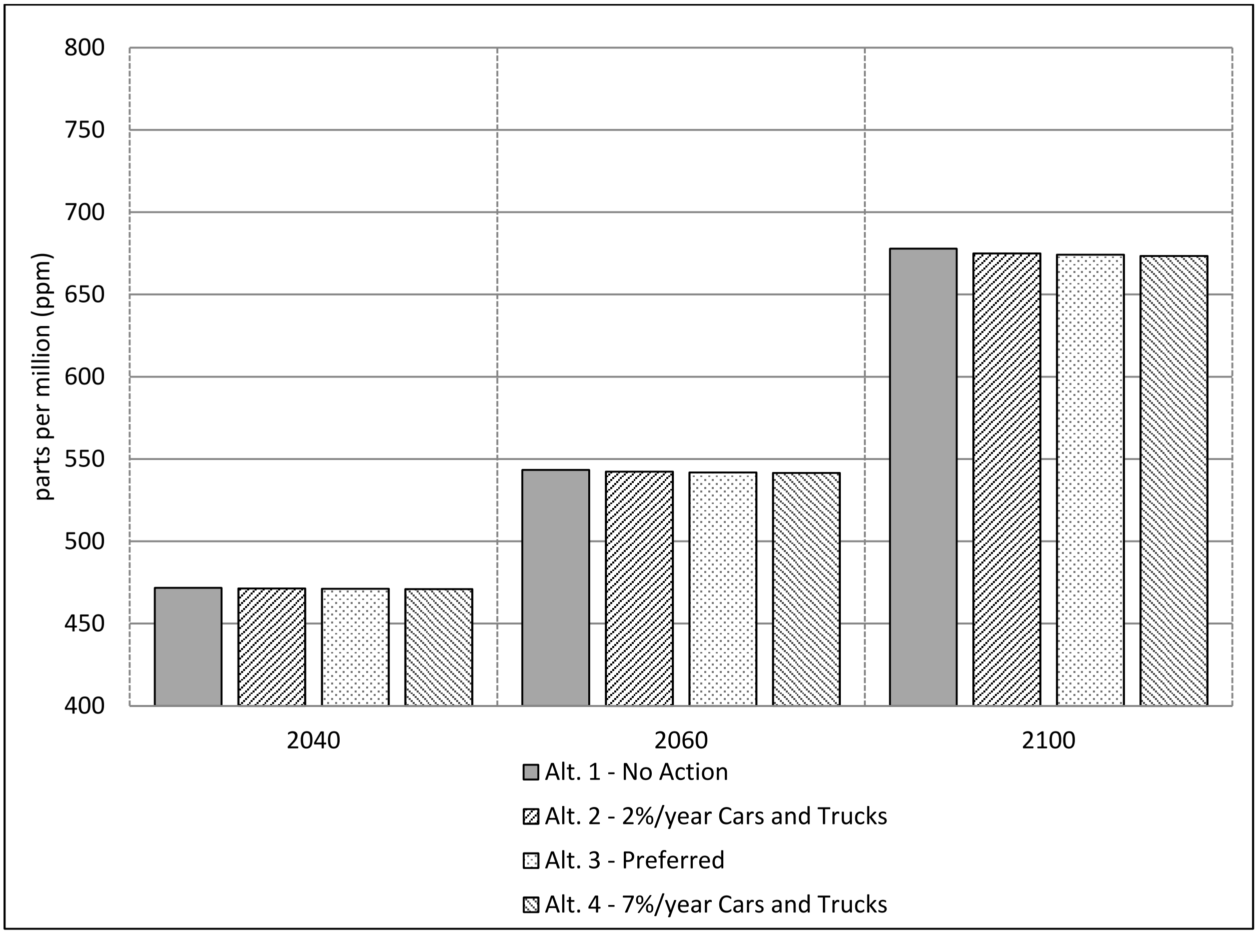


Figure 5.4.2-4-C1. Atmospheric CO_2 Concentrations (ppm) (Reduction Compared to the No Action Alternative), Analysis C1

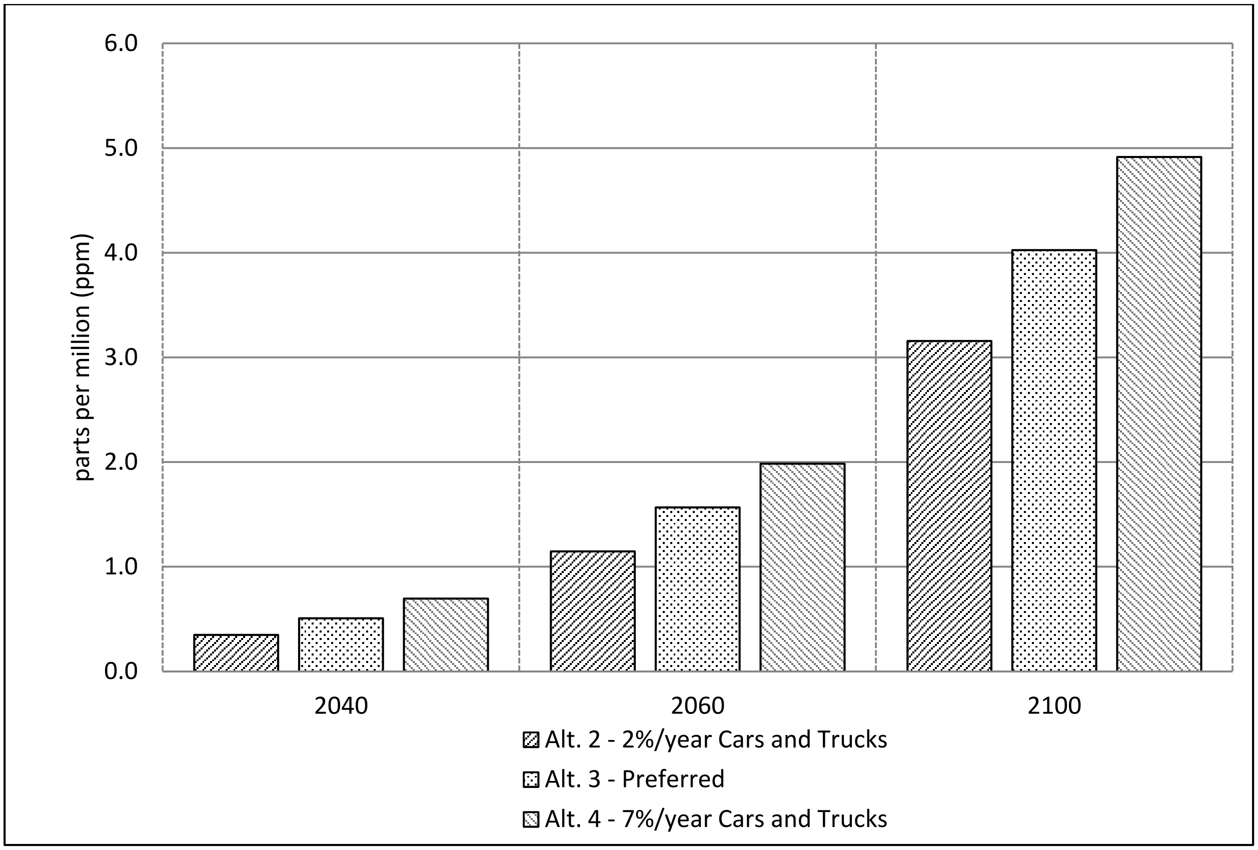


Figure 5.4.2-4-C2. Atmospheric CO_2 Concentrations (ppm) (Reduction Compared to the No Action Alternative), Analysis C2

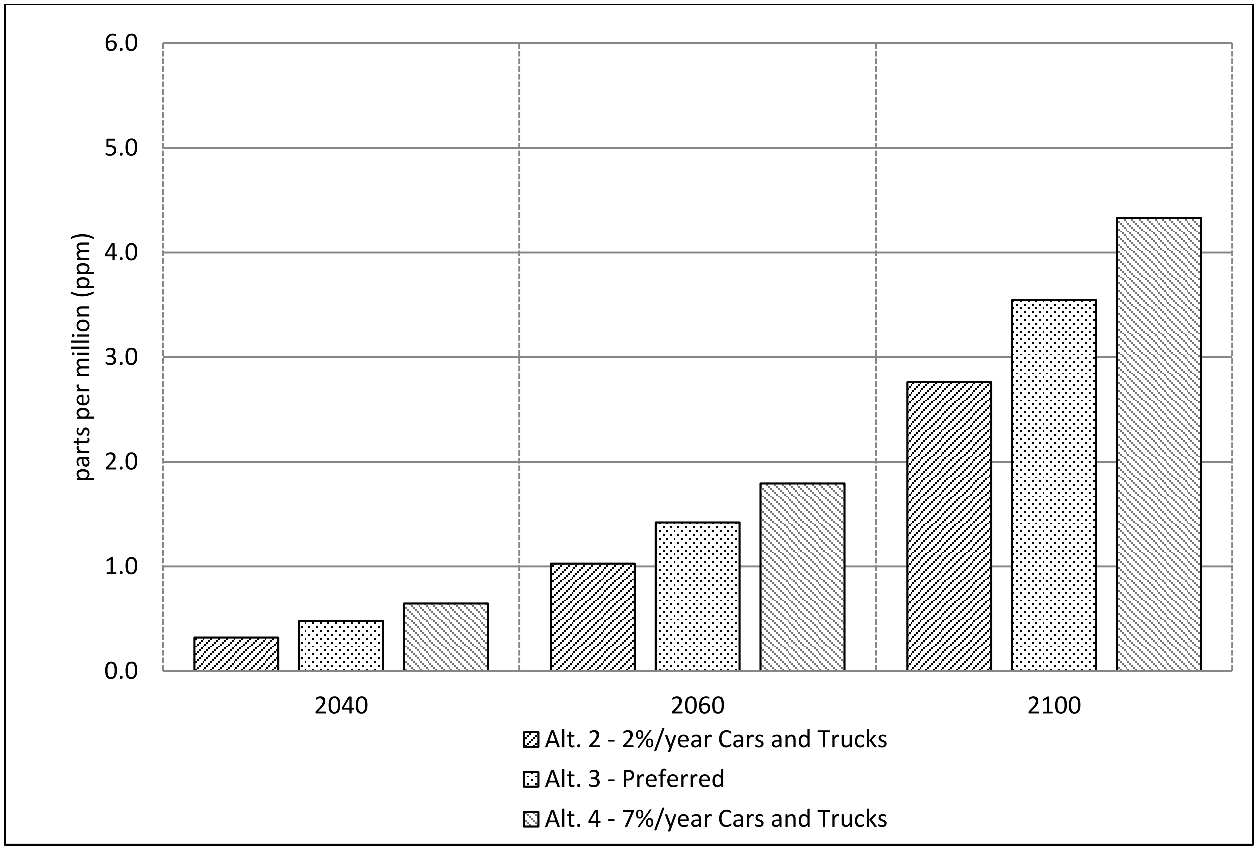


Figure 5.4.2-5-C1. Global Mean Surface Temperature Increase (°C), Analysis C1

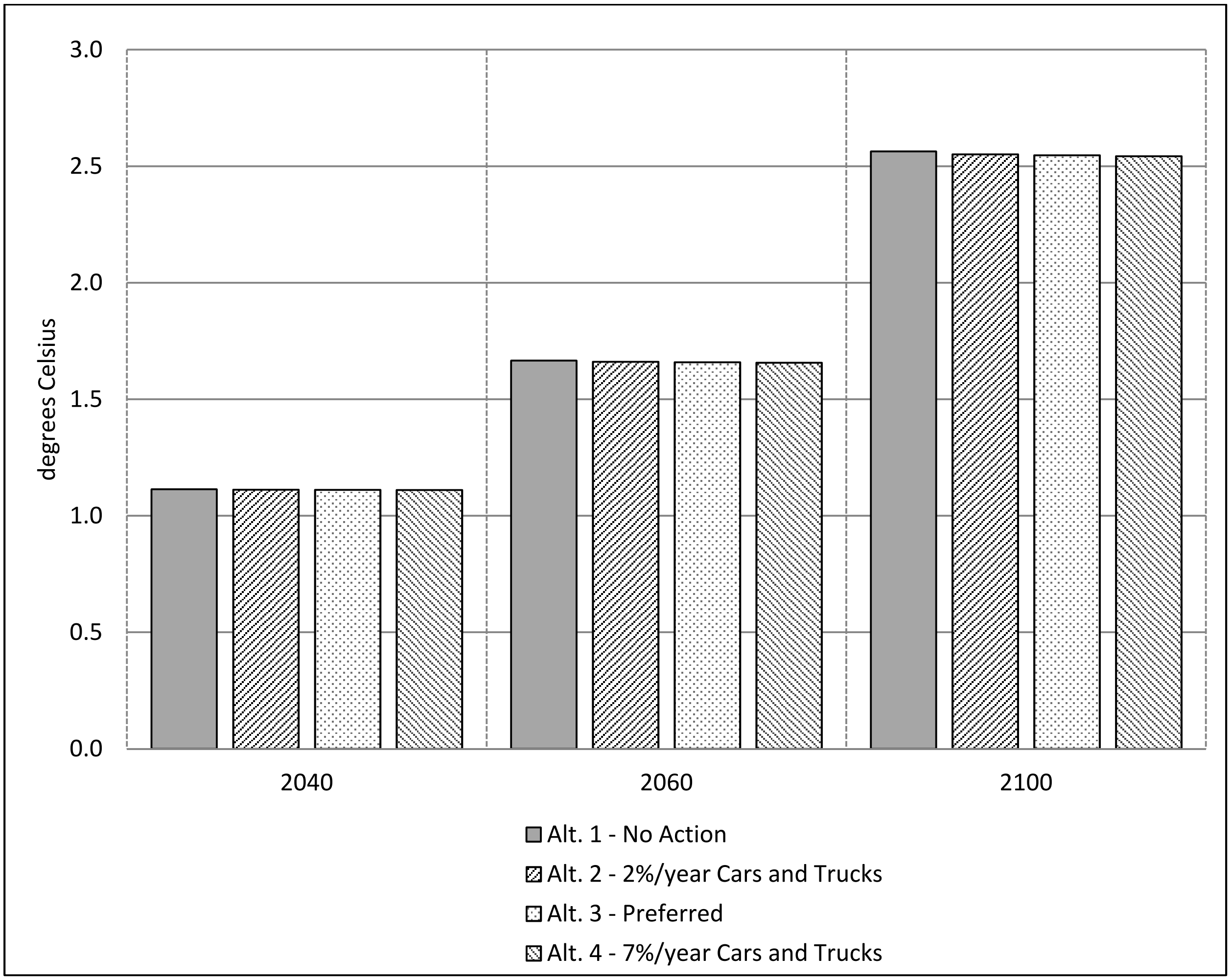


Figure 5.4.2-5-C2. Global Mean Surface Temperature Increase (°C), Analysis C2

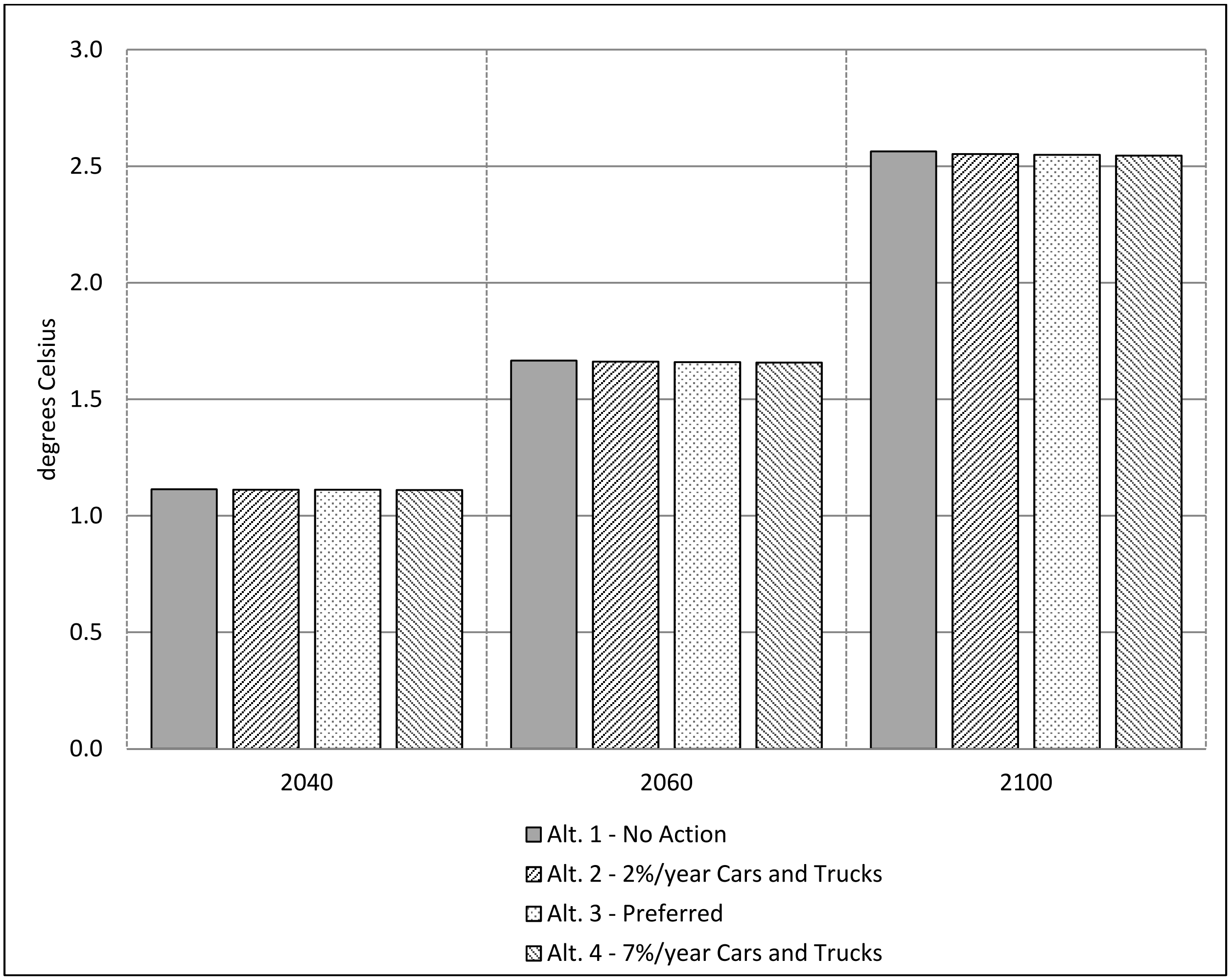


Figure 5.4.2-6-C1. Reduction in Global Mean Temperature Compared to the No Action Alternative, Analysis C1

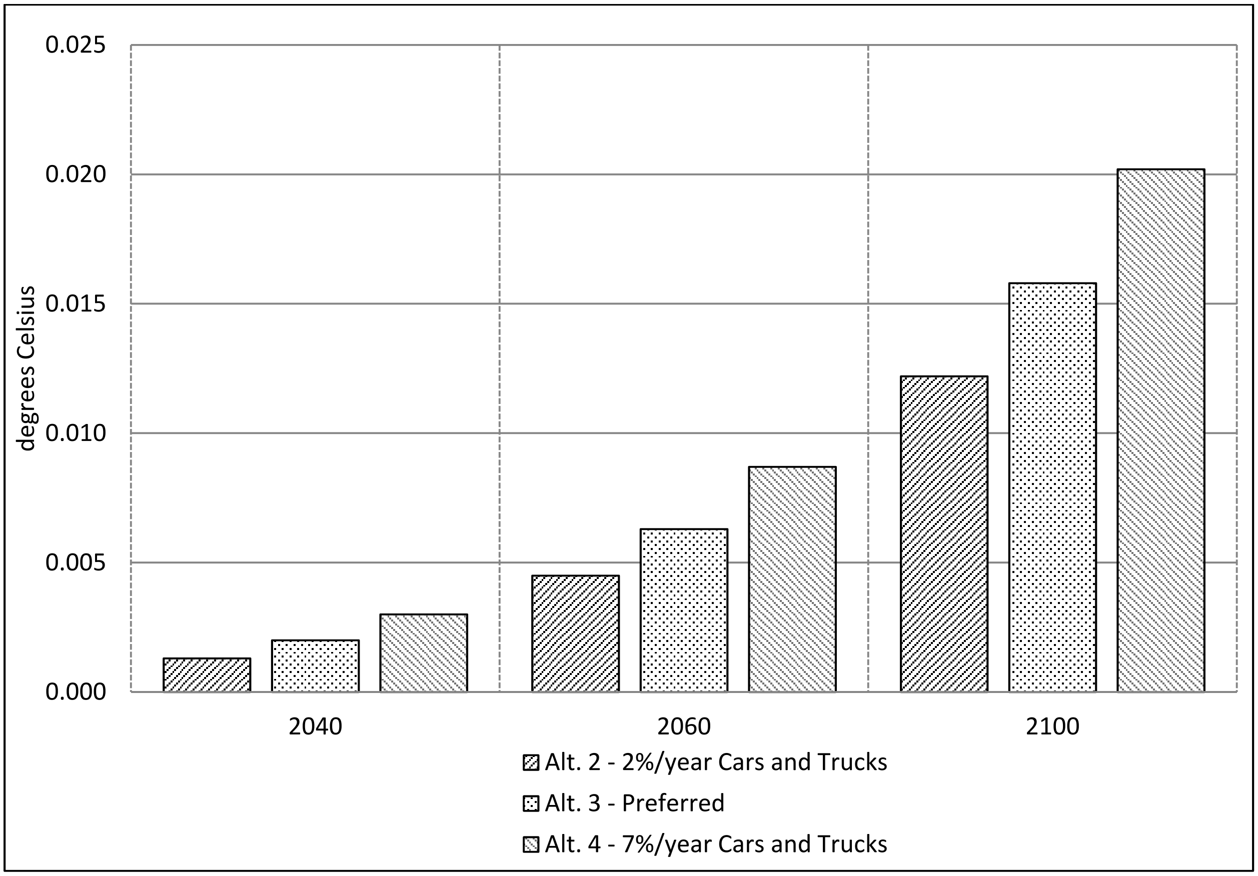
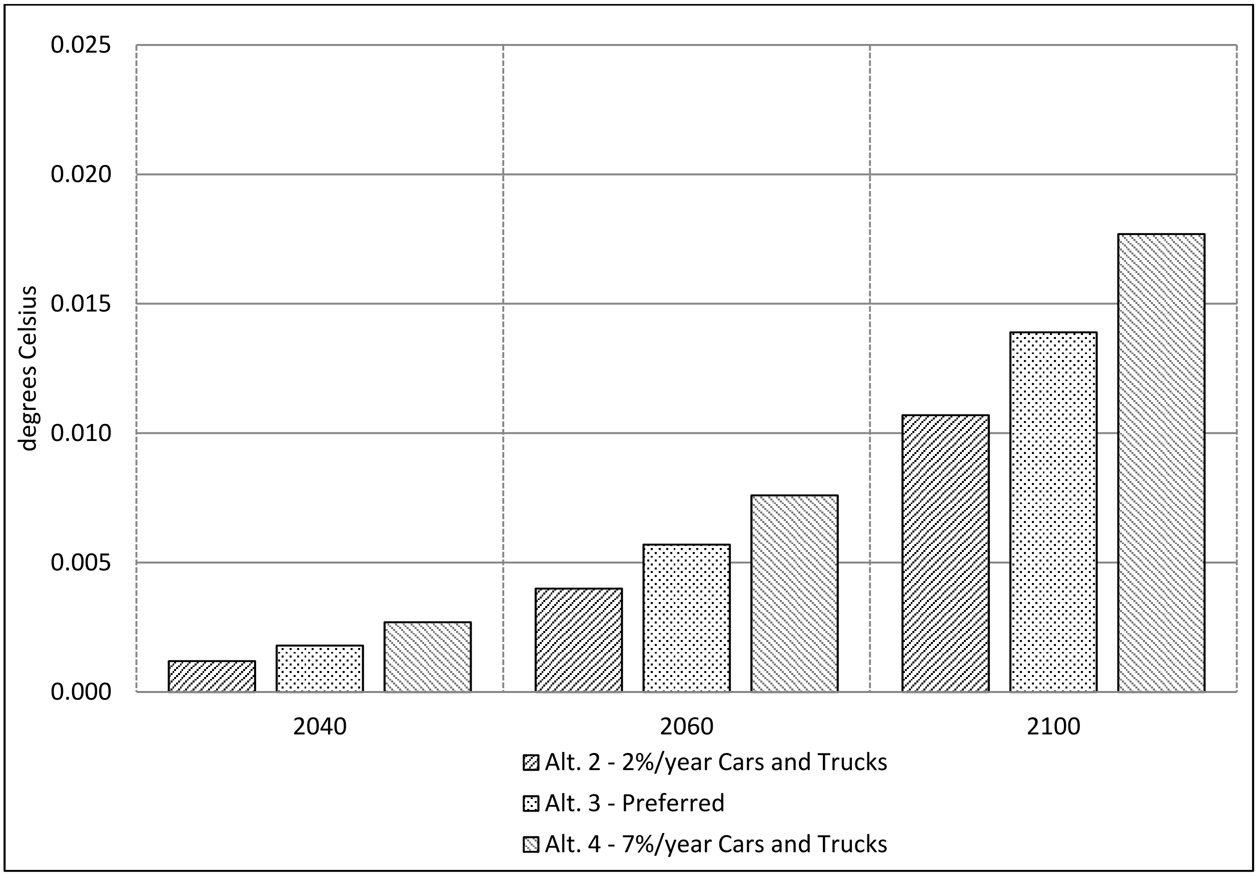


Figure 5.4.2-6-C2. Reduction in Global Mean Temperature Compared to the No Action Alternative, Analysis C2



5.4.2.3.2 Temperature

MAGICC simulations of mean global surface air temperature increases are shown in Tables 5.4.2-4-C1 and -C2. Under the No Action Alternative, the cumulative global mean surface temperature is projected to increase by 1.11 °C (2.00 °F) by 2040, 1.67 °C (3.01 °F) by 2060, and 2.56 °C (4.61 °F) by 2100.[15] The differences among alternatives are small. For example, in 2100 the reduction in temperature increase under the action alternatives compared to the No Action Alternative ranges from approximately 0.011 °C (0.020 °F) under Alternative 2 to 0.020 °C (0.036 °F) under Alternative 4.

Quantifying the changes to regional climate from the Proposed Action is not possible at this point due to the limitations of existing climate models. However, the alternatives would be expected to reduce the changes compared to the reduction in global mean surface temperature. Regional changes to warming and seasonal temperatures as described in the IPCC Fourth Assessment Report are summarized in Table 5.4.1-7.

[15] Because the actual increase in global mean surface temperature lags the commitment to warming, the impact on global mean surface temperature increase is less than the impact on the long-term commitment to warming. The actual increase in surface temperature lags the commitment due primarily to the time required to heat the oceans.

5.4.2.3.3 Precipitation

The effects of higher temperatures on the amount of precipitation and the intensity of precipitation events, as well as the IPCC scaling factors to estimate global mean precipitation change, are discussed in Section 5.4.1.3.3. Applying these scaling factors to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the action alternatives would reduce temperature increases slightly compared to the No Action Alternative, they also would reduce predicted increases in precipitation slightly, as shown in Tables 5.4.2-5-C1 and -C2.

Table 5.4.2-5-C1. Global Mean Precipitation (percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, Analysis C1[a]

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAM6.0 Scenario by Alternative			
Alternative 1 - No Action	0.583	1.533	2.386
Alternative 2 - 2%/year Cars and Trucks	0.583	1.529	2.376
Alternative 3 - Preferred	0.583	1.528	2.372
Alternative 4 - 7%/year Cars and Trucks	0.583	1.526	2.368
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[b]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.003	0.010
Alternative 3 - Preferred	0.000	0.005	0.014
Alternative 4 - 7%/year Cars and Trucks	0.000	0.007	0.018
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.85%	2.31%	3.89%
Alternative 2 - 2%/year Cars and Trucks	0.85%	2.31%	3.87%
Alternative 3 - Preferred	0.85%	2.31%	3.87%
Alternative 4 - 7%/year Cars and Trucks	0.85%	2.30%	3.86%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.01%	0.02%
Alternative 3 - Preferred	0.00%	0.01%	0.02%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.03%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. Global temperature change in 2020 is not zero, but is smaller than the precision being reported.

Table 5.4.2-5-C2. Global Mean Precipitation (percent Increase) Based on GCAM6.0 Scenario Using Increases in Global Mean Surface Temperature Simulated by MAGICC, Analysis C2[a]

Scenario	2020	2055	2090
Global Mean Precipitation Change (scaling factor, % change in precipitation per °C change in temperature)	1.45	1.51	1.63
Global Temperature Above Average 1980–1999 Levels (°C) for the GCAM6.0 Scenario by Alternative			
Alternative 1 - No Action	0.583	1.533	2.386
Alternative 2 - 2%/year Cars and Trucks	0.583	1.530	2.377
Alternative 3 - Preferred	0.583	1.528	2.374
Alternative 4 - 7%/year Cars and Trucks	0.583	1.527	2.371
Reduction in Global Temperature (°C) by Alternative, Mid-level Results (compared to the No Action Alternative)[b]			
Alternative 2 - 2%/year Cars and Trucks	0.000	0.003	0.009
Alternative 3 - Preferred	0.000	0.005	0.012
Alternative 4 - 7%/year Cars and Trucks	0.000	0.006	0.015
Global Mean Precipitation Increase (%)			
Alternative 1 - No Action	0.85%	2.31%	3.89%
Alternative 2 - 2%/year Cars and Trucks	0.85%	2.31%	3.87%
Alternative 3 - Preferred	0.85%	2.31%	3.87%
Alternative 4 - 7%/year Cars and Trucks	0.85%	2.31%	3.86%
Reduction in Global Mean Precipitation Increase by Alternative (% compared to the No Action Alternative)			
Alternative 2 - 2%/year Cars and Trucks	0.00%	0.00%	0.01%
Alternative 3 - Preferred	0.00%	0.01%	0.02%
Alternative 4 - 7%/year Cars and Trucks	0.00%	0.01%	0.02%

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions might not reflect the exact difference of the values in all cases.
b. Global temperature change in 2020 is not zero, but is smaller than the precision being reported.

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This inability is due primarily to the lack of availability of atmospheric-ocean general circulation models (AOGCMs) required to estimate these changes. AOGCMs are typically used to provide results among scenarios having very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios; very small changes in emissions profiles produce results that would be difficult to resolve. Also, the various AOGCMs produce results that are regionally consistent in some cases but inconsistent in others.

Quantifying the changes in regional climate from the action alternatives is not possible at this point, but the action alternatives would reduce the changes compared to the reduction in global mean surface temperature. Regional changes to precipitation as described by the IPCC Fourth Assessment Report are summarized in Table 5.4.1-10 in Section 5.4.1.3.3.

5.4.2.3.4 Sea-level Rise

The components of sea-level rise, MAGICC 5.3.v2 treatment of these components, and recent scientific assessments are discussed in Section 5.4.1.3.4. Tables 5.4.2-4-C1 and -C2 present the impact on sea-level rise from the scenarios and show sea-level rise in 2100 ranging from 33.42 centimeters (13.16 inches) under the No Action Alternative to 33.25 centimeters (13.09 inches) under Alternative 4, for a maximum reduction of 0.17 centimeter (0.07 inch) by 2100.

5.4.2.3.5 Climate Sensitivity Variations

NHTSA examined the sensitivity of climate effects on key assumptions used in the analysis. This examination reviewed the impact of various climate sensitivities and global emissions scenarios on the climate effects under the No Action Alternative and the Preferred Alternative. NHTSA performed the sensitivity analysis around two of the alternatives – the No Action Alternative and the Preferred Alternative – because the agency believes this is sufficient to assess the effect of various climate sensitivities on the results. Tables 5.4.2-6-C1 and -C2 present the results of the sensitivity analysis.

Table 5.4.2-6-C1. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C1[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Emissions Scenario: RCP4.5								
Totals								
1 - No Action	1.5	457.837	499.180	505.171	0.633	0.869	0.981	16.57
	2.0	459.231	502.018	511.117	0.793	1.101	1.284	20.71
	2.5	460.457	504.567	516.683	0.933	1.309	1.568	24.43
	3.0	461.543	506.860	521.878	1.057	1.494	1.831	27.77
	4.5	464.147	512.511	535.430	1.351	1.946	2.512	36.00
	6.0	466.054	516.785	546.399	1.564	2.282	3.053	42.26
3 - Preferred	1.5	457.332	497.657	501.630	0.631	0.864	0.970	16.47
	2.0	458.724	500.486	507.517	0.791	1.096	1.270	20.59
	2.5	459.950	503.026	513.030	0.932	1.303	1.551	24.29
	3.0	461.034	505.312	518.177	1.055	1.488	1.813	27.61
	4.5	463.636	510.947	531.607	1.349	1.938	2.489	35.81
	6.0	465.542	515.208	542.482	1.561	2.273	3.026	42.04

Table 5.4.2-6-C1. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C1 (continued)[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.505	1.523	3.541	0.001	0.004	0.012	0.10
	2.0	0.507	1.532	3.600	0.002	0.005	0.014	0.12
	2.5	0.507	1.541	3.653	0.002	0.006	0.017	0.14
	3.0	0.509	1.548	3.701	0.002	0.007	0.019	0.16
	4.5	0.511	1.564	3.823	0.002	0.008	0.023	0.19
	6.0	0.512	1.577	3.917	0.003	0.009	0.027	0.22
Emissions Scenario: GCAM6.0								
Totals								
1 - No Action	1.5	467.902	535.064	655.076	0.671	0.983	1.443	20.25
	2.0	469.342	538.148	663.231	0.839	1.238	1.852	25.17
	2.5	470.608	540.909	670.797	0.985	1.465	2.224	29.53
	3.0	471.725	543.388	677.811	1.114	1.666	2.564	33.42
	4.5	474.403	549.482	695.946	1.418	2.152	3.417	42.91
	6.0	476.362	554.079	710.493	1.638	2.510	4.077	50.02
3 - Preferred	1.5	467.397	533.521	651.221	0.670	0.978	1.434	20.16
	2.0	468.835	536.595	659.314	0.838	1.233	1.840	25.06
	2.5	470.100	539.348	666.824	0.984	1.459	2.210	29.41
	3.0	471.217	541.820	673.786	1.112	1.659	2.548	33.29
	4.5	473.893	547.897	691.791	1.416	2.144	3.397	42.74
	6.0	475.850	552.481	706.235	1.636	2.502	4.054	49.83
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.505	1.543	3.855	0.001	0.004	0.010	0.09
	2.0	0.507	1.553	3.917	0.002	0.005	0.012	0.11
	2.5	0.508	1.561	3.973	0.002	0.006	0.014	0.12
	3.0	0.508	1.568	4.025	0.002	0.006	0.016	0.13
	4.5	0.510	1.585	4.155	0.002	0.007	0.020	0.17
	6.0	0.512	1.598	4.258	0.003	0.008	0.023	0.19

Table 5.4.2-6-C1. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C1 (continued)[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Emissions Scenario: GCAMReference								
Totals								
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.292	553.146	753.656	0.721	1.086	1.752	22.72
	2.0	475.798	556.486	763.360	0.899	1.364	2.229	28.17
	2.5	477.119	559.471	772.343	1.054	1.610	2.660	32.99
	3.0	478.284	562.148	780.657	1.189	1.827	3.050	37.27
	4.5	481.072	568.717	802.118	1.509	2.349	4.019	47.65
	6.0	483.107	573.663	819.298	1.739	2.733	4.759	55.41
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.507	1.558	4.033	0.001	0.004	0.009	0.08
	2.0	0.509	1.568	4.096	0.002	0.005	0.011	0.10
	2.5	0.509	1.576	4.156	0.002	0.006	0.013	0.11
	3.0	0.511	1.583	4.212	0.002	0.006	0.015	0.13
	4.5	0.512	1.600	4.349	0.002	0.007	0.018	0.16
	6.0	0.513	1.614	4.459	0.003	0.008	0.021	0.18

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise are relative to levels in 1990.

Table 5.4.2-6-C2. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C2[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Emissions Scenario: RCP4.5								
Totals								
1 - No Action	1.5	457.837	499.180	505.171	0.633	0.869	0.981	16.57
	2.0	459.231	502.018	511.117	0.793	1.101	1.284	20.71
	2.5	460.457	504.567	516.683	0.933	1.309	1.568	24.43
	3.0	461.543	506.860	521.878	1.057	1.494	1.831	27.77
	4.5	464.147	512.511	535.430	1.351	1.946	2.512	36.00
	6.0	466.054	516.785	546.399	1.564	2.282	3.053	42.26
3 - Preferred	1.5	457.362	497.801	502.042	0.631	0.865	0.971	16.48
	2.0	458.754	500.631	507.936	0.791	1.097	1.272	20.60
	2.5	459.980	503.171	513.455	0.932	1.304	1.553	24.30
	3.0	461.065	505.458	518.608	1.055	1.488	1.815	27.63
	4.5	463.667	511.094	532.052	1.349	1.939	2.491	35.83
	6.0	465.573	515.357	542.936	1.562	2.274	3.030	42.07
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.475	1.379	3.129	0.001	0.004	0.010	0.09
	2.0	0.477	1.387	3.181	0.002	0.005	0.013	0.11
	2.5	0.477	1.396	3.228	0.002	0.005	0.015	0.13
	3.0	0.478	1.402	3.270	0.002	0.006	0.016	0.14
	4.5	0.480	1.417	3.378	0.002	0.007	0.021	0.17
	6.0	0.481	1.428	3.463	0.002	0.008	0.023	0.19

Table 5.4.2-6-C2. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C2 (continued)[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Emissions Scenario: GCAM6.0								
Totals								
1 - No Action	1.5	467.902	535.064	655.076	0.671	0.983	1.443	20.25
	2.0	469.342	538.148	663.231	0.839	1.238	1.852	25.17
	2.5	470.608	540.909	670.797	0.985	1.465	2.224	29.53
	3.0	471.725	543.388	677.811	1.114	1.666	2.564	33.42
	4.5	474.403	549.482	695.946	1.418	2.152	3.417	42.91
	6.0	476.362	554.079	710.493	1.638	2.510	4.077	50.02
3 - Preferred	1.5	467.425	533.665	651.679	0.670	0.979	1.435	20.17
	2.0	468.864	536.741	659.779	0.838	1.234	1.841	25.08
	2.5	470.128	539.494	667.295	0.984	1.459	2.212	29.42
	3.0	471.245	541.967	674.263	1.112	1.660	2.550	33.30
	4.5	473.921	548.045	692.282	1.416	2.145	3.399	42.76
	6.0	475.879	552.630	706.737	1.636	2.502	4.057	49.85
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.477	1.399	3.397	0.001	0.004	0.009	0.08
	2.0	0.478	1.407	3.452	0.001	0.004	0.011	0.09
	2.5	0.480	1.415	3.502	0.002	0.005	0.012	0.11
	3.0	0.480	1.421	3.548	0.002	0.006	0.014	0.12
	4.5	0.482	1.437	3.664	0.002	0.007	0.018	0.15
	6.0	0.483	1.449	3.756	0.002	0.008	0.020	0.17

Table 5.4.2-6-C2. CO_2 Concentrations, Global Mean Surface Temperature Increases, and Sea-level Rise for Varying Climate Sensitivities for Selected Alternatives, Analysis C2 (continued)[a,b]

Alternative	Climate Sensitivity (°C for 2 × CO_2)	CO_2 Concentration (ppm)			Global Mean Surface Temperature Increase (°C)[c]			Sea-level Rise (cm)[c]
		2040	2060	2100	2040	2060	2100	2100
Emissions Scenario: GCAMReference								
Totals								
1 - No Action	1.5	474.799	554.704	757.689	0.722	1.090	1.761	22.80
	2.0	476.307	558.054	767.456	0.901	1.369	2.240	28.27
	2.5	477.628	561.047	776.499	1.055	1.615	2.673	33.10
	3.0	478.795	563.731	784.869	1.191	1.833	3.064	37.40
	4.5	481.584	570.317	806.467	1.511	2.356	4.037	47.81
	6.0	483.620	575.277	823.757	1.741	2.741	4.780	55.59
3 - Preferred	1.5	474.323	553.292	754.131	0.721	1.086	1.753	22.73
	2.0	475.829	556.634	763.842	0.899	1.365	2.230	28.18
	2.5	477.150	559.619	772.831	1.054	1.610	2.661	33.00
	3.0	478.315	562.297	781.152	1.189	1.827	3.051	37.28
	4.5	481.103	568.867	802.628	1.509	2.350	4.021	47.67
	6.0	483.138	573.815	819.820	1.739	2.733	4.762	55.43
Reduction Under the Preferred Alternative Compared to the No Action Alternative								
	1.5	0.476	1.412	3.558	0.001	0.004	0.008	0.07
	2.0	0.478	1.420	3.614	0.001	0.004	0.010	0.09
	2.5	0.478	1.428	3.668	0.002	0.005	0.011	0.10
	3.0	0.480	1.434	3.717	0.002	0.006	0.013	0.12
	4.5	0.481	1.450	3.839	0.002	0.007	0.016	0.14
	6.0	0.482	1.462	3.937	0.002	0.007	0.018	0.16

a. The numbers in this table are rounded for presentation purposes. As a result, the reductions do not reflect the exact difference of the values.
b. The effects on climate change indicators shown in this table incorporate emission reductions that occur before 2017 due to early compliance with the rulemaking (as some manufacturers are expected to increase fuel economy in conjunction with other vehicle model changes made prior to 2017, in anticipation of the 2017 and later standards).
c. The values for global mean surface temperature and sea-level rise are relative to levels in 1990.

The use of alternative global emissions scenarios can influence the results in several ways. Emission reductions can lead to larger reductions in CO_2 concentrations in later years because more of the anthropogenic emissions are expected to stay in the atmosphere. The use of different climate sensitivities (the equilibrium warming that occurs at a doubling of CO_2 from pre-industrial levels) could affect not only warming but also indirectly affect sea-level rise and CO_2 concentration. Sea level is influenced by temperature. CO_2 concentration is affected by temperature-dependent effects of ocean carbon storage (higher temperature results in lower aqueous solubility of CO_2).

As shown in Tables 5.4.2-6-C1 and -C2, the sensitivity of simulated CO_2 emissions in 2040, 2060, and 2100 to assumptions of global emissions and climate sensitivity is low; stated simply, the incremental changes in CO_2 concentration (i.e., the delta between the Preferred Alternative and the No Action Alternative) are insensitive to different assumptions on global emissions and climate sensitivity. For 2040 and 2060, the choice of global emissions scenario has little impact on the results. By 2100, the Preferred Alternative has the greatest impact in the global emissions scenario with the highest CO_2 emissions (GCAMReference scenario) and the least impact in the scenario with the lowest CO_2 emissions (RCP4.5). The total range of the impact of the Preferred Alternative on CO_2 concentrations in 2100 is roughly 3.1 to 4.5 ppm. The Preferred Alternative using the GCAM6.0 scenario and a 3.0 °C (5.4 °F) climate sensitivity has an impact of a 3.5 to 4.0 ppm reduction compared to the No Action Alternative.

The sensitivity of the simulated global mean surface temperatures for 2040, 2060, and 2100 varies over the simulation period, as shown in Tables 5.4.2-6-C1 and C2. In 2040, the impact is low due primarily to the rate at which global mean surface temperature increases in response to increases in radiative forcing. In 2100, the impact is large due to climate sensitivity and change in emissions. In 2040, the reduction in global mean surface temperature from the No Action Alternative to the Preferred Alternative ranges from 0.001 to 0.003 °C (0.002 to 0.005 °F) across the climate sensitivities and global emissions scenarios, as shown in Tables 5.4.2-6-C1 and -C2. The impact on global mean surface temperature due to assumptions concerning global emissions of GHGs is also important. The scenarios with the higher global emissions of GHGs, such as the GCAMReference scenario, have a lower reduction in global mean surface temperature, and the scenarios with lower global emissions have a higher reduction. This is in large part due to the nonlinear and near-logarithmic relationship between radiative forcing and CO_2 concentrations. At high emissions levels, CO_2 concentrations are high; therefore, a fixed reduction in emissions yields a lower reduction in radiative forcing and global mean surface temperature.

The sensitivity of simulated sea-level rise to change in climate sensitivity and global GHG emissions mirrors that of global temperature, as shown in Tables 5.4.2-6-C1 and -C2. Scenarios with lower climate sensitivities have lower increases in sea-level rise; the increase in sea-level rise is lower under the Preferred Alternative than it would be under scenarios with higher climate sensitivities. Conversely, scenarios with higher climate sensitivities have higher sea-level rise; the increase of sea-level rise is higher under the Preferred Alternative than it would be under scenarios with lower climate sensitivities. Higher global GHG emissions scenarios have higher sea-level rise, but the impact of the Preferred Alternative is less than in scenarios with lower global emissions. Conversely, scenarios with lower global GHG emissions have lower sea-level rise, although the impact of the Preferred Alternative is greater than in scenarios with higher global emissions.

5.5 Health, Societal, and Environmental Impacts of Climate Change

As described in Section 5.4, ongoing emissions of GHGs from many sectors, including transportation, affect global CO_2 concentrations, temperature, precipitation, and sea level. This section describes how these effects can translate to impacts on key natural and human resources.

Although the action alternatives NHTSA is considering would decrease growth in GHG emissions, they alone would not prevent climate change. Instead, they would result in reductions in the anticipated increases of global CO_2 concentrations and associated impacts, including changes in temperature, precipitation, and sea level that are otherwise projected to occur under the No Action Alternative.

By limiting increases in CO_2 concentrations, the action alternatives will also contribute to reducing the impact of climate change across resources, as well as the risk of crossing atmospheric CO_2 concentration thresholds that trigger abrupt changes in Earth systems, known as "tipping points" (*see* Section 5.5.1.7). Delaying mitigation in the short term will require more stringent reductions in the future to limit climate change impacts.

NHTSA's assumption is that reductions in climate effects relating to temperature, precipitation and sea level rise would reduce impacts on affected resources. However, the magnitude of the changes in climate effects that the alternatives would produce (*see* Section 5.4) are too small to address quantitatively in terms of their impacts on the specific resources discussed below.[1] Consequently, the discussion of resource impacts in this section does not distinguish among the alternatives; rather it provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change. Nonetheless, it is clear that these resources are likely to be beneficially affected to some degree by the reduced climate change impacts expected to result from the action alternatives.

This section also briefly describes ongoing adaptation efforts for various resource areas. While mitigation efforts are required to lower the overall risk of triggering large or accelerating transitions to significantly different physical states within Earth systems, efforts to adapt to climate change are also necessary to increase the resilience of human and natural systems to the adverse risks of climate change. As a measure of the importance of current and potential climate change impacts, the Obama Administration has identified adaptation as a critical need through EO 13514. This order requires federal agencies to evaluate agency climate change risks and vulnerabilities to manage both the short- and long-term effects of climate change on the agency's mission, programs, and operations. Pursuant to this order, CEQ issued a set of Implementing Instructions for Federal Agency Adaptation Planning that

[1] This chapter does not compare the projected reductions in global climate effects in Section 5.4 to the national-, regional-, or local-scale reductions in climate effects presented in Section 5.5. The projected reductions in global climate effects do not translate to identical projected reductions at the national, regional, or local scale. In addition, the projected reductions in global climate effects for each of the alternatives are too small to incorporate into a regional/local-scale analysis, which would likely introduce uncertainties at the same magnitude or more than the projected change itself (i.e., the projected change would be within the noise of the model). However, it is understood that climate change is occurring due to the emissions from a collection of sources, and that mitigation across these sources is necessary to curtail additional warming. Although the projected reductions in CO_2 and climate effects in Section 5.4 are small compared to total projected future climate change, they are quantifiable and directionally consistent, and will contribute to reducing the risks associated with climate change. While NHTSA does quantify the reductions in monetized damages attributable to each action alternative (in the SCC analysis), many specific impacts on health, society, and the environment (e.g. number of species lost) cannot be estimated quantitatively. Therefore, NHTSA provides a detailed discussion of the impacts of climate change on various resource sectors in this section.

informed agencies how to integrate climate change adaptation into their planning, operations, policies, and programs (CEQ 2011).

To reduce repetition, this section incorporates by reference Section 4.5 of the MY 2012–2016 CAFE standards Final EIS (NHTSA 2010b) and Section 4.5 of the MY 2014–2018 HD Final EIS (NHTSA 2011b), as these sections describe potential impacts of climate change.[2] Both documents can be accessed on the NHTSA Fuel Economy website *available at:* <http://www.nhtsa.gov/fuel-economy> or the Federal Government's online docket *available at:* <http://www.regulations.gov/> (Docket No. NHTSA-2009-0059-0140 [MY 2012–2016 CAFE standards] and Docket No. NHTSA-2010-0079-0151 [MY 2014–2018 HD vehicle standards]). Overall, these sections present information from earlier studies on similar topics as those discussed in Section 5.5 of this EIS. As the scientific findings are still valid, NHTSA incorporates them by reference. In the sections below, NHTSA notes those instances where a specific study is not relevant or consistent with the findings presented in Section 5.5 of this EIS. In general, the recent findings presented in Section 5.5 in this EIS are consistent with the findings previously presented in reference Section 4.5 of the MY 2012–2016 CAFE standards Final EIS (NHTSA 2010b) and Section 4.5 of the MY 2014–2018 HD Final EIS (NHTSA 2011b). The health, societal, and environmental impacts discussion is divided into two parts: Section 5.5.1 discusses the sector-specific impacts of climate change, while Section 5.5.2 discusses the region-specific impacts of climate change. Section 5.5.1 further discusses ongoing adaptation efforts for various resource areas.

5.5.1 Sectoral Impacts of Climate Change

This section is divided into discussions of sector-specific impacts of climate change. Specifically, Sections 5.5.1.1 through 5.5.1.6 address cumulative impacts on the following key natural and human resources:

- Freshwater resources (the availability, resource management practices, and vulnerabilities of fresh water as a function of climate)
- Terrestrial and freshwater ecosystems (existing and potential vulnerabilities and benefits of the respective species and communities in response to climate change)
- Marine, coastal systems, and low-lying areas (the interplay among climate, environment, species, and communities in coastal and open-ocean waters, including coastal wetlands and coastal human settlements)
- Food, fiber, and forest products (the environmental vulnerabilities of farming, forestry, and fisheries to climate change)
- Industries, settlements, and society (how climate change might affect human institutions and systems, including industrial and service sectors; large and small urban areas and rural communities; transportation systems; energy production; and financial, cultural, and social institutions)
- Human health (how a changing climate might affect human mortality and morbidity)

Section 5.5.1.7 summarizes tipping points, abrupt climate change, and potential thresholds; it is cross-cutting because it addresses some of the resources in Sections 5.5.1.1 through 5.5.1.6.

[2] Under CEQ NEPA implementing regulations, material should be incorporated by reference when the effect is to reduce excessive paperwork without impeding agency or public review. 40 CFR § 1502.21. *See also* Memorandum for Heads of Federal Departments and Agencies: Improving the Process for Preparing Efficient and Timely Environmental Reviews under the National Environmental Policy Act, March 6, 2012 at p. 13. *Available at:* <http://ceq.hss.doe.gov/current_developments/docs/Improving_NEPA_Efficiencies_06Mar2012.pdf.> (CEQ 2012).

Each of the following sections (5.5.1.1 through 5.5.1.7) first summarizes new findings (findings since publication of the MY 2014–2018 HD Final EIS in June 2011, findings recommended by public commenters, and/or findings that were incorporated in newly released reports) related to the consequences of observed and projected climate change in the United States and globally on each resource, drawing from reports summarizing existing peer-reviewed information and peer-reviewed literature. The sections conclude with reviews of the potential to adapt to climate change and the extent to which adaptation could reduce climate change risks, if there is recent literature regarding adaptation. Because adaptation measures will become increasingly expensive in the face of large magnitude climate changes, and there are limits to systems' ability to adapt, adaptation cannot be considered a substitute for mitigation actions designed to limit climate change impacts.

Section 5.5.1.8 provides a comprehensive review of CO_2 and climate change impacts on stratospheric ozone.

Although the approach is systematic, these topics do not exist in isolation, and there is some overlap between discussions. The sections generally reflect the organization of topic areas in the climate literature, notably by the IPCC, a primary source for much of the information in this section. The categories do not match the classification of resources typically found in an EIS, such as biological resources, water resources, land use, or socioeconomics, although these resources are discussed.

To reflect the likelihood of climate change impacts accurately for each sector, NHTSA references and uses the IPCC uncertainty guidelines (*see* Section 5.1.1). This approach provides a consistent methodology to define confidence levels and percent probability of a predicted outcome or impact. More information about the uncertainty guidelines is provided in *Treatment of Uncertainties in the IPCC's Working Group II Assessment* in IPCC (2007a).

The following sections, like the corresponding sections in the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS, draw from panel-reviewed synthesis and assessment reports from the IPCC, the U.S. Climate Change Science Program, and the U.S. Global Change Research Program. NHTSA similarly relies on panel reports because they have assessed numerous individual studies to draw general conclusions about the state of science and have been reviewed and formally accepted by, commissioned by, or in some cases authored by U.S. Government agencies and individual government scientists. This material has been well vetted, both by the climate change research community and by the U.S. Government. In many cases, it reflects the consensus conclusions of expert authors. This section also references peer-reviewed literature that has not been assessed or synthesized by an expert panel, but which supplements the findings of the panel-reviewed reports.

5.5.1.1 Freshwater Resources

5.5.1.1.1 Recent Findings

This section provides an overview of the recent findings regarding observed and projected impacts of climate change on freshwater resources in the United States and globally. For information on previously reported findings, *see* Sections 4.5.3 (Freshwater Resources) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings were drawn primarily from the following major international or national scientific assessment reports: the IPCC *Fourth Assessment Report* (IPCC 2007a, IPCC2007b, IPCC 2007c); National Science and Technology Council's *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008)*,* Arctic Climate Impact Assessment (ACIA 2005); EPA's *Technical Support Document for*

Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act (EPA 2009e); National Resource Council's (NRC's) *America's Climate Choices* (NRC 2010c, NRC 2010d); NRC's *Climate Stabilization Targets* (NRC 2010a), and *The Copenhagen Diagnosis* (Allison et al. 2009) authored by 26 climate scientists. Overall, the new freshwater resources studies cited herein confirm previous results and add to the growing body of modeling results and field observations that indicate substantial impacts to freshwater resources as a result of climate change.

5.5.1.1.2 Precipitation, Streamflow, Runoff, and Surface Waters

NHTSA's two recent EISs reported model projections indicating that climate change is increasing precipitation extremes. Two new studies support this conclusion with observational data and estimate the contribution of climate change. Min et al. (2011) compared 6,000 observations of precipitation extremes for the period 1951 through 1999 with the World Climate Research Programme Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model simulated precipitation over the same period. The observational data covered most of the Northern Hemisphere land area, including North America and Eurasia. Results confirm that precipitation extremes for two-thirds of the data-covered land areas, measured by the annual maxima of daily precipitation and the 5-day consecutive precipitation amount, intensified over the past half century.

In another recent attribution study, Pall et al. (2011) isolated the contribution of climate change to the probability of a flood event in the United Kingdom in fall 2000. The researchers conducted a large number of model runs of autumn 2000 weather to determine how often the flood event would occur under present-day conditions, and then repeated the experiment under pre-industrial conditions when there was less CO_2 and cooler temperatures. The number of times the flood event occurred under present conditions compared to pre-industrial conditions was an indication of how much more likely the event was because of climate change. Results indicated that the increase in risk due to climate change is "very likely" to be more than 20 percent, and "likely" to be more than 90 percent.

A new study by the U.S. Bureau of Reclamation confirms the regional differences in climate-related changes in U.S. streamflows reported in MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS (Bureau of Reclamation 2011a). Consistent with previous findings, the study's analytical and modeling results for eight Reclamation river basins indicate that northwestern and north-central regions of the western United States are becoming wetter, while the southwestern and south-central regions are becoming drier.

The report also found that warming trends have led to more rainfall and less snow during the cool season in a number of locations in the western United States, resulting in less snowpack accumulation in those areas. Snowpack losses are projected to be greatest in low-lying valleys and low-altitude mountains where baseline climate is close to freezing. Projections also indicate that in high-latitude and high-altitude areas (e.g., Columbia headwaters in Canada and Colorado headwaters in Wyoming) there is a chance that snowpack losses could be offset by cool-season precipitation increases.

The study's runoff projections indicate that cool-season runoff will increase over the twenty-first century for river basins along the west coast of the United States (San Joaquin, Sacramento, Truckee, Klamath, and Columbia) and in the north-central United States (Missouri). Over the twenty-first century, a gradual decrease in runoff is projected for the area from the southwestern United States to the southern Rocky Mountains (Colorado River Basin and Rio Grande River Basin). Warm-season runoff is projected to show significant declines in the Bureau of Reclamation river basins in the area from southern Oregon, the southwestern United States, and the southern Rocky Mountains (San Joaquin, Sacramento, Klamath, Truckee, Rio Grande and Colorado). North of this region, in the Columbia and Missouri river basins, little change to a slight increase is expected.

A recent modeling study of a river basin in Oregon is consistent with earlier projections for the Pacific Northwest. The study showed that flow changes in this region could be substantial, especially in conjunction with the effects of ongoing urban development. Model simulations indicated average increases in winter flows of 10 percent and decreases in summer flows of 37 percent as a result of projected climate change. When land development was considered along with climate change, the increase in winter flows reached 71 percent, while summer decreases reached 48 percent (Praskievicz and Chang 2011).

As discussed in NHTSA's previous EISs, snowpack in western North America has shown significant warming-induced declines in recent decades, and the trend is projected to continue throughout this century. A new study examined snowpack reconstructions from 66 tree-ring chronologies in the major drainages of the northern Rocky Mountains to determine if snowpack declines in this region are within the range of natural variability or result from human-induced climate change. Results indicated that the decline in snowpack in the region is "almost unprecedented" in magnitude over the past 800 years. The dramatic decline in snowpack is especially serious because tens of millions of people rely on water that originates in the region's accumulated snow (Pederson et al. 2011).

Similarly, a study of the San Francisco Bay Estuary and its upstream tributaries projected a decline in runoff of 0.80 cubic kilometers (more than 28 billion cubic feet) per decade under the moderately high (A2) emission scenario, along with a decline in the snowmelt contribution to runoff of 1.1 percent per decade. In this water-stressed region, these declines would be significant for both people and ecosystems (Cloern et al. 2011).

The MY 2014–2018 HD Final EIS indicated that warming in the Arctic has proceeded at about twice the rate as elsewhere, leading to decreases in summer sea-ice extent, glacier and ice sheet mass loss, coastal erosion, and permafrost thawing. A recent study found that an additional effect of Arctic warming is the release of toxic chemicals previously held in the region's water, snow, ice, and soils. Persistent organic pollutants are evaporating into the atmosphere above the warming Arctic, where they can recirculate and once again pose a threat to human health and the environment (Ma et al. 2011).

More than half of the world's wetlands are in high northern latitudes where permafrost thawing has a significant influence on wetland dynamics. A new modeling study using the University of Victoria Earth System Climate Model, which includes thermal and hydrological characterization of frozen ground, projects that the area and seasonal duration of northern-latitude wetlands decline as permafrost thawing increases, under three high-emission scenarios for GHGs. Initially, permafrost thawing creates wetlands, because frozen layers below the upper limit of melting prevent surface moisture from draining into the soil. However, once thawing deepens beyond approximately 1 meter (approximately 3 feet), a significant amount of the near-surface moisture drains to deeper soil layers, reducing the area of wetlands. This finding has important implications for atmospheric concentrations of GHGs, because permafrost regions contain one of the world's largest carbon pools vulnerable to climate change, and CH_4 emissions from wetlands contribute an estimated 20 to 40 percent of total global CH_4 emissions. Modeling results imply that initial warming and permafrost thawing will result in greater release of CO_2 and CH_4 into the atmosphere. But as warming increases and thawing deepens, wetland extent will decline, reducing emissions. However, the net effect on emissions is difficult to predict given uncertainties about factors such as the ratio of CH_4 to CO_2 with permafrost thawing and release rates compared to plant uptake of carbon (Avis et al. 2011).

Glaciers

Studies discussed in NHTSA's previous EISs indicate that glaciers are receding worldwide as the climate warms. A new modeling study provides more details on glacier changes. The study simulated glacier volume changes (as a percentage of initial volume) of more than 120,000 glaciers worldwide in response to twenty-first century temperature and precipitation projections from 10 general circulation models (GCMs). The glacier data were from the World Glacier Inventory. The multi-model mean ranged from 8 to 75 percent volume loss by 2100, with the smallest values in Greenland (8 percent) and High Mountain Asia (10 percent) and the largest values in the European Alps (75 percent) and New Zealand (72 percent). The range in results is similar to the range reported in IPCC (2007d) (Radić and Hock 2011).

New observational studies in Canada, South America, Europe, Alaska, and Nepal also show glacier declines. There has been a significant loss of mass from glaciers in the Canadian Arctic Archipelago, and observations over the past decade indicate that the rate of loss is increasing (Gardner et al. 2011). In South America, there has been a dramatic increase in the melt rate and contribution to sea-level rise of glaciers in the two large Patagonian icefields (Glasser et al. 2011). Glacier retreat has also accelerated in the European Alps. A new analysis of glacial mass balance data for the past century shows that there has been a 13 percent increase in glacial runoff in the Alps during August over the past 2 decades. Modeling results indicate that this region could see a 55 to 85 percent reduction in runoff from glacial melt by the end of this century (Huss 2011).

A new update by the Arctic Monitoring and Assessment Program also indicates an increasing rate of loss among Arctic glaciers. In Alaska, significant glacial recession has been evident since the mid-1990s (AMAP 2011). Biannual observations of the inland Gulkana Glacier and the Wolverine Glacier near the southern coast of Alaska since 1965 suggest that loss of mass of both glaciers is largely the result of temperature increases (Arendt 2011).

In a recent modeling study of the Langtang catchment in Nepal, which is representative of high-altitude glacierized catchments in the central and eastern Himalayas, Immerzeel et al. (2011) projected decreases in glacier area of 32 percent by 2035, 50 percent by 2055, and 75 percent by 2088. These findings are important because they indicate that Himalayan glaciers are not likely to disappear as early as 2035, which was suggested in the IPCC Fourth Assessment Report. Projections from the new study also indicate a net increase in stream flow of 4 millimeters (0.16 inches) per year. Modeling results are consistent with observations in the Himalayas showing that rain runoff and base flow are increasing, snow runoff remains more or less constant, and glacier runoff is gradually declining (Immerzeel et al. 2011).

Extreme Events –Droughts

NHTSA's previous EISs observed that droughts will continue to increase in subtropical and mid-latitude regions in response to anthropogenic climate change, and cited a review by Dai (2011b) indicating that global aridity has increased substantially since the 1970s due to recent drying over Africa, southern Europe, East and South Asia, and eastern Australia. More recently, Dai (2011a) has considered how trends and model projections might vary using different forms of the Palmer Drought Severity Index, the most commonly used indicator of drought. Results show that all forms of the index effectively capture trends in streamflow and soil moisture in different regions of the world. Widespread drying from 1950 to 2008 from climate change is observed, confirming the results of studies reported in the previous EISs. The percentage of dry areas worldwide has risen by approximately 1.74 percent per decade over this period, and the trend in aridity suggests even more severe drying over this century (Dai 2011a).

Consistent with the timing of the global increase in aridity reported in these reviews, a new study reports a sudden shift to drier conditions in the Mediterranean region beginning in the 1970s. Records show that 10 of the 12 driest winters in the region since 1902 occurred in the last 2 decades (Hoerling et al. 2012).

Previous EISs also showed that human-induced climate change is leading to drying conditions in the western and southwestern United States. Supporting this conclusion is a new study by Cayan et al. (2010) reporting that the twenty-first century drought in the Colorado River Basin is the most extreme in more than 100 years. Simulations suggest that the rest of the century will see more severe droughts, with some droughts lasting for 12 or more years.

5.5.1.1.3 Adaptation

Adaptation has received increasing attention in recent years given the magnitude of declines in precipitation and runoff in a number of heavily populated regions, many of which were already experiencing water shortages. In the United States, the impacts of climate change on water resources have sparked several responses by water resource managers. In 2011, federal agencies, which manage most of the freshwater resources in the U.S., worked with stakeholders to develop a National Action Plan for managing freshwater resources in a changing climate to help ensure adequate freshwater water supplies, while also protecting water quality, human health, property, and aquatic ecosystems. A number of regional centers have been created, including DOI's eight regional Climate Science Centers, the 21 Landscape Conservation Cooperatives (LCCs) of the U.S. Fish and Wildlife Service, and NOAA's Regional Integrated Science Assessments (RISA) program. Water utilities are determining ways to adjust operation and maintenance schedules. Ecosystem-based adaptation is considered even more important in the least developed countries, where water infrastructure and alternative sources of water are often lacking. For example, there are a number of well-established techniques for improving watershed conditions to protect surface water resources and promote groundwater recharge (Colls et al. 2009). Water conservation and demand management are also important non-structural approaches for managing water supply. Integrated Water Resources Management helps manage water sustainably at the catchment scale. All of these adaptation measures are commonly referred to as "no regrets" actions, because they are beneficial even without considering climate change; therefore, they are increasingly considered essential for twenty-first century water management. Though it is not possible to eliminate the impacts of climate change on water resources through adaptation alone, such adaptation measures will help reduce impacts, and provide an important complement to climate change mitigation.

5.5.1.2 Terrestrial and Freshwater Ecosystems

5.5.1.2.1 Recent Findings

This section provides an overview of the recent findings regarding observed and projected impacts of climate change on terrestrial and freshwater ecosystems in the United States and globally. For information on previously reported findings, *see* Sections 4.5.4 (Terrestrial and Freshwater Ecosystems) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings are drawn primarily from the following major international or national scientific assessment reports: EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); the IPCC *Fourth Assessment Report* (IPCC 2007a, 2007b, 2007c); the U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources* (CCSP 2008d) and *Thresholds of Climate Change in Ecosystems* (CCSP 2009b); NRC's *America's Climate Choices: Advancing the Science of Climate Change* (NRC 2010c); NRC's *Climate Stabilization Targets* (NRC 2010a); and EPA's *Climate Change Indicators in the United States* (EPA 2010c). The ecosystems addressed in this section include terrestrial ecosystems, such as forests, grasslands, shrublands, savanna, and tundra; aquatic ecosystems, such as rivers, lakes, and ponds; and freshwater wetlands, including marshes, swamps, and bogs. Information from these sources is still relevant and the findings presented below supplement this information with the most up-to-date scientific assessments available. Findings that are contrary to those presented in MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS are noted.

Recent findings continue to indicate that terrestrial and freshwater ecosystems in the United States and around the world are experiencing rapid and observable changes. Steadily warming temperatures, rising CO_2 concentrations, and changing precipitation patterns are already leading to shifting species ranges and earlier spring migrations, as well as threatening the ability of some existing habitats to thrive. Climate change is also affecting the relative timing of species life-cycle events, referred to as "phenology," which can upset existing species interactions, dependencies, and predator-prey interactions. Terrestrial and freshwater ecosystems are also affected by wildfires, insect outbreaks, and changes in human activity such as land-use change, hydrologic modification, and pollution.

Phenology

Recent studies support the conclusions of earlier work indicating that the phenology of plant and animal species will continue to change in regions that experience warmer annual average temperatures and earlier spring weather. Amphibian reproductive behaviors heavily depend on temperature and rainfall patterns. One new study (Todd et al. 2011) examines the phenology of amphibians in a wetland situated in a hardwood-pine forest in South Carolina over a 30-year period (1978 to 2008). The study indicates that in recent years, several amphibian species that usually breed in autumn are breeding increasingly later in the year. This is consistent with an increase in local nighttime air temperature of approximately 1.2 °C (2.2 °F) during the September and February pre-breeding and breeding periods. (The increase in winter nighttime temperatures allows for autumn breeding to occur later.) Similarly, two amphibian species that breed in winter are breeding increasingly earlier in the year; this coincides with the increase in overnight temperature during the breeding season and an increase in rainfall during the pre-breeding and breeding seasons. Of the 10 species studied, 4 have changed their reproductive timing by a range of approximately 15 to 76 days over the 30-year period of record.

Another study of flowering patterns in a meadow system in the southern Rocky Mountains (Aldridge et al. 2011) found shifts in the timing of plant behavior. Historically, flowering in this system has occurred with one broad unimodal peak lasting most of the summer (based on three complementary peaks of the three meadow types in the system). However, recent increases in mid-summer temperatures have led to shifts in the timing of flowering within the three meadow types. Historically, flowering hits one peak during the summer. The study found that there are now two peaks in flowering during the summer, characterized by a mid-summer reduction in the total number of flowers. This pattern is potentially harmful to the montane[3] meadow system because it might not meet the continuous demand of pollinators throughout summer (in this case, several species of hummingbirds (broad-tailed and Rufous, primarily) and 13 species of bumblebees). If nectar food sources (a primary source of energy for pollinators) are not available, the lack of food can threaten population numbers.

Species Competitiveness and Abundance

Worldwide, ice cover on most lakes has declined in recent decades (Urban et al. 2011 citing Magnuson et al. 2000). This pattern is likely affecting the relative success of competing fish species in many areas (Urban et al. 2011). For example, one new study (Urban et al. 2011 citing Helland et al. 2011) on several cold-water fish species in Norwegian lakes indicates that recent reductions in lake ice cover, along with projected future losses in cover, could harm some species while potentially helping others. The study found that brown trout biomass is affected negatively by increases and positively by decreases in ice cover when Arctic char (the most widely distributed freshwater fish in the world at such high latitude) are present. When both species are present, trout biomass decreases with each additional day of ice cover. Helland et al. (2011) suggest that the mechanisms for this relationship are as follows: Arctic char ingest more food and grow more quickly in cold winter temperatures and during periods of darkness, outcompeting the brown trout. Thus, during periods with ice cover, Arctic char are better able to thrive than the trout. Conversely, trout outperform char when climate conditions are warmer. Changes in climate that result in shorter periods of winter weather and reduced ice cover therefore affect the relative competitiveness of these two species.

Changes in the Carbon Storage Capacity of Terrestrial Ecosystems

Terrestrial plants store atmospheric CO_2; increasing terrestrial plant mass will increase carbon storage, at least over the short-term. Plants can be considered a temporary storage pool for CO_2, because upon death of the plant, CO_2 will be released back into the atmosphere, as happens in the case of forest fires. For some ecosystems, the factors that affect the balance between carbon storage or carbon source are not well understood.

A recent study evaluated the capacity of the Greater Yellowstone Ecosystem conifer forests to act as a carbon storage pool under changing climate conditions and new fire regimes. Using climate projections downscaled to the ecosystem, and using these projections in the CENTURY model (a dynamic ecosystem process model), the authors simulated carbon storage in the ecosystems conifer forests over the twenty-first century. They found that more than one occurrence of wildfire within a 90-year period will cause lodgepole pines to shift from acting as a net carbon sink to a net carbon source. Although the projected warming conditions will likely increase forest productivity, thereby increasing carbon storage, net storage will not occur at a rate sufficient to recover more than 85 percent of the carbon lost during the initial wildfire. The authors concluded that while the magnitude of the shift is uncertain, the potential of the Greater Yellowstone Ecosystem to store carbon will decline under all warming climate scenarios (Smithwick et al. 2011).

Another recent study evaluates terrestrial vegetation productivity and the associated carbon storage in response to changes in carbon, nitrogen, and phosphorous nutrient cycles. The authors indicate that, in addition to nitrogen fixation, carbon storage in vegetation is likely to be closely linked to interactions

[3] Occurring in mountainous areas.

between carbon and phosphorus nutrient cycles. As plants gain more biomass, their net storage of carbon might be limited by nutrient availability in soils (Finzi et al. 2011).

Ecological Tipping Points and Biodiversity

A 2010 report by the Convention on Biological Diversity contributes to our understanding of the ecosystem-wide impacts in the event of the loss of keystone plant and animal species, the introduction of new species, and/or changes to the physical structure of the system (for example, loss of permafrost). Similar to the concept of tipping points in ocean or climate systems discussed in Section 5.3.4, ecological tipping points begin with initial changes in a biological system (for example, the introduction of a new predatory animal species to the system due to changes in climate that are favorable to the newly introduced species), which are then amplified by positive feedback loops that can lead to cascading effects throughout the system. The point at which the system can no longer retain stability is a threshold known as a tipping point. Changes in such situations are often long lasting and hard to roll back; managing these conditions is often very difficult (Leadley et al 2010). Leadley et al. (2010) recently evaluated the potential tipping point mechanisms and their effects on biodiversity and ecosystem services for several ecosystems, as described in the following paragraphs.

Arctic Tundra

By the end of the century, Arctic regions are projected to experience greater warming compared to other locations around the globe, with increases projected to range from 3 ^{o}C (5 ^{o}F) to 8 ^{o}C (14 ^{o}F) under the range of possible emissions scenarios (lowest to highest, respectively), compared to conditions during the baseline used in the report (1980 to 1999). Such warming is expected to cause high loss of permafrost, which is likely to lead to the release of emissions of GHGs from tundra soils. Additionally, the change of high-albedo tundra to lower-albedo boreal forest will provide a warming feedback. The lags in Earth's responses to increased atmospheric GHGs make these changes "inevitable and irreversible over the 21st century." The impacts on biodiversity due to changes in arctic tundra include decreases in herbaceous, bryophyte, and lichen species, and increases in boreal forests. The authors of the study suggest that certainty and understanding of these projections are high, while the potential for adaptive mechanisms is low (adaptive mechanisms are isolated to small areas) (Leadley et al. 2010).

Mediterranean Forest

Increasing abandonment of rural areas in Mediterranean regions (due to factors unrelated to changes in climate) is likely to decrease land use for crops. Consequently, these areas are likely to see natural regeneration of forests and other native vegetation. In addition, global climate models indicate that these areas will also experience warmer temperatures and decreased precipitation over the next century, leading to more frequent drought and a greater risk of fires. The resultant increase in fire disturbances is projected to encourage the growth of more shrublands, which provide a positive feedback for fire disturbances. Increases in fire-control demands could result in higher costs to the public for these services, while reducing the funds available for investment in infrastructure. Compared to forests and croplands, shrublands typically contain fewer species of plants and animals, so these changes are projected to lead to a great reduction in species diversity. Several regulating ecosystem services, such as carbon sequestration and watershed protection, will also be threatened by these shifts (Leadley et al. 2010).

Amazonian Forest

Leadley et al. (2010) suggest that two "interacting tipping points" in the Amazon could lead to widespread dieback of tropical forest. First, the large-scale change in land use from forest to managed agriculture could alter local and regional rainfall patterns, potentially initiating or exacerbating existing drought conditions; this situation could further reduce forest cover in the event of severe fire disturbance. Second, global climate models indicate that the region could experience substantial reductions in rainfall. A drier climate could result in forests permanently changing to shrubs and grasses more suited to the conditions. The region today might be close to a "forest dieback tipping point." Because the Amazon is home to many diverse species of plants and animals, a widespread dieback would likely result in a number of previously unforeseen species extinctions. Additional ecosystem services impacts (i.e., services that ecosystems inherently provide to humans) include loss of carbon sequestration in both vegetation and soils. The understanding of the mechanisms involved and the certainty of these projections is moderate to low (Leadley et al. 2010).

Freshwater Lakes and Rivers

An increase in phosphorus and nitrogen in freshwater resources (like lakes and rivers) is often referred to as *eutrophication*. Sources for these nutrients typically include agricultural fertilizers and sewage. The effects of eutrophication include excessive growth of algae (algal blooms), which reduce dissolved oxygen in the water, causing plants, fish, and invertebrates to die. Often, as native plant and animal species die, they are replaced with invasive species, changing the basic makeup of the ecosystem. Large increases in fertilizer use and sewage outputs in Asia, Africa, and Latin America, along with decreasing precipitation and increasing water stress in some regions, are projected to result in much more widespread problems with eutrophication (Leadley et al. 2010).

Another new study reports that the fossil record indicates that previous abrupt shifts in ecological regimes have been common throughout the Quaternary period (the geological period from approximately 2.6 million years ago until present), at least partially in response to significant changes in climate accompanying a long period of deglaciation. This historical record assists in projecting how Earth's systems are likely to respond to changes in the future. A combination of many factors (some extrinsic and some intrinsic to the system) are the likely reasons behind these abrupt shifts. Changes recorded include rapid changes in plant and animal species, and changes in the composition of entire ecological communities. While it is not possible to attribute the cause of these shifts entirely to changes in climate, the authors of the study suggest that the "demographic processes in plant populations are quite sensitive to abrupt climate change, with initial time lags measured on the order of decades" (Williams et al. 2011 citing Ammann et al. 2000, Williams et al. 2002, and Yu 2007). Abrupt shifts can be damaging to the overall health of populations, and some resilient species have demonstrated an ability to migrate in the face of ambient changes. However, previous estimates indicate that most plants can migrate (e.g., by seed propagation) no faster than 1.0 kilometer (0.6 mile) per year (Williams et al. 2011 citing Pearson 2006).

5.5.1.2.2 Adaptation

Ecosystem adaptation to climate change can be of the result of human activities intended to protect them, or can occur naturally by responses within the ecosystem (CCSP, 2008i). The ability or inability of ecosystems to adapt to change is referred to as adaptive capacity. There could be notable regional differences in the adaptive capacity of ecosystems, and adaptive capacity is moderated by anthropogenic influences and capabilities. The ultimate impact of climate change on ecosystems depends on the speed and extent to which these systems can adapt to a changing climate.

Adaptive actions taken by humans to help ecosystems (and the services they provide) can sometimes result in conflicts between systems. One new study (Verburg et al. 2012) found that there is a significant spatial component to the effects of adaptive actions. In particular, there are often synergistic responses found in the area of the adaptive action (such as restoring vegetation), but conflicts or trade-offs are more likely to occur at non-adjacent locations. Therefore, the study concludes that the impact of an adaptive action can be negligible, overall. In an example explored by the study, adaptive actions were taken in a region prone to flooding due to changes in land use. The adaptive active (restrictions on urbanization) resulted in positive changes to flood risk (although not a decrease, urbanization occurred in the flood prone area to a lesser degree than it would have without the regulated growth). However, the action resulted in less conversion of agricultural land back to its natural state (which would have occurred in a scenario allowing greater urbanization), so the impacts to native ecosystems were largely negative. Similarly, areas in which abandonment of agricultural land is encouraged see increases in biodiversity, but the migration of farmers to other areas negatively impacts biodiversity in those regions (Verburg et al. 2012).

5.5.1.3 Marine, Coastal, and Low-lying Areas

5.5.1.3.1 Recent Findings

This section provides an overview of the recent findings regarding observed and projected impacts of climate change on marine, coastal, and low-lying areas in the United States and globally. For information on previously reported findings, *see* Sections 4.5.5 (Marine, Coastal, and Low-lying Areas) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings are drawn primarily from the following major international or national scientific assessment reports: EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); U.S. Global Change Research Program's *Global Climate Change Impacts in the United States* (GCRP 2009); IPCC *Fourth Assessment Report* (IPCC 2007a, IPCC 2007b, IPCC 2007c); National Science and Technology Council's *Scientific Assessment of the Effects of Global Change on the United States* (National Science and Technology Council 2008); U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity* (CCSP 2008e); Arctic Climate Impact Assessment (ACIA 2005), NRC's *Climate Stabilization Targets* (NRC 2010a); and the United Nations Environmental Programme's (UNEP) *Climate Change Science Compendium* (UNEP 2009). Information from these sources is still relevant and the findings presented below supplement this information with the most up-to-date scientific assessments available. Findings that are contrary to those presented in MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS are noted.

These environments are particularly vulnerable to warming water temperatures, sea-level rise, melting of freshwater ice, storm events, and water acidification. Overall, new studies confirm the findings previously presented, although some newer published articles indicated that sea levels might be rising faster than anticipated due to the accelerated reduction of ice sheet loss in Greenland and Antarctica.

Anthropogenic Pressures

Climate change impacts on sea-level rise and ocean temperatures could affect large coastal populations. Roughly 200 million people worldwide live within coastal floodplains, along 2 million square kilometers (800,000 square miles) of land (Milne et al. 2009 citing Stern 2007). These populations are potentially at risk due to increased sea-level rise. The effects of global sea-level rise will be felt disproportionately by low-lying coastal areas, such as Tuvalu in the western tropical Pacific, where the rate of local sea-level rise has been measured to be approximately three times greater than that of global mean sea-level rise. The high rate of local sea-level rise is due to a combination of changes in vertical land motion; interannual and decadal sea-level variation caused by El Niño-Southern Oscillation; and global sea-level rise (Becker et al. 2011).

As discussed in the MY 2014–2018 HD Final EIS, recent studies project that sea-level rise could approach or exceed 1 meter (3.3 feet) by 2100. Weiss et al. (2011) developed a new geospatial dataset based on present-day local coastal elevations, taking into account hydrological connectivity (i.e., the path that water from rising sea level will take on the surface, accounting for infrastructure such as channels and levees) and the presence of tidal wetlands landward of the shoreline. This study identifies coastlines that would be vulnerable to increases in sea level of 1 meter and 6 meters (19.8 feet), suggesting that these amounts are possible by the end of the century. This study mapped surveys of which regions of the United States would be at risk, including 20 municipalities with more than 300,000 people each, and 160 municipalities with populations between 50,000 and 300,000. These coastal municipalities have elevations at or below 6 meters (19.8 feet). This study projects a number of coastlines to be at risk, including the Gulf and southern Atlantic coasts; cities especially at risk in the United States include Miami, New Orleans, and Virginia Beach, because these cities have more than 90 percent of their land at or below 6 meters above sea level along the coast (Weiss et al. 2011). A similar study by Strauss et al. (2012), using a recent high-resolution edition of the National Elevation Dataset and a tidal model for the contiguous United States, found 3.7 million people live within 1 meter (3.3 feet) of local high tide in the contiguous United States and 22.9 million Americans live within 6 meters (19.7 feet) of locally adjusted high tide. The authors note that communities will be vulnerable to localized storm surges and flooding long before a rising sea level permanently inundates coastlines.

Global sea-surface temperatures have risen at an average pace of 0.2 °C (approximately 0.4 °F) per decade since 1975, and the temperature gradients created might increase the likelihood of strong El Niño events (Hansen 2006). Sea-surface temperature increases could also play a role in the incidence of hurricanes in the Atlantic Ocean. The National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory used two hurricane simulation models driven with the projected sea-surface temperatures and atmospheric state described in 18 World Climate Research Programme CMIP3 climate models under a moderate (A1B) emission scenario. The models project that while the absolute number of total hurricanes and tropical storms might decrease on an annual basis by the end of the twenty-first century, there will be a near doubling of the most intense hurricanes (category 4 and 5 storms with sustained winds at or greater than 131 miles per hour), compared to the 1981 to 2005 average, with the largest increase projected to occur in the western Atlantic north of 20 degrees north latitude (Bender et al. 2010). These stronger hurricanes could threaten many coastal communities that have not yet undertaken adaptation measures to protect against stronger storms.

Ecological Changes

As discussed in the MY 2014–2018 HD Final EIS, coral species play an integral role in the environment and act as “fish nurseries” for many different marine species. Coral reefs participate in living symbiotic relationships that are long-lived, and are very sensitive to long-term changes in temperature. Multiple species of coral, including two key species important to ecosystems, have shifted their range toward higher latitudes since the 1930s as a result of warming ocean temperatures, with some species shifting northward by up to 14 kilometers (8.4 miles) per year (Yamano et al. 2011). Recent modeling described by Pereira et al. (2010) suggests that continued poleward shifts and greater dispersal of marine organisms will occur from rising ocean temperatures (Yamano et al. 2011).

Sea Level

Climate change increases global sea level through two dominant pathways: melting land-based ice caps and glaciers and the thermal expansion of ocean waters due to increasing temperatures. A recent study by Kemp et al. (2011) on a reconstruction of sea level over the last 2,100 years along the North Carolina coast found that sea level was relatively stable from 100 BC until 950 AD. Sea levels then increased at a rate of 0.6 millimeter (0.02 inch) per year for 400 years, followed by a long stable period that lasted into the nineteenth century, with drops in sea level during the last Little Ice Age. The century-scale sea-level rise is currently at its sharpest rate of increase within the entire 2 millennia study period of reconstruction, averaging 2.1 millimeters (0.08 inch) per year off the coast of North Carolina (Kemp et al. 2011).

Tebaldi et al. (2012) estimated projected changes in coastal flooding during storm events at 55 locations along the U.S. coastline. The study used a semi-empirical approach (i.e., a relationship derived between observed global annual temperature and observed annual sea level, driven by projections of global annual temperature) to estimate a 0.32-meter (1.05-foot) global sea-level rise by 2050. The authors translated the global sea-level rise projection to projections of local sea-level rise at each of the coastal locations, and then used the projections of local sea-level rise to estimate the change in storm-driven water heights for historic events for a number of return periods. This study projected that most of the 55 locations will experience an increase in the frequency of extreme storm-driven waters. For a third of the locations, flooding that used to occur once a century (i.e., a storm with a 1 percent probability of occurrence in any given year) could instead occur once a decade (i.e., a storm with a 10 percent probability of occurrence in any given year) or more frequently.

Recent studies find that the contribution of melting from large ice sheets to global sea-level rise is larger than previously modeled (Grinsted et al. 2010 citing Hansen 2007). A 20-year study funded by the National Aeronautics and Space Administration (NASA) suggests that ice sheets in Greenland and the Antarctic are melting at an increasing pace with each passing year (Rignot et al. 2011). The increased loss of ice sheets has been directly correlated to warmer summer temperatures (Gardner et al. 2011). Average losses from ice sheets in those regions grew each year by 21.9 billion metric tons (24.1 billion short tons) in Greenland and 14.5 billion metric tons (16.0 billion short tons) in Antarctica during 18 years of monitoring (Rignot et al. 2011). Total losses from both ice sheets averaged roughly 475 billion metric tons (534 billion short tons) of ice each year, enough to raise average global sea levels by 1.3 millimeters (0.05 inch) per year based on the added volume alone.

The NASA-funded study described above supports the findings cited in the MY 2014–2018 HD Final EIS that sea levels will rise faster than projected in the IPCC 2007 report due to the pace of ice sheet loss in Antarctica and Greenland (Rignot et al. 2011). The same study proposes that if current ice sheet melting rates continue, average total sea-level rise could reach 32 centimeters (12.6 inches) above current averages by 2050 from melting ice sheets, glacial ice caps, and thermal expansion. Another study projects changes in ice volume of all mountain glaciers and ice caps on Earth, using a surface mass balance model driven with temperature and precipitation projections from 10 World Climate Research

Programme CMIP3 climate models under a moderate (A1B) emission scenario. This study suggests that glaciers could lose up to 75 percent of their present ice volume by 2100 (Radić and Hock 2011). The thickness of Arctic sea ice has been declining since 1975, with the ice thickness decreasing from 2003 to 2008 at a rate up to 0.1 meter (0.33 foot) per year during winter and 0.2 meter (0.66 foot) per year during summer (Kwok and Rothrock 2009). A gradual decrease in the extent of Arctic sea ice was observed in the early 2000s, followed in 2007 by a substantial drop to less than 55 percent of the average area measured in the period 1980 through 1996 (Kwok and Rothrock 2009).

Hypoxia and Acidification

Hypoxia in ocean environments is a condition under which the dissolved oxygen level in the water is low enough to be detrimental to resident aquatic species. Recent research has found that the ability of marine organisms to survive in hypoxic conditions is further strained by warming ocean temperatures. Marine benthic organisms (i.e., organisms that live on or near the ocean floor) have been shown to have significantly shortened survival times when subjected to warmer hypoxic conditions, as the necessary dissolved oxygen threshold for survival increases with temperature (Vaquer-Sunyer and Duarte 2011).

Under projected global ocean warming, the vulnerability of marine organisms to hypoxic conditions will be increased and regions of hypoxia will continue to expand to a larger number of coastal ecosystems (Vaquer-Sunyer and Duarte 2011). Temperature increases are believed to be directly correlated to the expansion of hypoxic zones because they affect a variety of complex mechanisms, such as increasing the stratification of marine waters (Vaquer-Sunyer and Duarte 2011 citing Conley et al. 2007). Ocean acidification through the increased creation of carbonic acid (caused by increasing concentrations of CO_2 in the atmosphere) will reduce the ability of marine species to perform calcification, part of the process for making shells and creating coral habitats (Pereira et al. 2010). Higher mortality rates for marine organisms are expected due to the continuing acidification of oceans (Maclean and Wilson 2011 citing Orr et al. 2005).

Salinity

Ocean salinity levels can be affected by freshwater additions, ocean evaporation, and the freezing or thawing of ice caps and glaciers. Marine organisms are adapted to specific levels of ocean salinity and often become stressed by changing salinity levels. Additionally, changing ocean salinity levels affects the density of water, which in turn, impacts factors such as the availability of local drinking water and, potentially, global ocean circulation patterns. Durack and Wijffels (2010) investigated the decreased average salinity from 1950 to 2008 across global ocean systems. Although the globally averaged salinity change is small, changes in regional basins have been significant. Evaporation-dominated subtropical regions are exhibiting definite salinity increases, while regions dominated by precipitation are undergoing increasing freshening in response to intensification of the hydrological cycle. These effects are amplified in regions that are experiencing increasing precipitation or evaporation. New findings through surface water analyses of the Atlantic Ocean show increased salinity, while the Pacific Ocean demonstrates decreased salinity, and the Indian Ocean has observed minimal changes (Durack and Wijffels 2010). However, these are general trends and vary somewhat, both across the large bodies of water and below thermocline levels. Changes in salinity are likely to affect ocean density and structure in the future; they will also likely influence ocean circulations, especially at higher latitudes where salinity is a more active variable.

Productivity

Satellite observations of ocean chlorophyll indicate that global ocean annual primary production has declined by more than 6 percent since the early 1980s, with almost 70 percent of this decline occurring in the high latitudes (Brander 2010 citing Gregg et al. 2003). Chlorophyll is a constituent of photosynthetic organisms such as algae, and is an indicator of ecosystem productivity that is visible from satellite observations of Earth's oceans. The low latitudes generally experienced an increase in ocean primary productivity. In the northern high latitudes, these reductions correspond in part to increases in sea surface temperature.

In the past, ocean productivity has generally adjusted to natural variations in ocean climate. However, present climatic trends are expected to continue outside the bounds of previous variability at a much faster rate. Three factors are likely to affect projections of ocean productivity in response to climate change: warming temperatures, light (as described by ice cover, cloudiness, and mixed layer thickness), and altered nutrient supplies, with warming temperatures potentially the largest single factor affecting productivity (Brander 2010).

5.5.1.3.2 Adaptation

Projected impacts from climate change will require some level of adaptation from affected marine, coastal, and low-lying regions. Recent information on climate change adaptation supports previous findings. Adaptation for sea-level rise falls mostly into three major categories: retreat, accommodate, and protect (Nicholls 2011). Retreating allows the impacts of sea-level rise to occur unobstructed, while inhabitants pull back from inundated coastlines. Accommodation is the strategy of adjusting the use of coastal zones where impacts are likely (e.g., through constructing raised homes and implementing resilience measures such as early warning systems and increased insurance). Protection is the creation of barriers against sea intrusion through the use of replenished beaches and seawalls or ecosystem-based approaches such as wetlands and shellfish reefs.

Examples of coastal regions bolstering their resistance to coastal changes and sea-level rise are currently found at the state level. California's Coastal Program demonstrates the 'accommodate and protect' strategies by requiring new projects developed along shorelines to include planning for increased sea-level impacts (EPA 2012h). North Carolina's Administrative Code for Ocean Hazard Areas requires that a setback distance be calculated before placing new structures near shorelines, thus retreating from likely erosion and sea-level rise (NOAA 2011b).

5.5.1.4 Food, Fiber, and Forest Products

5.5.1.4.1 Recent Findings

This section provides an overview of the recent findings regarding observed and projected impacts of climate change on food, fiber, and forest product resources in the United States and globally. For information on previously reported findings, *see* Sections 4.5.6 (Food, Fiber, and Forest Products) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. These previously reported findings are drawn primarily from the following major international or national scientific assessment reports: IPCC's *Fourth Assessment Report* (IPCC 2007a, IPCC 2007b, IPCC 2007c); EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *The Effects of Climate Change on Agriculture, Land*

Resources, Water Resources, and Biodiversity (CCSP 2008e); U.S. Global Change Research Program's *Global Climate Change Impacts in the United States* (GCRP 2009); NRC's *Climate Stabilization Targets* (NRC 2010a); and EPA's *Climate Change Indicators in the United States* (EPA 2010c). Information from these sources is still relevant and the findings presented below supplement this information with the most up-to-date scientific assessments available. Findings that are contrary to those presented in the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS are noted.

Overall, recent studies confirm the previous research documenting and predicting changes in forest health and composition, agricultural yields, and fishery productivity. There is increasing evidence that climate change is already affecting forestry, agriculture, and fisheries across the world. Recent research has focused on detailing impacts to specific regions and systems to provide better information for adaptation.

Forests

Reports continue to focus on attributing drought-induced tree mortality events, regional forest die-offs, and vegetation shifts to climatic drivers (Carnicer et al. 2011, Sturrock et al. 2011). For example, there is strong evidence that climate change is contributing to severe droughts in the Northern Hemisphere, causing regional tree die-offs (Carnicer et al. 2011). Scientists are working to better understand the physiological mechanisms underlying drought-induced forest mortality to better predict the magnitude of future mortality events under climate change conditions (Anderegg et al. 2012). For example, a recent study indicates that while Amazon forests are well adapted to seasonal drought, multi-year drought conditions exceed this adaptive capacity, resulting in tree mortality and loss of living tree biomass carbon (Davidson et al. 2012). While changes in forest composition and structure have been observed for decades, recent studies attempt to distinguish the relative importance of climatic drivers to other factors such as land-use change. For example, a recent study of changes in forest composition in Panama since the 1980s found a correlation between climate changes and shifts toward tree species with a greater drought tolerance, although it did not establish causality, given that other factors such as El Niño could also be responsible for the increased occurrence of drought (Feeley et al. 2011).

Recent studies have also found changes in forest structure and composition across the world, though they have not attempted to distinguish climate change from other causes. For example, long-term studies have reported dramatic changes in the dynamics of tropical forests over the past few decades (Feeley et al. 2011). Forest composition has been changing in China as well, with species such as *Larix gmelinii* (a species of larch native to eastern Siberia, and adjacent northeastern Mongolia, northeastern China, and North Korea) and *Picea jazoensis* (Yezo spruce) shifting northward in recent decades (Sturrock et al. 2011). Recent warming has already resulted in earlier flowering and vegetative bud burst in some forest trees, a trend that is expected to continue (Chmura et al. 2011). Another study found that Iberian forests are experiencing long-term effects due to severe climate change-related droughts. There have also been trends toward increasing defoliation and mortality in southern European forests (Carnicer et al. 2011).

Recent work examines climate impacts on existing forest stressors to predict changes in forest composition and recommend management strategies. For example, climate change is projected to increase the frequency and severity of forest fires in areas such as the North American boreal forest (Krawchuk and Cumming 2011). A recent modeling study using the Canadian Regional Climate model under a moderately high (A2) emission scenario found that forest harvesting could be reducing the severity and frequency of wildfires. However, the combination of climate change and harvesting could permanently change the structure of boreal forests and negatively affect species and ecological communities that rely on that forest (e.g., songbirds). Loehman et al. (2011) simulated the warming associated with both the moderately high (A2) and low (B2) emissions scenarios and found that warming temperatures and increased wildfire frequency will promote the dominance of western white pine over other species in Glacier National Park in Montana. The study noted that future climate conditions could help buffer western white pine populations against the threat of white pine blister rust, a lethal fungus that kills seedlings, infects stems, and deforms trees.

Hannah et al. (2011) analyzed the potential impact of climate change on the California timber industry. The study modeled future changes in tree-species productivity and location in response to a changing climate simulated by downscaled climate projections under the moderately high (A2) and low (B1) emission scenarios. This was coupled with economic models describing landowner adaptation and returns from multiple harvesting strategies. The study projected that climate change will result in an overall decline in California's harvested timber value, with losses of up to $8.1 billion (undiscounted) by 2080. The study found significant spatial variation in impacts, and noted that forestry management strategies can mitigate lost value.

Agriculture and Croplands

Quantifying the impacts of climate change on food systems is challenging due to the complexity of interactions between crops and climatic drivers. Despite these complexities, the scientific consensus continues to be that climate change is expected to have an extensive impact on agriculture around the world, with the most severe damages expected in low latitudes (Dinar and Mendelsohn 2012). Irrigated agricultural lands are likely to be particularly vulnerable due to increased uncertainties in water supply. For example, Daccache et al. (2011) examined the impact of climate change on potato cultivation in England. The potato is very sensitive to water availability, and the study found that the combined effects of reduced rainfall and increased evapotranspiration could lead to an increase in average irrigation requirements of between 14 and 30 percent, depending on the site and emissions scenario. Recent work in this area has focused on understanding the geographic distribution of yield losses and determining viable adaptation options.

The impact of climate change on crop yields will vary by region and by crop. For example, climate change could have primarily positive impacts on production and range of favorable crop species in northern Europe but negative impacts in southern areas such as the Mediterranean basin (Moriondo et al. 2011). A simulation study of California's Central Valley found that under both moderately high (A2) and low (B1) scenarios, average cotton, sunflower, and wheat yields decreased by approximately 2 to 9 percent by 2050 compared to 2009 average yields. These results suggest that, except for alfalfa, climate change will decrease California crop yields in the long term (Lee et al. 2011).

The number of studies documenting the negative impacts of increasing temperatures on crop yields, particularly wheat continues to grow (Gouache et al. 2012). Studies show that these impacts are particularly severe when crops experience short periods of high temperatures during the reproductive period (Teixeira et al. 2011). For example, research in France suggests that heat stress in recent years during the grain-ripening phase of wheat cultivation could correlate to stagnating national wheat yields, which had been rising until recently (Gouache et al. 2012). A recent study used a modeling approach to isolate the impact of increasing temperatures on wheat yield. The study found that observed variations in average growing season temperatures of plus or minus 2 °C (3.6 °F) in the main wheat growing regions of Australia could cause reductions in grain production of up to 50 percent. The study also found that each additional day over 34 °C (93 °F) during sensitive crop growth periods resulted in a 5 percent grain yield decrease (Asseng et al. 2011). Increasing temperatures could impact crop yields, not only by exposing crops to high temperatures during sensitive growth periods, but also by failing to meet sufficient winter chill requirements. Cold temperatures in winter are important for many cultivated tree species, and insufficient winter chill can reduce crop yields and quality. For example, Luedeling et al. (2009) modeled winter chill conditions under 18 future climate scenarios in California. The study found that by the middle to end of the twenty-first century, chilling conditions will no longer be sufficient to support some of the main tree crops grown in California without adaptation measures.

Recent studies support the finding reported in the MY 2014–2018 HD Final EIS that Sub-Saharan Africa will likely be particularly vulnerable to climate change impacts on agriculture. In Sub-Saharan Africa, historical temperature increase and rainfall decrease have led to a production shortage since the 1970s. Sixteen recent studies project changes in crop yield by mid-century from minus 50 percent to plus 90 percent, with a median value of minus 11 percent (Roudier et al. 2011). Results indicate that impacts on crop yield in this region are most severe under intense warming scenarios, but rainfall can mitigate some of the projected damages (Roudier et al. 2011).

Fisheries

Changes in marine biodiversity, such as reductions in the abundance of large predatory fish and widespread mortality of reef structures and associated fish communities, are well documented. It is difficult to determine how global changes such as overfishing, coastal eutrophication, and climate change have each contributed to these trends (Rice and Garcia 2011). However, recent studies on climate change impacts on fisheries report that fishery production, spatial distribution, and phenology are at significant risk from climate change. For example, Overholtz et al. (2011) documented the sensitivity of Atlantic mackerel, which are found from Cape Hatteras to Newfoundland, to changes in temperature. The study found that over a recent 40-year period (1968 to 2008), the distribution of mackerel has shifted approximately 250 kilometers (155 miles) to the north and east. These changes are correlated with interannual temperature variability and gradual warming.

Researchers are currently developing models to project patterns of marine biodiversity under future climate change scenarios. Initial studies project that climate change will continue to alter community ranges and species biomass (Rice and Garcia 2011). For example, future changes in species distributions and maximum catch potential in the Northeast Atlantic will depend on changes in oxygen content, acidity, and phytoplankton community structure. A recently developed model, NOAA Geophysical Fluid Dynamics Laboratory Earth System Model 2.1, projects under a moderate (A1B) emission scenario that the distributions of 120 fish and invertebrate species in the Northeast Atlantic would shift northward at an average rate of roughly 46 to 52 kilometers (29 to 32 miles) per decade and deeper at an average rate of roughly 5 meters (16 feet) per decade, with the higher values of the range allowing for high physiological sensitivity to ocean acidification. Overall, the study found that the projected maximum catch potential in 2050 would decline substantially (Cheung et al. 2011). Despite recent advances in research, it is difficult to determine whether ocean primary productivity will rise or fall as a result of ocean warming, ocean acidification, and other global changes (Murawski 2011).

Disease, Pathogens, Insects, and Weed Species

Confirming findings reported in the MY 2012–2016 CAFE standards Final EIS, a recent study concludes that the last few decades have seen significant increases in large-scale decline and disease outbreaks in plant species, and this pattern is expected to continue globally (Grulke 2011). Climate variability and change can play a role in these outbreaks. For example, the hot and dry conditions of 2004 contributed to tree canker outbreaks in Alaska (cankers are localized dead areas on a tree) (Grulke 2011). The impact of climate change on pathogens will vary depending on the specific relationship between the host, the pathogen, and the environment.

Recent studies corroborate the findings reported in the MY 2012–2016 CAFE standards Final EIS that increased temperatures and earlier growing seasons are already resulting in decreased mortality and increased frequency of generations in certain insect species (Caffarra et al. 2012). For example, in 2006, the very high temperatures in southern Spain caused the European grapevine moth to complete 4 generations in 1 year rather than 3 (based on observations from 1991 to 2010). However, recent work emphasizes that while warmer temperatures might favor the development of certain pest species, they could also shorten the length of crop cycles, limiting the potential impact of pests on crop yields (Caffarra et al. 2012).

Recent research focuses on integrating analysis of pathogen dynamics into studies of how climate change impacts ecosystems and agricultural systems. For example, Olofsson et al. (2011) recently investigated how plant disease will mediate the response of ecosystems to climate change by studying tundra grass growth under increased snow-cover conditions in Sweden. They found that although the changing climate conditions favored increased biomass growth, the emergence of a parasite decreased growth. Another recent study found that projected changes in precipitation can dramatically influence the dynamics of forest pathogen species. A warmer and wetter future will likely promote pest impacts from species such as *Phytophthora* root rot and sudden oak death. Conversely, a warmer, drier future would promote increased impacts from pathogens such as *Armillaria* root disease (Sturrock et al. 2011).

5.5.1.4.2 Adaptation

Maintaining the complexity of forest structure and composition is an adaptation option that has garnered widespread political and scientific acceptance. However, because there could be tradeoffs between carbon storage and forest complexity (e.g., species diversity), it will be necessary to balance mitigation and adaptation goals (D'Amato et al. 2011). Additional adaptation options include assisting species migrations and managing forest composition and density to reduce drought stress and risk of fire and insect disturbance. In addition, post-disturbance periods could provide opportunities for adaptively altering species composition (Chmura et al. 2011). In the timber industry, Hannah et al. (2011) noted that adjusting rotation intervals and timber species could help conserve the value of California's timberlands.

Because agriculture is very sensitive to climate variability and change, this sector has already developed adaptation strategies to manage climate variation, such as increasing water efficiency and altering livestock feed composition. The costs of adaptation are difficult to quantify, but are likely to be high (Aisabokhae et al. 2012). Multiple studies have found that effective adaptation can mitigate losses or even result in higher crop yields under climate change scenarios. However, the adaptive capacity of the agriculture sector will vary across regions and crop types.

One recent modeling study investigated the potential impacts of climate change on crops by using a global crop model driven by annual mean temperature and precipitation data from two climate models under moderate (A1B) and low (B1) emission scenarios. This study found that while projected climate changes will decrease global crop yields by 2050 if planting and harvesting dates remain unchanged, adapting those dates and changing cultivar choices could avoid 7 to 18 percent of global losses (Deryng et al. 2011). In addition, using longer-season cultivars and cultivars with increased resilience to extreme temperatures and droughts could offset projected yield decreases (Turner et al. 2011). In some regions, farmers have already begun adapting to climate change. For example, in areas of Australia where farmers traditionally have grown oats, reduced precipitation and soil waterlogging has allowed them to begin producing wheat (Turner et al. 2011).

Teixeira et al. (2011) emphasized the need for local agricultural adaptations that are location and crop specific. For example, the study noted that wetland rice has a wide genetic variation for resistance to heat stress. Potential adaptations could involve selecting or genetically modifying rice plants to promote traits that confer protection against heat stress.

5.5.1.5 Industries, Settlements, and Societies

5.5.1.5.1 Recent Findings

This section provides an overview of recent findings regarding observed and projected impacts of climate change on industries, settlements, and societies in the United States and globally. For information on previously reported findings, *see* Sections 4.5.7 (Industries, Settlements, and Societies) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings are drawn primarily from the following major international or national scientific assessment reports: IPCC's *Fourth Assessment Report* (IPCC 2007a, IPCC 2007b, IPCC 2007c); EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* (CCSP 2008a); Transportation Research Board Special Report's *Potential Impacts of Climate Change on U.S. Transportation* (Transportation Research Board 2008); NRC's *Climate Stabilization Targets* (NRC 2010a); and EPA's *Climate Change Indicators* (EPA 2010c). Information from these sources is still relevant and the findings presented below supplement this information with the most up-to-date scientific assessments available. Findings that are contrary to those presented in the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS are noted.

Two literature synthesis reports, Gosling et al. (2011) and Hunt and Watkiss (2011), published after the issuance of the MY 2014–2018 HD Final EIS in June 2011, discuss projected climate change impacts in the industries, settlements, and societies sector. Gosling et al. (2011) state that literature published since the IPCC Fourth Assessment Report confirms the general trends from previous research findings pertaining to this sector. Hunt and Watkiss (2011) focus on projected impacts to cities and reaffirm the overall projected impacts of climate change on the industries, settlements, and societies sector. Overall, these new studies confirm previous findings with several minor exceptions noted in the relevant sections below.

One new study also suggests an impact not discussed in the MY 2012–2016 CAFE standards Final EIS or the MY 2014–2018 HD Final EIS: the potential direct damage to concrete infrastructure due to higher concentrations of CO_2 (Stewart et al. 2011). New research for this sector is trending toward an emphasis on city-specific studies (Gosling et al. 2011, Hunt and Watkiss 2011) that provide illustrative examples of potential climate change impacts to communities. Notably, city-specific factors and study methodologies make the results difficult to compare or transfer to other cities (Hallegatte and Corfee-Morlot 2011).

Industries

Established research, outlined in the MY 2014–2018 HD Final EIS, demonstrates that industries, including manufacturing, transportation, energy supply and demand, mining, and construction, are vulnerable to climate change, most notably in the form of extreme weather events, changes in precipitation, and heat stress.

Recent research by Pearce et al. (2011) and Ford et al. (2011) explores the vulnerability of the Canadian mining industry to climate change. Pearce et al. found that projected impacts to mining industries, including extreme weather events and associated structural weakening, and impacts to transportation systems, will have rippling effects throughout the economy, because mining is often a core industry. The study analyzed five in-depth case studies of Canadian mines, representing the range of mines over the industry, and found that all are already experiencing climate-related impacts, such as a reduction in ice roads for transporting goods to and from the mines, worsened dust emissions from quarries due to warmer temperatures, and limited water supplies. The study also identifies a new vulnerability of the mining industry – higher temperatures and diminished permafrost represent a large risk to the structural integrity of post-operational and abandoned mines. Ford et al. (2011) built on these findings, conducting a survey focusing on perceptions of climate vulnerabilities among mine operators. The authors found that the mining sector perceives climate change as an emerging risk and is developing response options, but its response is currently limited.

Services and the Economy

Projected impacts of climate change to services and the economy include impacts to the tourism and insurance industries due to changing weather norms and shifts in extreme events. Climate change also could affect the economy through impacts, direct or indirect, on trade, retail, and commercial services. For example, seaports play an important role in local economies and are vulnerable to climate change impacts such as storm surge and sea-level rise (Becker et al. 2012).

Any projected climate change impacts to cities and human settlements, as discussed throughout this section, are likely to have economic repercussions, because cities are concentrated areas of wealth and economic activity (Hallegatte et al. 2011). The potential effects of climate change on urban economies include the impacts of changes in tourism, decreases in worker productivity due to potential health problems, and impacts to long-term economic development (Hallegatte et al. 2011).

Climate and tourism are closely linked, but the economic consequences of climate change on tourism will vary by location. For example, Serquet and Rebetez (2011) show that higher summer temperatures could increase tourism to the Swiss Alps. In addition, sea-level rise associated with climate change would cause beaches in California to become narrower, affect erosion patterns during severe storms, and adversely impact beach visitation and the economic value of California's beaches (Pendleton et al. 2011). Climate change is projected to have an overall effect of redistributing tourism income globally, regardless of whether there is a net change in the size of the tourism industry (Hernandez and Ryan 2011).

Utilities and Infrastructure

Utilities and infrastructure are projected to experience damage as a result of changing temperature, precipitation patterns, extreme weather events, storm surges, and sea-level rise. For example, Hebeger et al. (2011) found that coastal flooding caused by climate change and sea-level rise would increase the level of the 100-year flood event (a flood that has a 1 percent probability of occurring in any year). The study estimated that by 2100, with 1.4 meters (4.6 feet) of sea-level rise, 480,000 people in California would be exposed to the 100-year flood. Such flooding would also inundate critical infrastructure such as emergency facilities, hospitals, schools, hazardous materials storage sites, roads, power plants, wastewater treatment plants, ports, airports, and other property. Extreme events are also projected to increase in California, exacerbating these risks (Mastrandrea et al. 2011).

Two new studies, Stewart et al. (2011) and Wang et al. (2012), introduce a projected vulnerability of infrastructure to climate change. Both studies focused on simulating concrete deterioration of Australian infrastructure using climate projections of temperature, relative humidity, and CO_2 provided by an Australian model, OZ-Clim, driven with nine World Climate Research Programme CMIP3 climate model projections. These studies found that concrete infrastructure is susceptible to corrosion directly from increased atmospheric concentrations of CO_2, notwithstanding projected physical vulnerabilities to storm events and sea-level rise. Stewart et al. (2011) estimate that climate change would increase concrete corrosion risks by 40 to 460 percent over a range of 4 emission scenarios for some regions in Australia. Wang et al. (2012) similarly concluded that existing concrete structures could deteriorate more rapidly than originally planned.

Climate change is also projected to affect transportation systems, which, as a whole, are vulnerable to the impacts of climate change in many ways. These impacts are discussed in the MY 2014–2018 HD Final EIS and include physical damage from weather events, increased safety concerns, and temperature effects on material types. Meyer and Weigel (2011) reiterate many of these concerns, including risks to infrastructural stability due to changing soil saturation, potential changes in materials selection, and the need to consider projected precipitation changes in drainage system designs. Walker et al. (2011) have delved into the specific projected impacts of climate change in Portland, Oregon, which include a projected 10 percent increase in precipitation, a seasonal shift from summer to winter precipitation, an increase in precipitation falling as rain rather than snow, reduced snowpack in nearby mountain ranges, and an overall temperature increase of 2 to 3 °C (3.6 to 5.4 °F) compared to the average temperature from 1901 to 1950. All of these projected changes could affect ground transportation systems by impacting operations and maintenance practices.

The energy sector is also broadly vulnerable to climate change. As discussed in the MY 2014–2018 HD Final EIS, climate change has the potential to affect energy supplies, including some forms of renewable energy. Schaeffer et al. (2012) indicate that climate change could impact energy demand, the availability of energy resources, and the ability to generate energy. These impacts could occur across all energy resources, including hydropower, wind power, solar energy, biofuels, marine energy, oil, natural gas, and coal.

Recent studies (Cai et al. 2011a, Doppelt et al. 2011, Reeve et al. 2011, Schaeffer et al. 2012) show that renewable energy supplies are potentially more vulnerable to climate change than fossil-based supplies. Hydropower resources are one renewable energy source that could be affected by climate change. While earlier research findings cited in the MY 2014–2018 HD Final EIS found that certain areas could experience increases in hydropower resources due to increased precipitation, more recent studies show that hydropower resources could be diminished in some areas due, for example, to decreases in snowpack (Doppelt et al. 2011) or increased evaporation from reservoirs (Cai et al. 2011a citing Gleick 1992). Reeve et al. (2011) found that climate change could also affect wave energy generation. Their study simulated potential wave energy in response to projected changes in wind off the coast of Cornwall, United Kingdom, and found that available wave power could increase 2 to 3 percent under the moderate (A1B) emission scenario. Reeve et al. (2011) note that these changes are small compared to natural variability, but could add up over the life of a wave energy farm. These latest reports reiterate the idea repeated throughout the literature that projected climate impacts, particularly on the scale of human settlements, depend on local conditions.

Two recent studies (Pryor and Barthelmie 2011, Auffhammer and Aroonruengsawat 2011) also examine the projected impact of climate change on wind energy resources. Earlier research cited in the MY 2014–2018 HD Final EIS found that wind energy resources are not expected to change significantly in northern Europe. The latest research reaches similar conclusions regarding the United States. Pryor and Barthelmie (2011) found that mid-century projected changes to wind resources as a result of climate change will not be outside the range of current wind variability, particularly in the areas of the United States with the greatest installed wind energy capacity. The study analyzed climate projections for the moderately high (A2) emission scenario from the North American Regional Climate Change Assessment Program regional climate model, nested within three atmosphere-ocean general circulation models, CGCM3, HRM3, and HadCM3, and one observationally derived dataset, the National Centers for Environmental Protection-U.S. Department of Energy reanalysis.

In addition to such impacts to energy supply, new research also expands on the projected impacts of climate change on energy demand discussed in the MY 2014–2018 HD Final EIS. Auffhammer and Aroonruengsawat (2011) estimate changes in California residential electricity demand under a number of scenarios, including combinations of the moderately high (A2) and low (B1) emission scenarios, two methods of downscaled climate model data, two electricity price scenarios, three population scenarios, and two climate adaptation scenarios. The study found that, holding population constant, climate change could increase residential electricity consumption between 18 and 55 percent by the end of the century. With population growth, those end-of-century projections increased to between a 65 and 124 percent increase in residential electricity consumption under low population growth and between 342 and 495 percent increase under high population growth.

Water and wastewater utilities could also be vulnerable to climate change. In a study projecting change in water demand in Puget Sound, in Washington State, Polebitski et al. (2011) found that climate change is likely to influence water demand and stress on public utilities. The study incorporates downscaled projections from a large climate model ensemble under a moderately high (A2) emission scenario, and finds that over the next 25 to 30 years these impacts will be counteracted by improvements in water conservation; however, Polebitski et al. state that over time, temperature-driven increases in demand could come to outweigh other factors and create stress on water resources. In addition, a study focused on central wastewater treatment systems in coastal North Carolina found that increased groundwater levels due to sea-level rise or heavy precipitation could impact wastewater treatment systems by reducing treatment efficiency, increasing the risk of treatment process bypasses, and causing physical damage from saltwater intrusion (Flood and Cahoon 2011).

Human Settlements

Human settlements are primarily vulnerable to flood risks from sea-level rise, physical damage from extreme events or precipitation, and impacts to water supplies from sea-level rise and changes in precipitation patterns.

Vulnerability of human settlements to climate change varies by city and depends on factors such as exposure to extreme events, local topography, building norms, the city's socioeconomic structure, and cultural aspects of the population (Hallegatte and Corfee-Morlot 2011). Hunt and Watkiss (2011) reviewed the literature on climate change impacts in cities and found that research has focused on sea-level rise, health impacts, and impacts to water resources, with less research on climate impacts to energy, transportation, and built infrastructure. In addition, research has focused predominantly on coastal cities, leaving a research gap on the projected impacts of climate change in cities across the range of geographic locations (Hunt and Watkiss 2011).

One recent study on climate change impacts to coastal cities projected that by 2070, 150 million people globally will be exposed to 100-year flood risks (i.e., a flood that has a 1 percent chance of occurring within a given year), or 3 times the number of people exposed at present (Hanson et al. 2011). The projection accounted for population growth, economic growth, natural and potentially human-induced land subsidence or uplift (i.e., descending or rising elevation of land), and a homogeneous global sea-level rise of 0.5 meters (1.6 feet) above current levels, which is in the upper range of IPCC sea-level projections (now considered conservative). The study projects that assets exposed to sea-level rise could increase tenfold by 2070, and that Asia will be the region with the most exposed population and assets. Two U.S. cities, Miami and New York, are in the top 20 cities world-wide in terms of population exposed to coastal flooding (Hanson et al. 2011). Four U.S. cities – Miami, New York, New Orleans, and Virginia Beach – are projected to be among the top 20 cities worldwide with the highest value of exposed assets (Hanson et al. 2011).

A recent study found that climate change and sea-level rise are changing the coastline in Alaska (Gorokhovich and Leiserowiz 2012). The study used projected sea-level rise of 0.2 meters (0.66 foot) by mid-century and 0.53 meters (1.74 feet) by the end of the century to estimate projections of mean erosion rates, and found that the Alaskan coastline could lose between 70 and 1,000 meters (230 to 3,281 feet) of shoreline, depending on specific location. These changing dynamics threaten Alaskan coastal communities and are prompting studies to better understand adaptation options (Karvetski et al. 2011).

In San Diego, climate change is projected to cause sea-level rise, increased storm surge, increased heat waves, and changes in water supply and demand (Messner et al. 2011). The study also states that climate change will cause increases in water demand along with decreases in water supply, presenting a challenge for water resource managers and planners. In California's Sierra Nevada region, climate change is projected to cause increases in flood magnitudes by the end of the century due to increases in wintertime soil moisture, heavy precipitation events, storm frequency, and days with precipitation in the form of rain rather than snow (Das et al. 2011).

Recent research has also focused on projected water shortages due to climate change in addition to coastal flood risks. Arnell et al. (2011) projected that unmitigated climate change resulting in a 4 °C (7.2 °F) increase in global mean temperatures compared to pre-industrial levels could lead to increased water shortages for between 6 and 22 percent of the global population by 2100. The study used the IMAGE integrated assessment model, accounting for projections of population, economic growth, energy and food production, land use change, GHG emissions, and climate. Climate change could also impact water quality, which would affect human populations. Tong et al. (2012) simulated conditions in 2050 by investigating streamflow and nutrient processes under five hypothetical climate change scenarios coupled with a land-use model for a watershed in Ohio. They found that total phosphorous and nitrogen concentrations would increase under all future climate and land use scenarios, thereby adversely affecting water quality.

Social Issues

Climate change is projected to have social impacts, including increased risks to vulnerable populations and cultural resources. These risks, including heat waves, food insecurity, disrupted sanitation systems, and physical damage to cultural resources, are expected to disproportionately impact the poor. However, a recent paper tempers some projections of the impacts of climate change on global poverty levels. Skoufias et al. (2011) performed a literature review of the projected impacts of climate change on poverty and found that, overall, previous studies are likely to have overestimated the impact that climate change could have on poverty. The authors note that climate change is indeed expected to slow the pace of global poverty reduction, but it is not likely to reverse declines in poverty achieved by continued economic growth.

However, climate change impacts on poverty are not likely to be distributed evenly, and could affect Africa, South Asia, and other developing regions of the world more severely, along with poorer households in general (Skoufias et al. 2011). A study by Samson et al. (2011) supports this view. They developed a global index of projected climate change impacts on populations, and found that the largest negative impacts will occur in Central America, parts of South America, the Middle East, Southeast Asia, and much of Africa. Samson et al. (2011) also found that the countries with the highest per capita GHG emissions are projected to experience relatively low impacts from climate change. These uneven impacts are expected both in the United States and across other countries. Shonkoff et al. (2011) showed that Californians of lower socioeconomic status could experience disproportionately high impacts from climate change through changes in the price of water, food, and energy; changes in agricultural employment opportunities; damage to infrastructure; and changes in insurance premiums. Low-income populations are also more likely to be vulnerable to sea-level rise and coastal flooding in California (Heberger et al. 2011, Mastrandrea et al. 2011). *See* Section 7.6 for a more complete discussion of the environmental justice issues associated with the Proposed Action.

National Security

Climate change is also projected to have implications for national security, as discussed in Sections 4.5.7.2 and 5.5 of the MY 2014–2018 HD Final EIS.

This section draws heavily from national security reports, as peer-reviewed studies are unavailable. These reports represent a collection of security assessments based on congressional testimonies and assessments from military advisory boards and councils on foreign relations.

Climate change has profound implications for America's national security, both domestically and abroad, as one of many factors influencing security and conflict (Scheffran and Battaglini 2011). Sea-level rise, storm surges, extreme weather events, and changes in temperature and precipitation patterns all pose serious threats to global stability. Regions in Asia, Africa, and the Middle East with marginal living standards will be particularly vulnerable as economic and environmental conditions worsen (NIC 2008, CNA 2007). Other examples of potential destabilizing conditions are water scarcity in the Middle East, flooding due to sea level rise in Bangladesh (Scheffran and Battaglini 2011, Stevenson et al. 2010), land-use conflict in Northern Africa due to desertification (Scheffran and Battaglini 2011), and decreased global food security due to changes in water availability and plant diseases (Chakraborty and Newton 2011). The national security impacts to the United States will be primarily indirect, as climate change impacts will exacerbate existing problems in other countries and increase the risk of domestic instability and intra-state conflict (Fingar 2008, NIC 2008). Further, climate change acts as a threat multiplier[4] for instability in volatile regions of the world (Campbell et al. 2007, DOD 2010, NIC 2008, CNA 2007).

Areas of conflict driven by climate change that might impact U.S. and international security include the following:

- Increased conflict over resources, stemming from changes in agricultural production and freshwater availability (Brown and Crawford 2009, Chakraborty and Newton 2011, CNA 2007, ECEC 2008, Pew Center on Global Climate Change 2009)
- Risk of economic damage to coastal cities and critical infrastructure from sea-level rise and an increase in natural disasters (CNA 2007, Pew Center on Global Climate Change 2009, Busby 2007, Scheffran and Battaglini 2011)
- Loss of territory and border disputes resulting from sea-level rise
- Environmentally induced migration from loss of coastal land, desertification, and a decreased availability of resources due to climate change (Pew Center on Global Climate Change 2009, ECEC 2008, Scheffran and Battaglini 2011)
- Potential for tension and instability over energy supplies (CNA 2007, ECEC 2008)
- Increasing pressure on international governance, stemming from the potential resentment of those impacted by climate change towards those considered responsible for climate change (ECEC 2008).

These areas of conflict could add political and social tension, as well as an economic burden, to the United States and other stable countries, if, for example, such countries were to accept large immigrant and refugee populations (CNA 2007, DOD 2010, ECEC 2008, Busby 2007). In addition, the U.S. military could become overextended as it responds to extreme weather events and natural disasters, along with current or future national security threats (CNA 2007, Pew Center on Global Climate Change 2009, DOD 2010, Busby 2007).

Potential resource-based conflicts overseas could result in impacts in the United States, such as increasing demand for foreign aid, and therefore reducing capacity to respond to domestic natural disasters. Conflicts over resources, particularly food and water, have been a major factor in historical episodes of warfare and violence (McNeely 2011). Projected impacts of climate change on crop productivity and on water resources, as discussed above, are therefore likely to result in future conflicts, particularly in developing areas where the availability of natural resources is already limited (McNeely 2011). As a result of the risks described above, the National Intelligence Council has expressed increasing concern regarding the geopolitical and national security consequences of climate change (NIC 2008).

5.5.1.5.2 Adaptation

Much of the recent literature on climate change and the industries, settlements, and societies sector has focused on ways that human settlements can adapt to the projected impacts of climate change (Cook and Dowlatabadi 2011, Doppelt et al. 2011, Hallegatte and Corfee-Morlot 2011, Hernandez and Ryan 2011, Hunt and Watkiss 2011, Kunreuther et al. 2011, Meyer and Weigel 2011, Pearce et al. 2011,

[4] "Threat multiplier" refers to an action that further intensifies the instability of a system that poses a security concern.

Rosenzweig et al. 2011, Winn et al. 2011). Adaptation efforts in the United States are also underway at the state level in many states, including but not limited to, Alaska, California, Maryland, North Carolina, New Hampshire, Massachusetts, Oregon, Pennsylvania, Vermont, and Virginia, and at the local level in major population centers, including New York City, Chicago, Miami-Dade County in Florida, and King County in Washington.

In general, settlement-level adaptation efforts to date have focused on vulnerability assessments to identify projected climate impacts and vulnerabilities at the local level and incorporation of adaptation concepts into ongoing planning efforts (Hallegate and Corfee-Morlot 2011, Hunt and Watkiss 2011). Adaptation efforts to date have also primarily focused on coastal areas and impacts such as sea-level rise and storm surge (Hunt and Watkiss 2011). New York City, for example, has developed a risk management approach for adaptation planning and is at the forefront of city climate adaptation efforts (Horton et al. 2011). New York City has begun to implement some adaptation measures, such as raising the elevation of pumps and electrical equipment at one of the city's wastewater treatment plants (Hunt and Watkiss 2011, Rosenzweig et al. 2011). Karvetski et al. (2011) have begun to develop a framework for identifying communities vulnerable to climate change in Alaska.

In addition to occurring at the city or government scale, adaptation can also occur for specific businesses or industries. Winn et al. (2011) propose a new framework for businesses to think about climate change as a "massive discontinuous change" in the context of organization science. The tourism and insurance sectors are also working to develop not just adaptation measures, but also processes for prioritizing and designing them (Cook and Dowlatabadi 2011, Hernandez and Ryan 2011). The mining (Ford et al. 2011) and seaport (Becker et al. 2011) sectors are also aware of the potential impacts of climate change, but overall, have not yet begun to adapt.

5.5.1.6 Human Health

5.5.1.6.1 Recent Findings

This section provides an overview of the recent findings regarding observed and projected impacts of climate change on the human health sector in the United States and globally. For information on previously reported findings, *see* Sections 4.5.8 (Human Health) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings were drawn primarily from the following major international or national scientific assessment reports: U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* (CCSP 2008f); IPCC *Fourth Assessment Report* (IPCC 2007a, IPCC 2007b, IPCC 2007c); EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); Harvard Medical School's *Climate Change Futures: Health, Ecological and Economic Dimensions* (Epstein et al. 2006); NRC's *America's Climate Choices: Advancing the Science of Climate Change* (NRC 2010c); NRC's *Climate Stabilization Targets* (NRC 2010a); and National Institute of Environmental Health Sciences' *Human Health Perspective on Climate Change* (Portier et al. 2010). Information from these sources is still relevant and the findings presented below supplement this information with the most up-to-date scientific assessments available. Findings that are contrary to those presented in the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS are noted. Overall, new studies corroborate the previous research documenting and predicting changes in human health.

Heat and Cold Events

Previous research cited in the MY 2014–2018 HD Final EIS found that the number of hot days, hot nights, and heat waves has increased, contributing to human morbidity and mortality directly through heat stress and indirectly through a heightened risk of forest fires, reduced air quality, and increased stress on the electrical grid causing brown- or blackouts. Cold days, cold nights, and frost days were found to be less common, generally producing beneficial health effects. Recent research reiterates these impacts.

Heat-related mortality and morbidity is a greater issue for cities than for rural areas, due to the urban heat island effect, in which temperatures in cities increase significantly faster compared to rural areas (Harlan and Ruddell 2011). A recent study estimated future heat-related mortality due to climate change compared to a 1961 to 1990 baseline rate using city-specific models for London, Lisbon, and Budapest, based on projections of temperature across 21 global climate models used in the IPCC Fourth Assessment Report under a moderate (A1B) emission scenario. The study found that climate change could have a minor impact on heat-related mortality in the 2030s, but by the 2080s, the death rate attributable to increased heat events would rise to the order of 2 to 6 per 100,000 people in London compared to a baseline of approximately 2 per 100,000 people; 4 to 50 per 100,000 people in Lisbon compared to a baseline of approximately 5 per 100,000 people; and 10 to 24 per 100,000 people in Budapest compared to a baseline of approximately 6 per 100,000 people (Gosling and Lowe 2011).

One study modeled the regional variations in seasonal mean temperatures that could occur under a global mean temperature rise of 2 °C (3.6 °F). This temperature threshold was found to adversely impact health and human services, as well as access to food and water (Anderson 2011 citing IPCC 2007). This study found that a mean increase of 2 °C (3.6 °F) could cause seasonal mean temperatures to consistently exceed the most extreme values experienced in the second half of the twentieth century. The study found that hot extremes are anticipated in the Amazon, much of Africa, Indonesia, and the Middle East, which can have significant implications for human health.

Although climate change is expected to bring about a rise in average temperatures, it is also anticipated to increase the intensity of winter storms in some places, potentially leading to an increase in cold-related mortality and morbidity. Skin exposure to cold weather can cause respiratory illness and infectious diseases such as pneumonia and influenza. In addition, older adults are generally more vulnerable to health effects from exposure to winter storms and other cold-weather events (Conlon et al. 2011).

Aeroallergens

As discussed in the MY 2014–2018 HD Final EIS, the state of the science continues to support the conclusion that pollen counts in North America have increased significantly in recent years, and the spring season is generally longer with the rise in temperatures, prolonging the allergy season (Friel et al. 2010 citing Food Agric. Organ. 2006, Ford et al. 2006, Frank et al. 2006).

Potential increases in allergens under a changing climate could increase respiratory health risks, particularly for children. Recent research has projected increases in weed pollen and grass pollen under various climate change simulations; these allergens are known to exacerbate children's asthma and cause hospitalizations (Sheffield and Landrigan 2011 citing Héguy et al. 2008, Schmier and Ebi 2009, and Ziska et al. 2008).

Consistent with earlier studies, increased temperatures from climate change are projected to increase ground-level ozone concentrations, triggering asthma attacks among children (Bernstein and Myers 2011). Exposure to smoke from forest fires, which are likely to occur more frequently in the future, cause asthma and respiratory illnesses in children (Bernstein and Myers 2011 citing Liu et al. 2010, Bernstein and Mysers 2011 citing Kunzli et al. 2006).

Water- and Food-Borne Disease

Climate change is also expected to significantly increase the incidence of diarrhea in some countries. A recent study investigates how six regions in the tropics and subtropics – including South America, North Africa, the Middle East, equatorial Africa, southern Africa, and Southeast Asia, all of which have high incidence of dehydration and diarrhea – could experience increases in diarrhea incidence as average temperatures rise. This study estimates an average temperature increase of 4 ^{o}C (7.2 ^{o}F) over land in the study area by the end of the century, compared to a 1961 to 1990 baseline, based on an ensemble average of 19 climate models using a moderate (A1B) emission scenario. A relatively simple linear-regression relationship was developed between diarrhea incidence and temperature increase based on the results of five independent studies. Applying this relationship, the projected mean increase in the relative risk of contracting diarrhea across the six study regions is eight to 11 percent in the period 2010 to 2039, 15 to 20 percent in the period 2040 to 2069, and 22 to 29 percent in the period 2070 to 2099 (Kolstad and Johansson 2011).

Climate change is also projected to affect the rates of water- and food-borne diseases. Currently, food-borne diseases cause an estimated 5,000 deaths, 325,000 hospitalizations, and 76 million illnesses annually in the United States (Ge et al. 2011 citing Mead et al. 1999). A new study tested how climate change can affect the spread of Salmonella. Both extended dryness and heavy rain were tested, and the authors found that these conditions facilitated the transfer of Salmonella typhimurium into the edible portions of lettuce and green onion when Salmonella was present in the soil. If climate change were to cause excessive drought or heavy rain, it could increase the risk of disease outbreaks (Ge et al. 2011).

Vector-Borne Disease

Vector-borne diseases are spread from one host to another through vectors, which are the transmitters of disease-carrying organisms. As discussed in the MY 2014–2018 HD Final EIS, there is significant evidence that climate change will affect vector-borne diseases such as malaria, cholera, dengue, and plague, but it is difficult to predict these impacts at local scales. For example, projecting the potential spread of mosquito-borne pathogens requires weighing conflicting responses to changes in temperature by mosquitoes. In areas with cooler average summertime temperatures (20 °C [68 °F]), a temperature increase can increase biting rates, parasite replication within mosquitoes, and mosquito development, but it can also increase mosquito mortality. The net effect could either increase or decrease the spread of vector-borne diseases, making it challenging to predict an end result (Rohr et al. 2011).

Another study found a strong relationship among Gross Domestic Product (GDP) per capita, climate change, and the risk of malaria. GDP and climate change have a direct impact on the risk of malaria in a given region. Socioeconomic development and public health systems have significantly reduced the incidence of malaria in many countries, although these impacts are generally not included in studies projecting the transmission of malaria. The study uses a logistic regression model of temperature, precipitation, and GDP per capita to project vulnerable regions in 2030 and 2050 under a moderate (A1B) emission scenario. By 2050, approximately 5.2 billion people are projected to be at risk of contracting malaria if only climate change impacts are considered, 1.95 billion people are at risk if climate change impacts and GDP per capita are considered, and 1.74 billion are at risk if only GDP per capita is considered, compared to an estimated 2.3 billion people who were at risk of malaria in 1994 (Béguin et al. 2011).

In China, the transmission and risk area of schistosomiasis, an infectious disease transmitted by parasitic worms, could be affected by rising temperatures. The study compared the temperature thresholds for both the development of the host (a type of snail) and the development of the disease itself to the projected temperature increase in China in 2030 of 0.9 °C (1.6 °F) and 2050 of 1.6 °C (2.9 °F) compared to the median of average January temperatures across China in 2000. The study projected that this disease could expand its geographical range by 783,900 square kilometers (approximately 303,000 square miles), covering 8.1 percent of China's surface area by 2050 (Kan et al. 2011 citing Zhou et al. 2008).

In the United States, Lyme disease is a common vector-borne disease, with children between the ages of 5 and 9 having the highest incidence of infection (Bernstein and Myers 2011 citing Bacon et al. 2008). In response to warming temperatures, populations of the black legged tick (*Ixodes scapularis*, often known as the deer tick) have been expanding and increasing in number across North America northward toward Canada and lower Michigan in the United States (Bernstein and Myers 2011 citing Ogden et al. 2010).

Skin Cancer

Climate change is expected to alter temperature, precipitation, and cloud cover, which can alter sun exposure behavior and change the risk of ultraviolet (UV) ray-related health outcomes. In addition, possible increases in the use of pesticides and herbicides to counteract projected increases in pests, diseases, and weeds in new areas could increase the risk of human exposure and health effects, including cancer (Friel et al. 2011).

Globally, there has been an increase in cases of skin cancer over the past several decades, due in part to increased exposure to UV-B radiation caused by factors such as lifestyle changes and stratospheric ozone depletion. Studies suggest that higher temperatures contribute to the development of skin carcinoma, and one new study estimates that a long-term temperature increase of 2 °C (3.6 °F) compared to 1990 temperatures could raise the carcinogenesis effects of UV radiation by 10 percent (Andersen 2011 citing van der Leun and de Gruijl 2002).

Indirect Impacts on Health

As discussed in the MY 2014–2018 HD Final EIS, some of the indirect impacts of climate change on health include water scarcity, food security, and psychological impacts. A recent study estimates that cereal grain yields in South Asia will decline by 10 to 20 percent by the end of the twenty-first century due to climate change (Friel et al 2011 citing Ingram et al 2008). Overall, the potential effects of climate change on food yield, water, and fuel costs will likely raise food prices, and in turn leave some people only able to purchase energy-dense, highly processed foods rather than healthful, more expensive foods, therefore increasing cases of malnutrition, obesity, and diabetes (Friel et al. 2011). The impacts of climate change on food and water security will be particularly burdensome on children, who are more susceptible to malnutrition and disease (Sheffield and Landrigan 2011). In the Sahel region of Africa, expanding arid climates could hinder agricultural production, resulting in an increase in malnutrition, stunting, and anemia throughout the population. By 2025, an additional six million people in Mali, Africa – of which one million are children – are at heightened risk of malnutrition due to climate and livelihood changes from increasing temperatures and decreased rainfall across the region. As the arid region expands, it is projected that approximately 250,000 children will suffer stunting, 200,000 children will be malnourished, and more than 100,000 will be anemic (Jankowska et al. 2012).

As discussed in the MY 2014–2018 HD Final EIS, climate change is also projected to have psychological impacts. An increased frequency of extreme weather events and the likely competition for natural resources will contribute to stress and anxiety (Friel et al. 2011). Natural disasters such as Hurricane Katrina have caused post-traumatic stress disorder, in addition to higher instances of depression and drug and alcohol abuse (Friel et al. 2011, Doherty and Clayton 2011 citing Anderson 2001).

5.5.1.6.2 Adaptation

As discussed above, it is becoming increasingly important for countries to address the impacts of climate change on human health through adaptation policies and strategies (Huang et al. 2011 citing WHO 2009). High-income countries, such as the United States, are more likely to have longer-term adaptation strategies with high governmental participation, such as increasing awareness, monitoring, and enhanced research, whereas low income countries are expected to take more reactive adaptation measures at the individual level, such as retreating, adjusting, and securing resources (Berrang-Ford et al. 2011). Jankowska et al. (2012) suggest that landscape-scale demographic processes, such as migration, could be necessary in areas where food access and availability decline due to the effects of climate change.

Harlan and Ruddell (2011) examined risk management strategies for various major cities throughout the United States that will help combat the effects of climate change on human health, including heat and health watch warning systems, air quality monitoring and alert systems, and urban forests, which will help increase shade and reduce heat-related illnesses. To ensure food security and prevent malnutrition due to climate change, Friel et al. (2011) suggest new food production techniques, improved food storage facilities to withstand extreme weather, and new crop varieties.

5.5.1.7 Tipping Points and Abrupt Climate Change

5.5.1.7.1 Recent Findings

This section provides an overview of recent findings regarding observed and projected impacts of climate change on tipping points, and abrupt climate change. For information on previously reported findings, *see* Sections 4.5.9 (Tipping Points and Abrupt Climate Change) of the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS. The previously reported findings are drawn primarily from the following major international or national scientific assessment reports: U.S. Climate Change Science Program and the Subcommittee on Global Change Research's *Abrupt Climate Change* (CCSP 2008g); IPCC *Fourth Assessment Report* (IPCC 2007a, IPCC 2007b, IPCC 2007c); EPA's *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (EPA 2009e); NRC's *America's Climate Choices: Adapting to the Impacts of Climate Change* (NRC 2010d); NRC's *America's Climate Choices: Advancing the Science of Climate Change* (NRC 2010c), and *The Copenhagen Diagnosis* (Allison et al. 2009). In addition, Lenton et al. (2008), a peer reviewed article, was an important resource for this discussion.

The previously reported findings remain valid and are relevant to the discussion on tipping points and abrupt change. The following sections augment the previous literature by summarizing recent scientific findings associated with specific systems that potentially have a tipping point, as well as the broader issues regarding decisionmaking in light of emerging knowledge about tipping points and abrupt climate change.

"Tipping points" refer to thresholds within Earth systems that could be triggered by continued increases in the atmospheric concentration of GHGs, incremental increases in temperature, or other relatively small or gradual changes related to climate change. Earth systems that contain a tipping point exhibit large or accelerating changes or transitions to a new physical state, which are significantly different than the rates of change or states that have been exhibited in the past, when the tipping point is crossed. Examples of tipping points in Earth systems include rapid melting or permanent loss of Arctic sea ice, the Greenland ice sheet, and the West Antarctic ice sheet; slowing of the Atlantic Meridional Overturning Circulation (AMOC); changes in the behavior of the El Niño-Southern Oscillation; changes in the Indian summer monsoon or the West African monsoon; increased forest dieback in the Amazonian rainforest; die-off events in boreal forests; changes in the behavior of dust storms in the Bodélé Depression at the southern edge of the Sahara Desert; rapid releases of CH_4 to the atmosphere from undersea hydrates or melting permafrost; and large-scale changes in precipitation and the hydrologic cycle.

Recent literature (e.g., Lenton 2011, Lenton and Schellnhuber 2011, Lenton 2012, Levermann et al. 2011) provides an overview of various potential tipping points, focusing largely on the set of Earth systems outlined above (e.g., ice sheet loss, slowing of AMOC, and changes in ENSO). The recent studies offer some estimates for the range of temperatures at which certain tipping points might be crossed and the likelihood of such an occurrence before 2100; however, these risk assessments are largely qualitative. The temperature ranges are typically broad and subject to large uncertainty but indicate that global average temperature increases of 1 to 3 °C (1.8 to 5.4 °F) above pre-industrial levels could threaten the stability of the Greenland ice sheet, Arctic sea-ice coverage, and the Hindu-Kush-Himalaya-Tibetan glaciers. Temperature increases above 3°C increase the risk of triggering large-scale discontinuities, and there is general agreement among recent studies (Schellnhuber 2009, Lenton and Schellnhuber 2011, McNeall et al. 2011) that these risks, although difficult to quantify, grow with greater anthropogenic warming.

Levermann et al. (2011) and Lenton (2012) focus on tipping points that could have important consequences for Europe and the Arctic, respectively. Their assessments of ice sheets and arctic summer sea ice agree with earlier analyses and show that the probability of occurrence increases with increasing global temperatures. Both studies find that there is low confidence and a low probability of occurrence for the shutdown of the AMOC, independent of the level of future warming. Losses of Arctic stratospheric ozone are also assessed as having a low probability of occurrence. The risk of ozone loss is expected to become negligible past 2060, at which point chlorine concentrations – which are associated with ozone loss – will have dropped below 1980 levels due to expected compliance with the Montreal Protocol. Lenton (2012) considers several other potential tipping points for the Arctic region (e.g., boreal forest dieback, permafrost, and loss of Arctic winter sea ice), but finds that many of these thresholds are unlikely to be crossed without relatively larger amounts of warming (greater than 4 °C (7 °F) warming above the 1980 to 1999 global mean temperature).

Arctic Sea Ice

Earlier research cited in the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS identified Arctic sea-ice coverage as a part of the climate system with a potential tipping point. Statistical measurements of Arctic sea ice suggest that ice coverage is declining at a faster rate in recent decades and could be exhibiting a non-linear response to warmer air temperatures, which is characteristic of a tipping point or abrupt change in system behavior. Sea ice declines might also have a primary role in the rapid temperature increases the Arctic is experiencing compared to the global average (a phenomenon known as "arctic amplification") (Screen and Simmonds 2010). The relationship between the loss of sea ice and regional temperature is an example of the ice-albedo feedback;[5] such feedbacks are a potential characteristic of a system that possesses a tipping point or is capable of exhibiting abrupt changes. Recent studies have presented a synthesis of current Arctic sea-ice research (Stroeve et al. 2011a), examined the response of Arctic sea ice to a period of favorable conditions for ice retention in 2009 and 2010 (Stroeve et al. 2011b), evaluated the potential for abrupt losses of Arctic sea ice (Holland 2010, Eisenman and Wettlaufer 2009, Wang and Overland 2009), and investigated recent transition points in observations of the mean and variability of sea-ice extent (Carstensen and Weydmann 2012).

Since satellite observations of Arctic sea ice began in 1979, a significant decline in the extent of summer sea ice[6] has been observed, with the record minimum extent recorded in 2007. The relatively steep decline has motivated discussion of the potential timing of the Arctic becoming ice-free during the summer at some point in the twenty-first century, potentially by 2030 (Stroeve et al. 2008). Despite a slight rebound in sea-ice extent in September 2009, which was due in part to a favorable shift in the atmospheric circulation for sea-ice retention during the previous winter (Stroeve et al. 2011a), the large melting events in recent years have increased the amount of thinner, younger sea ice across the Arctic in the springtime, which can increase the ice's overall vulnerability to melting (Holland 2010, Stroeve et al. 2011a). This vulnerability is expected to increase the year-to-year variability exhibited by Arctic sea ice (Holland 2010), because the ice is likely to exhibit an enhanced response to intrinsic climate variability. However, it is not clear whether this increase in variability is best classified as a "threshold response" or simply an "abrupt change" (Holland 2010). Several studies have argued that summer sea ice does not necessarily involve (Abbot et al. 2011) – or is unlikely to involve (Notz 2009, Tietsche et al. 2011, Serreze 2011) – an irreversible transition to an ice-free state, and that the system would only have a true tipping point compared to the loss of winter sea ice. Despite differences of opinion about the progression of sea-ice loss, the continuation of warming in the Arctic lowers the likelihood of a substantial future recovery in the extent of Arctic sea ice (Duarte et al. 2012, Stroeve et al. 2011b).

Greenland and West Antarctic Ice Sheets

The MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS summarized research evaluating the possible timing and sea-level rise effects of the collapse of the Greenland and West Antarctic ice sheets. Recent research has summarized the current state of knowledge and observed changes in the rate of mass loss from these ice sheets (Lenton and Schellnhuber 2011, Good et al. 2011).

The Greenland and West Antarctic ice sheets are currently losing mass (Lenton and Schellnhuber 2011, Good et al. 2011, Chen et al. 2009). Recent estimates using a longer time series of polar ice-sheet mass

[5] Ice-albedo feedback refers to how changes in ice coverage can affect reflectivity in such a way as to reinforce the initial change in ice coverage. For example, as sea-ice coverage is reduced, the exposed areas of ocean will absorb more incoming solar energy (i.e., ocean water has a lower albedo than ice), raising temperatures. This warming will lead to further losses of ice. The opposite case, involving an increase in ice coverage and cooling, is also a self-reinforcing mechanism.
[6] The September sea-ice extent is typically considered the annual minimum in ice extent. It should be noted that discussion of the September sea-ice extent (or late summer sea-ice extent) is simply one metric of the impact of sea ice on climate,and vice versa. For example, the loss of sea ice can have impacts on regional climate during subsequent months (e.g., thinner ice and ice-free areas in the fall and winter allow for more heat to be transferred from the ocean to the atmosphere) and in future years (e.g., thinner or less ice in one season may contribute to thinner or less ice in a following season).

measurements and improved error-correction techniques have found that East Antarctica ice sheets are also losing mass, whereas previous estimates showed no change or slight increases in mass in East Antarctica (Chen et al. 2009). Large, rapid losses of these ice sheets can have substantial consequences for sea-level rise. Uncertainties in the dynamics of melt in Greenland and West Antarctica are an important contributor to the uncertainty in overall estimates of sea-level rise in the future (*see* Section 5.1.5). Although there are significant uncertainties in our understanding of the mechanisms associated with abrupt ice loss, future rates of ice loss, and subsequent sea-level rise, scientists who convened for a recent workshop to discuss the state of the science agreed that “ice sheets are capable of highly nonlinear dynamical behavior that could contribute significantly to short-term sea-level rise (to 2100), and may also produce a long-term commitment (e.g., centuries-long) to substantial (many meters) of sea-level rise” (IPCC 2010).

Ecological Tipping Points

Examples of ecological tipping points could include dramatic changes in ecosystem functions and productivity, levels of biodiversity, or species populations in response to abrupt or incremental climate changes. Warren et al. (2011) reviewed a wide range of studies that examine the impacts of warming on ecosystems around the globe. For increases in global mean temperature less than 2 °C (3.6 °F) above pre-industrial temperatures, most impacts are related to changes in species’ ranges and enhanced degradation of biodiversity hotspots (i.e., areas with a high concentration of diverse species that are threatened by human activities), such as coral reefs. Above the 2 °C (3.6 °F) warming threshold, negative impacts to ecosystems are projected to become more widespread, with greater risks for the collapse of ecosystems and extinction of species. In addition, many ecosystems and land areas that have served as net sinks of CO_2 could transition to become sources, acting as a positive feedback to global warming (Warren et al. 2011).

Salazar and Nobre (2010) recently investigated critical thresholds for biome shifts in the Amazonian tropical rainforest. The authors found that, without accounting for CO_2 fertilization, seasonal forests or savanna would replace the tropical rainforest in response to changes in precipitation and temperature, given a global average temperature increase of 2 to 3 °C (3.6 to 5.4 °F). However, when accounting for CO_2 fertilization, the changes in Amazonian tropical rainforest biome were “considerably smaller,” suggesting that the CO_2 fertilization effect could play an important role in mitigating these impacts. The authors note that the response of tropical ecosystems to atmospheric CO_2 increases is a key area of uncertainty and that more research is necessary to reduce the uncertainty in projected shifts in Amazonian tropical forest biomes.

Recent research by Williams et al. (2011) documents examples of abrupt ecological changes from the paleo-climatological record. These events indicate that ecological systems can experience rapid change in response to abrupt climate change (extrinsically forced ecological change), or arising from internal dynamics (intrinsically forced ecological change) in which the climate forcing could have been relatively small or gradual. Each of these types of events is instructive for considering adaptation to future impacts of climate change; the impacts of extrinsically forced changes relate to the limits to adaptive capacity within ecological systems, while the results of intrinsically forced changes depend on site-specific conditions and the magnitude of other types of stressors (Williams et al. 2011).

Marengo et al. (2011) reviewed the state of knowledge of climate change in the Amazon region. The authors find that a 3 to 4 °C (5.4 to 7.2 °F) increase in temperature from climate change could be a possible tipping point threshold that could lead to savannization of the Amazon Basin. Large-scale deforestation, on the order of 40 percent of the original extent of the Amazon, could likewise trigger a tipping point that could decrease rainfall across the eastern Amazon. Complete deforestation could warm eastern Amazonia by more than 4 °C (7.2 °F) and decrease rainfall from July to November by 40 percent, in addition to climate change effects. Marengo et al. (2011) note that tipping points could be encountered either through incremental shifts in climate above a critical threshold, or through changes in the frequency or severity of extreme events.

Human-Environment Tipping Points

Human-environment tipping points could involve abrupt changes in socioeconomic systems (e.g., economic, societal, or political systems) in response to ecological shifts and regime changes. Recent modeling experiments by Horan et al. (2011) suggest that the rules established and enforced by institutions have an important role in establishing the nature of tipping points in managed human-environmental systems. This study investigated a simplified model involving simulation of the behavior of sport fishermen and the abundance of multiple freshwater species, subject to scenarios for management of the fish harvest rules. Horan et al. (2011) conclude that strong institutions – those with the ability to monitor and adjust to environmental and resource conditions – can best avoid abrupt changes and the crossing of tipping points.

Rasmussen and Birk (2012) examine the threats posed by tipping points to human and national security. By evaluating the security impacts of three tipping points – destabilization of the West-Antarctic ice sheet, acidification of Earth's oceans, and Amazon rainforest dieback – the authors argue that it is likely that, over the longer term, abrupt climate changes pose the greatest threat to human security. They suggest that strengthening and reforming international political institutions presents the most promising approach to addressing these security threats.

Separately, Sherwood and Huber (2010) examined temperature thresholds at which humans would be unable to adapt to climate change-induced warming. They conclude that a global average temperature increase of 7 °C (12.6 °F) compared to the last decade (1999 to 2008) would create certain small areas so hot that humans would be unable to dissipate enough heat to regulate their own body temperatures. A temperature increase of 12 °C (21.6 °F) – which could occur if all available fossil fuels were combusted – would cause large portions of the eastern United States, South America, North and West Africa, the Middle East, eastern Asia, and Australia to become uninhabitable.

Delaying Mitigation

Several recent studies have shown that delaying mitigation of GHG emissions results in a greater accumulation of CO_2 in the atmosphere, thereby increasing the risk of crossing tipping points and triggering abrupt changes (Anderson and Bows 2011, Friedlingstein et al. 2011, UNEP 2011, van Vuuren et al 2011, Ranger et al. 2012). These studies reinforce the findings cited in the MY 2014–2018 HD Final EIS, which concluded that delaying mitigation over the short term would require more stringent reductions in the future to limit climate change impacts. These studies state increases in global mean temperature will occur compared to pre-industrial levels. Anderson and Bows (2011) apportioned global cumulative emissions assessments into emission pathways for Annex 1 and non-Annex 1 countries[7], and found that global emissions of GHGs, and anticipated rates of future emissions, have

[7] Under the UNFCCC, Annex 1 countries are industrialized countries that were members of the Organization for Economic Cooperation and Development in 1992 and economies in transition. Non-Annex 1 countries are developing countries.

made it difficult to restrict increases in the global mean temperature to 2 °C (3.6 °F) or less compared to pre-industrial temperatures.

Friedlingstein et al. (2011) investigated the size of emission reductions required, the rate at which reductions must occur, and how soon they must be implemented to remain below a 2 °C (3.6 °F) temperature increase. The authors conclude that, under a median climate sensitivity assumption, if emission reductions start within the next two decades, anthropogenic emissions will need to decrease to zero or become negative (i.e., net uptake of atmospheric CO_2) by 2100 to stabilize below 2 °C (3.6 °F). Long-term positive emissions (even only at 10 percent of current CO_2 emission levels), slower rates of emission reductions, and delaying mitigation efforts severely constrain the likelihood of limiting warming to 2 °C (3.6 °F).

UNEP (2011) evaluated the "gap" between reduction pledges submitted by countries as part of the Copenhagen Accord and the estimated GHG emission reductions required to limit global warming to 2 °C (3.6 °F). The report found that bridging the gap by 2020 is possible, but that global GHG emission will need to peak before 2020 to have even a "medium" (i.e., 50 to 66 percent) chance of staying below the 2 °C (3.6 °F) target. After 2020, reductions would need to occur at a rate of roughly 2.5 percent per year. Rogelj et al. (2011) similarly found in an analysis of 193 emission pathways that, under most likely scenarios (i.e., greater than 66 percent chance) to limit global temperature increase to 2 °C (3.6 °F), GHG emissions peak before 2020 and decline at a median of 2.7 percent per year afterward.

Van Vuuren et al. (2011) describes the methodology and results of a Representative Concentration Pathway (RCP) that stabilizes the radiative forcing of GHG emissions at 2.6 watts per square meter by 2100 – a level with a likely probability of limiting global temperature increases to 2 °C (3.6 °F). To achieve this stabilization target, the authors find that emissions would need to be reduced at GHG intensity reduction rates that are substantially above historical rates, and that stringent emission reductions would be required in the present decade to avoid extremely high reduction rates in the second half of the century.

Ranger et al. (2012) find that this RCP would have less than a 5 percent probability of limiting warming to 1.5 °C (2.7 °F). The authors conclude that GHG emissions would need to begin to fall by 2015, that rapid reductions – on the order of 3 to 5 percent per year – would need to occur after 2020, and that annual emissions would need to be close to zero by 2100 to have at least a 50 percent probability of limiting warming to 1.5 °C (1.8 °F) over the long term.

Atmospheric Methane

CH_4 locked in hydrates in the sea bed and in Arctic permafrost could be a potential cause of abrupt climate change if warming triggers a large release of CH_4 gas from these sources, although there is considerable uncertainty associated with the rate and extent of possible CH_4 emissions. Archer et al. (2009b) estimate that a uniform 3 °C (5.4 °F) increase in ocean temperature could release between 30 and 940 pentagrams of carbon trapped in CH_4 hydrates. A key parameter is the "critical bubble fraction" – a measure of the volume of bubbles at which gas begins to escape from sea-floor sediments. The higher end of these estimates would increase warming in the atmosphere by an additional 0.5 °C (0.9 °F), persisting for thousands of years. There are still large uncertainties associated with CH_4 release mechanisms, but the authors conclude that sufficient fossil fuel reserves exist to destabilize a significant fraction of CH_4 hydrates in the ocean.

Schneider von Deimling et al. (2012) estimate that warming in a scenario with high atmospheric concentrations of CO_2 (RCP8.5) could trigger the release of between 33 and 114 gigatons of carbon by 2100, contributing between 0.04 and 0.23 °C (0.07 and 0.41 °F) of additional warming compared to pre-industrial temperatures. Emissions from hydrates and the associated warming impacts of these releases are likely to continue for several centuries.

In a separate study, Koven et al. (2011) used a terrestrial ecosystem model to investigate permafrost carbon changes due to warming in high latitudes. The model accounted for several critical soil processes previously excluded from other studies, including permafrost carbon dynamics, inhibition of decomposition in frozen soil layers, dynamics between vertical soil carbon layers, and CH_4 emissions from deep permafrost layers and wetlands. The authors found that terrestrial systems in high latitudes could shift from their current role as a sink for atmospheric carbon to a net source of CO_2 emissions under moderately high (A2) GHG emissions. CH_4 emissions from high-latitude regions could increase from 34 teragrams per year to between 41 and 70 teragrams per year.

Compost Instability in Drying Organic Soils

Luke and Cox (2011) and Wieczorek et al. (2011) have postulated that rates of long-term warming on the order of 10 °C (18 °F) per century could trigger a tipping point, leading to spontaneous peatland fires and increased CO_2 emissions from soils. The authors developed a mathematical model to show that heat released from increased microbial respiration in soils could theoretically lead to runaway soil temperatures when heat is generated more rapidly than it can escape from the soil to the atmosphere. The instability depends on the rate of warming, as opposed to the absolute amount of warming, and is more likely to occur in drying soils with high porosity that are covered by a lichen or moss layer, because these conditions decrease the soil's ability to dissipate heat generated from microbial respiration.

5.5.1.8 CO_2 and Climate Change Impacts on Stratospheric Ozone

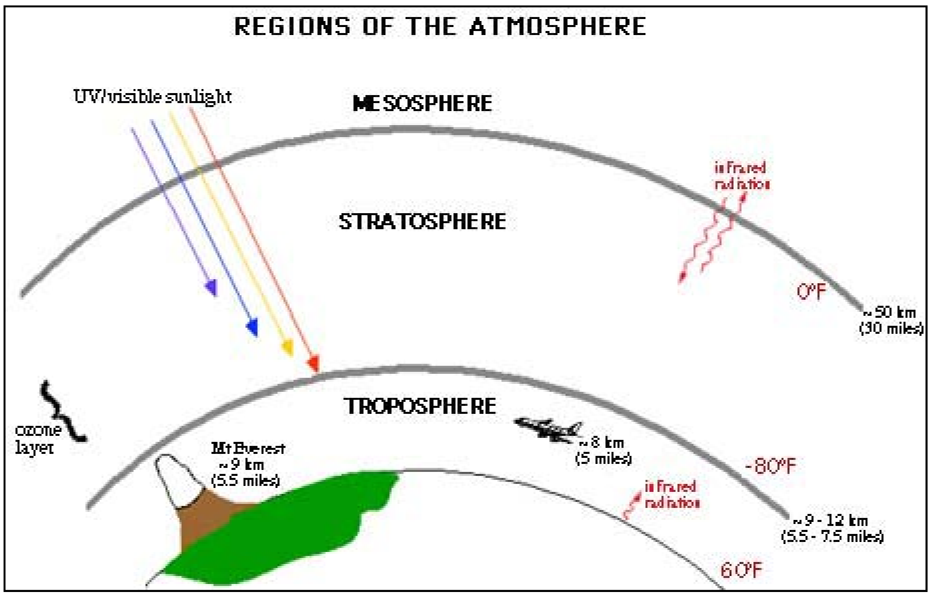
This subsection presents a review of stratospheric ozone and describes how CO_2 and climate change are projected to impact stratospheric ozone concentrations. This subsection does not incorporate by reference the analyses provided in NHTSA's previous EISs, and therefore does not build on information presented in the MY 2012–2016 CAFE standards Final EIS (NHTSA 2010b) or the MY 2014–2018 HD Final EIS (NHTSA 2011b). Although the previous EISs do not discuss this topic, this discussion has been incorporated to reflect the recent literature that has become available.

Ozone in Earth's stratosphere (the upper layer of the atmosphere) absorbs some harmful *UV* radiation from the sun, and therefore protects humans and other organisms (*see* Figure 5.5.1-1). Since the 1980s, satellite and ground observations have shown reductions in the concentrations of stratospheric ozone. There is an international consensus that man-made ozone-depleting substances (such as gases emitted by air conditioners and aerosol sprays) are responsible, prompting the establishment of international agreements to reduce the consumption and emission of these substances (Fahey and Hegglin 2011). In response, the rate of stratospheric ozone reduction has slowed. Although there are elements of uncertainty, stratospheric ozone concentrations are projected to recover over the next several decades to pre-1980 levels (Fahey and Hegglin 2011, WMO 2011).

Climate change could influence the recovery of stratospheric ozone. Although GHGs, including CO_2, warm the troposphere (the lower layer of the atmosphere), this process actually cools the stratosphere, slowing the chemical reactions between stratospheric ozone and ozone-depleting substances, hence assisting in ozone recovery. However, for polar regions, cooling temperatures can increase winter-time polar stratospheric clouds that are responsible for accelerated ozone depletion. Climate change will enhance atmospheric circulation patterns that affect stratospheric ozone concentrations, assisting in ozone recovery in the extra-tropics. Changes in stratospheric ozone, in turn, influence climate by affecting the atmosphere's temperature structure and atmospheric circulation patterns (Ravishankara et al. 2008). In sum, climate change has been projected to have a direct impact on stratospheric ozone recovery, although there are large elements of uncertainty within these projections.

This section discusses the interaction of stratospheric ozone, climate, and trace gases using information provided by the World Meteorological Organization (WMO) Scientific Assessment of Ozone Depletion: 2010 (WMO 2011) and the U.S. Climate Change Science Program (2008) report, Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure (CCSP 2008h).

Figure 5.5.1-1. The Three Lowest Layers in Earth's Atmosphere and the Location of the Ozone Layer[a]



a. Source: NOAA 2011a.

Ozone is a molecule consisting of three oxygen atoms. Ozone near Earth's surface is considered an air pollutant that causes respiratory problems in humans and adversely affects crop production and forest growth (Fahey and Hegglin 2011). Conversely, ozone in Earth's stratosphere (approximately 9 to 28 miles above Earth's surface) acts as a shield to block UV rays from reaching Earth's surface (Ravishankara et al. 2008).[8] This part of the atmosphere is sometimes referred to as the "ozone layer," and it provides some protection to humans and other organisms from exposure to biologically damaging UV rays that can cause skin cancer and other adverse effects (Fahey and Hegglin 2011, Fahey et al. 2008).

Ozone in the stratosphere is created when a diatomic oxygen molecule absorbs UV rays at wavelengths less than 240 nanometers, causing the molecule to dissociate into two very reactive free radicals that

[8] These height measurements defining the bottom and top of the stratosphere vary depending on location and time of year. Different studies might provide similar but not identical heights. The heights indicated for the stratosphere and the layers within the stratosphere are provided in this section as defined by each study.

then each combine with an available diatomic oxygen molecule to create ozone (Fahey and Hegglin 2011). Through this process, heat is released, warming the surrounding environment. Once ozone is formed, it absorbs incoming UV rays with wavelengths between 220 and 330 nm (Fahey and Hegglin 2011). Ozone, which is a very reactive molecule, may also react with such species as hydroxyl radical, nitric oxide, or chlorine (Fahey et al. 2008).

The concentration of ozone in the stratosphere is affected by many factors, including concentrations of ozone-depleting substances and other trace gases, atmospheric temperatures, transport of gases between the troposphere and the stratosphere, and transport within the stratosphere. Changes in climate affect many of these factors, as described in Sections 5.5.1.8.1 through 5.5.1.8.4.

5.5.1.8.1 Man-made Ozone-depleting Substances and Other Trace Gases

For the past few decades, stratospheric ozone concentrations have been declining in response to increasing concentrations of man-made ozone-depleting substances. Examples of ozone-depleting substances include chlorofluorocarbons (CFCs) and compounds containing bromine (Ravishankara et al. 2008, Fahey and Hegglin 2011). These ozone-depleting substances are chemically inert near Earth's surface, but decompose into very reactive species when exposed to UV radiation in the stratosphere.[9] In 1987, an international agreement, *the Montreal Protocol on Substances that Deplete the Ozone Layer*, was established to reduce the consumption and production of man-made ozone-depleting substances in order to protect and heal the ozone layer and rebuild the ozone hole.[10] Subsequent agreements have followed that incorporate more stringent reductions of ozone-depleting substances and expand the scope to include additional chemical species that attack ozone. Some ozone-depleting substances, such as CFCs, are potent GHGs; therefore, reducing the emissions of these gases also reduces radiative forcing, and hence, reduces the heating of the atmosphere.

Increases in the emissions of other trace gases (e.g., CH_4 and N_2O) and CO_2 affect stratospheric ozone concentrations (Fahey et al. 2008). When CH_4 is oxidized in the stratosphere, it produces water. Increases in stratospheric water lead to an increase in reactive molecules that assist in the reduction of ozone and an increase in polar stratospheric clouds that accelerate ozone depletion. Increases in N_2O emissions cause a reduction of ozone in the upper stratosphere as N_2O breaks down into reactive ozone-depleting species. CO_2 emissions affect atmospheric temperature; its impact on stratospheric ozone is discussed below.

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[9] For example, when a chlorofluorocarbon (CFC) molecule is exposed to UV radiation, it splits into a number of species, including a very reactive chlorine atom. The chlorine atom then combines with ozone, creating chlorine monoxide radical and a diatomic oxygen molecule. The chlorine monoxide radical can react with an oxygen atom (i.e., keeping the oxygen atom from reacting with diatomic oxygen to form ozone), creating the chlorine atom and another diatomic oxygen molecule. In essence, one chlorine atom has interrupted the natural ozone-producing cycle by consuming both a reactive oxygen atom and destroying an ozone molecule (Fahey and Hegglin 2011).

[10] The polar regions experience the greatest reduction in total ozone, with about a 5 percent reduction in the Arctic and 18 percent reduction in the Antarctic (Fahey and Hegglin 2011). Significant thinning in the ozone layer has been observed above the Antarctic since the spring of 1985, to such a degree it is termed the "ozone hole" (Ravishankara et al. 2008). This location is particularly susceptible to ozone loss due to a combination of atmospheric circulation patterns, and the buildup of ozone-depletion precursors during the dark winter months from June to September.

5.5.1.8.2 Changes in Atmospheric Temperature

Since the observational record began in the 1960s, global stratospheric temperatures have been decreasing in response to ozone depletion, increased tropospheric CO_2, and changes in water vapor (Fahey et al. 2008). Natural concentrations of GHGs increase the warming in the troposphere by absorbing outgoing infrared radiation; increasing GHG concentrations in the troposphere traps more heat in the troposphere, which translates to less incoming heat into the stratosphere. In essence, as GHGs increase, the stratosphere is projected to cool. However, model simulations suggest reductions in ozone in the lower to middle stratosphere (13 to 24 miles) create a larger decrease in temperatures compared to the influence of GHGs (Fahey et al. 2008 citing Ramaswamy and Schwarzkopf 2002). Above about 24 miles, both the reductions of ozone and the impact of GHGs can contribute significantly to stratospheric temperature decreases.

The cooling temperatures in the stratosphere could slow the loss of ozone (Fahey et al. 2008). In the upper stratosphere, the dominant reactions responsible for ozone loss slow as temperatures cool. For example, ozone in the upper stratosphere is projected to increase by 15 to 20 percent under a doubled CO_2 environment (Fahey et al. 2008 citing Jonsson et al. 2004). In the lower stratosphere, where transport plays an important role both within the stratosphere and between the troposphere and stratosphere, cooling temperatures have less influence on ozone concentrations (except in the polar regions). Since 1993, ozone in the lower stratosphere above the Arctic has been greatly affected by cooling temperatures, as cooling has led to an increase in polar stratospheric clouds (Fahey et al. 2008). Polar stratospheric clouds play a significant role in reducing ozone concentrations. Ozone in the lower stratosphere above the Antarctic does not demonstrate such a significant response to cooling temperatures because this region already experiences temperatures cold enough to produce these clouds.

5.5.1.8.3 Circulation and Transport Patterns

The large-scale Brewer-Dobson circulation represents the transport between the troposphere and stratosphere: an upward flux of air from the troposphere to the stratosphere occurs in the tropics balanced by a downward flux of air in the extratropics. This circulation carries stratospheric ozone from the tropics poleward.

Models suggest that the reduction of ozone above Antarctica is responsible for strengthening the circulation of stratospheric circumpolar winds of the wintertime vortex (i.e., the establishment of the vortex leads to significant ozone loss in late winter/early spring) (Fahey et al. 2008 citing Gillet and Thompson 2003, and Thompson and Solomon 2002).[11] Observations have shown that these winds can extend through the troposphere to the surface, leading to cooling over most of Antarctica. These studies suggest changes in stratospheric ozone can impact surface climate parameters.

[11] During the polar winter, a giant vortex with wind speeds exceeding 300 kilometers (186 miles) per hour can establish above the South Pole, acting like a barrier that accumulates ozone-depleting substances. In Antarctic springtime, temperatures begin to warm and the vortex dissipates. The ozone-depleting substances, now exposed to sunlight, release large amounts of reactive molecules that significantly reduce ozone concentrations (Fahey and Hegglin 2011).

5.5.1.8.4 Trends and Projections

Observations of global ozone concentrations in the upper stratosphere have shown a strong and statistically significant decline of approximately 6 to 8 percent per decade from 1979 to the mid 1990s, and a near zero or slightly positive trend thereafter (WMO 2011). Observations of global ozone within the lower stratosphere demonstrate a slightly smaller but statistically significant decline of approximately 4 to 5 percent per decade from 1979 to the mid 1990s (WMO 2011). The depletion of stratospheric ozone has been estimated to cause a slight radiative cooling of approximately -0.05 watts per square meter with a range of minus 0.15 to plus 0.05 watts per square meter, although there is great uncertainty in this estimate (Ravishankara et al. 2008).

The WMO (2011) used 17 coupled chemistry-climate models to assess how total column ozone (i.e., the total ozone within a column of air from Earth's surface to the top of the atmosphere) and stratospheric ozone will change in response to climate change and reductions in ozone-depleting substances. Under a moderate emission scenario (A1B), the model ensemble suggests changes in climate will accelerate the recovery of total column ozone. Projected ozone concentrations are compared to 1980 baseline conditions. Significant ozone reduction occurred between 1980 and approximately 2000. The model ensemble suggests the northern mid-latitudes total column ozone will recover to 1980 levels between 2015 to 2030, and the southern mid-latitudes total column ozone will recover between 2030 and 2040. Overall, the recovery of total ozone in the mid-latitudes to 1980 levels is projected to occur 10 to 30 years earlier due to climate change. The Arctic has a similar recovery time to 1980 conditions, while the Antarctic will regain 1980 concentrations around mid-century (because the chemistry-climate models underestimate present-day Arctic ozone loss, the modeled Arctic recovery period might be optimistic). The recovery is linked to impacts of climate that affect total column ozone, including (1) increased formation of ozone in the mid-to-upper stratosphere in response to cooling temperatures, (2) accelerated ground-level ozone formation in the troposphere as it warms, and (3) an accelerated Brewer-Dobson circulation increase in ozone transport in the lower stratosphere from the tropics to the mid-latitudes (WMO 2011).

In another study, doubled CO_2 concentrations simulated by 14 climate-change models project a 2 percent increase per decade in the annual mean troposphere-to-stratosphere exchange rate. This acceleration could affect long-lived gases such as CFCs, CH_4, and N_2O by reducing their lifetime and increasing their removal from the atmosphere. In addition, this could increase the vertical transport of ozone concentrations from the stratosphere to the troposphere over mid-latitude and polar regions (Fahey et al. 2008 citing Butchart and Scaife 2001).

5.5.2 Regional Impacts of Climate Change

This section discusses the regional impacts of climate change in the United States and is a supplement to the discussions of sectoral impacts provided previously. Specifically, Sections 5.5.2.1 through 5.5.2.8 address cumulative impacts on key natural and human resources by region (Northeast, Southeast, Midwest, Great Plains, Southwest, Northwest, Alaska, and the Islands [i.e., Hawaii and the U.S. territories in the Caribbean]). Each section begins with a brief description of observed and projected environmental change and then discusses impacts on the following sectors: freshwater resources; marine, coastal, and low-lying areas; food, fiber, and forest products; terrestrial and freshwater ecosystems; industries, settlement, and society; and human health. This section has been added to the Final EIS in response to comments the agency received regarding the unique regional impacts of climate change.

This section draws largely from panel-reviewed synthesis and assessment reports from the IPCC, the U.S. Climate Change Science Program, and the U.S. Global Change Research Program. NHTSA relies on panel reports because they have assessed many individual studies to draw general conclusions about the state of science, and have been reviewed and formally accepted by, commissioned by, or in some cases authored by U.S. Government agencies and individual government scientists. This material has been well vetted, both by the climate change research community and by the U.S. Government. In many cases, it reflects the consensus conclusions of expert authors. This section also references peer-reviewed literature that has not been assessed or synthesized by an expert panel, but that supplements the findings of the panel-reviewed reports

Although this section does not present specific examples of adaptation to climate impacts in each region or sector, adaptation is occurring at local, state, and regional scales. A number of organizations, state agencies, and planning bodies are considering adaptation options in response to climate change and climate variability. Across resources and regions, the process of incorporating adaptation into decisionmaking varies according to, for example, the awareness, frequency and severity of the climate change impacts. For some examples of general adaptation efforts at varying geographic scales, *see* the adaptation sections in each resource-sector discussion in Section 5.5.1, including those incorporated by reference from the MY 2012–2016 CAFE standards Final EIS and the MY 2014–2018 HD Final EIS.

5.5.2.1 Northeast

This section discusses climate change impacts in the Northeast region of the United States, which includes the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia. The Northeast is vulnerable to a variety of climate change impacts, including increasing temperatures, shorter snow seasons, more frequent heat waves, sea-level rise, and drought. These impacts will result in changes to the area's economy, landscape, and quality of life (GCRP 2009). In particular, the Northeast is vulnerable to impacts on human health; food, fiber, and forest products; marine, coastal, and low-lying areas; and industries, settlements, and societies.

Increasing temperatures have already had wide-ranging effects on the Northeast. Since 1970, the annual average temperature in the Northeast has risen 1.1 °C (2.0 °F) (GCRP 2009 citing Hayhoe et al. 2006) at an average rate of nearly 0.26 °C (0.5 °F) per decade (Frumhoff et al. 2007). Winter temperatures have increased by twice as much (GCRP 2009), at an even faster rate of more than 0.7 °C (1.3 °F) per decade (Frumhoff et al. 2007). Temperature increases vary across the region; for example, at Woods Hole in Massachusetts, the annual mean sea surface temperature increased by 1.3 °C (2.3 °F) between 1970 and 2002 (Commonwealth of Massachusetts 2011 citing Nixon et al. 2004). The average number of days with temperatures above 32 °C (90 °F) per year has increased by roughly two days over the last 45 years (NECIA 2006). Increasing temperatures have had a number of effects. The growing season has lengthened (GCRP 2009 citing Fahey 2007). In winter, more precipitation is falling as rain and less as snow; snowpack has decreased and winter ice has started to break up earlier on lakes and rivers (GCRP 2009 citing Field et al. 2007, NRC 2005, Jansen et al. 2007, and Gedney et al. 2006). Snow is melting earlier in spring, resulting in earlier peak river flows (GCRP 2009 citing Hansen et al. 2000). Sea surface temperatures have increased (GCRP 2009 citing Tarnocai et al. 2007). Another study has documented rising water temperatures in streams and rivers throughout the United States, finding statistically significant warming in 20 major U.S. streams and rivers, including prominent Northeast rivers such as the Potomac, Delaware, and Hudson (Kaushal et al. 2010).

Temperatures are projected to continue to rise. Northeast temperatures are projected to increase an additional 1.4 to 2.2 °F in winter and an additional 0.8 to 1.9 °F in summer over the next several decades (GCRP 2009). Sea surface temperatures could increase 1.7 °C (3.0 °F) by the middle of the century, and 2.2 to 4.4 °C (4 to 8 °F) by the end of the century (Commonwealth of Massachusetts 2011 citing Dutil and Brander 2003, Frumhoff et al. 2007, and Nixon et al. 2004). Heat waves are anticipated to increase in severity, frequency, and duration (CCSP 2008d). Under a higher emissions scenario, winters are projected to be much shorter by late in the century, with fewer cold days (GCRP 2009 citing Hayhoe et al. 2008). Cities that currently experience few days above 100 °F are projected to average 20 days above 100 °F each year; certain cities (e.g., Hartford, Connecticut, and Philadelphia, Pennsylvania) are projected to average nearly 30 days above 38 °C (100 °F) (GCRP 2009 citing Hayhoe et al. 2008). Hot summer conditions are projected to arrive 3 weeks earlier and last 3 weeks later (GCRP 2009 citing Hayhoe et al. 2008). In Massachusetts, projections indicate that the number of snow days per month will reduce; growing seasons will lengthen; short-term drought lasting 1 to 3 months will become more frequent; and precipitation amounts will increase in winter and decrease in summer (Commonwealth of Massachusetts 2011 citing Hayhoe et al. 2006).

Since 1918, precipitation in the Northeast has increased an average of 5 to 10 percent (Hayhoe et al. 2006, Keim et al. 2005). Since 1958, heavy precipitation has increased, with the amount of rain falling in the heaviest downpours rising by about 20 percent (GCRP 2009). Winter precipitation in the form of rain has increased (GCRP 2009, Hayhoe et al. 2006, Keim et al. 2005), while winter precipitation in the form of snow has decreased (GCRP 2009). In Maine, Hodgkins and Dudley (2006) show that between 1926 to 2004 the "slushiness" of snow has increased, the number of days of snow cover has decreased, and snowpack depth has decreased by an average of 16 percent across various sites, with an increase in snow density of 11 percent in March and April.

In the future, annual precipitation in the Northeast is projected to increase (EPA 2009e, Frumhoff et al. 2007, Christensen et al. 2007); a 10 percent increase is projected under both the low and high emissions scenarios by the end of the century (Frumhoff et al. 2007). Precipitation in summer is projected to decrease slightly, and precipitation in winter is projected to increase an average of 20 to 30 percent under a low and high emission scenario, respectively, with a greater amount falling as rain (Frumhoff et al. 2007). The snow season is projected to halve in length in northern New York, Vermont, New Hampshire, and Maine by the end of this century (Frumhoff et al. 2007, GCRP 2009 citing Scott et al. 2008); in southern parts of the region, the snow season is projected to shorten to just a week or two (GCRP 2009 citing Hayhoe et al. 2006 and Hayhoe et al. 2008).

New research providing projections of hydroclimatology over the northeastern United States[12] under a high emissions scenario demonstrates that changes in precipitation will vary within regions because of local differences in topography, vegetation, and other factors. Modeling by Anderson et al. (2010) projected that by late this century under a high emission scenario, summer precipitation will decrease across the central Northeast, but increase in the most northern and southern parts of the region compared to 1990–1999. Evaporation is projected to increase throughout the Northeast. The combined effect of these precipitation and evaporation changes is a projected 10-millimeter (0.39-inch) decrease in soil moisture content in summer across most of the Northeast, and a 10-millimeter per

[12] The definition of northeast is slightly different here than that used for this section generally. Here, the northeast is confined to just Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, and the upper portion of Pennsylvania.

month increase in summertime soil-moisture depletion. In line with these projections, short-term droughts that last 1 to 3 months are projected to increase in frequency, with droughts occurring as frequently as once per summer in the Catskill and Adirondack mountains, and across the New England states (GCRP 2009 citing Hayhoe et al. 2008 and Hayhoe et al. 2006).

Sea levels in the Northeast have been rising. Sea-level data show a rise of 2.0 to 3.0 centimeters (0.8 to 1.2 inches) per decade since 1958 along most of the Atlantic and Gulf coasts in the United States (EPA 2009e). In Massachusetts, sea level rose by 22 centimeters (8.7 inches) between 1921 and 2006 (Commonwealth of Massachusetts 2011 citing NOAA 2009). In the future, the Northeast could experience a rise in sea level greater than the projected global average of 0.8 to 2.0 meters (2.6 to 6.6 feet) due to changes in local ocean circulation (Yin et al. 2009, NRC 2010c, GCRP 2009). Sea levels could rise by 15 to 27 centimeters (5.9 to 10.6 inches) in Boston by 2100 (Commonwealth of Massachusetts citing Yin et al. 2009) and 10 to 30 centimeters (3.9 to 11.8 inches) in the Northeast by 2100 (Commonwealth of Massachusetts citing Hu et al. 2009). Sea-level rise would significantly increase the frequency of catastrophic flooding events that currently occur only once every 100 years (Kirshen et al. 2008). Assuming historical geological forces continue, 0.61 meter (2.0 feet) of global sea-level rise by the end of the century would result in relative sea-level rise of 0.70 meter (2.3 feet) at New York City (GCRP 2009). Another assessment by the New York City Panel on Climate Change projected sea-level rise of 3.2 to 7.1 meters (10.4 to 23.4 inches) for the New York City region by the 2090s using the IPCC global estimate plus local subsidence estimates, and a sea-level rise of 4.5 to 9.1 meters (14.9 to 30.0) inches using the IPCC-adapted methods for the New York City region relative to 2000–2004 (NPCC 2009).

Table 5.5.2-1 summarizes the projected trends for climate variables in the Northeast and the associated resources the trends will affect.

Table 5.5.2-1. Projected Trends in Environmental Variables for the Northeast

Environmental Variable	Projected Trend	Affected Resource
Temperature	Increase in annual average temperatures with shorter winters and longer growing seasons; increase in frequency, duration, and severity of heat waves	Food, fiber, and forest products; industries, settlements and society; human health
Precipitation	Increase in annual precipitation; decrease in summer precipitation and an increase in winter precipitation; increase in frequency of short-term droughts; decrease in length of snow season	Freshwater resources; industries, settlements, and society
Sea level	Increase in sea levels greater than global average	Marine, coastal, and low-lying areas

5.5.2.1.1 Freshwater Resources

Changes to freshwater resources are already occurring in the Northeast. For example, stream gauges in Maine demonstrate that there has been a shift in peak flows to earlier in spring and lower flows later in the season (Jacobson et al. 2009 citing Hodgkins and Dudley 2006). These local effects have been linked directly to global climate change (Jacobson et al. 2009 citing Kingston et al. 2007).

Climate change could have a wide range of further effects on the Northeast's freshwater resources. Earlier spring snowmelt resulting from increased temperatures could lead to earlier peak river flows

(GCRP 2009 citing Hayhoe et al. 2006). Changes in precipitation could increase nitrogen loads from rivers in the Chesapeake and Delaware Bay regions by up to 50 percent by 2030 (Kundzewicz et al. 2007). Expected increases in streamflow in winter and spring could increase nutrient loads in surface waters (Shortle et al. 2009 citing Neff et al. 2000). More-intense storm flows from heavy rainfall could also contribute to decreased water quality in streams, with increased runoff, erosion, and flooding causing increased flushing of contaminants, including sediment, sewage, pathogens, and pollutants (Shortle et al. 2009 citing Moore et al. 1997 and Rogers and McCarty 2000; Murdoch et al. 2000).

Meanwhile, decreases in streamflow in summer could reduce nutrient fluxes, thereby reducing eutrophication problems in late summer (Shortle et al. 2009 citing Neff et al. 2000). However, sea-level rise and storm surge could increase saltwater intrusion into freshwater aquifers and river mouths on the coast (Frumhoff et al. 2007). In addition to the Gulf of Mexico and Columbia River Basin, EPA has identified the Great Lakes and Chesapeake Bay as large water bodies for which climate change is a particular concern (EPA 2009e).

As much as 21 percent of the U.S. mid-Atlantic coastal wetlands are potentially at risk of inundation between 2000 and 2100 (EPA 2009e). Coastal wetlands already experiencing submergence are “virtually certain” to continue to shrink due to accelerated sea-level rise, among other climate- and non-climate-related factors (EPA 2009e). Wetlands and stream communities are also vulnerable to increased water temperature and increased hydrological variability, which could cause some surface-water wetlands to disappear entirely (Shortle et al. 2009 citing Moore et al. 1997 and Rogers and McCarty 2000).

5.5.2.1.2 Terrestrial and Freshwater Ecosystems

Changes to terrestrial and freshwater ecosystems are already being observed in the Northeast. Evidence suggests that climate change is accelerating biomass accumulation in certain forests, including temperate deciduous forests in Maryland (McMahon et al. 2010). Significantly higher seedling densities for northeastern tree species have been identified in the northern parts of their ranges, compared with those in the southern parts of their ranges, suggesting that a northward shift is already occurring (Shortle et al. 2009 citing Woodall et al. 2009). Plants are leafing out and blooming earlier (Commonwealth of Massachusetts 2011 citing Wolfe et al. 2005).

Ecological changes in response to climate change have been observed in the Northeast. The breeding seasons for amphibians are starting earlier (Commonwealth of Massachusetts citing Gibbs and Breish 2001). Atlantic salmon are starting their spring migrations earlier (Commonwealth of Massachusetts citing Juanes et al. 2004). Northeastern birds that winter in the southern United States return to the Northeast 13 days earlier than they did in the early twentieth century, and those that migrate to South America return to the Northeast an average of 4 days earlier (GCRP et al. 2009 citing Janetos et al. 2008). There have also been major changes in plant species abundance in Thoreau’s Walden Woods in Concord, Massachusetts, where meticulous records of species have been kept for 150 years. Much of the change is thought to be caused by changes in climate. The mean annual temperature in the Concord area has risen 2.4 °C (4.3 °F) in the last 100 years. Species in the area are now flowering 7 days earlier than they were during Thoreau’s recordkeeping days 150 years ago (Willis et al. 2008).

Climate change could cause many changes to terrestrial and freshwater ecosystems. Several projected impacts are forest-specific. Using GCMs to drive species suitability models, studies project that suitable habitat for eastern North American tree species will shift northward (Shortle et al. 2009 citing Iverson 2008a, 2008b). For example, suitable habitat for maple, beech, and birch, which dominate much of the Northeast, is projected to shift northward, with the extent of the shift depending on emission scenario

(GCRP 2009 citing Ryan et al. 2008). Under high emissions scenarios, species such as paper birch, quaking aspen, bigtooth aspen, and yellow birch are projected to be eradicated from Pennsylvania; under low emissions scenarios, these species are projected to be greatly reduced, if not eliminated (Shortle et al. 2009 citing Iverson et al. 2008a). Suitable habitat for spruce and fir, which dominate the mountainous and northern parts of the Northeast, is projected to contract dramatically (GCRP 2009); growth rates for these forests are also projected to decline significantly (Frumhoff et al. 2007). Under a higher emissions scenario, suitable habitat for balsam fir is projected to decrease by 70 to 85 percent across Maine, New Hampshire, New York, and Vermont, while habitat for red spruce is projected to decrease by 55 to 70 percent by the end of this century (Frumhoff et al. 2007 citing Iverson et al. 2008). Under a lower emissions scenario, reductions in these areas are projected to be 55 to 70 percent and 45 to 65 percent for balsam fir and red spruce, respectively (Frumhoff et al. 2007 citing Iverson et al. 2008). In New York, hemlock habitat is projected to diminish by 25 to 50 percent, depending on emissions scenario (Frumhoff et al. 2007 citing Iverson et al. 2008).

Meanwhile, increased atmospheric concentrations of CO_2 and the atmospheric deposition of nitrogen are projected to accelerate growth (through more wood production, and less foliage and root production in response to summer drought stress) in some tree species while slowing growth in others (Jacobson et al. 2009 citing Campbell et al. 2009 and Ollinger et al. 2008). Modest warming, longer growing seasons, increased photosynthesis due to increased CO_2, and more efficient water use (plants take in CO_2 through stomates in their leaves; they can open these stomates less, reducing water loss) could also promote growth rates in some species and communities, such as spruce, fir, and northern hardwood forests, especially under lower emissions scenarios (Frumhoff et al. 2007 citing Ollinger et al. 2008). However, Northeast forests could experience accelerated nitrogen losses due to shifting forest types, faster decomposition due to warmer soils, and decreased winter snowpack (Frumhoff et al. 2007 citing Ollinger et al. 2008).

It is projected with high confidence that the hemlock woolly adelgid, an important forest pest species, will expand its range northward, farther and more rapidly than before, because its northern range is currently limited by cold winter temperatures (Shortle et al. 2009 citing Paradis et al. 2008); this finding is consistent with research summarized in Section 4.5.6 of the MY 2012–2016 CAFE standards Final EIS. The adelgid is an introduced species from Asia that attacks eastern hemlock in the eastern United States. Expanded infestation would threaten to nearly eliminate this economically and ecologically important tree species. Although many pest species, like the hemlock woolly adelgid, are sensitive to harsh winter temperatures, the study found that projecting climate change impacts on pest species is extremely difficult. In addition, weeds including kudzu, Canada thistle, and Japanese honeysuckle are projected to further invade Northeast forests, promoted by increased CO_2 levels (Shortle et al. 2009 citing Ziska 2009 and Webster et al. 2006).

Climate change impacts extend beyond forest ecosystems. Climate change will affect bird distribution patterns. For example, under moderate climate change, Maine is projected to lose two bird species and gain seven. Under the most severe climate change, Maine is projected to lose 22 species and gain 12 by the end of this century (Jacobson et al. 2009 citing Matthews et al. 2004 and Rodenhouse et al. 2008).

Coldwater fish species in Pennsylvania streams are likely to be differentially affected by climate change, based on their thermal tolerance. As a result, some of the most valued coldwater communities could decrease in abundance, while less desirable communities, including invasive species, could increase (Shortle et al. 2009 citing Rogers and McCarty 2000 and Dukes and Mooney 1999). Warmer water temperatures could reduce dissolved oxygen in surface waters, stressing habitats for freshwater fish (Commonwealth of Massachusetts 2011 citing Jansen and Hesslein 2004).

5.5.2.1.3 Marine, Coastal, and Low-Lying Areas

The Northeast includes densely populated coastal areas that are extremely vulnerable to projected increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands (GCRP 2009). New York City is one of two U.S. cities projected to be among the top 20 cities worldwide in terms of population exposed to coastal flooding (Hanson et al. 2011). New York State has over $2.3 trillion of insured coastal property that is exceptionally vulnerable to sea-level rise and its related impacts (GCRP 2009 citing AIR Worldwide Corporation 2008).

These impacts are already being seen. New Jersey, with 60 percent of its population living along 127 miles of coastline, has experienced coastline subsidence and beach erosion, threatening communities and coastal wetlands (Kundzewicz et al. 2007, Aucott and Caldarelli 2006, and Jacob et al. 2000). Sea-level rise in the Chesapeake Bay has accelerated erosion rates, resulting in wetland destruction (National Science and Technology Council 2008). According to the Maryland Geological Survey, Tropical Storm Isabel resulted in the loss of an estimated 20 acres or more of land on the western shore of Chesapeake Bay, causing significant damage to shoreline structures (Maryland Department of Planning 2004). Extensive erosion has already been documented across the mid-Atlantic region, New England, and New York (National Science and Technology Council 2008 citing Rosenzweig et al. 2007).

As much as 21 percent of the U.S. mid-Atlantic coastal wetlands are potentially at risk of inundation between 2000 and 2100, and coastal wetlands already experiencing submergence are “virtually certain” to continue to shrink due to accelerated sea-level rise, among other climate- and non-climate-related factors (EPA 2009e). In addition, melting of the Greenland ice sheet could have an effect on ocean circulation and sea-level rise dynamics, which might exacerbate sea-level rise experienced on the northeastern coast of the United States and in Canada (Hu et al. 2009a).

Storm surges and flooding are projected to increase in frequency and severity. Under a higher emissions scenario, today’s 100 year coastal flood in New York City is projected to occur at least twice as often by the middle of the century and 10 times as often by late in the century. Under a lower emissions scenario, today’s 100 year flood is projected to occur about once every 22 years by late in the century. With rising sea levels, the 100-year flood is projected to inundate far larger areas of New York City than today, particularly under higher emissions scenarios. Flooding would affect critical transportation infrastructure in the Battery area of lower Manhattan (GCRP 2009 citing Titus and Newmann 2008). By midcentury, Boston and Atlantic City could experience what is currently a 100-year flood event every 2 to 4 years, and annually by the end of the century (Frumhoff et al. 2007).

In addition, toxic algal blooms or “red tides” could increase in length and intensity in Maine’s coastal waters due to warmer temperatures and increased precipitation (Jacobson et al. 2009 citing Edwards et al. 2006).

5.5.2.1.4 Food, Fiber, and Forest Products

While the growing season in the Northeast is projected to increase, climate change is likely to adversely affect agricultural production of dairy, fruit, and maple syrup (GCRP 2009). Extreme heat and summer drought, inadequate winter-chill periods, and increased stress from weeds, pests, and disease all threaten crop yields (GCRP 2009, Frumhoff et al. 2007, Shortle et al. 2009 citing Wolfe et al. 2008).

Under a higher emissions scenario, much of the region is likely to become unsuitable for popular varieties of apples, blueberries, and cranberries (GCRP 2009 citing Hauagge and Cummins 1991 and DeMoranville 2007). Increases in summer heat stress could harm apples, potatoes, and other cool-temperature-adapted crops (Shortle et al. 2009 citing Wolfe et al. 2008). The northward shift of conditions appropriate for maple, beech, and birch trees will reduce the area suitable for maple syrup production (GCRP 2009 citing Iverson 2008). Suitable habitat for the sugar maple is projected to decline dramatically under the higher emissions scenario, while habitat will also shrink for a number of other commercially valuable hardwood species, such as black cherry, yellow birch, paper birch, quaking aspen, bigtooth aspen, American beech, and white ash (Frumhoff et al. 2007, Shortle et al. 2009 citing Iverson et al. 2008a).

In New Jersey, higher summer temperatures are expected to depress the yields of a number of economically important crops adapted to cooler conditions (e.g., spinach and lettuce) by the middle of the century, while rising winter temperatures are expected to drive the continued northward expansion of agricultural pests and invasive weeds such as kudzu (Frumhoff et al. 2007, Shortle et al. 2009 citing Wolfe et al. 2008). The potentially habitable zone for kudzu and other invasive weeds is likely to expand significantly under both lower and higher emissions scenarios. By the middle of the century under both scenarios, the zone is projected to include most of Connecticut, Massachusetts, New Jersey, Pennsylvania, Rhode Island, and the lower half of New York. By the end of the century under the higher emissions scenario, the zone is projected to also include most of New Hampshire, New York, Vermont, and the lower half of Maine (Frumhoff et al. 2007, Shortle et al. 2009 citing Wolfe et al. 2008). In general, higher CO_2 concentrations are projected to promote more weed growth than crop growth (Frumhoff et al. 2007 citing Ziska et al. 2006a, 2006b).

Not all projected crop impacts are negative. In a detailed econometric analysis found that corn yields in the Northeast could increase by about 30 percent, and soybean yields could increase by 18 to 28 percent by 2030, controlling for technological change (Shortle et al. 2009 citing McCarl et al. 2008).

Increasing temperatures could stress dairy production, which is worth $3.6 billion annually in the Northeast. Heat stress depresses both milk production and birth rates in dairy cows for weeks to months at a time (GCRP 2009). Only a few days of high temperatures and humidity can have a prolonged impact on productivity or output (Jacobson et al. 2009 citing Wolfe et al. 2008). Increases in summer temperatures of 5 to 6 °C (9 to 11 °F) could reduce milk production by 10 to 25 percent (Shortle et al. 2009 citing Wolfe et al. 2008). Under a higher emissions scenario, most of the region (excluding the northern portions of Maine, New Hampshire, New York, and Vermont) is projected to experience declines in July milk production, while parts of the region (portions of Connecticut, Massachusetts, New Jersey, New York, and Pennsylvania) are projected to experience a decline of 20 percent or more. Under a lower emissions scenario, only the southern portions of the region are projected to experience declines in milk production of up to 10 percent. Due to analysis assumptions, these estimates are likely to underestimate the projected impacts on the Northeast dairy industry (GCRP 2009). It has also been suggested that heat stress would be prevalent throughout most of Maine under higher emission scenarios (Jacobson et al. 2009 citing Wolfe et al. 2008).

Lobster fishing, which has increased dramatically in the Northeast over the last 30 years, is projected to continue shifting northward (GCRP 2009 citing Atlantic States Marine Fisheries Commission 2005 and Fogarty 1995). Currently, the southern extent of the commercial lobster harvest appears to be limited by a temperature-sensitive bacterial shell disease, which contributed to catch declines in the late 1990s in the southern part of the region (GCRP 2009 citing Glenn and Pugh 2006). Near-shore water temperatures increasing above disease-specific thresholds are projected to increase the effect of this temperature-sensitive disease (GCRP 2009). Ocean acidification could combine with or magnify other stressors. For example, softer shells or different shedding timing could increase susceptibility to shell disease (Jacobson et al. 2009 citing Castro and Angell 2000). Meanwhile, analyses suggest that changing conditions could increase lobster survival and settlement in northern regions of the Gulf of Maine. These include warming water, a longer growing season, more rapid growth, an earlier hatching season, an increase in nursery grounds for larvae, and faster plankton development (GCRP 2009).

Climate change will also have implications for Northeast fish populations. Northward shifts of fish stocks have already been observed over the last four decades, as fish move to remain in their preferred temperature ranges (Commonwealth of Massachusetts citing Nye et al. 2009). Meanwhile, the timing of the migration of anadromous fish like the Atlantic salmon and alewives has shifted to earlier in the season (Commonwealth of Massachusetts citing Huntington et al. 2003 and Juanes et al. 2004). Impacts on fish populations are likely to continue. Climate changes under a higher emissions scenario are projected to stress cod populations in the North Atlantic (GCRP 2009). Increases in seafloor temperatures under a higher emissions scenario are projected to meet or exceed critical thresholds for cod populations (GCRP 2009). Temperatures above 8 °C (47 °F) lead to declines in growth and survival, while temperatures above 12 °C (54 °F) tend to be unsuitable for large cod populations (Frumhoff et al. 2007, GCRP 2009 citing Fogarty et al. 2008 and Dutil and Brander 2003). Cod populations in the Gulf of Maine are projected to decline by 2100 (Jacobson et al. 2009 citing Drinkwater 2005); populations south of Cape Cod are likely to disappear by the end of the century under a higher emissions scenario (Commonwealth of Massachusetts 2011 citing Drinkwater 2005 and Dutil and Brander 2003). Warm bottom temperatures are likely to restrict cod habitat in areas such as Georges Bank (Jacobson et al. 2009 citing Fogarty et al. 2008).

5.5.2.1.5 Industries, Settlements, and Societies

Climate change impacts could affect winter recreation and tourism in the Northeast (Frumhoff et al. 2007, GCRP 2009). Winter snow and ice sports contribute $7.6 billion annually to the regional economy (GCRP 2009 citing Scott et al. 2008). Since the 1800s, lake ice-out dates in New England have already advanced by up to 2 weeks (Jacobson et al. 2009 citing Hodgkins et al. 2002, 2003), shortening the seasons for ice fishing, skating, skiing, and snowmobiling.

Warmer winters with less snowfall will have significant impacts on the ski and snowboard industry by shortening the season, increasing artificial snowmaking requirements, and increasing operating costs (GCRP 2009, Frumhoff et al. 2007). These impacts could cause “further closures and consolidation of ski areas northward toward the Canadian border” (Frumhoff et al. 2007). One study found that the ski season would be 15 percent shorter in both eastern and western Pennsylvania during the 2010 to 2029 period under both the high (A1Fi) and low (B1) emission scenarios (Shortle et al. 2009 citing Scott et al. 2008). By the period 2080 to 2099, they found that the season would be 29 to 32 percent shorter under the B1 scenario and 46 to 50 percent shorter under the high (A1Fi) emission scenario. While artificial snowmaking can help in some cases, it requires significant amounts of water and energy, and depends on very cold nights, which are becoming less frequent (GCRP 2009). Under a higher emissions scenario, only one ski area in the region is projected to be able to support viable ski resorts by the end of the century (GCRP 2009). Because the snowmobiling industry cannot rely on snowmaking, most of the region is likely to have a marginal or nonexistent snowmobile season by the middle of the century (GCRP 2009). Ice sports are also at risk. For example, climate change could result in southern Maine no longer having safe ice conditions (Jacobson et al. citing Hodgkins et al. 2002, 2003).

Climate change will have other impacts on industries, settlements, and societies. For example, increases in summer temperature could require increased air conditioning use (GCRP 2009), while increased temperatures in winter could decrease heating demand (Commonwealth of Massachusetts citing Amato et al. 2005). Household electricity consumption in peak summer months could be nearly 3 times the 1960 to 2000 average, with more than 25 percent of the increase due to climate change(Commonwealth of Massachusetts citing Amato et al. 2005). As a more specific example regarding urban infrastructure, the New York City Department of Environmental Protection assessed potential climate change impacts on the city's drainage and wastewater collection systems, noting that if rainfall becomes more intense, sewer-system capacities could be exceeded, which would lead to street and basement flooding (NY City DEP 2008). In addition, extreme precipitation events could lead to an inundation of the Water Pollution Control Plants influent wells. Sea-level rise could threaten hydraulic capacity of the Water Pollution Control Plants outfalls by making peak flow discharges more difficult and increasing the salinity of influent to the Water Pollution Control Plant, which would upset biological treatment processes and lead to corrosion of equipment (NY City DEP 2008).

5.5.2.1.6 Human Health

The projected increase in heat wave frequency, duration, and severity in the Northeast will have significant implications for human health. Heat-related illnesses include heat exhaustion and kidney stones. Physiological stress from heat can even lead to death (GCRP 2009).

In addition, increased temperatures can worsen air quality. For example, ozone production peaks when ambient air temperatures exceed 32 ^{o}C (90 ^{o}F) (Connecticut Adaptation Subcommittee 2010). Poor air quality causes respiratory ailments and can lead to premature mortality. Rising temperatures are projected to cause an increase in the number of days that do not meet federal air quality standards in cities that currently experience ozone pollution absent additional emission controls (GCRP 2009). Warming temperatures are projected to decrease cloud cover in the Northeast, providing more sunlight for ozone creation (Connecticut Adaptation Subcommittee 2010 citing Kunkel et al. 2007). For many cities in the United States, including those in the Northeast, temperature increases could lead to an increase in ambient ozone of 4.2 to 4.4 parts per billion by 2050 in the absence of changes in anthropogenic emissions of ozone precursors (Connecticut Adaptation Subcommittee 2010 citing Bell et al. 2007 and Hogrefe et al. 2004).

Climate change might also have implications for allergies. Changes in temperature and precipitation patterns could change the amount and timing of airborne allergens like pollen grains and fungal spores. These changes could worsen allergy symptoms and even increase the prevalence of allergic diseases in the Northeast (Frumhoff et al. 2007 citing Ziska et al. 2008). As indicated in experiments, increased concentrations of CO_2 can increase the allergenic potential of poison ivy (Frumhoff et al. 2007 citing Mohan et al. 2006) and pollen-producers such as ragweed and pine trees (Frumhoff et al. 2007 citing Wayne et al. 2002, Ziska et al. 2000).

Not all human health impacts are projected to be negative. Along with an increase in heat-related deaths, a reduction in cold-related deaths is also projected. However, in temperate regions, including the Northeast, the reduction in cold-related deaths is not likely to entirely offset the increase in heat-related deaths (Frumhoff et al. 2007 citing Campbell-Lendrum and Woodruff 2006 and McMichael et al. 2006).

5.5.2.2 Southeast

This section describes climate change impacts in the southeastern United States, which for purposes of this document, includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, the southeastern coastal section of Texas , and Virginia. The Southeast has 29,000 miles of coastline, including some of the areas in the continental United States most vulnerable to sea-level rise. Coastal areas also face impacts from hurricanes and tropical storms, storm surge, erosion, and saltwater intrusion. In addition, increases in average temperatures and changes in precipitation will affect human health, freshwater resources, agriculture productivity, and the viability of terrestrial and freshwater ecosystems.

Table 5.5.2-2 summarizes the projected trends for climate variables in the Southeast and the associated resources the trends will affect.

Table 5.5.2-2. Projected Trends in Environmental Variables for the Southeast

Environmental Variable	Projected Trend	Affected Resource
Temperature	Increase in annual average temperatures, with largest increases in the winter months	Food, fiber, and forest products; terrestrial and freshwater ecosystems; human health
Precipitation	More frequent and intense heavy downpours	Freshwater resources, terrestrial and freshwater ecosystems
Sea level	Global mean sea-level rise projected from 0.5 to 2 meters (1.6 to 6.6 feet) above 1990 levels by 2100	Freshwater resources; marine, coastal, and low-lying areas; terrestrial and freshwater ecosystems

Due to land subsidence, the Southeast has experienced the highest rate of sea-level rise in the United States over the past century (Gutierrez et al. 2007). The average rate of sea-level rise has been nearly 2.5 times greater in Virginia than in Maine (Gutierrez et al. 2007 citing Zervas 2001). By reconstructing sea levels over the past 2,100 years, Kemp et al. (2011) found that sea level was relatively stable along the North Carolina coast from 100 BC until 950 AD, after which levels increased by 0.6 millimeter (0.02 inch) per year for 400 years, followed by a stable period until the nineteenth century. Currently, century-scale sea-level rise is at its steepest rate of increase in the 2-millennia period of data reconstruction, averaging 2.1 millimeters (0.08 inch) per year. Since the early twentieth century, relative sea levels have risen by 2.03 to 3.05 millimeters (0.08 to 0.12 inch) per year along the Atlantic and Gulf coasts (National Science and Technology Council 2008, EPA 2009e). Global sea levels are projected to rise by 0.5 to 2.0 meters (1.6 to 6.6 feet) above 1990 levels by 2100 (NRC 2010a).

Following a period of relatively stable temperatures over the past century, average annual temperatures have increased by about 1.1 °C (2.0 °F) since 1970 in the Southeast. The greatest increases have occurred in winter, where the number of days with temperatures remaining below freezing has fallen by 4 to 7 per year for most of the Southeast since the mid 1970s. Going forward, the rate of warming is projected to more than double compared to the warming experienced between 1975 and 2008, with an increase of about 2.5 to 5.0 °C (4.5 to 9.0 °F) by 2080 in annual average temperatures in the region (GCRP 2009).

Between the early 1900s and 2008, summer and winter precipitation declined by close to 10 percent in the eastern part of the region, with the greatest decreases in summer, reaching 20 percent in certain areas. Fall precipitation has increased by 30 percent for most of the region except in southern Florida, which has experienced a 10 percent decline in summer, spring, and fall. Climate models disagree about whether net precipitation in the region will increase or decrease in the future, although precipitation levels in southern Florida will likely decrease, and states along the Gulf Coast will experience less rainfall in winter and spring than will northern states in the region (GCRP 2009).

The region has also experienced an increase in heavy downpours and a higher incidence of drought, even in fall, when total precipitation increased throughout most of the region (GCRP 2009 citing Karl and Knight 1998 and Keim 1997). These trends are expected to continue, because rainfall associated with individual hurricanes will increase, and a warmer southeastern climate will increase water evaporation rates (GCRP 2009). Although there has been no observed increase in the frequency of hurricanes making landfall since 1970, the intensity and destructive potential of hurricanes in the Atlantic has increased over the same period (GCRP 2009 citing Emanuel 2005, Hoyos et al. 2006, Mann and Emanuel 2006, Trenberth and Shea 2006, and Webster et al. 2005).

Peak wind speeds, rainfall, and storm surge height and strength associated with hurricanes are likely to increase in the future, correlated with higher sea surface temperatures (GCRP 2009). By the end of the century, the literature indicates that the intensity of major storms could increase by 10 percent or more, which could result in more frequent Category 3 (or higher) storms along the Gulf and Atlantic coasts (Transportation Research Board 2008). Sea surface temperature increases could also play a role in the incidence of higher-intensity hurricanes in the Atlantic Ocean (Bender et al. 2010).

5.5.2.2.1 Freshwater Resources

Sea-level rise is contributing to a greater risk of saltwater intrusion into freshwater resources. Saltwater migration into the surface waters of the southern Everglades would contaminate the Biscayne Aquifer at its headwaters, threatening Miami-Dade County’s wellfields, which supply 2.5 million residents with potable water (Bloetscher et al. 2011). Water management will also face challenges from increased temperatures, longer periods between rainfall events, and increased societal demand for water resources (GCRP 2009). Emergency plans for drinking water and wastewater treatment will need to account for changes in the frequency and intensity of storm events and their effect on long-term high-flow and high-velocity events, and low-flow-period events (Bloetscher et al. 2011 citing EPA 2008).

5.5.2.2.2 Terrestrial and Freshwater Ecosystems

Projected climate change will affect natural ecosystems and wildlife in the Southeast. As much as 21 percent of wetlands along the U.S. mid-Atlantic coast are at risk of inundation by 2100, and it is virtually certain that those already experiencing submergence will continue to shrink, due to a combination of sea-level rise and other climate- and non-climate factors (EPA 2009e). Saltwater intrusion threatens estuarine and mangrove ecosystems, and has already been linked to the decline of bald cypress forests in Louisiana, cabbage palm forests in Florida, and the inland encroachment of salt-tolerant mangroves in Florida (EPA 2009e, NRC 2008).

Increases in seasonal and annual temperatures will also affect natural systems. For example:

- Kaushal et al. (2010) documented rising water temperatures in streams and rivers throughout the United States, including the Potomac River.
- In the Southern Appalachian Mountains, losses in wild trout populations are projected to exceed 60 percent due to higher stream temperatures in the future (Poff et al. 2002 citing Keleher and Rahel 1996, Mohseni et al. 2003 citing Rahel et al 1996, Battin et al. 2007 citing Rahel 2002).

- Warmer temperatures could trigger an increase in wildfires and pest outbreaks such as the southern pine beetle (GCRP 2009).
- Todd et al. (2011) examined the phenology of amphibians at a wetland in a hardwood pine forest in South Carolina between 1978 and 2008. They found that recently, several autumn-breeding species bred later in the season, consistent with increases in nighttime temperatures. Of the 10 species studied, 4 have changed their reproductive timing by roughly 15 to 76 days over the 30-year study period.
- Although it is uncertain whether the Southeast will be wetter or drier under future climate change, closed-canopy forests could be threatened by drought stress, even under somewhat wetter conditions, due to higher average temperatures and increases in fire disturbance (CCSP 2008d).

5.5.2.2.3 Marine, Coastal, and Low-Lying Areas

Sea-level rise, increased hurricane intensity, storm surge, erosion, and saltwater intrusion are among the most serious climate change impacts facing the Southeast. Miami is in the top 20 cities worldwide in terms of population exposed to coastal flooding, and Miami, New Orleans, and Virginia Beach are all among the top 20 cities with the highest value of assets exposed to coastal flooding impacts (Hanson et al. 2011, Weiss et al. 2011). In Miami, sea level rose 2.39 plus or minus 0.22 millimeters (0.09 plus or minus 0.009 inch) per year from 1913 to 1999, and barrier islands in the Tampa Bay region are already affected by significant beach erosion due to sea-level rise (Bloetscher et al. 2011). Sea-level rise will not only affect coastal areas, but will also increase the likelihood of damaging floods in interior floodplains by raising groundwater and surface water levels, reducing groundwater seepage through aquifers to the ocean, compromising stormwater drainage systems, and inundating barrier islands and coastal areas (Bloetscher et al. 2011).

The intensity of major storms originating in the tropics could increase, resulting in more frequent Category 3 (or higher) hurricanes along the Gulf and Atlantic coasts (Transportation Research Board 2008). In the Atlantic Ocean, sea surface temperatures are projected to increase, which could play a role in increasing the intensity of hurricanes. Using two hurricane simulation models, NOAA's Geophysical Fluid Dynamics Laboratory found that the number of total hurricanes and tropical storms developing in the Atlantic basin might decrease annually by the end of the twenty-first century, but the incidence of Category 4 and 5 storms with sustained winds at or greater than 131 miles per hour could nearly double compared to the 1981 to 2005 average (Bender et al. 2010). The combination of rising sea levels and a likely increase in hurricane intensity will contribute to greater storm-surge height and strength, erosion, flooding, and wind-related casualties (GCRP 2009). Model results for a study of climate change impacts (i.e., sea-level rise) along the Gulf Coast conservatively estimated a range of 6.7- to 7.3-meter (22- to 24-foot) potential maximum surge in major hurricanes compared to storm surges of 7.6 meters (25 feet) during Hurricane Camille and 8.5 meters (28 feet) during Hurricane Katrina (CCSP 2008a).

Many of the low-lying coastal areas exposed to sea-level rise, hurricanes, and storm surges are also at high risk of erosion. Significant erosion is already occurring along the east coast and in the coastal wetlands of Louisiana from a combination of factors, including climate-induced sea-level rise and land subsidence (National Science and Technology Council 2008 citing Rosenzweig et al. 2007). In Mississippi and Texas, erosion rates have been between 2.6 and 3.1 meters (8.5 and 10.2 feet) per year since the 1970s; in contrast, 90 percent of the Louisiana shoreline has eroded at 12.0 meters (39.4 feet) per year (EPA 2009e). In Louisiana, barrier-island erosion is resulting in increased wave height along the coast (National Science and Technology Council 2008 citing Nicholls et al. 2007).

Finally, climate change is expected to also affect coral reefs, which are already facing stresses from overfishing, pollution from land-based runoff of nutrients and sediments, and coastal developments. Reefs off the Florida Keys and in tropical waters in the United States face a "double threat" from warmer sea water and ocean acidification, which are expected to challenge their survival (NRC 2008 citing Hoegh-Guldberg et al. 2007).

5.5.2.2.4 Food, Fiber, and Forest Products

Warmer temperatures, declines in soil moisture, and water scarcity will have impacts on agriculture in the Southeast. Although temperature increases are expected to lead to a longer growing season, particularly in the Northeast, they could lead to increased crop sensitivity in the Southeast (National Science and Technology Council 2008 citing Carbone et al. 2003). In Florida, the citrus industry has moved farther south, despite higher average temperatures, due to greater extremes in temperature and weather (Bloetscher et al. 2011). Sustained temperatures above 32 °C (90 °F) significantly affect cattle, and higher temperatures will result in lower soil moisture, increasing the stress on crops. For poultry and swine operations, which primarily occur indoors, operators could face higher energy costs for cooling during high-temperature periods (GCRP 2009 citing Hatfield et al. 2008).

5.5.2.2.5 Human Health

Temperature increases in coastal waters are likely to increase the frequency of outbreaks of shellfish-borne disease. Between 1996 and 2006, food poisoning from shellfish infected with *Vibrio parahaemolyticus* bacteria, which causes gastrointestinal illness when ingested by humans, increased by 41 percent, although the overall incidence of illness was low (GCRP 2009). Higher temperatures could also affect human health, contributing to illness and even death in periods of extreme heat. At a time when the population is growing rapidly in the southeastern sunbelt, increasing heat and declining air quality will likely have greater impacts on the health and quality of life of people in the future. This is particularly true in cities already facing challenges in meeting air quality targets, and for elderly populations who are more sensitive to heat stress and other health impacts (GCRP 2009).

5.5.2.3 Midwest

The Midwest includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. The Great Lakes are a defining feature of the region, which consists largely of prairie land farmed for corn, soybeans, and wheat, or for raising livestock. There are a number of large urban centers in the Midwest, including Chicago, Cleveland, Detroit, Indianapolis, Kansas City, Milwaukee, Minneapolis, and St. Paul. The region experiences swings from hot, humid summers to cold winters due to its inland location away from the Atlantic and Pacific oceans that moderate climates closer to the coast. Increases in temperature and changes in precipitation, including more - intense downpours and potentially longer periods between precipitation events, are expected to affect air quality and human health, freshwater resources in the region, food and agricultural production, the types of plants and animals that flourish in the area, and beneficial uses provided by the Great Lakes to ecosystems and human society.

Table 5.5.2-3 summarizes the projected trends for climate variables in the Midwest and the associated resources the trends will affect.

Table 5.5.2-3. Projected Trends in Environmental Variables for the Midwest

Environmental Variable	Projected Trend	Affected Resource
Temperature	Increase in annual average temperatures, with largest increases in the winter months; increase in the severity, frequency, and duration of heat waves	Food, fiber, and forest products; terrestrial and freshwater ecosystems; human health
Precipitation	Increase in overall precipitation, particularly in winter and spring; more - intense heavy downpours and longer periods between precipitation events	Food, fiber, and forest products; terrestrial and freshwater ecosystems; industries, settlements, and society

Average temperatures in the Midwest have already increased over recent decades, and are projected to increase by an additional 1.7 °C (3 °F) over the next few decades. By the end of this century, average temperatures could increase by 5.6 °C (10 °F). These changes are most pronounced in the winter months, where the annual frost-free period has lengthened by more than a week in recent decades, primarily from earlier thaws in spring (GCRP 2009 citing Hayhoe et al. 2009). The severity, frequency, and duration of heat waves are projected to increase (CCSP 2008d, GCRP 2009).

Precipitation is projected to increase, particularly in winter and spring. A greater share of precipitation is projected to fall in heavy downpours, increasing the likelihood of flooding, property damage, travel delays, and service disruptions. Between heavy rainfall events, there will likely be longer periods without precipitation (GCRP 2009).

On the Great Lakes, changes in precipitation, ice cover, surface water temperature, and wind speeds could affect lake levels, although there is a high level of uncertainty in modeling projections. Over the short term, changes in lake levels will likely remain within the historical range, although extremely high or low levels are possible (IUGLS 2012).

5.5.2.3.1 Terrestrial and Freshwater Ecosystems

Changes in temperature and precipitation in the Midwest will likely affect plants and wildlife in the area. In Missouri, declines in oaks, especially red oaks, have been linked to long-term droughts in the area (Allen et al. 2010 citing Voelker et al. 2009 and Clinton et al. 1993). In the Great Lakes region, the “Plant Hardiness Zone” – a measure that can be used to determine which plants are likely to thrive in a given region – is projected to shift from an average annual extreme minimum temperature of -23 °C (-9 °F) to -18 °C (0 °F) by 2100. This would result in an ecosystem in the southwestern Lake Michigan region that would be similar to the hardiness zone that currently exists in northern Alabama (Hellmann et al. 2010). A recent study of the Muskegon River system in Michigan found that, by 2100, the habitat ranges of game fish could shift from predominantly coldwater fish to cool- and warmwater fish. The study projected declines in Coho salmon, brook trout, brown trout, and rainbow trout, although climate impacts on species will vary spatially within the river system (Woodward et al. 2010).

Climate change is expected to increase the difficulty of meeting water quality goals in the Midwest (Field et al. 2007). The Great Lakes are a key feature of the Midwestern geography and play an important role in regional transportation, agriculture, commerce, and recreation activities. EPA has identified the Great Lakes – in addition to the Chesapeake Bay, the Gulf of Mexico, and the Columbia River Basin – as a large body of water for which climate change is a particular concern (EPA 2009e). Restoration of beneficial uses (to address habitat loss, eutrophication, and beach closures) under the Great Lakes Water Quality Agreement will likely be vulnerable to declines in water levels, if they occur, warmer water temperatures, and more intense precipitation (Mortsch et al. 2003). For example, simulations in the Bay of Quinte[13] show that water temperature increases of 3 to 4 °C (5.4 to 7.2 °F) could contribute to a 77 to 98 percent increase in phosphorous concentrations (Field et al. 2007 citing Nicholls 1999), while changes in precipitation, stream flow, and erosion could increase average phosphorous concentrations by 25 to 35 percent (Field et al. 2007 citing Walker 2001).

5.5.2.3.2 Food, Fiber, and Forest Products

Higher temperatures and changes in precipitation will affect agriculture in the Midwest with mixed effects. Higher average temperatures are expected to lengthen the growing season, and crops could benefit from higher levels of CO_2 in the atmosphere. For example, soybean yield is projected to increase by 2.5 percent in the Midwest (EPA 2009e). At the same time, temperature increases could lead to increased sensitivity to climate change in the Corn Belt – which includes western Indiana, Illinois, Iowa, and Missouri in the Midwest (National Science and Technology Council 2008 citing Carbone et al. 2003). Studies based on weather-station readings and harvest statistics suggest that every degree of warming globally could decrease yield by 11 percent in the Corn Belt (NRC 2010a). Similarly, although fruit production could benefit from climate change in the Midwest, it might be harmed by the increased risk of winter thaws and spring frost (Field et al. 2007 citing Bélanger et al. 2002 and Winkler et al. 2002).

Soil management practices in some regions, such as the Corn Belt, might not provide sufficient erosion protection against projected increases in heavy downpours and the associated runoff (Field et al. 2007). Wetter conditions in spring could make it difficult for farmers to plant their crops, while increased evaporation during warmer summers could increase the likelihood of water shortages or drought (GCRP 2009).

A warmer climate in the Midwest is expected to put greater stress on livestock, decreasing animal productivity and increasing the costs of ventilation and cooling (GCRP 2009). Studies have shown that higher temperatures decrease summer milk production, interfere with immunological functions and digestion, and increase mortality rates in dairy cattle (Rogovska and Cruse 2011 citing Klinedinst et al. 1993, Nienaber and Hahn 2007, and Mader 2003). The number of cattle lost during heat waves in 1992, 1995, 1997, 1999, 2005, and 2006 exceeded 100 on some Midwestern farms (Rogovska and Cruse 2011 citing Backlund et al. 2008).

5.5.2.3.3 Industries, Settlements, and Society

In addition to impacts on natural ecosystems, changes in water levels in the Great Lakes could affect beaches, lengthen the distance to the lakeshore, affect coastal ecosystems, and increase dredging requirements. Lower water levels reduce the distance between the water line and the bottom of cargo ships. As a result, it could take more ships to carry the same amount of freight (GCRP 2009). There is a high level of uncertainty about how climate change in the Midwest will affect water levels in the Great Lakes. By the end of the twenty-first century, water levels could change between a decrease of 4.5 feet to an increase of 1.15 feet in the Great Lakes (Kundzewicz et al. 2007 citing Lofgren et al. 2002 and Schwartz et al. 2004). However, a recent assessment by the International Upper Great Lakes Study found that changes in levels of the Great Lakes might not be as extreme as previous studies have predicted, and will likely remain within the relatively narrow historical range. The study authors could

[13] The Bay of Quinte is located on the north shore of Lake Ontario, roughly 200 kilometers (124 miles) east of Toronto, Ontario.

not rule out the potential for extremely high or low water levels beyond 30 years, given the large uncertainties in climate modeling projections (IUGLS 2012).

5.5.2.3.4 Human Health

Warmer temperatures in the Midwest will likely have adverse impacts on human health. Heat waves in the Midwest are anticipated to increase in severity, frequency, and duration (CCSP 2008d, GCRP 2009). Longer, hotter heat waves are expected to increase the risk of heat-related deaths (GCRP 2009 citing Hayhoe et al. 2009, Tao et al. 2007, Kling et al. 2003, Lin et al. 2008, Holloway et al. 2008, and Hedegaard et al. 2008). By the end of the century, heat waves of the same severity as the 1995 Chicago heat wave, which was responsible for almost 800 heat-related deaths, could occur every other year or up to three times a year, depending on the extent of climate change (Hayhoe et al. 2010).

Ticks and mosquitoes will likely survive milder winters in greater numbers, increasing the risk of diseases such as Lyme disease and West Nile virus (GRCP 2009). In 2009, a new species of mosquito with the potential to transmit both the West Nile virus and the Lacrosse virus was documented in Iowa (Dunphy et al. 2009).

It will be harder for urban areas of the Midwest to meet air quality standards in a warmer climate. Ground-level ozone – a pollutant that damages lung tissue when inhaled – forms in hot, sunny, stagnant air conditions. More frequent and intense heat waves are likely to increase ozone formation, increasing the risk of health impacts absent further emission reductions (GCRP 2009).

5.5.2.4 Great Plains

This section discusses the impacts of climate change on the Great Plains region. This region covers the area including eastern Colorado, North and South Dakota, Kansas, central and eastern Montana, Nebraska, eastern New Mexico, Oklahoma, central Texas, and Wyoming. The Great Plains have been characterized by seasonal climate variations (GCRP 2009) and are vulnerable to climate-related impacts, including increasing and extreme temperatures, variability and changing intensities of rainfall, and related extreme events (e.g., floods and droughts). These impacts have implications for the region’s ecosystems, freshwater resources, and agriculture.

Since 1906, climate in the Great Plains has been generally warmer and wetter. Minimum daily temperatures have been increasing in winter, while maximum daily temperatures in summer have been decreasing. The average temperature has increased by roughly 0.83 °C (1.5 °F) compared to 1960 to 1970. By the 2100s, these temperatures are projected to increase by 1.4 to 7.2 °C (2.5 to 13.0 °F) compared to the same years. Summer temperatures are projected to increase more than those in winter in the southern and central parts of the Great Plains. The northern Great Plains is expected to experience the greatest projected increases (GCRP 2009).

Between 1971 and 2000, parts of eastern Oklahoma and Texas experienced more than 127 centimeters (50 inches) of rainfall per year, while some of the western parts of the Great Plains received less than 25 centimeters (10 inches) per year. These precipitation patterns are also projected to change. There are seasonal and regional variations in this change. Winter and spring will be most affected, and conditions will become wetter in the northern part of the region and drier in the southern part (GCRP 2009).

Changes in these basic climate indicators point to the more frequent occurrence of extreme events such as heat waves, droughts, and floods. These trends and events will affect the region, including exacerbating its water stresses and affecting some key economic activities. Table 5.5.2-4 summarizes the projected trends for climate variables in the Great Plains and the associated resources the trends will affect.

Table 5.5.2-4. Projected trends in Environmental Variables for the Great Plains.

Environmental Variable	Projected Trend	Affected Resource
Temperature	Increasing temperatures across all parts of the region, with greater increases in the northern areas than in the southern; summer temperatures are projected to increase more than winter temperatures	Freshwater resources; food, fiber, and forestry products; terrestrial and freshwater ecosystems; human health
Precipitation	Winter and spring will become wetter in the northern areas, but drier in the southern areas; summer months are projected to receive less rainfall.	Freshwater resources; food, fiber, and forestry products; terrestrial and freshwater ecosystems

5.5.2.4.1 Freshwater Resources

A new study by the U.S. Bureau of Reclamation describes the regional differences in climate-related changes in U.S. streamflows (Bureau of Reclamation 2011b). The study's analytical and modeling results for eight Bureau of Reclamation river basins indicate that the north-central region of the western United States, which includes much of the Great Plains region is becoming wetter. The study's runoff projections indicate that cool-season runoff will increase over the twenty-first century for river basins in the north-central United States (Missouri) (Bureau of Reclamation 2011b). Further, increases in winter rather than spring runoff could affect flood control procedures already in place.

A warming scenario of 2.5 °C (4.5 °F) or greater is projected to decrease the recharge of the Ogallala aquifer region (the Great Plains' most important aquifer and primary water source) by 20 percent (EPA 2009e). However, projections also indicate that in high-latitude and high-altitude areas (e.g., Columbia headwaters in Canada and Colorado headwaters in Wyoming), there is a chance that snowpack losses could be offset by cool-season precipitation increases (Bureau of Reclamation 2011b).

Warmer water temperatures could exacerbate the presence of invasive species, jeopardizing the health of existing wetlands. Warmer waters could also increase the probability of eutrophication in wetlands and water sources, thereby decreasing water quality levels (US Bureau of Reclamation 2011b).

5.5.2.4.2 Terrestrial and Freshwater Ecosystems

The Great Plains region is home to unique ecosystems and wildlife, and over 10 percent of its land is federally or state protected. Climate change is likely to affect Great Plains terrestrial and freshwater ecosystems in a number of ways; the following paragraphs describe some key impacts.

The millions of wetlands in the North American Prairie Pothole region covering the Northern Great Plains, which provide essential breeding habitat for waterfowl, are considered particularly vulnerable to a warmer and drier climate. The wetlands of this region are considered to be the most productive habitat for waterfowl in the world, and are estimated to support up to 80 percent of North America's ducks. Simulations suggest that in a drier climate, the most productive habitat for breeding waterfowl would shift from the center of the region in the Dakotas and southeastern Saskatchewan to the wetter eastern and northern fringes, areas that are less productive or where most wetlands have been drained, resulting in significant declines in productivity (Johnson et al. 2005).

In the Great Plains region, red fire ant and rodent populations are projected to increase due to warming temperatures associated with climate change (GCRP 2009 citing Cameron and Scheel 2001 and Levia and Frost 2004). In the desert Southwest and the southern Great Plains, where rivers drain to the east and west, fish species will have no opportunity for northward migration, and it is expected that many native fish species in these regions could become extinct with only a few degrees of warming (Poff et al. 2002). Studies suggest that the yellow-billed cuckoo is at risk of declining with continued warming. Similarly, reindeer and caribou will face the same risks (Post et al. 2009b).

The Hadley and Canadian climate and ecological models project an increase in the fire season hazard by 10 percent in the twenty-first century in the United States, with small regional decreases in the Great Plains (CCSP 2000). Both the frequency of large wildfires and changes in fire season length have increased substantially since 1985, and are closely linked with advances in timing of spring snowmelt (Bureau of Reclamation 2011b).

5.5.2.4.3 Food, Fiber, and Forest Products

Agricultural, range, and crop lands cover more than 70 percent of the Great Plains, representing much of the region's economic activities. These activities are fundamentally sensitive to climate, including temperature, rainfall, and extreme events. For example, studies have estimated that wheat yields in the region will decline by 7 percent for each 1 °C (1.8 °F) increase in annual average air temperatures between 18 and 21 °C [64 and 70 °F] and about 4 percent for each 1 °C (1.8 °F) increase above 21 °C (70 °F) (CCSP 2008e citing Lobell and Field 2007). Such findings are corroborated by more recent work by Kirilenko (2010) that shows that for a 1 to 4 °C (1.8 to 7.2 °F) increase in temperature, spring wheat yields could decrease by as much as 11.5 percent by the 2050s.

In the Great Plains region, the projected increase in drought frequency and severity will stress the region's water resources that supply water for the agriculture sector. The irrigated agricultural areas in the southern Great Plains will be especially vulnerable to these water resource impacts, particularly because the region is already experiencing unsustainable water use (GCRP 2009 citing Lettenmaier et al. 2008). Combined with growing urban areas, demands on water are likely to grow.

Over the past 50 years, certain crop plants have begun flowering and maturing earlier in the season. For example, winter wheat grown on the Great Plains has flowered 0.8 to 1.8 days earlier per decade since 1950 (Craufurd and Wheeler 2009 citing Hu et al. 2005). Further, as temperatures increase, pests previously unable to survive in the cooler climes of the northern Great Plains are expected to spread (GCRP 2009 citing Lettenmaier et al. 2008).

Since 1994, winter mortality of bark beetle larvae in Wyoming has dropped from 80 percent to 10 percent due to mild winters (Epstein et al. 2006 citing Holsten et al. 2000). The U.S. Forest Service reports that bark beetles have now affected more than 1.5 million acres in northern Colorado and southern Wyoming, killing lodgepole pines and affecting watersheds, timber production, and wildlife habitats (USFS 2008).

5.5.2.4.4 Human Health

As temperatures warm, concentrations of some airborne pollutants are projected to increase (CCSP 2008d). Air pollution causes a number of respiratory ailments and can lead to premature death. Under a moderate (A1B) emission scenario, a regional climate simulation projected air quality to decline in Texas in midcentury compared to 1995 to 2005 in response to temperatures warming up to 3 °C (5.4 °F), an increase in sunlight, more than 8 days of rainfall per season, and up to 4 more stagnation days per season (i.e., trapping air pollutants at Earth's surface). However, the air quality over the Great Plains is projected to improve by midcentury compared to 1995 through 2005 driven by modest warming conditions, reduced sunlight, up to 6 more days of rainfall per season, and a reduction of up to 8 days of stagnation (Ebi et al. 2008 citing Leung and Gustafson 2005).

5.5.2.5 Southwest

The Southwest is projected to face significant impacts from climate change. This region includes Arizona, California, the western portions of Colorado, Nevada, New Mexico, Utah, and Texas. Limited water availability in this dry, warm region has resulted in more than a century of negotiations over water rights. Over the past 30 years, the timing of snowmelt and runoff has shifted. Clow (2010) found that from 1978 to 2007, a 1.5 °C (2.7°F) increase in average winter temperatures per decade resulted in Colorado snowmelt occurring 2 to 3 weeks earlier. Changes in snowmelt and runoff will likely have major impacts on the freshwater supply in the Southwest, the health of ecosystems, and human activities such as agriculture and managed lands.

The Southwest is already experiencing warmer temperatures. Compared to a 1960 through 1979 baseline, the average annual temperature in the Southwest has already increased by 0.8 °C (1.5 °F) . By the end of the twenty-first century, the region's average annual temperature is projected to increase by between about 2.2 and 5.5 °C (4.0 and 10.0 °F), under lower (B1) and moderately high (A2) emissions scenarios. For some parts of the region, projected increases are more pronounced in summer (GCRP 2009).

The amounts and types of precipitation in the Southwest are expected to change. The percentage of annual precipitation falling as rain rather than snow has increased at 74 percent of the weather stations studied in the western mountains of the United States from 1949 through 2004 (EPA 2009e). Precipitation that falls in the mountains as rain instead of snow reduces runoff from snowmelt during spring and summer months. Regional annual precipitation is projected to decrease (EPA 2009e, Christensen et al. 2007a). Projected spring precipitation at the end of the century compared to a 1961 through 1979 baseline is expected to either increase slightly or decrease by up to 25 percent under a lower (B1) emissions scenario, and decrease by as much as 45 percent in the driest regions under a moderately high (A2) emissions scenario (GCRP 2009).

Drought has historically stressed many areas of the Southwest; additional decreases in precipitation are anticipated to exacerbate this existing stress (EPA 2009e). On average, during drought peak years, there has been a 63 percent decline in annual runoff in the Southwest (Cayan et al. 2010). There is some evidence of long-term drying and increase in drought severity and duration in the West and Southwest (National Science and Technology Council 2008) that is probably a result of decadal-scale climate variability and long-term change (EPA 2009e). Changes in the amount, timing, and type of precipitation have cascading effects on the mountain snowpack and streamflows in the region.

Table 5.5.2-5 summarizes the projected trends for climate variables in the Southwest and the associated resources the trends will affect.

Table 5.5.2-5. Projected Trends in Environmental Variables for the Southwest

Environmental Variables	Projected Trend	Affected Resource
Temperature	Average annual temperature increase between 2.2 and 5.5 °C (4.0 and 10.0 °F) by the end of the century.	Freshwater resources; food, fiber, and forest products; terrestrial and freshwater ecosystems
Precipitation	Average annual precipitation declines, with up to 25 to 45 percent decline in spring precipitation by the end of the century (low and high emissions scenarios); number and duration of extreme dry events will increase in the second half of the century; increases in winter and spring temperatures will shift the timing of spring runoff to earlier in the year.	Freshwater resources; food, fiber, and forest Products; terrestrial and freshwater ecosystems
Sea level	Sea levels will rise to varying degrees along the California coast and present threats to both the managed and natural environments.	Terrestrial and freshwater ecosystems

Recent IPCC climate model simulations show that, as a general pattern, there will be a substantial decrease in annual runoff in the interior West, including the Colorado basin (Bates et al. 2008, Kundzewicz et al. 2007). A study by Cayan et al. (2010) reported that the twenty-first century drought in the Colorado River basin is more extreme than any other drying conditions over the past 100 years. Simulations project more severe droughts during the second half of the century, with some lasting for 12 or more years (Cayan et al. 2010).

The timing of runoff is also anticipated to change over the twenty-first century. A recent study projected that cool-season runoff will increase over the century for river basins in the West, including the San Joaquin, Sacramento, and Truckee basins. However, the runoff is projected to decrease in the southwestern United States and the southern Rocky Mountains (Colorado River basin and Rio Grande River basin). In addition, throughout the region warm-season runoff is projected to decline (Bureau of Reclamation 2011b).

Sea-level rise is expected to affect the California coast. Over the last century the sea level on the California coast rose by approximately 18.0 centimeters (7.1 inches) (EPA 2009e). The observed rates in San Francisco and San Diego were 15.0 to 20.1 centimeters (5.9 to 7.9 inches) (Cayan et al. 2006). However, there is much variability in sea-level trends across the U.S. western coastline, depending on such factors as local land subsidence/uplift, changes in ocean circulation, and changes in ocean salinity. Since 1993, tide gauge measurements and altimetry suggest no change in observed sea level along the U.S. west coast (Bromirski et al. 2011). Bromirski et al. (2011) found the shifts in ocean circulation driven by the recent prevailing wind patterns are responsible for effectively suppressing sea level rise, and suggest that when these wind patterns shift, a noticeable rise in regional sea level may occur. Continued gradual sea-level rise will exacerbate the impacts of high tides, storm surges, and freshwater floods (Cayan et al. 2008).

Models project that sea-level rise will continue to increase the vulnerability of coastal cities and tidal ecosystems to flooding and other hazards. Under a scenario of 40 centimeters (16 inches) of sea-level rise by 2050, approximately 180,000 acres of shoreline in the San Francisco Bay Area would be vulnerable to inundation. In addition, 90 to 95 percent of existing tidal marshes and flats would be affected, 20 percent of which would be vulnerable to permanent submersion or erosion (BCDC 2009 citing Heberger et al. 2009). Similarly, Santa Cruz sits 20 feet above sea level, and levees were constructed to withstand floods associated with the 100-year storm surge. However, combined with the projected 30 centimeters (12 inches) of sea-level rise, the level of storm surge that now has a 100-year recurrence interval could occur approximately every decade (California Energy Commission 2006).

5.5.2.5.1 Freshwater Resources

The major climate-related concern in the Southwest is the availability of freshwater resources. The region has historically been faced with limited resources, large-scale agriculture, and rapid population growth. Freshwater is also critical to the health of natural ecosystems. Reduced snowpack and irregular streamflow are two major driving factors in the availability of fresh water in the Southwest. Observed and projected changes suggest that snowpack and streamflow are likely to be affected by climate change. Using historical trends, the coupled impacts of low precipitation and warm temperatures are likely to put additional strain on water supplies (Cayan et al. 2010).

Snowpack in the western United States declined over the twentieth century. Observed snowpack decline has been most pronounced in lower elevations and in locations where winter temperatures are close to freezing, 0 °C (32 °F) (National Science and Technology Council 2008 citing Lettenmaier et al. 2008). In lower elevations in the western states, April spring snow water equivalent has declined by 15 to 30 percent since the 1950s (National Science and Technology Council 2008 citing Mote et al. 2003, 2005, Lemke et al. 2007).

Water in the Southwest is projected to become scarcer over the course of this century. Several authors project that Lake Mead (on the Colorado River system) could go dry (CCSP 2008e citing Barnett and Pierce in 2008). An article by Rauscher et al. (2008) suggested that a 3.0 to 5.0 °C (5.4 to 9.0 °F) increase in seasonal temperature by 2100 could cause snowmelt-driven runoff to occur as much as two months earlier than the present trend. This would have significant implications not only for freshwater resources but also for hydroelectric generation, agriculture, land use, and water management. A reduced water supply also will likely add conflict to the already contentious water rights issues in the region. Federal agencies have identified a number of areas, mostly in the West, where conflicts could arise over growing water shortages (DOI 2005, Brekke et al. 2009).

There is a trend toward earlier spring snowmelt across much of the western United States. The National Science and Technology Council 2008 (citing Stewart et al. 2005) reported that streamflow peaks in the snow-melt-dominated western mountains of the United States occurred 1 to 4 weeks earlier in 2002 than in 1948. Over the last century, stream discharge in the Rocky Mountain region has decreased by about 2 percent per decade (EPA 2009e). A study by the U.S. Bureau of Reclamation (2011b) found that basins in the Southwest are becoming drier. According to EPA (2009b), loss of snowpack in the Sierra Nevada and Colorado River Basin could leave 41 percent of the water supply in southern California vulnerable by the 2020s.

5.5.2.5.2 Terrestrial and Freshwater Ecosystems

Plant and animal species in the Northern Hemisphere are shifting ranges to the north and west and to higher elevations (Montoya and Rafaelli 2010). The following list provides examples of plant and animal species in the Southwest that have been observed or projected to be affected by changes in climate.

- A recent publication indicated that the lower bound of the elevation range of half of the 28 mammal species in Yosemite National Park in California moved approximately 500 meters (1,640 feet) upward since they were first studied a century ago. This is apparently consistent with the observed increase in local minimum temperatures of 3 °C (5 °F) (Pimm 2009 citing Moritz et al. 2008).

- Flowering patterns are shifting in timing and behavior. Alpine meadow systems in the southern Rocky Mountains have shifted the timing of flowering from a unimodal peak, lasting most of the summer, to bimodal peaks. This has led to a reduction in the total number of mid-summer flowers. A shift in the timing and abundance of flowers might not coincide with traditional pollinators (Aldridge et al. 2011). If nectar is a primary food source for the pollinators, the shift could result in a cycle of declining flowers and pollinators.
- The percentage of Rocky Mountain wildflower buds exposed to frost has doubled, hindering their reproductive ability (GCRP 2009). Early warmth in spring could cause some wildflowers to emerge before the danger of frost has passed.
- By 2050, coldwater stream fish habitat is projected to decline by 35 percent in the Rocky Mountain Region (Preston 2006).
- In the desert Southwest, where many rivers run east-west, fish species do not have the opportunity for northward migration. An increase of a few degrees in water temperature could cause many native fish species in the region to become extinct (Poff et al. 2002).
- In lowland California, 70 percent of 23 butterfly species advanced the date of first spring flights by an average of 24 days over 31 years (National Science and Technology Council 2008 citing Forister and Shapiro 2003).
- Populations of the American pika are declining (EPA 2009e). Several populations of the pika in the Rocky Mountain region appear to have disappeared as of the 1990s. The decline of the pika populations is likely correlated to changes in the availability of sufficient food and adequate habitat (Janetos et al. 2008).

This collective set of observed and projected impacts of climate change on Southwestern ecosystems suggests that in the Southwest, terrestrial and freshwater ecosystems are vulnerable.

5.5.2.5.3 Food, Fiber, and Forest Products

Warmer temperatures and less precipitation will affect the diversity, type, and health of forests in the Southwest. Bioclimatic modeling indicates that diversity in Southwest tree species will decline (GCRP 2009). A recent study analyzing tree ring patterns found that if temperature and precipitation patterns change as projected, forest growth in the southwestern United States will decrease substantially (Williams et al. 2010).

Declines in certain tree species have been linked to an increase in bark beetle and pine beetle outbreaks. Hotter, drier conditions in Colorado’s mountains have enabled bark beetles to cause a measurable decline in aspen trees (Saunders et al. 2008). Forest disturbances such as insect outbreaks are likely to intensify under warmer conditions with drier soils and a longer growing season (Saunders et al. 2008 citing Field et al. 2007). Similarly, mountain pine beetle outbreaks are currently occurring throughout high-elevation whitebark pine forests. Research suggests that the warmer temperatures are enabling the mountain pine beetle to survive the winter, resulting in more significant disturbances to whitebark pine forests (Logan et al. 2010).

Several studies have suggested a correlation between warmer temperatures and forest fires. Spracklen et al. (2009) projected that increases in temperature will cause the average acres burned in the western United States to increase by 54 percent by the 2050s compared to current rates. The Rocky Mountains are projected to experience the greatest increase, with 175 percent more area burned by the 2050s (Spracklen et al. 2009). Some types of forests that are also exposed to drought, such as the pinion pine-juniper forests in the Southwest, will be particularly vulnerable to forest fire (GCRP 2009). According to two climate models (the Geophysical Fluid Dynamics Laboratory model and National Center of Atmospheric Research Parallel Climate Model), the increased fire risk by the 2070 to 2099 time period will be greater in Northern California (15 to 90 percent) than in Southern California (between a 29 percent decline to a 28 percent increase). However, parts of the San Bernardino Mountains in Southern California are projected to experience an increase in fire risk under all scenarios (Westerling and Bryant 2006).

5.5.2.6 Northwest

This section discusses the impacts of climate change in the Northwest, which includes Idaho, the western portion of Montana, Oregon, and Washington. The region is vulnerable to a range of climate change impacts, including temperature increases, changes in precipitation patterns, and sea-level rise. These shifts will likely lead to more extreme heat, more frequent coastal inundation, and less reliable freshwater resources. These impacts will have a combined effect on the region's natural resources, energy production, agriculture, urban settlements, and human health.

Over the past century, the Northwest has experienced an average temperature increase of approximately 0.8 °C (1.5 °F), with some areas experiencing as much as a 2.2 °C (4.0 °F) increase (GCRP 2009 citing Mote 2003 and Mote et al. 2008). Projections for the next century range from 1.6 °C (3.0 °F) under the lower (B1) emissions scenario up to 5.5 °C (10.0 °F) for the higher (A2) emissions scenario (GCRP 2009 citing Mote et al. 2008). Using a moderate (A1B) emissions scenario, the University of Washington Climate Impacts Group projected an annual average temperature increase in the Northwest region of 1.1 °C (2.0 °F) by the 2020s, 1.8 °C (3.2 °F) by the 2040s, and 3.0 °C (5.3 °F) by the 2080s compared to the period 1970 through 1999 (Climate Impacts Group 2009).

Few statistically significant changes in precipitation have been observed in the region (Climate Impacts Group 2009). However, observed changes in streamflow timing and amount indicate a shift in precipitation patterns in the Northwest. Precipitation projections are less clear for the region because the impact varies by location and season. While summer precipitation is projected to decrease throughout much of the region, winter precipitation and the occurrence of heavy rainfall are projected to increase; annual precipitation obscures these seasonal changes. According to the Climate Impacts Group (2009), total annual precipitation in the region is projected to increase by 1 to 2 percent (compared to a 1970 through 1999 baseline). According to the Oregon Climate Change Research Institute (2010), the multi-model average projects a 14 percent decrease for summer precipitation by the 2080s. Walker et al. (2011 citing Mote and Salathe 2009) produced downscaled projections for Portland, Oregon, which include a 10 percent increase in precipitation by the end of this century.

The Northwest experiences precipitation-related extreme events, including flooding and droughts. The North Pacific winter storm track is projected to shift northward, which will likely result in slightly fewer, but more intense storms (Oregon Climate Change Research Institute 2010). This projection is consistent with the projection for an enhanced seasonal precipitation cycle with wetter autumns and winters and drier summers. In addition, changes in snowpack and streamflow are likely to contribute to increases in flood and drought risk (GCRP 2009 citing Stewart et al. 2004).

Table 5.5.2-6 summarizes the projected trends for climate variables in the Northwest and the associated resources the trends will affect.

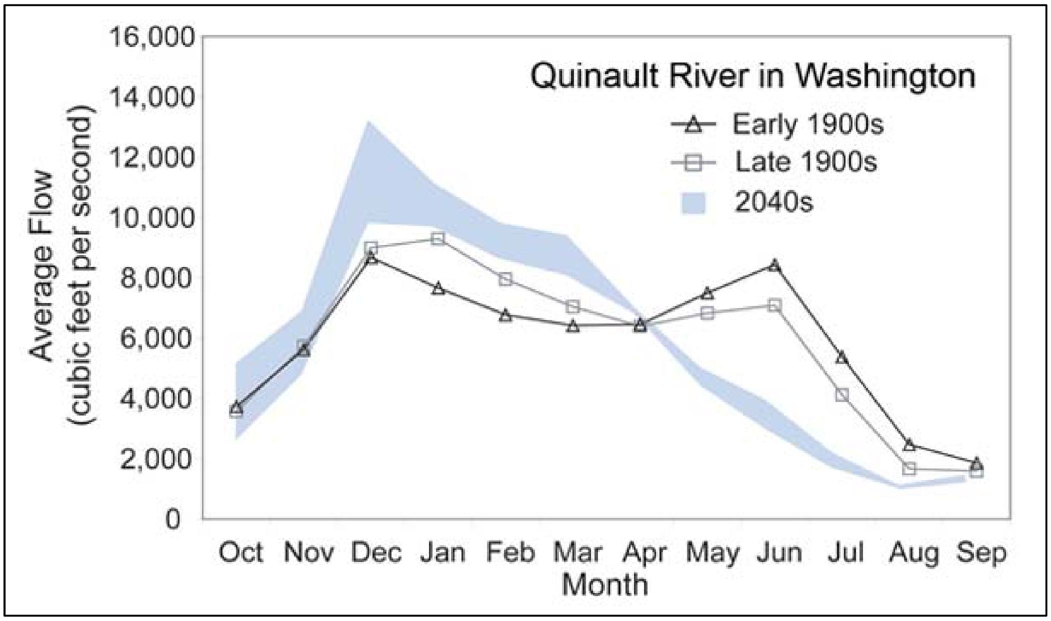
Table 5.5.2-6. Projected Trends in Environmental Variables for the Northwest

Environmental Variables	Projected Trend	Sectors at Risk
Temperature	Average annual temperature increase between 1.6 and 5.5 °C (3 and 10 °F)	Freshwater resources; food, fiber, and forest Products; terrestrial and freshwater ecosystems; industries, settlements, and societies; human health
Precipitation	Decreased summer precipitation, increased autumn and winter precipitation, more precipitation will fall as rain than snow; decrease in frequency and increase in intensity of precipitation events (less frequent, but heavier rains)	Freshwater resources; food, fiber, and forest products; terrestrial and freshwater ecosystems; industries, settlements, and societies; human health
Sea-level rise	Along the Pacific coast, 5 and 32 centimeters (2 to 13 inches) of sea-level rise by the end of the century	Terrestrial and freshwater ecosystems; industries, settlements, and societies

The snowpack in the Northwest is a significant factor in the availability of fresh water for human consumption (including agriculture), seasonal streamflow, and aquatic habitats. Climate Impacts Group (2009) ran models of two global climate simulations using the fine-scale Weather and Research Forecasting regional climate models. Both models suggest that temperature and precipitation projections will vary spatially based on interactions with the local terrain and coastlines. Despite differences, both simulations project losses in the Washington snowpack. Over the past 40 to 70 years, temperature increases have resulted in an average April 1 snowpack decline of about 25 percent (GCRP 2009 citing Christensen et al. 2007 and Mote 2006). The snowpack is projected to continue to decline by up to 40 percent in the Cascades by the 2040s (GCRP 2009 citing Payne et al. 2004). Over the past 50 years, the timing of peak spring runoff has also shifted by a few days earlier to as much as 25 to 30 days earlier (GCRP 2009 citing Stewart et al. 2004).

The Northwest has already seen a shift in the timing of streamflow. Data collected in the Quinault River, in northern Washington, show a pronounced shift in peak streamflow from the early 1900s to the late 1900s (*see* Figure 5.5.2-1). The earlier, more pronounced peak streamflow is projected to continue to shift through the 2040s (GCRP 2009 citing Hamlet et al. 2005 and Casola et al. 2005). Increases in winter and early spring flows will raise the seasonal flooding potential and substantially decrease summer flows (National Science and Technology Council 2008 citing Field et al. 2007). Recent low-flow years, in 2001 and 2005, have coincided with years of low winter precipitation (Oregon Climate Change Research Institute 2010).

Figure 5.5.2-1. Observed and Projected Average Streamflow of the Quinault River, Washington[a]



a. Source: GCRP (2009).

April 1 snowpack is a key indicator for streamflow. Historically, the snowpack melts in spring and summer, regulating the streamflow in the watershed. Compared to the 1916 through 2006 historical average, the April 1 snowpack is projected to decrease by 28 percent across Washington by the 2020s, 40 percent by the 2040s, and 59 percent by the 2080s (Climate Impacts Group 2009). Snowpacks in the lower elevations are most vulnerable (Oregon Climate Change Research Institute 2010). Peak spring runoff is also projected to continue to shift 20 to 40 days earlier by the end of the century (GCRP 2009 citing Stewart et al. 2004). According to the U.S. Bureau of Reclamation (2011b), projections indicate that snowpack losses in high-latitude and high-altitude areas (including the Columbia headwaters) could be offset by increases in cool-season precipitation.

Local sea-level rise along the Pacific coast will vary with local vertical movement of the land and atmospheric circulation (GCRP 2009 citing Mote et al. 2008). Low-lying areas of the United States Pacific coast are also at increasing risk of flooding as sea level rises (EPA 2009e). Mid-range estimates range from 5 to 33 centimeters (2 to 13 inches) of sea-level rise by the end of the century (Climate Impacts Group 2009). If the rates of ice melt from Greenland and Antarctica increase, projections for some areas suggest sea-level rise could be on the scale of 127 centimeters (50 inches) (GCRP 2009 citing Mote et al. 2008). By the middle of the twenty-first century, the rate of sea-level rise will likely exceed vertical land movement on the Oregon coast. Submerged areas will experience erosion and flooding (Oregon Climate Change Research Institute 2010). The heavily populated areas of the south Puget Sound (including Olympia, Tacoma, and Seattle, Washington) are most vulnerable to sea-level rise. Because the severity of individual events has been increasing, the frequency and magnitude of coastal flooding events will probably continue to increase (Oregon Climate Change Research Institute 2010). Although the frequency of precipitation events is projected to decrease, the frequency and intensity of extreme events is projected to rise; changes in the frequency and magnitude of coastal flooding will likely coincide with increases in the frequency and intensity of extreme events.

5.5.2.6.1 Freshwater Resources

The timing and availability of freshwater resources in the Northwest is likely to be affected by climate change. Although the annual amount of precipitation might remain relatively constant, population growth, increased temperatures, and the timing and type of precipitation will likely stress the availability of sufficient fresh water in the Northwest.

In a study projecting change in water demand in the Puget Sound region of Washington, Polebitski et al. (2011) found that projected climate change is likely to influence water demand and stress on public utilities. Temperature-driven increases in demand (both residential and commercial), combined with population growth, will likely outweigh conservation efforts (Polebitski et al. 2011). The Oregon Climate Change Research Institute (2010) projects that a 1.0 °C (1.8 °F) temperature increase would increase irrigation demand for agriculture by 10 percent.

5.5.2.6.2 Terrestrial and Freshwater Ecosystems

Aquatic ecosystems in the Northwest, such as those along the coasts or in lakes, rivers, and streams, will be affected by warmer temperatures, changes in precipitation patterns, sea-level rise, and storms.

Near-coastal and estuarine habitats will be affected by changes in water temperature, coastal upwelling, erosion, inundation, storminess, and ocean acidification (Oregon Climate Change Research Institute 2010). The Pacific coast has the greatest estimated long-term rate of coastal wetland loss for any area in the United States. These changes will affect near-shore ecosystems and estuarine habitats (Oregon Climate Change Research Institute 2010). Impacts on species will likely range from elevation shifts in distribution, disruption of shell formation for calcifying organisms, alteration of the phenology of phytoplankton blooms, shoreward migration of tidal marshes, and an increase in non-indigenous aquatic species (Oregon Climate Change Research Institute 2010). Changes in ocean acidity, shifts in disease and growth patterns, and more frequent harmful algal blooms could negatively affect shellfish production in the Pacific Northwest (Climate Impacts Group 2009).

Changes in streamflow and water temperatures can impact stream ecology; many plant and animal species will shift their distributions and abundance (Oregon Climate Change Research Institute 2010). In the Northwest, stream habitat is critical to the survival of several coldwater fish species, including salmon and trout. Salmon populations are already stressed by human activity, and climate change will likely exacerbate that stress. Historically, years characterized by low salmon abundance correlate to warmer periods (GCRP 2009 citing Janetos et al. 2008 and Crozier et al. 2008). Models of Pacific Northwest salmon populations project losses of 20 to 40 percent by 2050 (Battin et al. 2007). Both land use changes and climate change can alter riparian vegetation and influence the viability of stream habitats (Oregon Climate Change Research Institute 2010). Studies suggest that by the end of the century, one-third of the current salmon habitat in the Northwest will no longer be suitable (GCRP 2009 citing Francis and Mantua 2003).

In addition to changes in streamflow and water temperature, EPA has identified the Columbia River Basin as one of four large water bodies for which climate change is a particular concern (EPA 2009e). Another study, examining the effects of warming in Lake Washington in Seattle, Washington, found that spring thermal stratification occurs approximately 21 days earlier now than in the 1960s, and that the associated phytoplankton bloom has shifted accordingly. The zooplankton that feed on the phytoplankton have not adapted to the earlier bloom. This suggests that climate change can create timing (phenology) issues that could weaken trophic interactions on which freshwater fisheries depend (Woodward et al. 2010 citing Winder and Schindler 2004).

5.5.2.6.3 Food, Fiber, and Forest Products

Increased temperatures and decreased summer precipitation will likely affect the fire cycle, the survival of invasive species, the locations and diversity of forests, and the viability for agriculture in the Northwest. Higher CO_2 levels could temporarily increase productivity of forests and agricultural yields; however, over the long term, deficits in soil moisture (GCRP 2009), water shortages, and drought (Malmsheimer et al. 2008) will counteract any short-term gains.

Forested regions of the Pacific Northwest will be particularly vulnerable to increases in wildfires. An increase in annual temperatures of 1.0 °C (1.8 °F) compared to the 1950 through 2003 annual average could double the area burned during wildfires (NRC 2010a). Warmer and drier summers are projected to increase the vulnerability of forests west of the Cascades. Currently, most wildfires in the region occur on the east side of the mountains. Oregon Climate Change Research Institute (2010) estimates that the regional forest area burned will increase by 180 to 300 percent by the end of the century compared to the historical average from 1916 to 2006. Similarly, Climate Impacts Group (2009) projects that the area burned will double by the 2040s and triple by the 2080s compared to 1916 through 2006. In addition, the probability that more than 2 million acres will burn in any given year is projected to increase from 5 percent today to 33 percent by the 2080s (Climate Impacts Group 2009). Over time, the extensive warming and wildfires could exhaust the fuel for fire, gradually creating a negative feedback loop, reducing wildfire severity (NRC 2010a).

Changes in temperature and precipitation will likely create climates that are hospitable to new plant pathogens, insects, and weeds (Oregon Climate Change Research Institute 2010). Over the past 8 years, the occurrence of mountain pine beetles has increased in Oregon. Thirty-three million acres of trees in British Colombia have been destroyed by a mountain pine beetle outbreak, and Idaho's Sawtooth Mountains are now threatened (GCRP 2009 citing Ministry of Environment (British Columbia) 2007). The abundance and range of mountain pine beetles is likely to continue to increase in a warmer, drier climate (Oregon Climate Change Research Institute 2010).

Vegetation types will also shift under changing climate conditions. Vegetation models project a decrease in subalpine forest and tundra under warmer temperatures at higher elevations (Oregon Climate Change Research Institute 2010). Forests and woodlands are projected to expand into parts of eastern Oregon that are currently dominated by grasses and shrubs. Along the Oregon coast, areas of mixed evergreen and subtropical forest are projected to expand, transitioning from temperate to subtropical species (Oregon Climate Change Research Institute 2010). The extent and species composition of forests throughout the Northwest are projected to change. Some local populations may go extinct and biological diversity may decrease if the environmental changes outpace the species' ability to adapt to new conditions or migrate (GCRP 2009). Recent bioclimatic modeling shows that the Northwest could experience increased diversity of tree species over the long term (GCRP 2009).

Agriculture in the Northwest is projected to experience some benefits and face new obstacles with climate change. Over the past century, the length of the frost-free period has increased from 17 to 35 days in Oregon's wine grape growing regions (Oregon Climate Change Research Institute 2010). While a longer growing period could benefit crops in some ways, insects and pests might thrive in a warmer climate, survive over the winter, or increase reproduction and create additional stress on crops (Oregon Climate Change Research Institute 2010). In addition, warmer temperatures increase the need for irrigation. As long as there are sufficient irrigation supplies, the impact of climate change on apples, potatoes, and wheat in eastern Washington is projected to be mild over the next few decades. However, the impact will be increasingly detrimental over time and irrigation might not be sufficient; potential yield losses could reach 25 percent by the end of the century (Climate Impacts Group 2009).

5.5.2.6.4 Industries, Settlements, and Societies

Hydropower currently supplies approximately 66, 75, and 80 percent of the energy in Oregon, Washington, and Idaho, respectively (EIA 2012d). Energy demand is likely to increase with warmer summer temperatures and population growth, while summer hydropower supply is expected to decline with changes in seasonal streamflow (Hamlet et al. 2010). Increased winter streamflow could increase the supply of hydropower in the winter months (Hamlet et al. 2010). The combined effects of population growth and increased summer temperatures are expected to increase summer cooling demand by up to 363 to 555 percent by the 2040s (Climate Impacts Group 2009).

Urban stormwater infrastructure in the Northwest was designed based on mid twentieth century rainfall records. Although only a limited number of statistically significant extreme precipitation events have been observed in the region, models generally predict an increase in extreme high precipitation over the next half century. Extreme rain events can overload stormwater infrastructure and result in flooding and combined sewer overflows (events where mixed stormwater and raw sewage enter local waterbodies).

5.5.2.6.5 Human Health

Health impacts in the Northwest are likely to include an increase in heat- and air pollution-related deaths throughout the twenty-first century. A heat-mortality study projected that Seattle could sustain between 89 and 401 excess deaths in 2045 and between 107 and 988 excess deaths in 2085 compared to the average annual excess deaths experienced between 1997 and 2006, with residents older than 65 being more vulnerable than the general population (Jackson et al. 2010). Summertime (May through September) daily 8-hour maximum ozone concentrations are also projected to increase by 5.8 parts per billion in King County, Washington, and 6.1 parts per billion in Spokane County, Washington, resulting in 63 and 37 additional non-traumatic annual deaths per 100,000 by mid-century, respectively, compared to the rate from 1997 through 2006 (Jackson et al. 2010).

5.5.2.7 Alaska

This section discusses the impacts of climate change on Alaska. Alaska’s large and diverse land area results in important spatial and temporal variations in climatic conditions. Nevertheless, a significant statewide warming trend is apparent, with a rate of warming that is twice the national average (Trenberth et al. 2007, GCRP 2009, DOT 2010, Scenarios Network for Alaska Planning 2010). This has had major impacts on Alaska’s economy, ecosystems, and human settlements (Hinzman et al. 2005, GCRP 2009). Because of heightened concerns about the dramatic changes already observed, Alaska was one of the first states to focus on climate change adaptation (Alaska Adaptation Advisory Group 2010).

Between 1958 and 2008, annual temperatures across Alaska increased an average of 1.88 °C (3.4 °F), with warming nearly twice as high in winter, increasing an average of 3.5 °C (6.3 °F) (GCRP 2009). Some communities have experienced winter increases as high as 5 °C (9 °F) since the middle of the last century (ACRC 2012). By 2050, average annual temperatures in Alaska are projected to increase 1.94 to 3.9 °C (3.5 to 7.0 °F) above a 1961 through 1979 baseline, depending on the emissions scenario (GCRP 2009, DOT 2010). By the end of the century, Alaska's average annual temperature is projected to rise about 2.8 to 7.2 °C (5.0 to 13.0 °F) above the baseline (GCRP 2009, DOT 2010). Increases in warm days and large increases in warm nights above the 1961–1990 baseline are expected, along with very large decreases in cold days and large decreases in cold nights (IPCC 2012)14. Dai (Dai et al. 2011b) identified a recent trend toward more severe drought conditions.

Based on current trends, Alaska is expected to become wetter in winter and drier in summer. By 2050, mean winter precipitation is projected to increase by 7 to 24 percent compared to a 1961 through 1979 baseline; projections for the end of the century indicate an increase of 13 to 48 percent (DOT 2010). In addition, heavy precipitation events are increasing (Groisman et al. 2005); between 1950 and 2008, southern Alaska saw a 39 percent upward trend in heavy downpours (Kunkel et al. 2008).

Table 5.5.2-7 summarizes the projected trends for climate variables in Alaska and the associated resources the trends will affect.

Table 5.5.2-7. Projected Trends in Environmental Variables for Alaska

Environmental Variable	Projected Trend	Vulnerable Sectors
Temperature	By 2050, annual average temperatures are projected to increase 1.94 to 3.9 °C (3.5 to 7.0 °F) compared to a 1961 through 1979 baseline; the projected increase by 2100 is 2.8 to 7.2 °C (5.0 to 13.0 °F) .	Freshwater resources; ecosystems; food, fiber, and forest products; industries, settlements and societies; health
Precipitation	By 2050, mean winter precipitation is projected to increase 7 to 24 percent compared to a 1961 through 1979 baseline; by 2100, an increase of 13 to 48 percent is projected	Possible ecosystem effects
Extreme Events	Trend toward more severe droughts and heavy precipitation events.	Freshwater resources; ecosystems; food, fiber, and forest products; industries, settlements, and societies

5.5.2.7.1 Reductions in Permafrost, Glaciers, Snow Cover, and Sea Ice

Warming is increasing permafrost melting, glacial retreat, and reductions in snow cover. Permafrost is the frozen ground 0.31 to 0.61 meter (1 to 2 feet) below the surface in cold regions. Temperatures in the colder permafrost of northern Alaska, the Canadian Arctic, and Russia have increased up to 3.0 °C (5.4 °F) near the permafrost table and 1.0 to 2.0 °C (1.8 to 3.6 °F) at depths of 10 to 20 meters (32.8 to 65.6 feet) since the late 1970s and early 1980s (Osterkamp 2007, 2009). As a result, permafrost thickness is declining an average 0.02 meter per year (0.79 inch per year) (Kundzewicz et al. 2007), and large areas of thermokarst terrain (subsidence from thawing) are observed (Jorgenson et al. 2006, Osterkamp et al. 2009). The subsidence averages 1 to 2 meters (3.3 to 6.6 feet), reaching as much as 6 meters (19.7 feet) in some locations (CCSP 2009). Thawing is projected to accelerate under future warming, with as much as the top 3 to 9 meters (10 to 30 feet) of discontinuous permafrost thawing by 2100 (Romanovsky et al. 2007). A recent IPCC report is consistent with these observations, concluding

[14] Cold/warm/days/nights are indices for 10th and 90th percentiles of Tmax/Tmin computed on daily time frames are referred to as 'cold/warm days/nights' (IPCC 2012).

that there is *high confidence* that permafrost temperatures will continue to increase, resulting in increases in active layer thickness and reductions in the area of permafrost throughout the Arctic and subarctic (IPCC 2012).

Arctic glaciers are melting, with a particularly rapid retreat of Alaska's glaciers (ACIA 2005). All three of the U.S. Geological Survey "benchmark" glaciers in the United States (the South Cascade Glacier in Washington, the Wolverine Glacier near Alaska's southern coast, and the Gulkana Glacier in Alaska's interior) have shown an overall decline in mass since the 1950s and 1960s (EPA 2010c). In southern Alaska, there has been a vertical reduction in glacier cover of several hundred meters (Sauber and Molnia 2004). Over the past few decades there has been an Arctic-wide reduction in seasonal sea-ice extent. The trends are smallest in winter and largest in September, the end of the melt season. When referenced to the 1979 through 2000 mean, the rate of decline in sea-ice extent in September is about 12 percent per decade (Serreze 2011), a rate of decline that has been even greater than expected based on model projections (Stroeve et al. 2007). Sea-ice melting can be very rapid in a single season (Stroeve et al.2007), and periods of rapid sea-ice loss lead to faster warming over land in the northern polar region (Serreze et al. 2009).

5.5.2.7.2 Freshwater Resources

Alaska is relatively rich in freshwater resources, although declines are apparent from a number of global changes (Alessa et al. 2011). For example, permafrost thawing and increased evaporation have led to a substantial decline in Alaska's closed-basin lakes (lakes without stream inputs and outputs) (Klein et al. 2005, Riordin et al. 2006).

5.5.2.7.3 Terrestrial and Freshwater Ecosystems

There have been rapid and complex changes in ecological dynamics across the Arctic associated with climate change (Post et al. 2009a). Permafrost thawing disturbs the root systems of trees, causing trees to sink into the ground. As the trees in Alaska's forest sink, they lean over, creating what are called "drunken forests." Alaska's treeline is moving northward, and there has been an expansion of boreal forest into tundra (Chapin et al. 2010), encroaching on habitat for a number of migratory birds and land mammals, such as caribou (wild reindeer) (GCRP 2009). The change from high-albedo tundra to lower-albedo boreal forest results in a warming feedback (Leadley et al. 2010). Shrub cover is increasing (Tape et al. 2006), although expansion has been constrained to some extent by herbivory by caribou and muskoxen (Post and Pederson 2008).

Other changes to tundra vegetation include decreases in herbaceous, bryophyte, and lichen species (Leadley et al. 2010). Lichens are an important food source for caribou in winter, and loss of this food supply can lead to declines in caribou growth and abundance. Caribou are a critical food source for Alaska Natives and animals such as bears and wolves (GCRP 2009).

There is a significant increasing trend in the length of the growing season in Alaska as a result of an earlier start to spring and a later first frost in autumn. The increase is as much as 3.8 days per decade in boreal forest and 2.0 days per decade in tundra ecosystems. Over the past 100 years, the length of the growing season in the area around Fairbanks increased by 45 percent (Wendler and Shulski 2009). Earlier springtime has advanced flowering dates in 6 plant species, the median emergence dates of 12 taxa of arthropods, and clutch initiation dates in 3 species of birds. These events have advanced by more than 30 days during the last decade in the High Arctic (northern regions within the Arctic Circle) (Høye et al. 2007).

Higher temperatures and reduced soil moisture increase the risk of drought, fire, and insect infestations. Alaska's spruce forest has declined substantially in recent decades from both fire and insect damage (GCRP 2009). Tundra burning is unprecedented in the central Alaskan Arctic in the last 5,000 years (Hu et al. 2010). Over the past 60 years, there have been fires in all major tundra regions in Alaska in association with exceptionally warm and dry weather conditions in summer and early autumn (Hu et al. 2010). During the 2000s, 50 percent more area in Alaska burned than during any decade since recordkeeping began in the 1940s, and 4 of the 11 largest fire years since 1940 occurred between 2002 and 2009 (Kasischke et al. 2010). By the middle of the century, the average area burned by wildfire in Alaska each year is likely to double (Balshi et al. 2009).

During the 1990s, south-central Alaska experienced the largest outbreak of spruce beetles in the world, attributable to the combination of rising temperatures speeding up the life cycle of the beetle and extended drought weakening the trees (Bentz et al. 2010, GCRP 2009). Spruce budworm in Alaska can now complete its lifecycle in 1 year, rather than the 2 years required previously (Berg et al. 2006). This allows many more individuals to survive the overwintering period, resulting in heavy damage to boreal forests. It is estimated that more than 1 million hectares (2.5 million acres) of spruce trees in Alaska have been lost in recent years (Berg et al. 2006) due to spruce beetles.

5.5.2.7.4 Marine, Coastal, and Low-lying Areas

Changes in sea ice are reducing habitat for species such as the polar bear (Post et al. 2009a). Observed decadal changes from 1985 through 1995 and 1996 through 2006 show pronounced losses of polar bear habitat during spring and summer in the southern Beaufort, Chukchi, Barents, and East Greenland seas. Increasing habitat losses are projected for the twenty-first century (Durner et al. 2007), and it is estimated that two-thirds of Alaska's polar bears could disappear from Alaska by the middle of this century (GCRP 2009).

5.5.2.7.5 Food, Fiber, and Forest Products

Declines in abundance and local and global extinctions of the Arctic's commercial fish species are projected for this century. Species vulnerable to declines include Arctic char, broad whitefish, and arctic cisco, which are important components of the diets of indigenous peoples (ACIA 2005). The Bering Sea produces the largest commercial fishery harvests in the United States and supports subsistence economies of the Alaska Natives (ACIA 2005). Current observations indicate that continued climate-related changes in the north Bering Sea could result in major shifts in marine fish stocks, including commercially important species such as pollock (Grebmeier et al. 2006). Alaska's surface waters and wetlands provide breeding habitat for millions of waterfowl and shorebirds, and are important to Alaska Natives who hunt and fish (GCRP 2009). Alaska Natives also hunt polar bears, walruses, seals, and caribou, all of which are experiencing habitat declines in association with changing climatic conditions. This not only diminishes the food supply of Alaska Natives, but it also affects their spiritual and cultural identity (ACIA 2005; GCRP 2009).

5.5.2.7.6 Industries, Settlements, and Societies

The rate of erosion along Alaska's northeastern coastline has doubled over the past 50 years as a result of melting sea ice, increasing summer sea surface temperatures, rising sea level, thawing coastal permafrost, and increases in storminess and waves (Jones et al. 2009). Increased coastal erosion is causing some shorelines to retreat at rates averaging tens of feet per year (GCRP 2009). Most of Alaska's more than 200 native villages are experiencing serious coastal erosion and flooding, resulting in millions of dollars in property damage and threats to lives and property (GAO 2009). Since 2003, federal, state, and village officials have identified 31 villages facing imminent danger (USACE 2009), and 12 of these have decided to relocate. Relocating villages considered to face the most immediate threats (Shishmaref, Kivalina, Koyukuk, Newtok, Unalakleet, and Shaktoolik) is already underway, a process expected to take many years and cost hundreds of millions of dollars (State of Alaska 2008, GAO 2009).

Melting permafrost is also a major concern. As temperatures rise and permafrost thaws, the frozen soil softens and sinks, damaging structures built on or in the soil and interfering with ecosystem structures and functions. It is estimated that as many as 100,000 Alaskans (14 percent of the population) live in areas where permafrost is melting (USARC 2003).

5.5.2.7.7 Human Health

A recent study found that an additional effect of Arctic warming is the release of toxic chemicals previously held in the area's water, snow, ice, and soils. Persistent organic pollutants are evaporating into the atmosphere above the warming Arctic, where they can recirculate and once again pose a threat to human health and the environment (Ma et al. 2011). Melting permafrost releases GHGs from tundra soils (Leadley et al. 2010). Schuur and Abbott (2011) calculated that permafrost thaw will release the same order of magnitude of carbon as deforestation, but because there will also be significant releases of CH_4, the overall effect on climate could be 2.5 times greater.

5.5.2.8 Islands (Hawaii and the Caribbean)

This section discusses the impacts of climate change on the U.S. tropical islands of Hawaii, Kauai, Lanai, Maui, Molokai, Oahu, and territories in the Caribbean, Puerto Rico and the U.S. Virgin Islands. Small islands are vulnerable to a variety of climate change impacts, including sea-level rise, coastal erosion, ocean acidification, an increase in the frequency of heavy rain events, and increases in the wind speeds and rainfall rates of tropical storms. These impacts have major implications for island ecosystems, economies, and communities (GCRP 2009). In particular, freshwater resources; ecosystems; agriculture and fisheries; and industries, settlements, and societies are projected to be at risk.

Table 5.5.2-8 summarizes projected trends in key environmental variables and affected resources. Rising temperatures have been observed on U.S. tropical islands in recent decades (GCRP 2009). For example, data show a relatively rapid rise in surface temperature in Hawaii in the last 30 years that average 0.17 °C (0.30 °F) per decade, with stronger warming at the higher elevations of above 792 meters (2,600 feet) (Giambelluca et al. 2008). An increase in annual mean air and ocean surface temperatures is projected for both Hawaii and islands in the Caribbean for the rest of this century.

Table 5.5.2-8. Projected Trends in Environmental Variables for the Islands

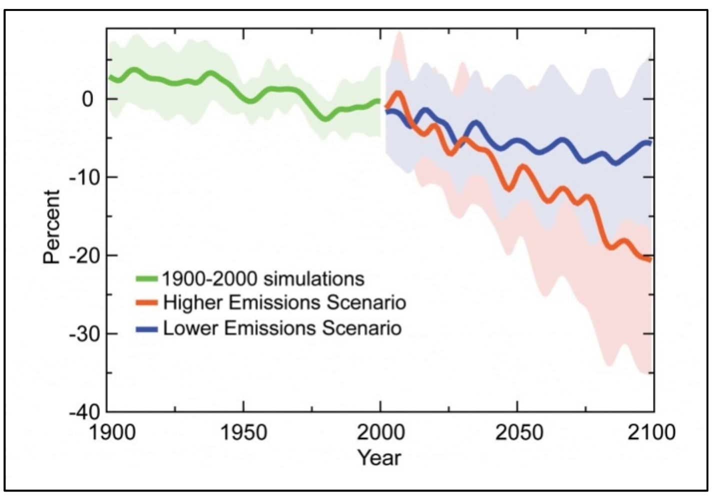
Environmental Variable	Projected Trend	Affected Resource
Temperature	Increase in annual mean air and ocean surface temperatures for both Hawaii and islands in the Caribbean	Terrestrial, marine, and coastal ecosystems
Precipitation	Increase in summer precipitation and frequency of heavy downpours in the Pacific (although the range of rainfall projections for the Pacific is still quite large); decrease in precipitation in the Caribbean.	Freshwater resources; terrestrial, marine, and coastal ecosystems; food, fiber, and forest products; industries, settlements, and societies

Environmental Variable	Projected Trend	Affected Resource
Sea level	Increase in sea levels for both Hawaii and many islands in the Caribbean	Freshwater resources; terrestrial, marine, and coastal Ecosystems; food, fiber, and forest products; industries, settlements, and societies

Total annual precipitation has declined in Puerto Rico and other Caribbean islands over the last 100 years, and stronger declines are projected for the rest of the twenty-first century (Figure 5.5.2-2). Hawaii has also experienced declines in average precipitation between 1901 and 2008 due to shifting weather patterns (EPA 2010c). The annual maximum number of consecutive dry days in the Hawaiian Islands has been increasing since the 1950s, with longer dry periods of 35 to 80 days occurring more frequently in the last 30 years (Chu et al. 2010). Hawaii and other Pacific islands are projected to see an increase in rainfall and the frequency of heavy downpours during summer months. However, the range of rainfall projections for Hawaii is still large (GCRP 2009). A recent downscaling exercise of the IPCC Fourth Annual Report climate change scenarios for Hawaiian rainfall shows equivocal results: 2 of the 6 models indicate opposite signs, with 1 model projecting a rainfall increase of 20 to 30 percent over the islands, and the other suggesting a 10 to 20 percent rainfall decrease during the wet (winter) season from November to April. The most likely scenario for Hawaii from this 6-model ensemble is a 5 to 10 percent reduction of the wet (winter) season precipitation and a 5 percent increase during the dry (summer) season (Timm and Diaz 2009). Total annual precipitation has declined in the Caribbean and is projected to further decline in the future. A stronger decrease is projected under higher emission scenarios. The shaded areas in Figure 5.5.2-2 show the likely ranges, while the lines show the central projections from a set of climate models (GCRP 2009).

Both Hawaii and many of the islands in the Caribbean have experienced rising sea levels in recent decades, and this trend is projected to continue during the twenty-first century. In addition, hurricanes and typhoons are projected to be more severe because temperature increase is likely to result in greater storm wind speeds and rainfall rates (GCRP 2009).

Figure 5.5.2-2. Observed and Projected Precipitation Changes in Caribbean Islands (1900–2100)[a]



a. Source: GCRP (2009).

5.5.2.8.1 Freshwater Resources

Because rainfall recharges island groundwater and surface water, a decline in overall precipitation for the Caribbean will reduce the availability of freshwater resources. While projected increased summer precipitation in the Pacific islands could initially appear beneficial, heavy rainfall could lead to increased flooding, which would reduce the quality of drinking water. Furthermore, sea-level rise causes salt water contamination of water resources and increases the frequency of flooding due to storm high tides, therefore exacerbating water pollution from sources such as agriculture or sewage. Coastal inundation and erosion could result in permanent loss of land, which would also reduce supplies of fresh water (GCRP 2009).

5.5.2.8.2 Terrestrial and Freshwater Ecosystems

The unique terrestrial ecosystems of islands are climate sensitive, and changes in temperature and precipitation can have major impacts on these ecosystems. A study shows that as climate changes, deadly nonnative bird diseases including avian malaria and pox will likely move upslope along mountainsides, invading most of the last disease-free refuges for the already endangered honeycreepers in Hawaii (Atkinson et al. 2009). Another study found the warming trend at high elevations (above 792 meters [2,600 feet]) in Hawaii to be greater than the global rate, and indicates that this trend could have significant ecological impacts such as the spread of avian disease, decreased rainfall, and threats to native forests. It also identified a much larger increase in minimum temperatures than maximum temperatures, suggesting that the rapid rise in minimum temperatures could be due to increases in cloud cover. Nighttime (minimum) temperature increase could have significant negative impacts on Hawaii's vulnerable terrestrial ecosystems, because native plants could have to compete with nonnative species that are better adapted to higher nighttime temperatures (Giambelluca et al. 2008).

5.5.2.8.3 Marine, Coastal, and Low-lying Areas

Sea-level rise, together with storm surge and coastal erosion, make Hawaii and islands in the Caribbean particularly vulnerable to coastal inundation, which can have significant effects on island freshwater resources, infrastructure, and economic activities. Loss and inundation of coastal habitats also destroys or degrades mangrove and coral reef ecosystems, while warmer and increasingly acidic ocean waters present additional threats to coral reefs (e.g., bleaching and reduced calcification). Furthermore, climate change can increase the spread of invasive species, pathogens, and diseases that further endanger the islands' marine and coastal ecosystems (GCRP 2009 citing Donner et al. 2005, Paulay et al. 2002, Graham et al. 2006, and Mimura et al. 2007).

5.5.2.8.4 Food, Fiber, and Forest Products

Climate change is projected to affect agriculture and fisheries, which are critical to the livelihoods of island communities. Damage to mangrove or coral reef ecosystems will negatively affect fisheries that depend on the health of such ecosystems. In addition, climate change is projected to cause a decrease in tuna stocks and an eastward shift in their location, therefore reducing the catch of tuna in Hawaii (GCRP 2009).

Other impacts such as sea-level rise, salt-water intrusion, flooding, and reduced freshwater availability can reduce crop yield (GCRP 2009 citing Burns 2002). For example, a study of seasonal climate change impacts on evapotranspiration, precipitation deficit, and crop yield in Puerto Rico indicates that the rainy season will become wetter and the dry season will become drier. Based on this scenario, the study finds that between 2000 and 2090, the 20-year average relative crop yield for all scenarios is likely to decrease on average from 6 to 12 percent during September, but increase on average from 51 to 64 percent during February. However, the study notes that these results need to be used with caution, as they are based in part on coarse resolution data of a single GCM downscaled to local sites (Harmsen et al. 2009). Indeed, an ensemble of 15 different models gives a different projection of a decline in overall precipitation for the Caribbean (*see* Figure 5.5.2-2) (GCRP 2009).

5.5.2.8.5 Industries, Settlements, and Societies

Most island settlements and economic activities, and therefore their supporting infrastructure, are concentrated close to the coast, making them vulnerable to shoreline erosion and flooding from sea-level rise and storm surge. Long-term damage to critical infrastructure such as roads, airports, ports, and hospitals would disrupt social services such as disaster risk management, health care, education, freshwater resource management, agriculture, and tourism. Tourism in particular plays a vital role in the islands' economies, and will be negatively affected by extreme weather events, reduced availability of fresh water, public health concerns about diseases, and destruction or degradation of ecosystems such as mangroves and coral reefs that attract tourists (GCRP 2009 citing Shea et al. 2001, CEO 2004, Burns 2002, Cesar and van Beukering 2004, and Hoegh-Guldberg et al. 2007). Furthermore, sea-level rise and shoreline erosion could result in a reduction in island size and the abandonment of inundated areas, which would have major social and economic impacts for island communities (National Science and Technology Council 2008, EPA 2009e).

5.6 Non-climate Cumulative Impacts of Carbon Dioxide

5.6.1 Background

In addition to its role as a GHG in the atmosphere, CO_2 is exchanged between the atmosphere and water, plants, and soil. CO_2 readily dissolves in water, combining with water molecules to form carbonic acid. The amount of CO_2 dissolved in the upper ocean is related to its concentration in the air. About 30 percent of each year's emissions (Canadell et al. 2007) dissolves in the ocean by this process; as the atmospheric concentration continues to increase, the amount of CO_2 dissolved will increase. Although this process moderates the increase in the atmospheric concentration of CO_2, it also increases the acidity of the ocean. Increasing CO_2 concentrations in the atmosphere and surface waters will have a global effect on the oceans; by 2100, the average ocean pH could drop by 0.3 to 0.4 unit compared to ocean pH today (Caldeira and Wickett 2005, Feely et al. 2009).

Terrestrial plants remove CO_2 from the atmosphere through photosynthesis, using the carbon for plant growth. This uptake of carbon by plants can result in an atmospheric CO_2 concentration approximately 3 percent lower in the growing season than in the non-growing season (Perry 1994 citing Schneider and Londer 1984). Increased levels of atmospheric CO_2 essentially act as a fertilizer, positively influencing normal annual terrestrial plant growth. Over recent decades, terrestrial carbon uptake has been equivalent to approximately 30 percent of each year's CO_2 emissions (Canadell et al. 2007); this process is about equal to CO_2 dissolution in ocean waters in moderating the effect of increasing CO_2 emissions on the atmospheric CO_2 concentration.

In addition, atmospheric CO_2 concentration affects soil microorganisms. Only recently has the relationship between aboveground and belowground components of ecosystems been considered significant; there is increasing awareness that feedbacks between the aboveground and belowground components play a fundamental role in controlling ecosystem processes. For example, plants provide most of the organic carbon required for belowground decomposition. Plants also provide the resources for microorganisms associated with roots (Wardle et al. 2004). The "decomposer subsystem in turn breaks down dead plant material, and indirectly regulates plant growth and community composition by determining the supply of available root nutrients" (Wardle et al. 2004).

Specific plant species, depending on the quantity and quality of resources provided to belowground components, might have greater impacts on soil biota and the processes regulated by those biota than other plants. Variations in the quality of forest litter produced by coexisting species of trees, for example, "explains the patchy distribution of soil organisms and process rates that result from 'single tree' effects" (Wardle et al. 2004). The composition of plant communities has a consistent and substantial impact on the composition of root-associated microbes. However, the effects of plant community composition on decomposer systems are apparently context-dependent. In one study, manipulating the composition of plant communities in five sites in Europe produced distinct effects on decomposer microbes, while root-related soil microbes experienced no clear effect (Wardle et al. 2004).

Terrestrial communities contain as much carbon as the atmosphere. Forest ecosystems, including forest soils, play a key role in storing carbon. The amount of carbon stored in soils of temperate and boreal forests is about 4 times greater than the carbon stored by vegetation, and is "33 percent higher than total carbon storage in tropical forests" (Heath et al. 2005). Forest soils are the longest-lived carbon pools in terrestrial ecosystems (King et al. 2004). Several experiments involving increases of atmospheric CO_2 resulted in increasing carbon mass in trees but a reduction of carbon sequestration in soils. This observation is attributable to increased soil microorganism respiration (Heath et al. 2005, Black 2008); respiration is associated with "root herbivory, predation, consumption of root exudates, and the decomposition of root and leaf litter" (King et al. 2004). Under climate change, the reduction of soil carbon via increased soil respiration could be counterbalanced by an increase in litter on the forest floor due to increased productivity. However, one recent study suggests that while increasing carbon could increase root production, it could decrease the quality of forest litter (Pritchard 2011).

5.6.2 Environmental Consequences

Sections 5.6.2.1 and 5.6.2.2 provide a qualitative analysis of non-climate cumulative impacts of CO_2.[15] As with the climatic effects of CO_2, the changes in non-climate impacts associated with the action alternatives are difficult to assess quantitatively. This is because the projections of incremental change in atmospheric CO_2 associated with the action alternatives are not large enough to translate to noticeable changes in ocean acidification or CO_2 fertilization. Nonetheless, it is clear that a reduction in the rate of increase in atmospheric CO_2, which all the action alternatives would provide to some extent, would reduce non-climate impacts of CO_2, such as the ocean acidification effect and the CO_2 fertilization effect described in Section 5.6.2.1. This section provides in-depth detail on this topic because it is an area of active research where findings are continuously being updated and refined.

5.6.2.1 Ocean Acidification

Ocean acidification occurs when CO_2 dissolves in seawater, initiating a series of chemical reactions that increases the concentration of hydrogen ions and makes seawater less basic (and therefore more acidic) (Bindoff et al. 2007, Menon et al. 2007, Doney et al. 2009a, 2000b, Feely et al. 2009). An important consequence of this change in ocean chemistry is that the excess hydrogen ions bind with carbonate ions, making the carbonate ions unavailable to marine organisms for forming the calcium carbonate minerals (mostly aragonite or calcite) that make up their shells, skeletons, and other hard parts. Once formed, aragonite and calcite will re-dissolve in the surrounding seawater, unless the water contains a sufficiently high concentration of carbonate ions (recent reviews by Doney 2009, Doney et al. 2009a, 2009b, EPA 2009e, Fabry et al. 2008, Fischlin et al. 2007, Guinotte and Fabry 2008, The Royal Society 2005, SCBD 2009).

For many millennia before the present, ocean pH changed little. Even during the warm Cretaceous period, about 100 million years ago, when atmospheric CO_2 concentrations were between 3 and 10 times higher than at present, it is considered unlikely that there was a significant decrease in ocean pH. This is because the rate at which atmospheric CO_2 changed in the past was much slower than at present, and during slow natural changes, the carbon system in the oceans has time to reach a steady state with sediments. If the ocean starts to become more acidic, carbonate is dissolved from sediments, buffering the chemistry of the seawater so that pH changes are lessened (The Royal Society 2005).

As anthropogenic emissions have increased, CO_2 in the atmosphere has accumulated and a net flux of CO_2 from the atmosphere to the oceans has occurred. As a result, the pH and carbonate ion concentrations of the world's oceans have declined compared to the pre-industrial period by 0.1 pH

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[15] *See* U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); CEQ (1997b) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

units (on a logarithmic scale), representing a 30 percent increase in ocean acidity (Caldeira and Wickett 2003, EPA 2009e).

By 2100, depending on the emission scenario modeled, the average ocean pH could decline by another 0.3 to 0.4 pH units from today's levels (Orr et al. 2005, Fischlin et al. 2007, Feely et al. 2009). The current atmospheric concentration of CO_2 (389 ppm per NOAA 2012) is already more than 38 percent higher than pre-industrial levels (EPA 2009e). Further increases will have important consequences for marine life (Doney 2009). In fact, Caldeira et al. (2007) estimated that atmospheric CO_2 would need to be stabilized below 500 ppm for the change in locally measured ocean pH to remain below the limit of 0.2 pH units of human-caused variation established in 1976 under Clean Water Act Section 304(a) to protect marine life (EPA 1976).

At present, the oceans' surface waters contain enough carbonate ions to sustain marine life. As the oceans absorb increasing amounts of CO_2, the greatest pH decline in the oceans' surface waters compared to the global average will occur in polar and subpolar regions. Approximately 42 percent of the ocean volume is saturated with respect to aragonite (a form of calcium carbonate) (Bindoff et al. 2007). The saturation horizon (the depth above which super-saturation occurs and within which most of the oceans' marine life occurs) is becoming shallower (Feely et al. 2004, 2009). As the ocean absorbs more CO_2 and ocean acidity increases, fewer carbonate ions will be available for organisms to use for calcification.

CO_2 dissolves more readily in cold water, which is naturally low in carbonate ion concentration and more acidic than surface waters (Meehl et al. 2007). Orr et al. (2005) used 13 climate models of the ocean-carbon cycle to assess calcium carbonate saturation under the IPCC IS92a "business as usual" scenario (1 of the 6 IPCC emission scenario alternatives developed in 1992) (Leggett et al. 1992). Under these model runs, Southern Ocean surface waters would begin to become undersaturated with respect to aragonite as early as 2050; by 2100 all of the Southern Ocean south of 60 degrees south and portions of the Subarctic North Pacific Ocean could become undersaturated (EPA 2009e). Simulation of the IPCC IS92a scenario predicted wintertime aragonite undersaturation in the Southern Ocean starting between 2030 and 2038 (McNeil and Matear 2008), with 10 percent of the area becoming undersaturated at least 1 month per year during this decade (Hauri et al. 2009). Simulation of the SRES A2 scenario (IPCC 2000) predicts aragonite undersaturation in Arctic surface waters once the atmospheric CO_2 concentration increases above 450 ppm (Steinacher et al. 2009). Under this scenario, the ocean volume that is saturated with respect to aragonite could decrease from approximately 42 percent today to 25 percent by 2100, resulting in a significant loss of marine life (Steinacher et al. 2009).

A model developed recently by Friedrich et al. (2012) estimated that 30 to 50 percent of ocean water above 40 ° latitude will become undersaturated by 2100. The model indicated large variability between regions, with fluctuations in upwelling near the Galápagos Islands causing large swings in the aragonite saturation state, while conditions will remain steady in the Caribbean. On average, aragonite saturation states at reefs in the Caribbean and western Pacific were simulated to drop by five times the range of natural variability. In areas where that range is small, such as Melanesia, the drop is as high as 30 times the range of natural variability. In all areas where coral reefs are found, Friederich et al. estimated that calcification rates of reef organisms have already dropped by approximately 15 percent (compared to pre-industrial levels), and indicated rates could decrease by a total of 40 percent under the moderate (A1B) emissions scenario by 2100. The authors estimate that 30 to 50 percent of ocean water above 40 degrees latitude will become undersaturated by 2100. The Southern Ocean, the most sensitive region, will be undersaturated with aragonite as early as 2030.

Recent observations indicate that ocean acidification is increasing in some areas faster than expected (Hauri et al. 2009). Hydrographic surveys have found that this differential acidification occurs, for example, when wind-induced upwelling of seawater undersaturated with respect to aragonite spreads out over the continental shelf; evidence of this is reported from western North America during unusual weather conditions, decades earlier than model predictions for average weather conditions (Feely et al. 2008, Hauri et al. 2009). Seasonal upwelling is also observed in the California Current System, the Humboldt Current System, and other eastern-boundary upwelling systems (Hauri et al. 2009). Measurements of ocean pH off the coast of Washington State over 8 years found that acidity in the region has increased more than 10 times faster than in other areas (Wootton et al. 2008). Because measurements in other parts of the ocean will not reflect this regional variability, there is concern that the more immediate vulnerability of marine organisms in upwelling areas might be overlooked (Hauri et al. 2009).

5.6.2.1.1 Impacts of Ocean Acidification on Marine Life

The results of most laboratory and field studies to date indicate that the reduction in calcium carbonate resulting from ocean acidification reduces the calcification rates of marine organisms, a finding that holds over a wide range of taxa (NRC 2010b). Other studies suggest that some species could benefit from conditions of low pH, at least during certain life stages. A complex picture is emerging, indicating that there will be “winners” and “losers” in acidified oceans (Ries et al. 2009, NRC 2010b).

Recent reviews of available studies are provided by Doney et al. (2009a, 2009b), Fabry et al. (2008), Guinotte and Fabry (2008), Fischlin et al. (2007), The Royal Society (2005), Haugan et al. (2006), SCBD (2009), and UNEP (2010). Details about the available literature are presented in Table 1 of Fabry et al. (2008), Table 2 of Guinotte and Fabry (2008), and Tables 2 and 3 of SCBD (2009). The following paragraphs provide representative results from the peer-reviewed literature as of September 1, 2011. Both modeling results and observations indicate that ocean acidification has adverse impacts on a variety of marine taxa ranging from the individual to ecosystem levels. This will affect the marine-based diets of billions of people (UNEP 2010).

***Warmwater Corals*.** Under the SRES A2 scenario, ocean waters with an aragonite saturation level suitable for coral growth are projected to disappear between 2050 and 2100 (Guinotte et al. 2006). Models of CO_2 concentrations up to 560 ppm (a doubling of pre-industrial levels), which could occur by mid-century, predicted a 20 to 60 percent decrease in the calcification rates of tropical reef-building corals, depending on the species (Guinotte and Fabry 2008, Hoegh-Guldberg et al. 2007, Kleypas et al. 1999). A study by Silverman et al. (2009) produced even more dramatic results, predicting that existing reefs could stop growing and start to dissolve once atmospheric concentrations reach the 560-ppm level. Other studies indicate that the percent decreases in calcification rates will be species- and life-stage specific (Cohen and Holcomb 2009, Kleypas and Yates 2009). Fine and Tchernov (2007) studied two species of coral that showed complete dissolution of their shells in highly acidified water but were able to regrow their shells when returned to water of normal pH. Langdon et al. (2000) and Leclercq et al. (2000) found that saturation state was the primary factor determining calcification rates of coral reef ecosystems grown in a large mesocosm (i.e., an outdoor containment). Krief et al. (2010) held fragments of two species of stony coral for 6 to 14 months at pH values of 8.09, 7.49, and 7.19, and found that although all of the coral survived and added new skeleton, skeletal growth and zooxanthellae density decreased, whereas coral tissue biomass and zooxanthellae chlorophyll concentrations increased under low pH. A recent mesocosm study of a subtropical coral reef community found that although the community as a whole showed reduced calcification in acidified waters, some individuals were able to continue calcification, but at a reduced rate (Andersson et al. 2009).

A recent study examined the effects of ocean acidification on early life history processes of the Caribbean coral *Porites astreoides*. Larvae were collected in ocean waters and observed in the laboratory at 3 levels of atmospheric CO_2: 380 microatmospheres (µatm) (ambient seawater), 560 µatm (projected seawater concentration mid-century), and 800 µatm (projected concentration end of century). Compared to controls, larval metabolism was depressed by 27 percent and 63 percent at 560 µatm and 800 µatm, respectively. Settlement was reduced by 42 to 45 percent at 560 µatm and 55 to 60 percent at 800 µatm. Post-settlement growth decreased by 16 percent at 560 µatm and 35 percent at 800 µatm. Other findings indicated that the reduction in settlement was an indirect effect of changes to the substrate community that reduced settlement cues, rather than a direct effect on the larvae themselves (Albright and Langdon 2011).

Measurement of the calcification rates of 328 corals from 69 reefs along the Great Barrier Reef showed a decline of 14.2 percent in calcification rates from 1990 to 2005. The researchers hypothesize that the main causes of the continuing decline are increased sea surface temperatures combined with a lower aragonite saturation state (De'ath et al. 2009).

High CO_2 is also a bleaching agent for corals and crustose coralline algae under high irradiance and acts synergistically with warming to lower thermal bleaching thresholds (Anthony et al. 2008). Bleaching occurs when corals eject their symbiotic algae because the temperature of surface waters increases above a threshold near 30 °C (86 °F). The combined effects of increased CO_2 and bleaching events resulting from elevated sea surface temperatures have heightened concerns about the survival of tropical and subtropical corals worldwide (Hoegh-Guldberg et al. 2007, Kleypas and Yates 2009). Increases in sea surface temperatures have contributed to major bleaching episodes in subtropical and tropical coral reefs (EPA 2009e, Kleypas and Yates 2009). These bleaching events increase the risk of disease among surviving coral (EPA 2009e, Hoegh-Guldberg et al. 2007, Kleypas and Yates 2009). For example, in Virgin Islands National Park, 50 percent of the corals have died from bleaching or subsequent disease outbreaks (EPA 2009e). The IPCC concluded that it is *very likely* that a projected future increase in sea surface temperature of 1 to 3 °C (1.8 to 5.4 °F) above average seasonal maxima will result in more frequent bleaching events and widespread coral mortality, unless there is long-term thermal adaptation by corals and their algal symbionts (Nicholls et al. 2007, EPA 2009e). A group of 39 coral experts from around the world estimated that one-third of reef-building corals face elevated risk of extinction (Carpenter et al. 2008).

A new study indicates that temperature could have a greater impact on coral growth than acidification (Cooper et al. 2012). Scientists examined core samples of annual density banding to determine coral growth over the past 110 years in 6 populations off the western coast of Australia. Some populations lived in cold, high-latitude waters, while others lived in warmer waters. The scientists compared changes in the sea surface temperature at each location to the changes in calcification rates. Coral populations in the coldest water, where the sea had warmed the most, had the largest increases in calcification rates, and populations in warm water, which had experienced smaller increases in sea surface temperature, either had no change in calcification or underwent declines.

The vulnerability of warmwater corals to thermal stress will depend on the severity and extent of additional anthropogenic stressors, such as overfishing, pollution, invasive species, and available nutrients (EPA 2009e). Cohen and Holcomb (2009) observed that global warming has increased ocean stratification, reduced the depth of the mixed layer, and slowed circulation, all of which reduce nutrient availability and therefore could magnify the adverse effects of ocean acidification. They noted that not only would this combination of effects reduce growth and calcification rates in corals, it could also reduce sexual reproduction and genetic diversity, interfering with adaptation mechanisms. A modeling exercise by Anthony et al. (2011) examined how acidification and fishing pressure on herbivores might affect the ecological resilience of a simplified benthic reef community made up of corals and macroalgae. Resilience was defined by the reef's capacity to maintain and recover to coral-dominated states. Results indicated that corals already subject to anthropogenic stressors that reduce growth and survival will show reduced resilience. A recent analysis of 23 years of Chesapeake Bay water quality data showed significant reductions in oyster biocalcification compared to a 0.5 unit decline in pH from pollution alone (Waldbusser et al. 2010).

There is also evidence that eutrophication increases the susceptibility of coastal waters to ocean acidification (Cai et al. 2011b). Eutrophication occurs when excess nutrients in coastal waters lead to the excessive production of algae. During the day, algae produce oxygen through photosynthesis, while at night, algae continue to undergo cellular respiration, which depletes oxygen in the water column. When the algae die, additional oxygen is removed because of bacterial decomposition of the dead cells. Low dissolved oxygen in the water column is a condition referred to as *hypoxia*, which contributes to ocean "dead zones," where there is little life because of the lack of oxygen. Eutrophication also contributes to ocean acidification, because cellular respiration by algae produces CO_2, in addition to oxygen (Cai et al. 2011b). A field study in Puget Sound found that excess nutrients could increase eutrophication in the near term, while also increasing rates of acidification over time as plankton die and decompose (Feely et al. 2010). The researchers observed that the synergistic effects of lowered seawater pH and hypoxia could cause affected organisms to reach the limits of their physiological tolerances and cross critical thresholds, with abrupt and major changes to ecosystem health.

Potential for Acclimation. Scientists do not know whether, or to what extent, marine organisms will acclimate or adapt to climate change. Observations over sufficient time to determine the potential for genetic adaptation are lacking, and it is not clear whether responses of individual species in laboratory and mesocosm studies can be extrapolated to populations in natural systems. Also, little information is available about how key variables such as temperature, light, and nutrients might interact with acidification to influence calcification rates (Pandolfi et al. 2011). Some scientists have suggested that critical thresholds at which adverse effects occur as a result of elevated CO_2 could be relatively low for many animals (Pörtner et al. 2005). Veron et al. (2009) argue that CO_2 levels below 350 ppm are needed to protect coral reef ecosystems from collapse.

***Coldwater Corals*.** As the aragonite saturation horizon (the limit between water that is saturated with aragonite and that which is undersaturated) becomes shallower, saturated waters are becoming limited to the warm surface layers of the world's oceans. As a result, under the IPCC IS92a (business as usual) scenario, which assumes countries do little to curb emissions (IPCC 2000), it is projected that by 2100, only 30 percent of existing coldwater corals will remain in saturated waters (Guinotte et al. 2006).

***Marine Algae*.** Crustose coralline algae are critical for coral reefs, because they cement carbonate fragments together. Under high CO_2 conditions in an outdoor mesocosm experiment, the recruitment rate[16] and percentage cover of crustose coralline algae decreased by 78 percent and 92 percent, respectively, whereas that of non-calcifying algae increased by only 52 percent (Kuffner et al. 2008).

Although some marine phytoplankton grow well over a wide range of pH, others have growth rates that vary greatly over a 0.5- to 1.0 pH unit change (Hinga 2002). Eutrophication and ocean acidification might interact to increase the frequency of blooms of those species that tolerate extreme pH (Hinga 2002).

Coccolithophores are tiny "shields" made from dozens of individual calcite crystals produced by some planktonic microalgae. Coccoliths – the main calcifiers in the ocean – show a mix of responses to ocean acidification. In one study, the coccolithophores on algae showed reduced calcification when grown in water in contact with air at 750 ppm CO_2 (Riebesell et al. 2000), although in another study they showed no change (Langer et al. 2006). Another study analyzed both contemporary surface water samples and fossil sediment cores, and showed that the effect of calcification rates in response to increases in dissolved CO_2 varies by species (Beaufort et al. 2012). In another laboratory study, photosynthesis and nitrogen fixation in some coccolithophores, prokaryotes, and cyanobacteria showed either no change or increases in water in contact with higher CO_2 (Doney et al. 2009a). A new study by Hassenkam et al. (2011) indicates that the organic material associated with the biogenic calcite in coccolithophores makes it more stable than inorganic calcite. However, once pH drops to 7.8 or lower, which is projected by 2100, biogenic calcite also dissolves.

Mollusks. It is estimated that the adverse effects of ocean acidification on mollusks could carry a $100 billion price-tag world-wide by 2100 considering such factors as economic loss associated with loss of aquaculture and capture, and consumer and producer surplus loss (Narita et al. 2012). Gazeau et al. (2007) found that calcification in a mussel species and the Pacific oyster declined by 25 percent and 10 percent, respectively, when grown in seawater in contact with air at 740 ppm CO_2, which is the concentration expected by 2100 under the IPCC IS92a scenario. Two of the largest oyster hatcheries in the Pacific Northwest reported an 80 percent decline in production rates since 2005, which could be the result of acidification of surface waters combined with lower pH water in the deeper ocean that is brought to the surface during the upwelling season (Miller et al. 2009). A study of the Sydney rock oyster found that fertilization declined significantly from the combined effects of acidification and temperature (Parker et al. 2009). Prolonged exposure to these stressors also impaired growth and survival of early developmental stages.

The effects of ocean acidification alone on an intertidal gastropod included slowed development and abnormal growth of early life stages. Within 14 to 35 days, there was significant dissolution in the shells of 4 species of Antarctic benthic mollusks (2 bivalves, 1 limpet, 1 brachiopod) held in pH 7.4 seawater (McClintock et al. 2009). Barnacles exposed to the same low pH showed a trend of larger basal shell diameters during growth, which researchers suggest could indicate a compensatory response to declining pH (McDonald et al. 2009). Nonetheless, dissolution weakened shell walls as the barnacles grew. Shifts in community composition were observed in a mussel-dominated rocky intertidal community experiencing rapid declines in pH (0.4 pH units over 8 years). Years of low pH were accompanied by declines in calcareous species (e.g., mussels and stalked barnacles) and increases in non-calcareous species (e.g., acorn barnacles and algae) (Wootton et al. 2008).

[16] Recruitment rate refers to the number of new individuals added to a biological population.

Effects on species at high latitudes will likely be apparent earlier than in other areas, given the more rapid accumulation of acidification in these regions (Fabry et al. 2009). Pteropods, small marine snails that are ubiquitous at high latitudes, show shell dissolution in seawater undersaturated with respect to aragonite (Feely et al. 2004, Orr et al. 2005). When live pteropods were collected in the Subarctic Pacific and exposed to a level of aragonite undersaturation similar to that projected for the Southern Ocean by 2100 under the IPCC IS92a emission scenario, shell dissolution occurred within 48 hours (Orr et al. 2005). A 28 percent reduction in calcification was observed in one species of pteropod in response to pH levels expected by 2100 (Comeau et al. 2009). Declines in pteropods are a particular concern in oceans at high latitude, where they are a critical food source for marine animals ranging from krill (small shrimp-like organisms) to whales, and including highly valued fish such as salmon. Therefore, their loss could affect high-latitude food webs (Guinotte and Fabry 2008). Recent observations in the Gulf of Alaska, for example, show that pteropods are especially vulnerable in Alaska waters, which show higher acidification than elsewhere (Bates and Mathis 2009). Researchers estimated that a 10 percent decline in pteropod abundance in this region could mean a 20 percent decrease in an adult salmon's body weight.

Echinoderms. Some sea urchins show reduced early development (Kurihara and Shirayama 2004), shell growth (Shirayama and Thornton 2005), and fertilization success (Kurihara and Shirayama 2004, Reuter et al. 2011) in seawater with elevated CO_2 concentrations. However, a study by Byrne et al. (2010) found that fertilization and early development were unaffected by the levels of pH (0.2 to 0.4 pH units) and warming (2 to 4 °C [3.6 to 7.2 °F]) projected for the end of this century, compared current levels. Urchin embryos were sensitive to elevated temperature (Byrne et al. 2009).

Crustaceans. Laboratory studies of larval stages of the European lobster found physiological changes in calcification and carapace development in low-pH, high-acidity seawater (Arnold et al. 2009). Another study found that North American lobsters, crabs, and shrimp were able to build more shell as acidity increased (Ries et al. 2009). Changes in pH upset acid-base regulation in many animals, including crustaceans and fish, and affect processes that are important for growth and the control of neurotransmitter concentrations such as ion exchange, oxygen transport, and metabolic equilibria (Pörtner et al. 2004).

Marine Fish and Marine Mammals. The use of calcium minerals in gravity sensory organs is common in marine species at higher trophic levels. A study of responses to olfactory cues by clownfish larvae found that responses were impaired at pH 7.8 and below, interfering with the ability of the larvae to identify suitable settlement sites on reefs (Munday et al. 2010). A study of predator detection by early life stages of another marine fish species found that when eggs and larvae were exposed to low-pH water, larvae at the settlement stage were unable to distinguish between predators and non-predators, and in some cases were actually attracted to the smell of predators (Dixson et al. 2010). Nilsson et al. (2012) found evidence in larval clownfish that the impairment of olfactory ability occurs because high CO_2 interferes with the function of the GABA-A receptor, an important neurotransmitter. Another study of clownfish showed that ocean acidification also impairs auditory responses in this species (Simpson et al. 2011).

A recent study looked at the effects of acidification on the larvae of Atlantic cod over a 2.5-month period by rearing larvae under present-day conditions (approximately 380 ppm), simulated year 2200 conditions (1,800 ppm), and an extreme coastal upwelling scenario (4,200 ppm) (Frommel et al. 2012). Fish in acidified waters grew faster but matured later and died at progressively higher rates. As CO_2 levels increased, cod larvae developed severe damage to their liver, pancreas, kidney, eye, and gut within a month after hatching. Another recent study looked at the effects of acidification on silversides, a common species in estuaries along the North American coast. Silverside embryos were placed in current CO_2 concentrations (approximately 400 ppm), those expected by mid-century (approximately 600 ppm), and at levels projected for the end of the century (approximately 1,000 ppm). Survival fell steadily from approximately 50 percent at current pH levels to approximately 10 percent at 1,000 ppm. Hatchling length also fell, while rates of severe body malformations increased (Baumann et al. 2011).

Other studies suggest that high CO_2 in seawater can lead to cardiac mortality in some fish (Ishimatsu et al. 2004). Cooley and Doney (2009) observed that losses of calcifying organisms at the base of marine food webs will ultimately be transmitted to fish species of high ecological and economic value. While indirect effects via transmission through the food web is important, Haugan et al. (2006) reviewed a number of studies that show that there are also direct effects of elevated CO_2 on the growth, reproduction, and activity of higher trophic level organisms. For example, there is evidence that even a small decrease in pH has a dramatic effect on the oxygen carrying capacity of squid (Turley et al. 2006).

***Analogs*.** Some recent studies have examined geologic and natural analogs to help determine potential effects of ocean acidification on marine life. A period about 55 million years ago known as the Paleocene-Eocene Thermal Maximum (PETM) is considered the closest geological analog to today's oceans. During this time, a massive and rapid input of carbon to the atmosphere and ocean occurred. Marine plankton survived a period of intense warming and acidification, lasting 1,000 to 2,000 years. Another study compared predicted future levels of ocean acidity with PETM conditions and found that under the IPCC IS92a emissions scenario, the extent and rate of acidification in today's ocean is on track to greatly exceed that during the PETM (Ridgwell and Schmidt 2010).

A recent study by Hönisch et al. (2012) examined all events over the past 300 million years known or hypothesized to involve ocean acidification, and found that if the current rate of acidification continues, it will be much faster than at any other time in the past 300 million years. Moy et al. (2009) found direct evidence in the fossil record that ocean acidification affects shell formation, noting that the shells of foraminifera in the current Southern Ocean are 30 to 35 percent lighter than shells of the same species in core samples from ocean sediments that predate the Industrial Revolution.

A number of recent studies have examined the response of marine life to varying pH levels along natural CO_2 vents. Meron et al. (2012) examined changes in coral microbial communities in response to a natural pH gradient associated with volcanic CO_2 vents off the coast of Italy, and found that pH did not have a significant impact on the microbial communities and coral physiology and health. Hall-Spencer et al. (2008) found that in near-subsurface vents with natural, volcanic release of CO_2, stony corals were absent and numbers of calcifying sea urchins, coralline algae, and gastropods were low. Rodolfo-Metalpa et al. (2011) found that corals and mollusks transplanted along gradients of carbonate saturation state at Mediterranean CO_2 vents could calcify and grow at even faster than normal rates when exposed to the high CO_2 levels projected for the next 300 years. However, the scientists also observed that rising sea surface temperatures would damage tissues and external organic layers that play a major role in protecting calcified shells and skeletons. As a result, the ongoing dissolution of the shells and skeletons of corals and mollusks could leave them exposed to the corrosive effects of acidified sea water and make them vulnerable to reduced growth and survival.

5.6.2.1.2 Changes in the Effectiveness of the Ocean Sink

As CO_2 increases in surface waters and carbonate concentrations decline, the effectiveness of the ocean as a "sink" for CO_2 could decrease (Sabine et al. 2004, Le Quéré et al. 2009). In addition, ocean warming also decreases the solubility of CO_2 in seawater (Bindoff et al. 2007, Menon et al. 2007). Observations and modeling studies indicate that the large regional sinks in the North Atlantic (Lefèvre et al. 2004, Schuster and Watson 2009), the Southern Ocean (Le Quéré et al. 2007, Lovenduski et al. 2008), and the North Sea have declined in recent decades (Fabry et al. 2009). Between 2000 and 2008, emissions increased by 29 percent. One study estimated that from 2000 to 2006, the oceans absorbed approximately 25 percent of anthropogenic CO_2 emissions, representing a decline in the ocean sink from 29 percent absorption in earlier decades (Canadell et al. 2007). Recently, Khatiwala et al. (2009) reconstructed the history of CO_2 concentrations in the ocean from 1765 to 2008 and found that ocean uptake has decreased by as much as 10 percent since 2000. Tans (2009) argued that although these findings could be true locally, the available data indicate that they do not apply globally. He concluded that the decrease in the rate of uptake of atmospheric CO_2, despite increased emissions, can only be explained if there has been a more effective uptake by the oceanic or terrestrial biosphere. Le Quéré et al. (2009) reported that over the past 50 years, the fraction of CO_2 emissions that remains in the atmosphere each year has increased from 40 percent to 45 percent, supporting the conclusions of Khatiwala et al. (2009) that there has been a decline in the oceanic uptake of CO_2. Recent modeling suggests that this results from the responses of carbon sinks to both climate change and climate variability (Le Quéré et al. 2009).

If climate variability is the primary cause, current trends might be short in duration and not signals of long-term climate change. However, the measurements by Khatiwala et al. (2009) indicate that the slowdown in the ocean uptake of carbon results from physical and chemical limits on the oceans' ability to absorb carbon. The researchers concluded that the more acidic the oceans become, the less they are able to absorb carbon. Other measurements of actual CO_2 concentrations found that in the Canada Basin in the Arctic in areas where sea ice had melted dramatically, uptake of carbon (measured in units of CO_2 pressure at 120 to 150 micropascals) was well below atmospheric CO_2 pressure (375 micropascals), whereas in ice-free areas offshore, seawater pressure (320 to 360 micropascals) was much closer to atmospheric pressure (Yamamoto-Kawai et al. 2009, Cai et al. 2010). In the Chukchi Sea during the summertime retreat of sea ice, increased phytoplankton productivity decreases the concentration of CO_2 over the continental shelf, causing aragonite saturation states to increase, while deeper waters become undersaturated (Bates and Mathis 2009).

5.6.2.1.3 IPCC Conclusions about Ocean Acidification

The 2007 IPCC conclusions about ocean acidification are as follows (Menon et al. 2007, EPA 2009e):

- The biological production of corals, and the calcification of phytoplankton and zooplankton in the water column, could be inhibited or slowed as a result of ocean acidification.
- Cold-water corals are likely to show large reductions in geographic range this century.
- The dissolution of calcium carbonate at the ocean floor will be enhanced, making it difficult for benthic calcifiers to develop protective structures.
- Acidification can influence the marine food web at higher trophic levels.

5.6.2.2 Plant Growth and Soil Microorganisms

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2 concentrations in the atmosphere could increase the productivity of terrestrial systems. CO_2 can have a stimulatory or fertilization effect on plant growth (EPA 2009e). Plants use CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report states that "[o]n physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising CO_2, referred to as 'CO_2 fertilization'" (Menon et al. 2007). The IPCC projects with *medium* confidence that forest growth in North America will likely increase 10 to 20 percent, due to both CO_2 fertilization and longer growing seasons, over this century (EPA 2009e, Field et al. 2007).

In addition to EPA (2009e) noting the known fertilization effect of CO_2 on plant growth, several investigators have also found that higher CO_2 concentrations have a fertilizing effect on plant growth through bench-scale and field-scale experimental conditions (e.g., Long et al. 2006, Schimel et al. 2000). Through free air CO_2 enrichment experiments, at an ambient atmospheric concentration of 550 ppm CO_2, unstressed C_3 crops (e.g., wheat, soybeans, and rice) yielded 10 to 25 percent more than under current CO_2 conditions, while C_4 crops (e.g., maize) yielded up to 10 percent more (EPA 2009e).[17] In addition, the IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing net primary productivity increases of 23 to 25 percent (Norby et al. 2005), but much smaller increases for grain crops (Ainsworth and Long 2005). Overall, approximately two-thirds of the experiments show positive response to increased CO_2 (Ainsworth and Long 2005, Luo et al. 2004). Because saturation of CO_2 stimulation due to nutrient or other limitations is common (Dukes et al. 2005; Körner et al. 2005), the magnitude and effect of the CO_2 fertilization is not yet clear.

Forest productivity gains that might result through the CO_2 fertilization effect can be reduced by other changing factors, and the magnitude of this effect remains uncertain over the long term (EPA 2009e). Easterling et al. (2007) discussed studies suggesting that the CO_2 fertilization effect might be lower than previously assumed, with the initial increases in growth potentially limited by competition, disturbance (e.g., storm damage, forest fires, and insect infestation), air pollutants (primarily tropospheric ozone), nutrient limitations, ecological processes, and other factors (EPA 2009e). One study's results show that the magnitude of increased production was determined primarily by the availability of water and nitrogen, with greater CO_2-induced net primary productivity in environments with plentiful water and nitrogen (McCarthy et al. 2010).

The CO_2 fertilization effect could mitigate some of the increase in atmospheric CO_2 concentrations by resulting in more storage of carbon in biota. It should also be noted that although CO_2 fertilization can result in a greater mass of available vegetation, it can also increase the carbon-to-nitrogen ratio in plants. In one study, such fertilization of forage grasses for livestock increased their abundance but reduced their nutritional value, affecting livestock weight and performance (EPA 2009e). Although studies have shown that elevated CO_2 levels resulted in an increase in plants' carbon-to-nitrogen ratio, one experiment found that higher levels actually triggered enhanced photosynthetic nitrogen use efficiency[18] in C_3 plants, which was predominantly caused by improved CO_2 uptake (Leakey et al. 2009).

Additionally, some evidence suggests that long-term exposure to elevated ambient CO_2 levels, such as areas near volcano outgassing, will result in a die-off of some plants. Although, under typical atmospheric CO_2 concentrations, soil gas is 0.2 to 0.4 percent CO_2, in areas of observed die-off, CO_2 concentrations comprised as much as 20 to 95 percent of soil gas (EPA 2009e). Any CO_2 concentration

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[17] C_3 and C_4 plants are differentiated by the manner through which they use CO_2 for photosynthesis, lending explanation to the differences in plant yield under similar ambient CO_2 conditions.

[18] "Photosynthetic nitrogen efficiency" is the amount of carbon in the plant that is converted to usable sugars during photosynthesis. With greater atmospheric CO_2, the amount of carbon converted to sugars is greater even when the amount of nitrogen available to the plant does not change.

above 5 percent is likely to adversely impact vegetation, and if concentrations reach 20 percent, CO_2 is observed to have a phytotoxic[19] effect (EPA 2009e).

The current annual exchange in CO_2 between the atmosphere and terrestrial ecosystems is estimated at 9 to 10 times greater than annual emissions produced as a result of burning fossil fuels. Even a small shift in the magnitude of this exchange could have a measurable impact on atmospheric CO_2 concentration (Heath et al. 2005). The aboveground/belowground processes and components in terrestrial ecosystems typically sequester carbon.

Recent studies have confirmed that variations in atmospheric CO_2 have impacts not only on the aboveground plant components, but also on the belowground microbial components of these systems. Experiments have shown that elevated CO_2 levels cause an increase in belowground net primary production and fine-root biomass (Pritchard 2011, Jackson et al. 2009 citing Fitter et al. 1995, Hungate et al.1997, Matamala and Schlesinger 2000, King et al. 2001, Norby et al. 2004, Finzi et al. 2007), with one study showing a 24 percent increase of fine-root biomass in the top 15 centimeters (approximately 6 inches) of soil and a doubling of coarse-root biomass in elevated CO_2 (Jackson et al. 2009).

In one study, an increase in CO_2 directly resulted in increased soil microbial respiration due to faster outputs and inputs, observed through amplified photosynthesis (Jackson et al. 2009 citing Canadell et al. 1995**,** Luo et al. 1996**,** Bernhardt et al. 2006, Gill et al. 2006**,** Hoosbeek et al. 2007**,** Wan et al. 2007). After 4 to 5 years of increased exposure to CO_2, "the degree of stimulation declined" to only a 10- to 20-percent increase in respiration over the base rate (King et al. 2004). Additionally, the degree of stimulation was linked to variability in seasonal and interannual weather (King et al. 2004), with root biomass, soil respiration, and other variables found to typically peak in midsummer and lessen in winter (Jackson et al. 2009). Increased soil respiration and changes in other variables, such as productivity, alters the concentration of CO_2 in soil pore spaces, which impacts weathering of carbonates, silicates, and other soil minerals (Jackson et al. 2009 citing Sposito 1989, Andrews and Schlesinger 2001, Pendall et al. 2001, Karberg et al. 2005). Ryan et al. (2008) suggest that for forest ecosystems, several unresolved questions prevent a definitive assessment of the effect of elevated CO_2 on components of the carbon cycle other than carbon sequestration primarily in wood (EPA 2009e).

The increase in microbial respiration could, therefore, diminish the carbon sequestration role of terrestrial ecosystems. Because of the number of factors involved in determining soil respiration and carbon sequestration, the threshold for substantial changes in these activities varies spatially and temporally (King et al. 2004).

Elevated CO_2 levels were also found to change the functional structure of soil microbial communities, which could have significant impacts on soil carbon and nitrogen dynamics (He et al. 2010). More specifically, the study found that when CO_2 levels increased, genes involved in labile carbon degradation[20], carbon fixation, nitrogen fixation, and phosphorus release also increased. Furthermore, no significant changes were found in the quantity of genes associated in recalcitrant carbon degradation and CH_4 metabolism. Structural and functional alterations, such as these, could modify the way microbial ecosystems regulate changes in CO_2 concentrations (He et al. 2010). However, a 2011 study suggests that although increasing atmospheric CO_2 positively affects root growth, it might not have any

[19] Phytotoxicity is an abnormal adverse reaction of a plant to ultraviolet radiation.
[20] Labile refers to microbial biomass carbon.

significant effect on soil microbes, simply because the increase is dwarfed by the amount of carbon already available to microbes in soil pore space (Pritchard 2011).

Elevated CO_2 concentrations have physiological impacts on plants, which result in further climatic changes, a process referred to as "CO_2-physiological forcing" (Cao et al. 2010). Increased CO_2 levels cause plant stomata to open less widely, resulting in decreased plant transpiration. A reduction in canopy transpiration causes a decrease in evapotranspiration that triggers adjustments in water vapor, clouds, and surface radiative fluxes. These adjustments ultimately drive macro climatic changes in temperature and the water cycle (Cao et al. 2010). One study found that the physiological effects from a doubling of CO_2 on land plants resulted in a 0.42 plus or minus 0.02 ^{o}C (0.76 plus or minus 0.04 ^{o}F) increase in air temperature over land and an 8.4 plus or minus 0.6 percent increase in global runoff (generally caused by reduced evapotranspiration). Furthermore, the study reported that a reduction in plant transpiration caused a decrease in relative humidity over land (Cao et al. 2010).

CHAPTER 6 LITERATURE SYNTHESIS OF LIFE-CYCLE ENVIRONMENTAL IMPACTS OF CERTAIN VEHICLE MATERIALS AND TECHNOLOGIES

6.1 Introduction

6.1.1 Purpose of Including a Literature Synthesis of Life-cycle Environmental Impacts of Certain Vehicle Materials and Technologies

NHTSA anticipates that, to meet the Proposed Action, manufacturers will incorporate advanced technologies that allow vehicles to achieve increasing levels of fuel economy. As noted in public scoping comments and in comments to previous fuel economy rulemakings, the wider use of some of these technologies in automotive manufacturing could result in environmental impacts different from those associated with the use of more conventional automotive technologies. Commenters suggested that understanding the life-cycle implications of vehicles is important; particularly the upstream emissions associated with electricity generation for electric vehicles (EVs) and potential changes in types of materials used in an effort to reduce vehicle weight. Recognizing the potential importance of these impacts, NHTSA has performed a literature synthesis of studies that have analyzed the life-cycle environmental implications of producing certain materials and technologies the agency expects will be employed in the light-duty vehicle sector in the future.[1] This information is helpful to the decisionmaker in the specific context of this rulemaking, where manufacturers could employ a suite of technology options, with different potential environmental impacts, in meeting the proposed standards. In response to comments on the Draft EIS from stakeholders, NHTSA has included in this Final EIS a review of studies identified by commenters and a review of additional studies identified through an updated literature search.

A complete life-cycle assessment (LCA) of the impacts of this rulemaking, which is beyond the scope of this EIS, would include specific energy, emissions, and other environmental impact estimates associated with manufacturing the regulated vehicles, producing materials, constructing facilities for producing and assembling vehicle components, and dismantling, recycling, and disposing of end-of-life vehicles and their components. Modeling tools exist that can estimate the energy and emissions associated with vehicle production and the energy and emissions savings associated with recycling vehicle components – the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Vehicle-Cycle model is an example. However, there are other facets of a complete LCA of the standards that make this effort beyond the scope of this EIS. Namely, an LCA would also require extensive information about many variables that are highly uncertain, including the future behavior of automobile manufacturers in response to the proposed standards – what technologies they would apply to each future vehicle and how many vehicles they would manufacture. CAFE standards are performance-based rather than technology-mandating, so NHTSA does not and cannot require that manufacturers employ specific technologies to meet those standards. As a result, in setting CAFE standards, NHTSA does not attempt to predict precisely how each manufacturer will respond to the standards, because manufacturers may choose from a suite of available technologies to meet the proposed standards. NHTSA's analysis of

[1] By including this chapter on LCA in this EIS, NHTSA does not mean to imply that CAFE standards direct the development and adoption of these materials and technologies, only that such development and adoption is reasonably foreseeable and therefore its effects are a valid factor for considering the broader environmental implications of the rulemaking action.

technology application provides a reasonable level of information based on what is foreseeable and not speculative. Therefore, while NHTSA's analysis of the proposed standards is based on the best available information about what vehicles the agency expects manufacturers to build and what technologies they might apply to those vehicles to improve their fuel economy, NHTSA does not attempt to predict or analyze exactly how manufacturers will respond to the proposed standards.

As discussed in Chapter 2, CEQ regulations provide a means for handling environmental reviews where an agency has incomplete or unavailable information.[2] Because NHTSA cannot precisely forecast the specific technology choices of individual manufacturers, the agency is presenting a summary, or literature synthesis, of existing credible scientific evidence relevant to evaluating the reasonably foreseeable environmental impacts of the Proposed Action and alternatives. NHTSA believes this information will help decisionmakers understand some of the life-cycle implications associated with some of the most prominent emerging materials, technologies, and systems the agency expects will be employed in the future in the light-duty vehicle sector. As described in the following sections, the literature synthesis provides a qualitative assessment of the life-cycle environmental impacts of materials and technologies to help inform decisionmakers. Environmental impacts related to air pollutant emissions and greenhouse gas (GHG) emissions are more thoroughly analyzed in Chapters 4 and 5 of this EIS. This assessment is not intended to provide a basis for comparative assertions between different materials and technologies that reduce fuel use, GHGs, and air pollutant emissions.

6.1.2 Overview of Life-cycle Assessment in the Vehicle Context

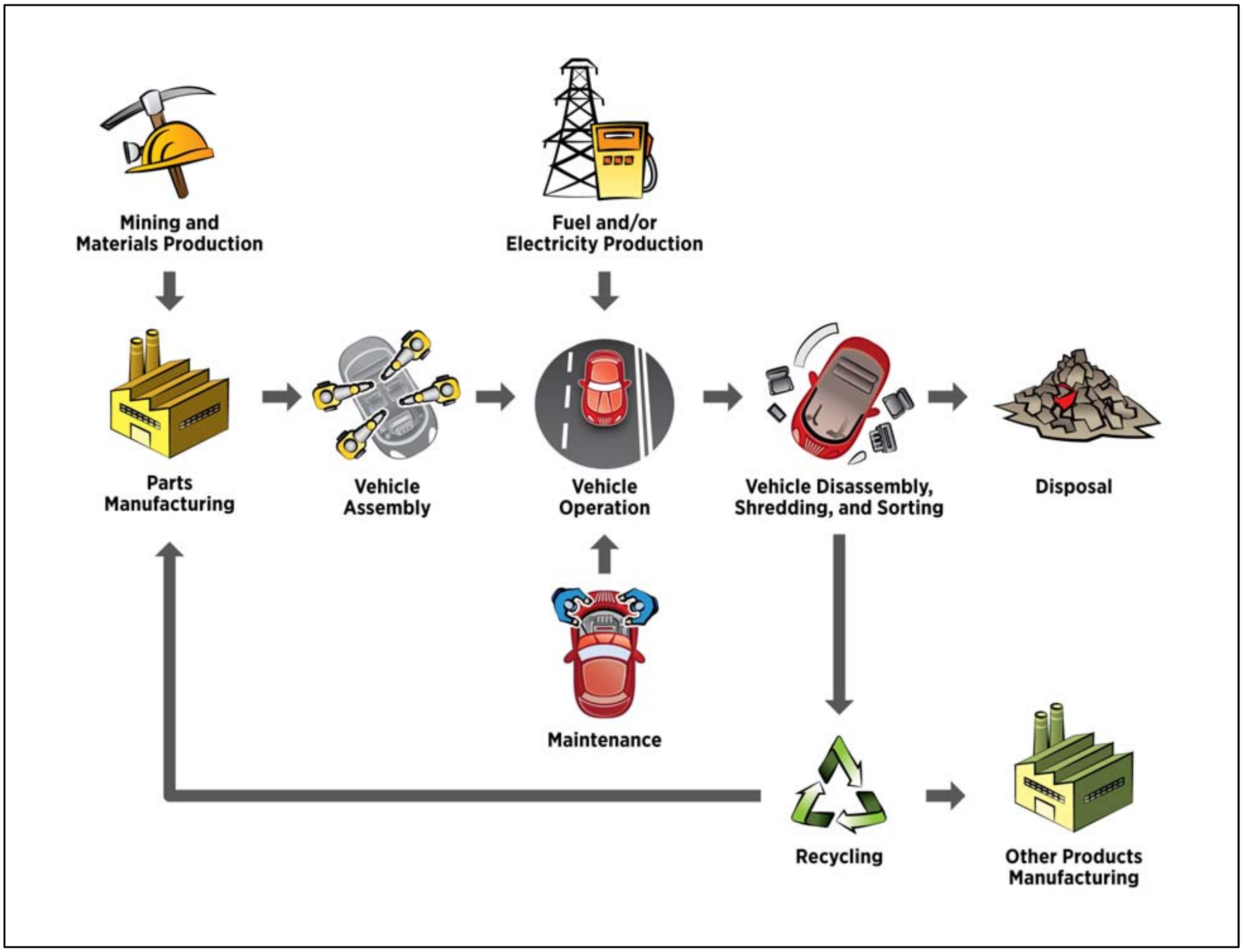
LCA is an analytical method based on a systems perspective used to evaluate the environmental impacts of materials, products, processes, or systems throughout their life cycles. A systems perspective offers a holistic way to identify, view, assess, and solve environmental problems that takes into account interactions between industrial and natural systems (Garner and Keoleian 1995). The International Organization for Standardization (ISO), the leading standards-setting organization that provides guidance on developing and reporting LCAs, defines LCA as the "compilation and evaluation of the input, output, and potential environmental impact of a product system throughout its life cycle" (ISO 2006). The literature synthesis for this EIS focuses on existing LCAs that evaluate the life-cycle impacts of certain vehicle technologies, materials, and systems NHTSA expects to be used to improve fuel economy in light-duty vehicles during the years covered by the proposed rule. By looking at the environmental impacts of the entire life cycle of a vehicle, rather than only its use (i.e., driving), LCA allows a holistic evaluation of vehicle technologies.

Like any product, a vehicle's environmental impacts do not accrue exclusively during the time it spends on the production line. Activities at each stage of a vehicle's life cycle contribute to emissions of GHGs, energy use, and other environmental impacts. For example, mining and transporting ore requires energy (usually in the form of fossil fuels), as does transforming ore into metal, shaping the metal into parts, assembling the vehicle, driving and maintaining the vehicle, and disposing of and/or recycling the vehicle at the end of its life. Recycling vehicle components can save energy and resources and can reduce emissions by displacing the virgin production of materials, but even recycling requires energy and produces emissions. Vehicle LCAs typically evaluate environmental impacts associated with five primary stages: raw-material extraction, manufacturing, vehicle use, end-of-life management, and transportation between these various stages. Raw-material extraction includes the mining and sourcing of material and fuel inputs. The manufacturing stage often consists of sub-stages, including material

[2] 40 CFR § 1502.22(b).

and part production and vehicle assembly. The use stage is typically comprised of two sub-stages: the driving sub-stage (e.g., gasoline production and combustion) and the maintenance sub-stage (e.g., part repair or replacement). End-of-life management can include such steps as parts recovery, disassembly, shredding, recycling, and landfilling. Figure 6.1.2-1 provides a diagram of the vehicle life cycle.

Figure 6.1.2-1. Vehicle Life Cycle



Changes in vehicle design and materials can impact the energy use and associated GHG emissions and other environmental impacts at various stages of the vehicle life cycle. For example, materials and technology substitutions can result in less energy consumption during the vehicle use phase. However, obtaining the components and manufacturing the materials can be energy intensive. Because LCA examines multiple life-cycle stages, an LCA study can help determine whether certain materials and technologies save energy over the vehicles' entire life cycles, keeping all other factors (e.g., vehicle life and weight) equal. Changes in the material composition of vehicles could decrease the global warming potential (GWP) of the use stage, but could increase that of the raw-material extraction and manufacturing stages (Geyer 2008). On the other hand, because of the length of vehicle lifetimes, the fuel-saving benefits realized during a vehicle's use stage due to improved fuel economy could very likely outweigh the additional energy investment associated with material changes (Cheah et al. 2009).

As these examples illustrate, LCA allows users to evaluate the environmental impacts of using different vehicle technologies on an equal basis within a given study. However, LCAs vary greatly in their scope, design, data sources, and assumptions, making it challenging to compare results between studies. In setting the scope of each study, LCA practitioners decide on the unit of measure, life-cycle boundaries, and environmental impact categories to consider, among other factors that address the defined purpose of the study. For example, the use of different functional units (i.e., the basis to measure the results across different materials and technologies) varies among studies. Most studies in this literature synthesis evaluate different types of passenger cars with different assumptions for car weight, vehicle life, and miles traveled underlying the functional unit. In terms of impacts, some studies include those across the entire cradle-to-grave life cycle (i.e., from resource extraction through end of life), including impacts from extraction of all energy inputs in addition to materials. Others include impacts only from cradle to gate (i.e., from resource extraction through manufacturing and assembly, but excluding vehicle use and end of life). Most of the studies in this literature synthesis evaluated energy use and climate change impact measured by GHG emissions, but several also included other environmental impact categories (e.g., acidification, eutrophication, odor and aesthetics, water quality, landfill space, ozone depletion, particulates, solid and hazardous waste generation, and smog formation). Data availability often influences the boundaries and impacts included.

LCA practitioners also use different approaches. Some perform bottom-up analyses (e.g., Khanna and Bakshi 2009) using data at the unit process level (i.e., the smallest sub-stage for which input and output data are quantified in a life-cycle inventory); others perform a top-down analysis using economic data (e.g., Lloyd and Lave 2003); still others use a hybrid LCA approach. Most LCAs considered for purposes of this EIS follow an *attributional* LCA approach that evaluates impacts associated with the physical flows (inputs and outputs) relevant to the specific material or technology being analyzed. In contrast, *consequential* LCAs estimate the environmental impacts influenced by product system change; such studies require broader system boundaries. In establishing the system boundaries, when several products are produced from a system, LCA practitioners also must decide how to assign or allocate environmental impacts between the functional unit (i.e., the product under study) and other co-products produced by the system.[3] For example, scrap materials can be used for other, secondary purposes outside the vehicle life cycle. Studies that consider scrap flows outside the vehicle life-cycle boundary might: (1) allocate a portion of the impacts associated with vehicle manufacture or recycling to the scrap flow, (2) treat scrap as a waste flow and not allocate any impacts to it, or (3) expand the system to include the scrap output flow within the system boundary. The varying treatment of scrap material and other LCA aspects and assumptions in each study limits the comparability of the results.

For some of the studies considered in this chapter, the authors used existing models to assess life-cycle emissions. Other studies included independent assessments of life-cycle implications using study-specific models developed from life-cycle inventory data sources such as the ecoinvent database.[4]

The most commonly used model in the surveyed literature was Argonne Laboratory's GREET, a public-domain model that allows users to estimate life-cycle energy and emissions impacts on a full fuel-cycle and vehicle life-cycle basis. Argonne National Laboratory developed GREET in 1996 and has continually managed and updated the model to reflect data updates, new fuel pathways, and vehicle technologies. GREET uses a process-based approach wherein the model calculates life-cycle results by modeling the

[3] ISO advises that LCAs avoid allocation by dividing the process into separate production systems or through system expansion, including the additional co-product functions (ISO 2006).
[4] Life-cycle inventory data is information on the inputs, outputs, and potential environmental impacts of a product or process. The ecoinvent database, managed by the Swiss Centre for Life Cycle Inventories, is a large source of life-cycle inventory data on products and processes from different countries around the world, including the United States.

various processes and technologies used to extract, refine, and distribute fuels, and to manufacture, use, and dispose of vehicles.

In addition, several studies used the Economic Input-Output Life Cycle Assessment Model developed by Carnegie Mellon's Green Design Institute. The model is not specific to fuel and vehicle LCA, but can be used to estimate the energy and emissions impacts of components, materials, and industries involved in the automobile component manufacturing supply chain. The Green Design Institute continually manages and updates the model to reflect new input-output data and impact characterization data and methods. As an economic input-output model, the Economic Input-Output Life Cycle Assessment Model assumes that GHG emissions are linked to economic flows through different sectors. Therefore, unlike GREET, the model is not process-based; it is generally suitable when assessing impacts from an industry (e.g., vehicle manufacturing as a whole) rather than specific products (e.g., a specific vehicle make or model).

Some studies used the Mobile Source Emission Factor (MOBILE) model, which calculates gram-per-mile emissions of hydrocarbons, carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO_2), particulate matter (PM), and toxics from vehicles, to refine estimates of pollution from the use phase of vehicles. MOBILE is not a life-cycle model; rather, it focuses only on emissions from vehicles during the use phase. Data in MOBILE are based on emissions testing of vehicles and account for several factors, including changes in vehicle emission standards, changes in vehicle populations and activity, and variation in local conditions, such as temperature, humidity, and fuel quality. MOBILE, which was developed and updated by EPA from 1978 to 2010, has since been replaced by EPA's Motor Vehicle Emission Simulator (MOVES).

Finally, Hadley and Tsvetkova (2008) used the Oak Ridge Competitive Electric Dispatch Model, which models how electricity is supplied to the grid based on different levels of demand to determine the temporal effects charging EVs has on emissions and bulk electricity markets. Oak Ridge National Laboratory developed the model in 1996, and currently maintains and updates it. The Oak Ridge Competitive Electric Dispatch Model is not a life-cycle model; rather, it focuses on closer examination of how changes in supply and demand of electricity affect environmental impacts from electricity consumption instead of just assuming a fixed average or marginal electricity rate. However, because the model can be used to examine the electricity consumed by EVs, it also models the environmental impacts of upstream electricity production.

Because LCAs are highly sensitive to design and input assumptions, such analyses are subject to variation in calculated impacts and associated conclusions. Generally, however, based on the studies considered for this synthesis, it appears that most energy is consumed and most GHGs are emitted during the vehicle use stage. This stage is estimated to account for approximately 80 percent of the life-cycle vehicle GHG emissions in conventional internal combustion engine vehicles (Hakamada et al. 2007). The manufacturing stage is the second most energy- and GHG-emission-intensive LCA stage (Hakamada et al. 2007). This stage can account for 5 to 15 percent of total vehicle life-cycle GHG emissions (Geyer 2008, Hakamada et al. 2007). As manufacturers strive to improve fuel economy (in response to regulatory requirements and other factors), vehicle emissions associated with the use stage are expected to decrease as a percentage of overall life-cycle emissions. Therefore, it may be important to consider a life-cycle perspective to understand the implications of materials and technologies used to meet vehicle fuel economy regulations. This perspective can help inform decisionmakers about certain broader environmental implications of the rulemaking action.

6.1.3 Scope of Literature Synthesis of Life-cycle Environmental Impacts of Certain Vehicle Materials and Technologies

NHTSA performed a comprehensive literature synthesis to find and synthesize studies that assess the implications and potential environmental effects of emerging materials and technologies associated with improving fuel economy in the light-duty vehicle sector using a life-cycle perspective.

Materials and technologies of particular interest included aluminum, high-strength steel, and battery technologies associated with EVs. Most studies identified focus mainly on the life-cycle energy and climate change impacts (i.e., as characterized by GHG emissions, which is sometimes referred to as GWP), although other environmental implications (e.g., air quality impacts) also are addressed to a lesser extent in the literature.

The approach to developing the literature synthesis involved the following steps:

1. Establishing the scope for the review
2. Identifying and reviewing relevant academic, peer-reviewed studies
3. Developing a tailored literature review matrix spreadsheet to compile, track, and compare different key elements
4. Evaluating results and synthesizing findings

NHTSA performed research to identify studies across a range of sources, including academic journals and industry association and non-governmental organization publications. In addition, NHTSA performed an electronic search using DIALOG – an online literature service that aggregates 530 databases covering a range of disciplines into one searchable source. NHTSA also contacted stakeholders involved in relevant research at Argonne National Laboratory, the Massachusetts Institute of Technology Materials Systems Laboratory, the University of Michigan, the University of California at Davis, and the International Institute for Clean Transportation. The stakeholders contacted provided feedback on additional relevant studies to include as part of the literature synthesis. In total, the literature survey originally identified 50 studies that represent the perspectives of various stakeholders, including industry, government, academic, and non-governmental organizations. In response to comments received from stakeholders on the Draft EIS, for this Final EIS NHTSA reviewed 12 additional studies identified by commenters. In addition, NHTSA performed an updated search using DIALOG to capture the latest literature, identifying 33 more studies. In total, NHTSA reviewed an additional 45 studies resulting from the updated search.

Appendix D lists all of the studies reviewed. Most of the studies identified were published within the last 10 years. For each study reviewed, NHTSA tracked various elements in the study, including information on the geographic applicability of the study, the technologies or materials discussed, the scope of the LCA boundaries (e.g., cradle to grave) and the environmental impacts analyzed. NHTSA also gathered general study information (e.g., study purpose, reference year, and overarching assumptions). Table 6.1.3-1 lists the key elements tracked in the literature synthesis.

Table 6.1.3-1. Key Elements Tracked in the Literature Synthesis

General Elements	LCA Elements
Publication date	Geographic applicability
Study-wide assumptions	Technologies or materials
Purpose	Scope of LCA boundaries
Study type	Environmental impacts
Peer reviewed	Limitations and items of particular note

6.2 Emerging Materials and Technologies

Emerging developments in technology and vehicle design offer the potential for increased vehicle fuel economy and reduced environmental impacts during the rulemaking time frame and beyond. Trends addressed in this literature synthesis include mass reduction through material substitution (including aluminum, high-strength steel, polymer composites, magnesium, and titanium) and EV technologies. Although there are other materials and technologies (such as fuel-cell vehicles[5]) that could lead to reduced environmental impacts from light-duty vehicles, NHTSA chose to analyze only the select set of materials and technologies that are currently or likely to be commercially deployed in MY 2017–2025 described below.

Aluminum, which is currently used most intensively in the packaging and transportation sectors and can be used as a replacement for conventional (mild) steel, combines a high strength-to-weight ratio, corrosion resistance, and processability (Cheah et al. 2009).

High-strength steel has the same density as conventional steel, but provides greater strength, such that less high-strength steel is required than conventional steel to fulfill the same function. Consequently, high-strength steel provides the greatest weight-reduction benefits when used in structural or load-bearing applications, rather than non-load bearing uses, where strength is less of a factor in material use (Kim et al. 2010b).

Polymer-based composites, including nano-based technologies, have also received increasing attention as an alternative to other materials (e.g., mild steel and aluminum) used in transportation and other sectors. These materials can offer enhanced properties, such as high strength-to-weight ratios, thermal and flame resistance, enhanced barriers that reduce or eliminate gas permeation, and corrosion resistance (Khanna & Bakshi 2009).

[5] Fuel-cell vehicles operate similarly to battery electric vehicles (BEVs), because their engines are powered by the electricity generated within a cell. However, unlike a traditional battery, fuel cells in vehicles are typically powered by hydrogen. The tailpipe emissions from the consumption of hydrogen in a fuel-cell vehicle are minimal, because the chemical conversion process from hydrogen to energy generates mostly water and heat. However, the life-cycle environmental impacts of fuel-cell vehicles are dominated by the energy-intensive upstream impacts of isolating the hydrogen fuel via electrolysis or natural gas reforming. The life-cycle GHG emissions of fuel cell vehicles vary widely based on the hydrogen production technology used to supply the hydrogen for the fuel cell (Nitta and Moriguchi 2011). A variety of factors are barriers to wider fuel-cell vehicle manufacture and consumer adoption, namely cost, the lack of a hydrogen distribution infrastructure, and the high energy intensity of hydrogen production (National Academy of Engineering & National Research Council 2010). For these reasons, it is uncertain that hydrogen fuel-cell vehicles will constitute a significant portion of on-road light-duty vehicles by 2025; therefore, the technology falls outside the scope of this literature review (National Academy of Engineering & National Research Council 2010).

Magnesium is a very lightweight metal that is already used in a limited way for mass reduction in vehicles; current on-road vehicles use an average of approximately 11 pounds per vehicle (Cheah 2010). Magnesium is more expensive and energy intensive to produce than the mild steel it replaces, but offers significant fuel economy improvements due to a 60 percent weight reduction.

Titanium is denser than magnesium, but provides the highest strength-to-weight ratio of all metals. It can also offer significant fuel economy savings, but is costly.

EVs have the potential to significantly reduce life-cycle environmental impacts compared to conventional vehicles. This literature synthesis focuses specifically on two primary determinants of EV life-cycle emissions: emerging battery technologies being employed in EVs and the upstream electricity generation grid mix associated with charging EVs. While nickel-metal-hydride batteries are currently used in hybrid vehicles, nickel-metal-hydride battery energy density is insufficient for full EVs (Boncourt 2011). Batteries that employ lithium chemistries offer higher energy density than nickel-metal-hydride batteries. Lithium-ion (Li-ion) batteries are therefore currently being used to power some plug-in hybrid electric vehicles (PHEVs) and full EVs (Boncourt 2011), and it is anticipated that EVs will continue to use Li-ion battery chemistries in the near future (NRC 2011a). Because of the future potential of Li-ion batteries, the literature synthesis focuses primarily on batteries using Li-ion based chemistries.

6.2.1 Mass Reduction by Material Substitution

Mass reduction reduces fuel consumption by lowering vehicle mass while maintaining the same vehicle size. It can be achieved by removing or reducing the mass of vehicle components or by replacing heavier materials with lighter-weight materials without compromising strength and rigidity of components.

Reducing vehicle mass has implications across the life cycle of a vehicle. The potential impacts of mass reduction include reducing the amount of conventional material required to manufacture vehicles; increasing the amount of alternative, lighter-weight materials used to manufacture vehicles; saving fuel over the life of the vehicle; and influencing disassembly and recycling at end of life.

In addition to mass reduction by material substitution, improvements in vehicle manufacturing processes and technologies can also help achieve mass reduction. The literature that describes the life-cycle implications of these production-related mass reduction technologies is limited. However, one study identified that using laser welding in production processes, which enable improved and more efficient manufacturing of vehicles, reduces material use for the same level of energy use compared to standard arc welding techniques (Kaierle et al. 2011). Similarly, a second study explored hydroforming, which allows manufacturers to produce whole components that would otherwise be made using multiple parts joined together. Hydroforming has been applied to steel and aluminum automobile parts to reduce vehicle weight. For example, hydroforming leads to mass savings by eliminating the flanges required for welding and allowing for the use of thinner steel (Kocańda and Sadłowska 2008).[6]

This section summarizes literature related to vehicle mass reduction with a focus on material substitution. Replacing conventional materials such as mild steel with other lightweight material reduces vehicle fuel consumption, but also could increase the upstream environmental burden associated with producing these materials. This section focuses on three primary material categories:

[6] Kocańda and Sadłowska (2008) did not perform an LCA of hydroforming, but instead discussed the mass savings achieved from the production technology.

aluminum and high-strength steel, polymer composites, and magnesium and other components. Sections 6.2.1.1 through 6.2.1.3 describe the materials, summarize the relevant literature, and identify important limitations across the studies reviewed.

6.2.1.1 Aluminum and High-strength Steel

Aluminum and high-strength steel can be used to reduce weight while providing similar levels of strength and rigidity to mild steel. Aluminum is lighter than the mild steel it replaces, whereas high-strength steel is stronger and saves weight by using less material than mild steel to provide the same level of strength. Aluminum is a suitable substitute for cast-iron components and stamped-steel body panels, while high-strength steel is suited for replacement of structural steel parts (Cheah and Heywood 2011).

Thirteen studies[7] in the literature synthesis examine or discuss the life-cycle environmental impacts of substituting aluminum and/or high-strength steel for mild steel components in vehicles (Kim et al. 2010a, Hakamada et al. 2007, Bertram et al. 2009, Dubreuil et al. 2010, Cáceres 2009, Stodolsky et al. 1995, Lloyd and Lave 2003, Geyer 2008, Birat et al. 2003, Weiss et al. 2000, Bandivadekar et al. 2008, Ungureanu et al. 2007, and Mayyas et al. 2012). Some of these (Bertram et al. 2009, Geyer 2008, Lloyd and Lave 2003, Hakamada et al. 2007, and Mayyas et al. 2012) focus on material substitution in specific vehicle components, whereas others (Weiss et al. 2000, Bandivadekar et al. 2008, Ungureanu et al. 2007, and Kim et al. 2010a) estimate overall mass reduction from material substitution and vehicle redesign. The feasible amount of mass reduction is discussed in Chapter 3 of the Joint Technical Support Document. The studies show the following trends, which are discussed in more detail below:

- In general, the life-cycle analyses reported in the studies reviewed show that, across the entire vehicle life cycle, reductions in energy use and GHG emissions during the use stage of vehicles due to aluminum and high-strength steel material substitution exceed the increased energy use and GHG emissions needed to manufacture these lightweight materials at the vehicle production stage.
- However, the magnitude of life-cycle GHG-emission and energy-use savings are influenced by the amount of recycled material used in automobile components, the materials recycling rate at end of life, the lifetime of vehicles in use, and – in the case of lightweighting through aluminum substitution – the location of aluminum production.

Aluminum and high-strength steel vehicle component production requires more energy and leads to higher GHG emissions compared to the production of mild-steel vehicle components due to the high energy requirement for new ingot production from mined ores (Bertram et al. 2009, Hakamada et al. 2007). However, substituting aluminum and high-strength steel vehicle components for comparable mild-steel components can lead to a reduction in total vehicle weight and an increase in fuel efficiency during the use stage. Studies have found that, over the total vehicle life-cycle, the energy savings and reduced GHG emissions from this increase in fuel efficiency exceed the increased energy use and GHG emissions from aluminum production, resulting in an overall reduction in total life-cycle energy use and

[7] The following studies in this literature review indicated that they relied – at least partially – on industry funding or industry-funded data to evaluate the life-cycle impacts of aluminum and high-strength steel material substitution: Kim et al. (2010a), Geyer (2007, 2008), Dubreuil (2010), and Birat et al. (2003). All of the studies reviewed have undergone peer review for publication in academic journals. Certain studies noted where critical reviews were conducted in accordance with ISO 14044 standards on either the methodology (Geyer 2008) or life-cycle inventory inputs (Dubreuil 2010), or where critical review was not performed (Bertram et al. 2009).

as much as a 5.3 percent decrease in total life-cycle GHG emissions (Bertram et al. 2009, Hakamada et al. 2007, Stodolsky et al. 1995). For example, one study determined that the increased energy (i.e., fossil fuels and electricity) and GHG emissions associated with producing the aluminum parts substituted for mild steel front-end parts of a GM-Cadillac CTS were offset by use-stage savings after the first 35,000 kilometers (21,748 miles) of travel (Dubreuil et al. 2010). A separate study found that a 23 percent reduction in total vehicle mass through material substitution with aluminum decreased life-cycle GHG emissions by approximately 13.1 metric tonnes (29,000 pounds) of CO_2 compared to a baseline vehicle, and a 19 percent mass reduction through high-strength steel material substitution reduced life-cycle GHG emissions by approximately 12.5 metric tonnes (27,600 pounds) of CO_2 (Kim et al. 2010a).

On a fleetwide scale, substituting aluminum for steel in body panels in 1 year's sales volume of vehicles in the United States in 2000 (16.9 million vehicles) would, according to one study, have led to a decrease in 3.8 million tons of GHGs over the life cycle of the vehicles (Lloyd and Lave 2003). One study that included vehicle-level and fleet-level comparisons of aluminum substitution for mild-steel and cast iron components showed that the additional CO_2 emissions that resulted from the production of aluminum for aluminum castings were offset by fuel savings after 2 to 3 years of vehicle use, and CO_2 emissions from aluminum beams and panels were offset in 4 to 7 years of vehicle use (Cáceres 2009).

It is important to note that many studies emphasized the sensitivity of LCA results to the amount of recycled material used in automobile components and the materials recycling rate at end of life. Substituting rolled aluminum or high-strength steel for mild-steel sheet in vehicles reduces life-cycle GHG emissions, but the savings from aluminum results can depend on scrap recycling rather than just vehicle fuel economy improvement (Geyer 2008). Life-cycle GHG savings from aluminum vehicle component substitution also depend heavily on the location of aluminum production and the share of secondary aluminum used (Kim et al. 2010a). In practice, recycling aluminum results in the accumulation of impurities, typically other metals that are challenging and energy-intensive to remove. Consequently, recycled aluminum is usually blended with primary aluminum to mitigate the buildup of contaminants. This practice results in an effective cap on the share of post-consumer aluminum that can be in recycled aluminum (Gaustad et al. 2012).

Several studies found that GHG emissions savings from vehicles using lightweight materials in relation to their respective baselines might or might not depend on the materials recycling rates achieved, with estimates ranging from lower life-cycle GHG emissions only under scenarios with "very high recycling levels" for aluminum components, to significantly lower life-cycle GHG emissions compared to comparable mild-steel components, even with a "non-realistic" recycling rate of 0 percent (Bertram et al. 2009, Birat et al. 2003). In a recent study comparing life-cycle energy and GHG emissions from various Body-in-White (BiW)[8] designs, the high-strength-steel- and aluminum-intensive BiW structures were estimated to have lower energy and GHG emissions impacts compared to conventional steel baseline BiW structures for vehicles whose lifetimes were 100,000 miles or more. In addition to sensitivity to vehicle lifetime assumptions, the life-cycle energy and GHG emissions impacts of various material BiW designs are sensitive to recyclability of materials at end-of-life (Mayyas et al. 2012). Another study noted that the replacement of conventional steel with recycled aluminum for a BiW structure reduced life-cycle emissions of CO_2 by 7 percent within 1 year and 11 percent after 10 years of use (Ungureanu et al. 2007).

[8] BiW contributes to approximately 25 percent of total vehicle mass. BiW is essentially the body frame of the car and includes the car body's sheet metal that has been welded together but does not include additional moving parts (doors, hoods, deck lids, and fenders) the motor, chassis sub-assemblies, or trim (glass, seats, upholstery, and electronics).

6.2.1.2 Polymer Composites

Various types of reinforced polymer composites are in use or in development as substitutes for mild steel or aluminum, predominantly in vehicle body panels. These materials offer added tensile strength and weight reduction potential compared to mild steel[9] and include glass- and carbon-fiber-reinforced polymer composites and nanocomposites, such as those reinforced with nanoclays or carbon nanotubes (Lloyd and Lave 2003, Cheah 2010). At the nano scale, carbon fibers offer additional tensile strength and provide other functionalities such as electrical conductivity and antistatic properties, which are useful properties for automobile components such as body panels and casings for electronic equipment (Khanna and Bakshi 2009).

Eleven studies in the literature synthesis examine or discuss the life-cycle environmental impacts of substituting reinforced polymers or composites for aluminum or mild-steel components in vehicles (Lloyd and Lave 2003, Khanna and Bakshi 2009, Cheah 2010, Overly et al. 2002, Gibson 2000, Weiss et al. 2000, Sullivan et al. 2010, Das 2011, Keoleian and Kar 1999, Tempelman 2011, and Spitzley and Keoleian 2001). Two of these studies (Lloyd and Lave 2003 and Khanna and Bakshi 2009) focus on applications based on nanotechnology. Although not a full LCA, one study focuses on the life-cycle energy implications of using nanomaterials in Li-ion batteries in EVs to ultimately improve battery efficiency (Kushnir and Sandén 2011).

The studies show the following trends, which are discussed in more detail below:

- Polymer composites (including those reinforced with glass, carbon fiber, or nanoclays) used in vehicle body panels are more energy and GHG intensive to produce compared to mild steel (but greater or less than aluminum, depending on the study).
- Carbon-fiber-reinforced polymer composites used for specific automotive parts (e.g., a floor pan) are less GHG intensive than similar components made from conventional materials across the life cycle (including end of life), but the magnitude of the difference depends on the vehicle weight reduction afforded by the composite materials.
- When considering the full life cycle of the vehicle, the use of polymer composites in vehicle body panels and air intake manifolds leads to reduced energy use and GHGs emitted over the vehicle life cycle compared to vehicles with similar aluminum or steel parts. This reduction is a result of the significant reductions in vehicle weight and the subsequent improvements in fuel economy.
- When considering other environmental impact categories (e.g., acidification, water use, water quality, landfill space), these polymer composite materials also result in overall lower life-cycle impacts compared to mild steel, and, in most cases, compared to aluminum.
- Certain aspects (e.g., end-of-life assumptions, the post-consumer material content of composite materials) deserve additional analysis in future studies.
- Polymer composites are more difficult to recycle than their metal counterparts; however, many studies assign a credit for the assumed end-of-life handling of these components – specifically an energy credit for incineration in a waste-to-energy plant. In practice, waste-to-energy incineration could be unavailable for composites, and this assumption could overstate its life-cycle benefits related to metals.

[9] Estimates of the weight reduction in automobile body parts range from 38 to 67 percent (Overly et al. 2002, Cheah 2010, Lloyd and Lave 2003, Khanna and Bakshi 2009).

Several studies show that the upstream extraction, materials processing, and manufacturing stages for carbon-fiber- and glass-fiber-reinforced composites used in vehicles are more energy- and GHG-intensive than those for conventional (mild) steel, but less than those for aluminum (Overly et al. 2002,[10] Cheah 2010, Weiss et al. 2000, Gibson 2000, Tempelman 2011, Khanna and Bakshi 2009). For example, estimates of the cradle-to-gate[11] energy required for carbon nanofiber polymer composites range from nearly 2 to 12 times greater than the energy requirements for steel[12] (Khanna and Bakshi 2009). Other estimates of cradle-to-gate energy indicate that carbon-fiber production is almost 20 times more energy intensive than conventional galvanized steel, and 15 times more CO_2 intensive on a weight basis (Das 2011). According to one study, in relation to aluminum used in automobile bodies, polymer composites require less primary energy and are associated with lower GHG emissions;[13] however, if recycled aluminum is used, the energy requirements and upstream GHGs are comparable to that of polymer composites (Weiss et al. 2000). Finally, two studies demonstrated that upstream extraction, materials processing, and manufacturing stages for nylon composite air intake manifolds are more energy and GHG intensive than those for aluminum (Keoleian and Kar 1999, Spitzley and Keoleian 2001).

While polymer composites used in vehicle body panels are more energy- and GHG-intensive to produce compared to mild steel and, in some cases aluminum, inclusion of the product use phase results in net life-cycle energy savings and reduced GHGs. This “cross-over” occurs sometime during the lifetime of the vehicle (Gibson 2000). One study estimates that substituting a high-performance clay-polypropylene nanocomposite for steel in a light-duty vehicle could reduce life-cycle GHG emissions by as much as 8.5 percent, and that GHG emissions associated with material production of that high-performance material are 380 times smaller than those associated with vehicle use[14] (Lloyd and Lave 2003). This energy and GHG reduction is a result of the significant reductions in vehicle weight and the subsequent improvements in fuel economy. As one study concludes, the life-cycle energy and CO_2 emissions benefits of using carbon-fiber rather than conventional steel depend on the weight reduction potential of the part and the type of precursor material used in the carbon fiber polymer composite. A larger weight reduction potential combined with bio-based precursor materials (e.g., lignin) leads to net life-cycle GHG emissions and energy savings compared to conventional steel (Das 2011).

In general, the studies that look at multiple environmental impact categories conclude that these lightweight composite materials offer overall environmental benefits compared to mild steel – and in most cases, compared to aluminum – across the vehicle life cycle. Carbon-fiber-reinforced polymer composite used in vehicle closure panels[15] show lower environmental impacts compared to steel, aluminum, and glass-fiber-reinforced polymer composite in most impact categories – including nonrenewable and renewable resource use, energy use, GWP, acidification, odor/aesthetics, water quality (biochemical oxygen demand), and landfill space (Overly et al. 2002). Applications of glass-reinforced-polymer composites result in the lowest environmental impacts in ozone depletion and PM formation (Overly et al. 2002). Other studies note additional carbon composite benefits in air emissions,

[10] Note that Overly et al. (2002) include extraction and material processing, but not manufacturing, in the study scope due to data limitations, but note that the impacts are typically the smallest during this stage.
[11] Including carbon nanofiber production, polymer resin production, carbon nanofiber dispersion, and composite manufacture; excluding vehicle use and associated gasoline production and the end-of-life stages.
[12] Standard steel plate used in this study.
[13] This upstream energy and GHG impact for a plastic automobile body is approximately about one-third of that of one with virgin aluminum components (Weiss et al. 2000).
[14] Including petroleum production, which refers to the upstream emissions associated with producing the petroleum that the vehicles consume.
[15] Includes four door panels, the hood, and the deck lid.

water emissions, and hydrogen fluoride emissions over the entire vehicle life cycle compared to mild steel and aluminum (Gibson 2000). A clay-polypropylene nanocomposite substituted for steel shows reduced life-cycle environmental impacts across all impact categories (including electricity use, energy use, fuel use, ore use, water use, conventional pollutants released, GWP, and toxic releases and transfers), except for a slight increase for hazardous waste generation (Lloyd and Lave 2003). The lower impacts are largely because the vehicle production requires less material with the lighter material. When carbon-fiber-reinforced polymer replaces a much larger share of the steel in the vehicle body panel (i.e., beyond the closure panels), the environmental benefits of carbon fiber lessen (Overly et al. 2002). When a nylon composite manifold was compared to two similar aluminum parts (sand-cast and multi-tubed brazed), the composite manifold showed lower life-cycle energy use and GHG, CO, non-methane hydrocarbons, and NO_x emissions. However, the life-cycle emissions of methane, PM_{10}, and sulfur dioxide (SO_2) for the composite manifold were higher than one or both of the aluminum manifolds (Keoleian and Kar 1999). Similarly, when two nylon composite manifolds (manufactured using lost-core molding and vibration welding) were compared to an aluminum sand-cast manifold, the composite manifolds showed lower life-cycle energy use, solid waste generation, and CO_2 and CO emissions. However, the life-cycle emissions of lead, NO_x, and sulfur oxide (SO_x) for one or both of the composite manifolds were higher than for the aluminum manifold (Spitzley and Keoleian 2001).

One study analyzed the life-cycle energy implications of using nanomaterials and technologies (namely lithium iron phosphate and lithium titanate) rather than using conventional materials such as cobalt and graphite for battery production (Kushnir and Sandén 2011). The study examined the use of the nanomaterials not for the purpose of mass reduction of the vehicle, but for improvements in efficiency and performance of the battery itself. However, it is likely that using nanomaterials in batteries used in EVs will provide the ancillary benefit of vehicle mass reduction. The study concludes that, in agreement with other LCAs on nanocomposite materials, the upstream energy required for production of nanomaterials is greater than conventional materials used in Li-ion batteries, such as cobalt. However, the potential for improvements afforded by nanomaterials in battery energy efficiency and battery lifetimes in the use phase of vehicles would outweigh the additional upstream energy requirements.

Studies acknowledge that large uncertainties underlie the results and that certain assumptions have a significant influence on the results. For example, consideration of fleet effects, such as upstream production energy mix (e.g., the high share of hydropower used in the production of aluminum), could change the results (Lloyd and Lave 2003, Spitzley and Keoleian 2001). Studies handled the impacts from end of life in different ways (e.g., assuming composites were landfilled at end of life [Overly et al. 2002] or excluding the impacts altogether [Khanna and Bakshi 2009]). Studies noted that a more complete analysis would look at impacts associated with recycling composites and the effect of using recycled versus virgin material inputs in their production (Lloyd and Lave 2003, Weiss et al. 2000) and would consider reparability (Lloyd and Lave 2003, Overly et al. 2002). Composites demonstrate lower recyclability than metals, but this is partially offset by their high energy content for the purposes of incineration. If waste-to-energy disposal is not an option for composite auto body components, the low recyclability of these materials results in significantly more life-cycle waste generation than their metal alternatives (Tempelman 2011). If composite-based vehicle panels are more difficult to repair and therefore need to be discarded more frequently or earlier in the vehicle's life cycle and repeatedly replaced, the environmental benefits could be diminished. It is important to note that the composite and nanotechnologies are rapidly developing and evolving.

Using sensitivity analyses to test different assumptions – including different end-of-life treatments and technology assumptions – is one approach to improve the robustness of findings from LCAs, and is referenced in ISO standards for LCAs.[16] To reflect some of the current variations, studies evaluated different types of materials, including lower and higher performance materials. However, the environmental impacts are expected to change as material design advances and processes evolve.

6.2.1.3 Magnesium and Titanium

Magnesium is an abundant metal with a density approximately one-fifth that of steel and approximately 60 percent that of aluminum. At present, on average, magnesium content per vehicle is approximately 5 kilograms (11 pounds), but it is estimated that this average content will double to approximately 10 kilograms (22 pounds) by 2020 (Cheah 2010). Magnesium-substituted vehicles have higher fuel efficiencies than conventional and aluminum-substituted vehicles due to lighter vehicle weights from magnesium's low density (Hakamada et al. 2007, Cáceres 2009). On average, magnesium provides a 60 percent weight reduction over steel and 20 percent over aluminum, with equal stiffness (Cheah 2010).

Eight studies in the literature synthesis examined the life-cycle environmental impacts of substituting magnesium and/or titanium for steel and aluminum components in vehicles (Hakamada et al. 2007, Dubreuil et al. 2010, Cheah 2010, Tharumarajah and Koltun 2007, Dhingra et al. 2000, Sivertsen et al. 2003, Cáceres 2009, Gibson 2000). However, only two of the studies (Dhingra et al. 2000 and Gibson 2000) examined titanium. Dhingra et al. (2000) only included titanium as part of the collective impact of several simultaneous mass reduction strategies in one vehicle, so it was not possible to draw any firm conclusions about the use of titanium for mass reduction.

Magnesium is abundant throughout Earth's upper crust, although it does not occur naturally in its isolated form. Instead, magnesium is typically refined from salt magnesium chloride using electrolysis or from ore (mainly dolomite) using the Pidgeon process, which involves reducing magnesium oxide at high temperatures with silicon. The Pidgeon process is used mainly in China (Dubreuil et al. 2010). In general, magnesium is more expensive and energy-intensive to produce than steel. Titanium is not as abundant as magnesium or aluminum, and is similarly energy-intensive and expensive to refine into its metallic form. Titanium is denser than magnesium or aluminum, but has a higher strength-to-weight ratio than steel, aluminum, or magnesium, meaning that using less of it will achieve equivalent strength.

Overall, the studies reviewed show the following trends:[17]

- Magnesium and titanium are more energy- and GHG-intensive to produce than steel or aluminum.
- Significant reductions in vehicle weight and GHG emissions can be achieved in the future by substituting magnesium and titanium for heavier components currently in use. However, break-even distances (the driving distance at which fuel economy savings outweigh increased production energy) can be relatively high in relation to other materials. For example, examining only mass reduction of the engine block, use of coal-based Pidgeon process magnesium could result in a break-even distance of between 20,000 kilometers and 236,000 kilometers (12,500 miles and 147,000 miles) compared to other materials ranging from iron to aluminum produced from different production processes and locations (Tharumarajah and Koltun 2007). The use of coal-based Pidgeon

[16] *See* ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines.

[17] Differences in scope and functional units (i.e., the reference unit against which environmental impacts are compared) across the studies limit their comparability with each other. For example, modeling different magnesium production processes and recycled contents has a great effect on the life-cycle emissions. Assumptions about which parts are replaced or supplemented with magnesium vary widely across studies, as do methodologies such as the weight-for-weight ratio at which magnesium is substituted for steel.

process magnesium decreases the life-cycle energy and GHG benefits of magnesium. The greater the amount of GHG-intensive Pidgeon process magnesium incorporated into the vehicle, the longer the break-even distance becomes (Cáceres 2009).

- If a large proportion of recycled magnesium is used, the production energy and GHG disadvantages of using magnesium can be significantly offset (Hakamada et al. 2007). Generally, the higher the proportion of recycled magnesium, the shorter the break-even distance.
- Several of the studies looked at the effects of replacing particular automotive parts. Given the heterogeneity of the studies, it is difficult to make conclusive statements, but which part of the automobile is substituted could make a difference to LCA results. In general, however, weight reduction is probably the primary consideration in use-phase GHG emissions, and which parts are replaced will be subject mostly to engineering considerations (Hakamada et al. 2007).

According to Gibson (2000), the life-cycle energy consumption of an automotive part manufactured from titanium is the highest of all materials analyzed in that study, including advanced automotive materials such as carbon-fiber-epoxy composite and conventional materials such as steel. This is due to the high energy use associated with titanium production, including extraction of titanium dioxide ore and subsequent oxidation of magnesium metal. Cradle-to-grave GHG emissions and air pollutant emissions are similarly highest for titanium compared to alternative materials such as steel and carbon fiber due to higher electricity use — and subsequent emissions associated with coal power plants — during the manufacturing of titanium.

The LCA literature generally agrees that magnesium substituted in vehicles requires more energy to produce than conventional and aluminum-substituted vehicles, and therefore produces more GHGs during that stage (e.g., Dubreuil et al. 2010, Tharumarajah and Koltun 2007). Both electrolysis and the Pidgeon process are energy intensive, although electrolysis is 3 to 5 times more energy efficient than the Pidgeon process (Cheah 2010). China produces approximately 80 percent of the world's magnesium, almost entirely using a coal-powered Pidgeon process (Dubreuil et al. 2010). This process leads to higher GHG emissions per unit of magnesium than magnesium produced using electrolysis, a process that is often powered by hydroelectricity or other lower-carbon energy sources. In addition, three potent GHGs are used during primary metal production: sulfur hexafluoride and two perfluorocarbons (Dhingra et al. 2000). Sulfur dioxide is also used as a protective gas to cover molten magnesium during production (i.e., cover gas) (Dubreuil et al. 2010).

Even considering the energy required to produce magnesium, several LCAs have found that, over vehicle life, the high fuel efficiency of magnesium-substituted vehicles lowers total energy use below that of conventional and aluminum-substituted vehicles. How much less energy is determined by which vehicle parts are substituted and methods used in manufacturing the magnesium. For titanium, even when considering the use stage of vehicles with a lifetime distance of 177,000 kilometers (109,983 miles) the higher production energy and environmental impacts associated with titanium material are larger than the avoided energy and environmental impacts associated with fuel consumption from the lighter weight vehicle.

The results of each LCA vary, depending on which component in the vehicle was substituted and manufacturing methods. Key assumptions that affect life-cycle environmental impacts associated with magnesium substitution include:

- Method of magnesium production – Assumptions about what proportion of magnesium comes from the Pidgeon process and what portion from electrolysis, as well as the assumed fuel sources, will have an effect on GHG emissions and energy use, because the Pidgeon process is more energy and GHG intensive.

- Sulfur hexafluoride (SF_6) – SF_6 is a potent GHG[18] and might be phased out of manufacturing in the near future in most countries. At present, SF_6 is used as a cover gas, (i.e., a protective gas to cover molten magnesium during production). To lower GHG emissions, SO_2 can also be used to treat magnesium, but it is toxic. Using SF_6 in manufacturing leads to a vehicle break-even point of approximately 200,000 kilometers (124,000 miles), while using SO_2 in manufacturing leads to a vehicle break-even point of approximately 67,000 kilometers (41,600 miles) (Sivertsen et al. 2003).
- Substitution characteristics – The weight-to-weight ratio at which one metal is substituted for another will affect LCA results, as will assumptions about metal stiffness and strength.
- Recycling – Magnesium is generally considered well suited to recycling. Approximately 5 percent of the energy used in production of virgin materials is needed for re-melting. Two types of materials are recycled: manufacturing scraps and post-consumer materials (Sivertsen et al. 2003). Because magnesium uses more energy to produce from virgin materials than to recycle, whether the material is recycled and at what rate, can have a great impact on LCA results.

6.2.2 Electric Vehicles

The term "electric vehicle" covers a range of different vehicle types, including battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and PHEVs (Notter et al. 2010, Patterson et al. 2011). EVs use battery technologies to provide power, therefore reducing or even eliminating liquid fuel consumption during vehicle operation. BEVs are purely electrically powered and do not incorporate an internal combustion engine. HEVs incorporate a battery and electric motor system coupled with an internal combustion engine and have on-board charging capabilities (e.g. regenerative breaking). PHEVs are fitted with a large capacity rechargeable battery that can also be charged from the electric grid; like HEVs, they also utilize an internal combustion engine as a backup when battery life is depleted.

This section discusses two important life-cycle issues associated with EVs: battery production and upstream electricity generation used to charge EVs.

6.2.2.1 Environmental Impacts Associated with Battery Production

Most current HEVs use nickel-metal-hydride or sodium-nickel-chloride batteries, but the trend in the near future for all EVs is a shift toward Li-ion batteries (Majeau-Bettez et al. 2011, NRC 2011a). The Li-ion battery is currently the preferred battery technology because of its electrochemical potential, lightweight properties, comparatively low maintenance requirements, and minimal self-discharge characteristics, which enable Li-ion batteries to stay charged longer (Notter et al. 2010). There are different types of Li-ion batteries that vary by chemistry and cathode technology, including lithium-iron-phosphate, manganese-spinel, nickel-cobalt-aluminum, and manganese-nickel-spinel, to name a few (Gaines et al. 2011). Each of these Li-ion battery types offers a different balance of performance and economic characteristics, including cost, specific energy, energy density, specific power, safety, and cycle life (Gaines et al. 2011, NRC 2011a). Regarding material composition, Li-ion batteries consist mostly of heavy metals such as aluminum, steel, cobalt, gold, tin, and copper, as well as plastics (Notter et al. 2010). Lithium as a constituent in Li-ion batteries represents a small fraction (typically between 1 and 3 percent, depending on specific chemistry) of total battery composition (Gaines et al. 2011).

[18] SF_6 has a GWP of 23,900.

The most common process for extracting lithium is through extraction from lithium carbonate concentrations originally derived from brine-lake or salt-pan deposits (Gaines et al. 2011). One of the key environmental impacts from the lithium extraction industry is its impact on water use. Industrial facilities extracting lithium require the diversion of large quantities of water and are likely to return it to local ecosystems with higher concentrations of salts and other process chemicals, impacting local irrigation agriculture and regional biodiversity. Additionally, the evaporation ponds for the separation of lithium salts from liquids are lined with polyvinyl chloride (commonly called PVCs) and are a potential source of leachates (Hollender and Shultz 2010).

Several recent studies analyze the environmental impacts of Li-ion batteries across their life cycle and use in vehicles, including the impacts of upstream battery production. This literature synthesis indicated the following overarching trends of the environmental impacts associated with Li-ion battery production:

- The environmental impacts from Li-ion battery production, such as GWP and energy demand (i.e., fossil fuels and electricity), are a significant contributor to total BEV production-related environmental impacts. The inclusion of Li-ion batteries in BEV production causes the total environmental impacts associated with the production of a BEV to be larger than a conventional vehicle.
- However, across the full vehicle life cycle, including the use stage (i.e., operation), the environmental impacts associated with upstream battery production are small (less than 10 percent across most environmental impact categories).
- Battery size affects use-phase energy and GHG emissions in EVs. For example, the additional weight of a battery in a PHEV with a 60-mile all-electric range increases use-phase GHG emissions by 10 percent compared to a PHEV with a 7-mile all-electric range when charging every 7 miles or less (i.e., comparing only all-electric energy use per mile between the two vehicles) (Shiau et al. 2009).
- Life-cycle emissions from BEVs and PHEVs vary based on the grid mixes used for battery charging. Section 6.2.2.2 describes the life-cycle environmental impacts of varying grid-mix assumptions.
- Most recent studies have not quantified the environmental impacts from recycling Li-ion batteries. The recycling market for Li-ion batteries is still in its infancy, with limited feedstock, because BEVs are still a relatively niche market in the automotive sector.

Several studies have analyzed the environmental burdens associated with EV production, concluding that the upstream impacts of producing Li-ion batteries for EVs is significant, and that the production of EVs has greater environmental impacts than the production of conventional vehicles. A study by Samaras and Meisterling (2008) examined life-cycle GHG emissions of Li-ion batteries used in HEVs and PHEVs. The study analyzed the upstream energy and associated GHG emissions from raw-material extraction, battery production, and processing to determine the cradle-to-gate analysis of different sizes of Li-ion batteries, depending on the range of the EV. Notably, the impacts from battery end-of-life are omitted. The total energy required for upstream production is determined to be 1,700 megajoule of primary energy per kilowatt-hour of Li-ion battery capacity. Roughly 500 megajoule per kilowatt-hour is associated with raw-material extraction alone, so most of the primary energy requirement is associated with battery manufacture. Total GHG emissions associated with lithium battery production are approximately 120 kilograms (265 pounds) carbon dioxide equivalent (CO_2e) per kilowatt-hour of battery capacity.[19] Although the upstream production GHG emissions of Li-ion batteries are sensitive to assumptions about fuel mix for production and relative mix of virgin and recycled materials used in production, the total GHG emissions attributable to the production of an HEV or a PHEV are generally larger than those attributable to the production of a conventional vehicle because of the additional GHG emissions associated with battery production (Samaras and Meisterling 2008). A comparison of life-cycle GHG emissions of BEVs and conventional vehicles similarly concluded that the vehicle manufacturing stage life-cycle emissions for BEVs are higher than for conventional vehicles due to battery manufacture (Ma et al. 2012).

Further, the overall efficiency and performance of a vehicle is measurably affected by the extra weight associated with battery packs and structural supports in EVs. The additional weight of batteries in a PHEV with a 60-mile all-electric range increases GHG emissions during the use phase by up to 10 percent compared to a PHEV with a smaller battery and a 7-mile all-electric range when charging every 7 miles or less (i.e., comparing only all-electric energy use per mile between the two vehicles) (Shiau et al. 2009).

The environmental impacts of the battery production life-cycle stage itself are dominated by the production of the battery pack, which includes energy for heating and roasting various components in the production of metals. However, within the framework of the assumed battery size (300 kilograms [approximately 660 pounds]) and vehicle life (150,000 miles), Notter et al. (2010) determined that the environmental impacts associated with the production of Li-ion batteries used in an EV are relatively small compared to the full life-cycle environmental impact of the vehicle.[20] The environmental impacts analyzed included abiotic depletion, nonrenewable cumulated energy demand, GWP, and Ecoindicator 99, which is a weighted average impact assessment score consisting of human health and ecosystem quality impact categories. Across the impact categories measured, the battery production share of the total life-cycle environmental impacts of EV manufacture, use, and disposal ranged between 7 (cumulated energy demand) and 15 percent (Ecoindicator99). The authors also note that the environmental impacts of the battery life cycle analyzed in their study are a worst-case scenario because no recycling benefits were assumed at end of life. According to the study, the natural resources required to manufacture a battery could be reduced by 51 percent by using recycled inputs to supplement virgin materials.

In the context of the total vehicle life cycle environmental impacts of HEVs and PHEVs (i.e., including vehicle production, battery production, and use stage of vehicles), Samaras and Meisterling (2008) concludes that GHG emissions associated with Li-ion battery materials and production account for only 2 to 5 percent of total life-cycle vehicle emissions, depending on the percentage of recycled material included and the grid mix assumed for battery manufacturing.[21] This figure does not account for GHG

[19] Assuming 75 percent of primary energy is fuel for electricity generation and the remainder (25 percent) is from diesel fuel combustion.

[20] The relatively minor environmental impacts of battery production are due to small weight of lithium content (0.007 kilograms per kilogram Li-ion battery) and low energy intensity of lithium extraction from brines. However, "If the lithium components were based on spodumene, a silicate of lithium and aluminum, the extraction of the lithium would require a considerable amount of process energy" (Notter et al. 2010, p. E).

[21] The energy intensity of producing nickel-metal-hydride batteries is double that of Li-ion batteries, so use of nickel-metal-hydride batteries would increase battery impacts to 3 to 10 percent of life-cycle GHG impacts from PHEVs. Although nickel-metal-hydride batteries have been used in earlier EVs and hybrids, the higher energy density of Li-ion batteries and technological improvements have made them better suited for use in future PHEV and EV applications (Samaras and Meisterling 2008).

emissions impacts from battery and vehicle end of life because the authors determined that these stages were negligible across the full vehicle life cycle. The authors indicated that future research is needed to identify the environmental tradeoffs of other environmental impacts in addition to GHGs.

The cradle-to-gate GHG impacts associated with battery production (specifically lithium-iron-phosphate) calculated by Majeau-Bettez et al. (2011) (7 to 10 grams CO_2e per kilometer traveled) are comparable to Notter et al. (2010) (12 grams CO_2e per kilometer traveled) and Samaras and Meisterling (2008) (7 to 10 grams CO_2e).[22] However, due to the sensitivity of assumptions about battery mass, life expectancy, and battery life cycle, the environmental impacts of batteries could be higher than documented (Majeau-Bettez et al. 2011). For Li-ion batteries produced and sourced in regions with a more carbon-intensive electricity grid mix, the life-cycle impacts of batteries increase significantly (Majeau-Bettez et al. 2011).[23] In terms of other environmental impacts, this study determined that most (30 to 50 percent) of the human toxicity and ecotoxicity impacts were associated with the copper used in the battery management system and the electrode constituents.

A paper by Gaines et al. (2011) focuses on the life-cycle energy implications of various types of Li-ion battery production for a PHEV with a nominal all-electric 20-mile range. Although GHG emissions are not calculated explicitly, Gaines et al. (2011) indicate that GHG emissions align closely with energy use. Recognizing the limitations of life-cycle data, particularly the lack of process-based data on lithium-constituent materials, Gaines et al. (2011) calculate that the energy associated with battery production accounts for only 2 percent of the total vehicle life-cycle energy use. As corroborated by other studies (e.g., Notter et al. 2010), the largest contributors to the battery production life-cycle energy profile include the constituent metals production (e.g., aluminum, steel, and cobalt) and the production and assembly of the battery pack itself.[24] There is potential to reduce the life-cycle energy implications (and therefore the associated GHG emissions) through recycling of battery components at end of life. Gaines et al. (2011) determined through scenario analysis that recycling metals, including aluminum, steel, nickel, and copper, and other battery components, could reduce energy consumption of batteries by 30 percent compared to a base-case scenario of no recycling.

The recycling market for Li-ion batteries is still in its infancy, and, of the studies reviewed, only Gaines et al. (2011) evaluated the environmental impact of battery recycling. Although there have been robust state-level policies in the United States since the early 1990s for most states to manage lead-acid battery recycling processes, there are currently no similar policies for Li-ion or other battery types. However, public and private efforts are underway to advance and implement Li-ion battery recycling. For example, Tesla Motors, an EV manufacturer, launched a Li-ion battery recycling program in 2011 to recover metals from their vehicles' battery packs in Europe. Research and development initiatives have also been launched by the U.S. Department of Energy (DOE) Argonne National Laboratory, and at academic and research facilities in Germany through the LithoRec Project and Lithium Battery Recycling Initiative. As Li-ion battery recycling infrastructure becomes more established, life-cycle energy use could be reduced through the recovery of metals.

[22] To provide this comparison, Majeau-Bettez et al. (2011) convert their results, which are based on the functional unit of 50 megajoule energy delivered from the battery to the powertrain, into a distance-based functional unit (i.e., emissions per distance traveled) assuming a powertrain efficiency of 0.5 megajoule per kilometer traveled.

[23] Using average Chinese electricity grid mix during the production of Li-ion batteries to replace the average European electricity grid mix, life-cycle impacts of battery production would increase by 10 to 16 percent for GWP impacts and 10 to 29 percent for PM and photochemical oxidant formation (Majeau-Bettez et al. 2011).

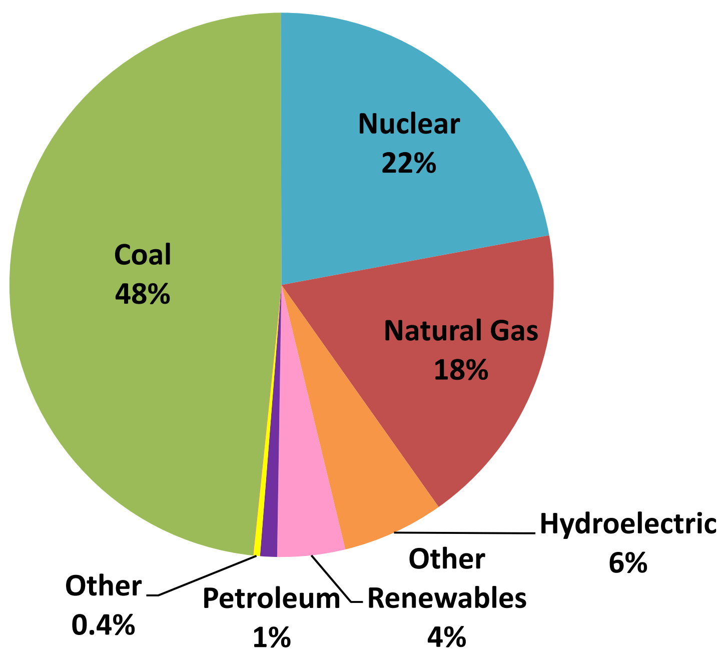
[24] Assuming a 160,000-mile life and no battery replacement.

6.2.2.2 Electricity Associated with the Operation of Electric Vehicles

EVs, unlike conventional vehicles, have the potential for reduced (or zero in the case of "pure" EVs) tailpipe emissions. For EVs, the emissions associated with their mobility are shifted mostly upstream to the electric power grid. An accounting of the full life-cycle environmental impacts of EVs therefore includes the upstream impacts from generating the electricity (fuel) used as the source for the mobility energy.

Similar to conventional vehicles that use liquid fuels, most of the energy use and associated environmental impacts occur during the operation or use stage of an EV throughout its life (Samaras and Meisterling 2008, Gaines et al. 2011, and Notter et al. 2010). However, a 2010 study by the National Research Council and several partners indicates that the process of calculating the energy use and emissions associated with EVs is more complex than a similar calculation for conventional vehicles because the associated impacts depend strongly on how and where the electricity is generated (National Academy of Engineering & National Research Council 2010). Emissions and other environmental impacts from electricity production depend on the efficiency of the power plant and the mix of fuel sources used, also referred to as the "grid mix." In the United States, the grid mix is comprised of coal, nuclear, natural gas, hydroelectric, oil, and renewable energy sources (Figure 6.2.2-1). This section focuses on the environmental impacts associated with upstream electricity production used to charge EVs and power them during operation.

Figure 6.2.2-1. U.S. Electric Power Industry Net Generation by Fuel, 2010[a]



a. Source: EIA 2011d

Based on this literature synthesis, the following conclusions are highlighted:

- Life-cycle GHG emissions (and most other environmental impacts) on a per-mile-traveled basis across different types of EVs (e.g., BEVs and PHEVs) are dominated by the use stage (e.g., the impacts associated with electricity generation upstream).

- The life-cycle environmental impacts of the EV use phase depend on many variables associated with the upstream generation of electricity used for charging EVs, including: (1) overall mix of fuels used to generate electricity, (2) whether the electricity generation impacts are based on the average mix of fuels used to generate electricity (typically a mix of fossil fuels and renewable energy sources) or the marginal mix of fuels used to meet short-term spikes in electricity demand (typically fossil fuels), and (3) the temporal aspect of electricity generation (e.g., peak versus non-peak).
- There is a potential for EVs to significantly reduce petroleum energy use, as well as GHG emissions and other environmental impacts associated with reduced petroleum consumption, but the electricity grid mix used to charge EVs significantly affects the mitigation potential.
- The environmental impacts associated with electricity generation and consumption during the use of EVs depends on the location and timing of vehicle charging. In the future, among EVs, the use of PHEVs would cause no more SO_2 emissions, comparable or slightly higher GHG emissions, and limited increases in NO_x emissions than hybrids aggregately throughout the United States if charged during peak electricity generating hours.[25] Furthermore, they will likely cause fewer emissions than hybrids in areas with non-coal generated electricity, regardless of charging time.
- Assuming that BEVs and PHEVs charge from a carbon-intensive grid mix (i.e., electricity generation from mostly coal-fired power plants), total vehicle life-cycle GHG emissions from PHEVs and BEVs are comparable or less than conventional gasoline vehicles. However, one study found that mid-size BEVs driven in the United Kingdom might generate more GHG emissions over their life cycle compared to conventional vehicles when driven at higher speeds and loads and charged using marginal electricity generated from exclusively GHG-intensive power sources, such as coal-fired power plants (Ma et al. 2012).

As summarized in Table 6.2.2-1, the energy and GHG emissions associated with the EV life cycle are compared to a conventional vehicle across three studies. Note that due to underlying assumptions about the vehicle type, vehicle life, specific EV battery, life-cycle boundaries, and electricity grid mix, the energy and GHG emissions listed in the table are not directly comparable across studies. However, the table clearly indicates that despite different assumptions, all studies find that the total life-cycle energy and GHG emissions on a per-mile basis are significantly less for BEVs compared to conventional vehicles at average U.S. and European grid-mix GHG intensities. In addition, on a per-mile-traveled basis across different types of EVs, the GHG emissions and energy impacts are dominated by the use stage (i.e., the impacts associated with electricity generation upstream).

Mitropoulos and Prevedouros (2011) quantified various environmental metrics associated with the life cycle of different types of EVs compared to gasoline light-duty vehicles. Across all environmental indicators studied, including GHG emissions and emissions of criteria air pollutants (except SO_x and PM), the analyzed EVs were estimated to have the lowest environmental life-cycle impact on a grams-per-mile basis (Mitropoulos and Prevedouros 2011[26]). The higher life-cycle SO_x and PM emissions for EVs were a result of the electricity grid-mix assumptions.

Table 6.2.2-1 indicates the use stage is the dominant contributor to environmental impacts across EV life cycle, representing 67 to 84 percent of the total life-cycle impacts, although the environmental impacts of the use phase are highly dependent on the mix of fossil fuels used to generate the electricity (Notter et al. 2010).

[25] Based on dispatch modeling using the Oak Ridge Competitive Electric Dispatch Model (Hadley and Tsvetkova 2008).
[26] The modeling was performed using the GREET model, but the study did not document the GREET grid-mix assumptions.

Table 6.2.2-1. Comparison of Vehicle Life-cycle Energy and GHG Emissions

Environmental Impact Study	Energy (Btu per mile)[a]					GHG Emissions (grams CO_2e per mile)[a]				
	Notter et al. (2010)[b]		Samaras and Meisterling (2008)		Gaines et al. (2011)[c]	Notter et al. (2010)[d]		Samaras and Meisterling (2008)[e]		Gaines et al. (2011)
Vehicle Type	BEV	CV	BEV (PHEV 30)[f]	CV	BEV (PHEV 20)[g]	BEV	CV	BEV (PHEV 30)[f]	CV	BEV (PHEV 20)[g]
Vehicle Production	1,140	1,203	610	610	600	67	68	56	56	NE
Battery Production	317	0	76	0	100	19	0	5	0	NE
Use[h]	3,424	4,827	2,898	4,881	3,800	175	336	233	377	NE
Total	4,881	6,030	3,585	5,491	4,500	261	404	295	433	NE

a. NE = not estimated; BEV = battery electric vehicle; CV = conventional vehicle; Btu = British thermal unit; CO_2e = carbon dioxide equivalent; PHEV = plug-in hybrid electric vehicle.
b. Vehicle production stage includes maintenance and end of life. Vehicle use stage includes road infrastructure.
c. Energy estimates derived from Figure 5 in Gaines et al. (2011, p. 13).
d. Assumes average electricity production mix in Europe.
e. Assumes U.S. average electricity production mix.
f. PHEV with a 30-kilometer (18.6-mile) all-electric driving distance capacity.
g. PHEV with a 20-mile all-electric driving distance capacity.
h. Use stage includes energy and GHG emissions associated with upstream gasoline and electricity production.

This was demonstrated in a recent study in which Notter et al. (2010) compared the environmental impacts of a BEV powered entirely by electricity derived from hard coal (i.e., anthracite coal) to the impacts of the same BEV powered by the average electricity production mix in Europe.[27] Notter et al. (2010) found that the Ecoindicator 99 impact category[28] for the use stage increased by 13 percent, demonstrating substantially greater environmental impacts. Alternatively, when the authors adjusted the baseline to a scenario in which EVs were powered by electricity produced using hydropower, the Ecoindicator 99 impact category for the use stage decreased by more than 40 percent, demonstrating substantially decreased environmental impacts. Therefore, the relative share of environmental burdens associated with the use stage of EVs is significantly affected by the underlying electricity grid mix.

Another study by Samaras and Meisterling (2008) performed a similar sensitivity analysis of use-stage GHG emissions due to differences in underlying electricity generation grid mix for three different PHEV all-electric travel ranges – 30 kilometers (19 miles), 60 kilometers (37 miles), and 90 kilometers (56 miles), denoted in Table 6.2.2-2 as PHEV 30, PHEV 60, and PHEV 90, respectively. In the base-case scenario, the carbon intensity of the electricity used was assumed to be equivalent to the average intensity of the U.S. power sector, or 670 grams (approximately 1.5 pounds) CO_2e per kilowatt-hour. In the carbon-intensive scenario, the authors assumed that coal supplied most of the fuel source used to generate electricity, with the resultant emissions totaling roughly 950 grams (2 pounds) CO_2e per kilowatt-hour. Finally, in the low-carbon scenario, the authors assumed an electricity grid mix dominated by renewable energy and nuclear power, amounting to only 200 grams (approximately 7 ounces) CO_2e per kilowatt-hour required to generate electricity used to power EVs (Table 6.2.2-2). The

[27] The authors developed their own life-cycle inventory of environmental impacts for purposes of the study.
[28] Ecoindicator 99 is a weighted average environmental impact assessment score consisting of human health and ecosystem quality impact categories.

study concluded that PHEVs charged from an electricity source equivalent to the average of the U.S. power sector (the base-case) reduced the use-stage GHG emissions by 38 to 41 percent compared to conventional gasoline vehicles, and by 7 to 12 percent compared to HEVs. In terms of total life-cycle impacts, in the carbon-intensive scenario, the total life-cycle GHG impacts of PHEVs are 9 to 18 percent higher than HEVs, but still less than (15 to 21 percent) conventional gasoline vehicles.

Table 6.2.2-2. Sensitivity of Life-cycle GHG Impacts Associated with BEVs from Samaras and Meisterling (2008)

	Life-cycle GHG Emissions (grams CO_2e per kilometer)[a]				
	CV	HEV	PHEV 30	PHEV 60	PHEV 90
Base-case (670 grams CO_2e per kWh)	269	192	183	181	183
Carbon-intensive scenario (950 grams CO_2e per kWh)	276	199	217	228	235
Low-carbon scenario (200 grams CO_2e per kWh)	257	180	126	104	96

a. CO_2e = carbon dioxide equivalent; CV = conventional vehicle; HEV = hybrid electric vehicle; PHEV = plug-in hybrid electric vehicle; kWh = kilowatt-hour.

Finally, in the low-carbon scenario, total life-cycle GHG impacts of PHEVs are 51 to 63 percent less than conventional vehicles and 30 to 47 percent less than HEVs. The results of the sensitivity analysis by Samaras and Meisterling (2008) illustrate that through different scenarios of upstream electricity generation mix, the GHG implications of the full life cycle of an EV (including upstream battery production, vehicle production, and use) are less than those of a conventional vehicle.

Ma et al. (2012) compared life-cycle GHG emissions of BEVs and conventional vehicles for both average grid GHG intensity, as in most studies, and marginal grid GHG intensity.[29] For purposes of the study, the authors assumed that marginal electricity would be used to meet additional demand from BEVs. Marginal electricity demand cannot typically be met by solar, wind, or other renewable energy sources without the use of storage technology, so marginal demand is typically met using electricity generated from fossil fuels. Because of this, the average GHG intensity of the marginal grid is generally higher than the average grid. For purposes of this study, the authors did not take into account variations in carbon intensity of the grid based on time of charging. Because instantaneous marginal grid GHG intensities tend to be lower at night than in the middle of the day in California, and lower in winter than in summer, actual GHG emissions vary according to daily and seasonal variations (Ma et al. 2012).[30]

The study examined these effects across two sets of driving-condition scenarios for mid-size vehicles in the United Kingdom and sport utility vehicle-class vehicles in California, both in 2015: lower speed and load (urban driving) and higher speed and load (extra-urban driving). For the lower-speed and -load scenario, BEV life-cycle emissions rose when switching from average grid intensity to average marginal grid intensity, but remained below life-cycle emissions for HEVs and conventional vehicles in both the United Kingdom and California. Under the higher-speed and -load scenario, BEV life-cycle emissions

[29] The results from Ma et al. (2012) are representative of average and marginal grid GHG emissions intensities in the United Kingdom and California in the near term (i.e., approximately 2015). The authors accounted for California's "potential to decarbonize its grid considerably in the next decade primarily due to growth in renewable electricity generation" by assuming a lower average GHG intensity than projected by the California Air Resources Board (CARB) analysis for the state's Low Carbon Fuel Standard. The authors used an annual demand-weighted average marginal grid intensity from McCarthy and Yang (2010).

[30] The effect of regional and peak and off-peak charging variations is discussed below in the summary of Hadley and Tsvetkova (2008).

using an average grid GHG intensity were lower than HEVs and conventional vehicles in both the United Kingdom and California. BEV life-cycle emissions using an average marginal grid GHG intensity were higher than for HEVs but still lower than for conventional vehicles in California. In the United Kingdom, life-cycle emissions for BEVs using marginal grid intensity were higher than for both HEVs and conventional vehicles (Ma et al. 2012).

The LCA literature concludes that use-phase GHG emissions from EVs depend on *where* they are charged; that is, the mix of resources used to supply electricity to the area where the vehicles are charged, as follows:

- The difference in grid mix emissions can play a large role in dictating the emissions from charging EVs, because the most carbon-intensive regions of the United States emit more than 2.5 times as much CO_2 per kilowatt-hour on average as the least carbon-intensive (Anair and Mahmassani 2012).
- Elgowainy et al. (2010) used detailed electricity supply and demand models to simulate regional power grids to determine the influence of different recharging scenarios for PHEVs. This study concluded that a shift from conventional vehicles to PHEVs would significantly reduce petroleum consumption, but that the corresponding reduction in GHG emissions would depend on the electricity generation mix used for recharging PHEVs. For example, replacing internal combustion engine vehicles with PHEVs using electricity equivalent to the U.S. average electricity generation mix would reduce life-cycle GHG emissions by 20 to 25 percent (Elgowainy et al. 2010). Where PHEVs are assumed to be charging from a predominantly natural gas grid mix (e.g., the Western Electricity Coordinating Council electricity region), life-cycle GHG emissions are even lower compared to conventional vehicles. However, in a scenario in which PHEVs charge from a coal-intensive grid mix (e.g., Illinois), the associated life-cycle GHG emissions are comparable to a conventional gasoline vehicle.
- In a scenario featuring an electricity grid powered largely by hydropower, PHEVs and BEVs offer substantial emissions savings over both conventional vehicles and hybrids (Michalek et al. 2011).[31] However, in the context of a baseline scenario or a carbon-intensive grid mix relying on large amounts of coal and natural gas electricity generation, the GHG emissions of the use phase in conjunction with the higher relative GHG intensity of manufacturing larger batteries can result in higher life-cycle emissions for plug-in vehicles compared to HEVs (Michalek et al. 2011).
- After accounting for differences in grid mixes, an estimated 45 percent of Americans live in regions where an EV charging from the grid emits fewer GHGs than the typical hybrid vehicle, whereas another 37 percent live in regions where the emissions are comparable (Anair and Mahmassani 2012).
- While it is impossible to know exactly where PHEVs will be deployed and linked to the grid, general regional forecasts anticipate that "the adoption of electric cars will likely occur first in the West Coast states" (Becker et al. 2009) with the highest amount of the EVs located in California (CAR 2011, Becker et al. 2009). In addition, study projections indicate that most PHEVs will be heavily concentrated in metropolitan areas (KEMA and IRC 2010). These projections are based on current hybrid registration rates by state, a likely indicator of where future EVs will be deployed.

When analyzing emissions from PHEVs, Hadley and Tsvetkova (2008) note that not only *location*, but also the *time* of charging will affect the level of emissions produced. As discussed above, the location of

[31] The reference-case conventional vehicle in this case is an internal combustion engine vehicle with a highway fuel economy of 31.4 mpg and an urban driving fuel economy of 26.4 mpg.

charging determines the mix of energy used to produce electricity, some sources (such as coal) being more carbon-intensive than others (such as natural gas). Similarly, the time of charging, specifically during peak or non-peak hours, determines if the use of less-efficient gas turbines and gas-fired steam turbines will be necessary to meet additional electricity demand.

As EVs increase market share in the future, charging may occur when vehicle users are at home (i.e., in the evening and at night) and while they are at work if charging facilities are available at the workplace (i.e., during the day). Marginal electricity, whether consumed during peak or off-peak hours, is typically more GHG intensive than average electricity generation (i.e., the average mix of generation, including nuclear and wind power sources), because the additional demand is met through less-efficient fossil-fuel generation operating at lower capacity factors that can be increased to meet marginal demand at lowest cost (Ma et al. 2012, Elgowainy et al. 2010). For grids, such as California, where marginal demand during peak hours is met by less-efficient or more carbon-intensive power plants, marginal electricity consumed during off-peak hours (e.g., during nighttime charging at home) tends to be lower in emissions than in the middle of the day and evenings (McCarthy and Yang 2010, Ma et al. 2012).

Smart-charging technologies and time-of-use pricing systems are two developments that would shift EV charging to later in the night during off-peak hours, helping to level out electricity demand and reduce the potential need for new generation capacity to meet additional demand from EVs. In areas where marginal electricity demand during peak hours is met by less-efficient or more emission-intensive plants, charging during off-peak hours could lower emissions.[32] Smart-charging technologies are designed to monitor vehicle charge levels and, in some cases, electricity rates. Using these data, they control vehicle charging schedules to take advantage of off-peak charging while still ensuring that EVs are fully charged when needed. For example, IBM has announced a demonstration project in collaboration with Honda and California utility Pacific Gas & Electric to develop a smart-charging system that will use vehicle data, information on when the user would like the vehicle to be fully charged, and utility data communicated by Pacific Gas & Electric to charge Honda Fit EVs while optimizing the vehicle's charge rate (Environmental Leader 2012b). Time-of-use pricing is a system already adopted by some utilities that charges customers higher rates for power consumed during peak hours and lower rates for power consumed during off-peak hours. Time-of-use pricing would provide EV owners with a financial incentive to charge their vehicles during off-peak hours while mitigating the impact of EV charging on peak electricity demand (Seligman 2011). Recently, Burbank Water and Power announced the Early Adopter Time of Use Billing option that would allow Burbank, California, EV owners to opt in to time-of-use rates that would be lowest during overnight hours, beginning at 11 p.m (Sherwood 2012).

To compare emissions from efficient hybrid vehicles, Hadley and Tsvetkova (2008) analyzed fuel use, emissions, and cost of using a PHEV versus a hybrid vehicle.[33] Assuming a constant market penetration of 25 percent of all new vehicles sold in each region of the U.S. to be either PHEVs or hybrids by 2020, the study aggregated regional fuel use, emissions, and cost under both *PHEV*-dominated market (with no hybrids) and a separate *hybrid*-dominated market (with no PHEVs). Conventional gasoline/diesel vehicles and EVs were not included in the comparison. Based on this PHEV versus hybrid comparison, Hadley and Tsvetkova (2008) found that CO_2 emissions on the aggregate basis for the United States

[32] For example, McCarthy and Yang (2010) found that BEVs charged using electricity generated during off-peak hours in the spring in California would have 20 percent less GHG emissions than a BEV charged using electricity generated at the average marginal rate.

[33] Both vehicles are assumed to travel up to 20 miles per day. The hybrid vehicle fuel economy is assumed to be 40 miles per gallon.

would be slightly higher from the PHEVs scenario than from hybrids scenario, assuming charging during off-peak energy demand hours (37.8 versus 34.4 million tons in 2020, and 94.5 versus 88.5 million tons in 2030). In addition, national SO_2 and NO_x emissions were higher from the PHEVs scenario than from the hybrids scenario (for SO_2, 246 thousand tons in the PHEV scenario versus virtually no emissions in the hybrids scenario in 2020, and 500 thousand tons in the PHEV scenario versus virtually no emissions in the hybrids scenario in 2030; for NO_x, 44.5 versus 7.8 and 102.2 versus 20.2 thousand tons in 2020 and 2030, respectively, for PHEVs versus hybrids in the same years). However, the authors state that these increases would be offset by reductions elsewhere from existing emissions caps; the net SO_2 emissions would be zero, while the corresponding increase in NO_x emissions would be limited.[34]

These types of impacts, however, would vary widely depending on time of day, seasonality, regional generation mix and grid dispatch characteristics, consumer behavior, and economics (Elgowainy et al. 2010, Ma et al. 2012, Hadley and Tsvetkova 2008). For example, Hadley and Tsvetkova (2008) also examined how charging at peak (i.e., evening) and off-peak (i.e., nighttime) hours affected emissions of GHGs and air pollutants. The study found that the difference depended very much on region, but on a national scale, off-peak charging led to similar or slightly higher emissions than peak charging across all scenarios examined.[35] However, off-peak charging was also more likely to result in an increase in renewable electricity generation for regions where these sources are available to meet increased demand – such as hydropower generation in the Northwest – than charging during peak periods. PHEV charging produced lower emissions compared to HEVs when charged at non-peak hours from regional grids with high deployment of renewable power generation and low reliance on coal, such as in California and Texas (Hadley and Tsvetkova 2008).[36] Because it is more likely that market penetration will increase in certain regions, like the Western Electricity Coordinating Council-California region, compared to other regions like the southern and central United States (CARB 2011, Becker et al. 2009), CO_2 emissions from PHEVs could be lower than hybrid CO_2 emissions due to the higher use of non-coal generated electricity in these areas (Hadley and Tsvetkova 2008). Additional PHEV deployment in low-carbon grid regions would result in greater emissions reductions, provided that additional demand from deployment does not exceed generation capacity (Hadley and Tsvetkova 2008).

Separately, Elgowainy et al. (2010) examined three grid charging scenarios for a vehicle fleet with 10 percent PHEVs by 2020:[37] (1) a scenario in which PHEVs were "unconstrained" and allowed to charge beginning 1 hour after the last use of the vehicle for the day; (2) a constrained scenario in which charging was delayed until 3 hours after the last use of the vehicle for the day, and (3) a smart charging scenario in which charging was only performed during hours with the lowest system loads. The authors investigated the effects on electric power systems in New England, New York, 14 western states, and

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[34] While this study acknowledges the existence of emissions-trading schemes, it does not address the quantitative impact of regulated caps on SO_2 and NO_x emissions beyond speculating on their ability to curb incremental criteria air pollutant emissions caused by additional EV charging.

[35] Emissions from marginal electricity demand in the peak scenario are lower than off-peak marginal electricity emissions because, on a national level, natural gas combustion turbines and oil power plants contribute to a greater share of the additional electricity generated to meet marginal demand during peak periods, instead of more emissions-intensive coal generation.

[36] For example, in Hadley and Tsvetkova's comparison of PHEV emissions to hybrid emissions for the Western Electricity Coordinating Council-California region, PHEV CO_2 emissions are modeled to be lower than hybrid CO_2 emissions (3.3 versus 4.6 million tons in 2020 and 9.3 versus 11.7 million tons in 2030), due to the less carbon-intensive electricity grid mix in that region.

[37] The study developed estimates for baseline plant generation available in 2020 based on inventories of existing and proposed power plants, projections of renewable energy generation capacity in 2020, and state-level policies (i.e., the State of Illinois Renewable Portfolio Standard [RPS]).

Illinois. They found that, although electricity demand in the unconstrained and constrained scenarios exceeded peak loads in the base case, only "small amounts" of new capacity – ranging from 1,230 to 5,400 megawatts across the regions – were needed to meet the demand. No expansion of generating capacity was needed in the smart charge scenario that restricted PHEV charging to only the lowest load hours of the day. Most of the additional demand was met by generation from natural-gas-fired plants, particularly combined-cycle facilities. Plants using heavy fuel oil and biofuel increased very slightly relative to the base case (Elgowainy et al. 2010).

In terms of air quality emissions, other studies have reported on the life-cycle criteria pollutant emissions from various vehicle and fuel systems compared to EVs using both the U.S. and California electricity generation mix. In general, the California electricity generation mix is less carbon-intensive compared to the national average electricity generation mix.[38] The results of a study by Huo et al. (2009) show that EVs powered using the California electricity generation mix have roughly 30 percent lower life-cycle NO_x emissions, 50 percent lower emissions of particulate matter with diameters of 10 micrograms or less (PM_{10}), and 50 percent lower emissions of particulate matter with diameters of 2.5 micrograms or less ($PM_{2.5}$) compared to vehicles powered by the U.S. national average electricity generation mix.[39] The large differences in NO_x, PM_{10}, and $PM_{2.5}$ emissions are due to the higher contribution of coal in the average U.S. electricity generation mix. However, emissions of volatile organic compounds (VOCs) and carbon monoxide throughout the life cycle of EVs are similar for both electricity generation mix assumptions.

The impact of a more carbon-intensive grid mix on criteria air pollutants is estimated by a recent study by Keoleian et al. (2011), which examined the emissions impact of increased PHEV deployment in Michigan. The study found that the marginal SO_x emissions increased in both grid mix scenarios (EG1 and EG4) by 182 percent and 172 percent, respectively, compared to a fleet with zero PHEVs deployed because the SO_x emissions of electricity generation were higher than those of gasoline combustion.[40] However, the authors concluded that the additional SO_x emissions are unlikely to push Michigan into nonattainment status in relation to the Clean Air Act (CAA) in 2020.[41] For the other criteria air pollutants, the impact of PHEV deployment largely resulted in reductions across scenarios, although the EG1 scenario resulted in a slight increase in both NO_x and PM_{10}.

A recent study (Shulock et al. 2011) by the International Council on Clean Transportation (ICCT) presents air pollution results for the incremental criteria air pollutants resulting from the electricity needed to power BEVs based on California's grid mix target of 33 percent renewable electricity in 2020. The

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[38] Huo et al. (2009) assume a U.S. electricity generation mix of 48.7 percent coal, 22.5 percent natural gas, 17.6 percent nuclear, 2.6 percent residual oil, 1.3 percent biomass, and 7.3 percent others. The report assumes a California electricity generation mix of 21.0 percent coal, 42.0 percent natural gas, 15.6 percent nuclear, 0.6 percent residual oil, 1.5 percent biomass, and 19.3 percent others (p. 1797). In general, the California electricity generation mix is less carbon intensive compared to the national average electricity generation mix.

[39] In Huo et al. (2009), the well-to-wheels boundaries include feedstock recovery and processing, feedstock transportation and storage, fuel production, fuel transportation, storage and distribution, and vehicle operation activities.

[40] For the EG1 case, Michalek et al. (2011) assume a conservative, high carbon-intensity case with a low RPS – a policy mandating increased energy production from renewable resources – whereas for the EG4 scenario, it is assumed that there is a stronger RPS in place and high nuclear deployment. In EG1 it is assumed that renewables reach 20 percent penetration by 2030, whereas under EG4 they constitute 33 percent of generation.

[41] The authors estimate that EPA's 2010 revisions to the Sulfur Dioxide Primary National Air Quality Standard could cause Wayne County to reach nonattainment status. However, it is expected that the county will reach compliance by 2020, and it is not clear if PHEV deployment would prevent Wayne County or other counties in Michigan from complying with the revised standard.

incremental criteria air pollutants for NO_x and SO_x associated with electricity production are "significantly less than" air pollutant emissions associated with upstream refinery operations used to produce petroleum-derived fuels (Shulock et al. 2011). However, VOCs and fine PM are comparable. ICCT concludes that by accounting for both tailpipe and upstream emissions, EVs "should have a very positive overall effect on ozone and fine particulates." Relevant to vehicles in California, the ICCT study also references another life-cycle study developed by TIAX (TIAX LLC 2007) to show that the total cradle-to-gate NO_x emissions associated with model year 2010 conventional gasoline vehicles (0.29 grams NO_x per mile) are significantly higher than a battery hybrid electric vehicle (0.01 grams NO_x per mile), assuming an electricity generation grid mix that is natural gas combined with California-mandated renewable electricity generation sources.[42] Similarly, the 2012 CARB staff report on impacts from proposed amendments to the California Zero Emission Vehicle Program[43] concluded that statewide well-to-wheels criteria air pollution (reactive organic gas and NO_x) and PM emissions per day in 2030 will decrease with increased adoption of PHEVs and BEVs under the Zero Emission Vehicle amendments. However, the CARB report only includes fuel life-cycle emissions and assumes an increase in natural gas and renewable energy facilities in the grid mix by 2030 (CARB 2012).

Future changes in the mix of resources used to generate electricity will also affect GHG emissions and air pollutants from EVs. In a 2012 staff report by CARB studying the projected environmental impacts of proposed amendments to the state's Zero Emission Vehicle Program regulations, CARB assumes that by 2020 new power facilities will replace older, higher-emitting facilities including natural-gas facilities and renewable energy facilities added in accordance with California's 33 percent renewable energy portfolio standard. These additions to California's grid are reflected in CARB's emissions estimates for PHEVs (CARB 2012).

Two other studies, ICCT (Shulock et al. 2011) and Hadley and Tsvetkova (2008), developed projections showing how GHG and criteria air pollutant emissions from the electricity sector might change in future years. The magnitude of emission reductions and regional effects are uncertain, and the results of the studies differ depending on factors such as the extent to which the effects of planned regulations are included, timing and location of grid charging, and other study-specific assumptions and data sources.

The ICCT report concluded that "the magnitude of reductions in future California emission rates (because of the adoption of renewable electricity standards and other policies to encourage GHG reduction) is uncertain, but such reductions are likely to favor deployment of BEVs, PHEVs, and, to a lesser extent, FCVs [fuel cell electric vehicles] over conventional vehicles if upstream emission factors are taken into account (p. 34)."

In their analysis, Hadley and Tesvetkova examined the difference in baseline grid electricity CO_2, NO_x, and SO_2 emissions (i.e., before accounting for increased demand from PHEVs) in 2020 and 2030 was examined. The study found that emissions between the two periods varied significantly across each of the 13 electricity supply regions specified by the North American Electric Reliability Corporation (NERC) and the DOE. While most regions showed lower or comparable SO_2 emissions from 2020 to 2030, CO_2 emissions were higher in 2030 for all but two regions and NO_x emissions rose in 2030 for more than half

[42] Total cradle-to-gate NO_x emissions are 0.29 grams per mile, with 0.04 grams per mile emitted in urban areas (TIAX 2007, Figure A-2, p. 87).

[43] The Zero Emission Vehicle Program is a California state program that aims to reduce GHG emissions from vehicles in the state by requiring manufacturers to offer for sale vehicles with lower environmental impacts than conventional gasoline vehicles, including BEVs, fuel-cell vehicles, and PHEVs.

of the regions. The study did not include the effects of increased regulation under the CAA, but the authors note that more stringent standards for SO_2 and NO_x will help curb incremental criteria air pollutant emissions caused by additional EV charging.

6.3 Conclusions

The overarching conclusion based on this synthesis of the LCA literature considered is that except for a few cases (e.g., magnesium material manufactured via coal-intensive process substitutes for steel with very high recycled content, or titanium material substitution of mild steel in automotive parts), the materials and technologies addressed in this literature synthesis appear to reduce GHG emissions, energy use, and most other environmental impacts when considered on a life-cycle basis. This information helps the decisionmaker by demonstrating the net life-cycle environmental reductions in environmental impacts achievable by these materials and technologies, and the factors that contribute to increases or decreases in environmental impacts at other life-cycle stages beyond the vehicle use stage.

The LCA literature synthesis revealed the following trends for emerging materials and technologies:

- Aluminum and high-strength steel material substitution are both effective at reducing life-cycle energy use and GHG emissions (i.e., the increased energy use and GHG emissions at the vehicle production stage are offset by use-phase savings over the vehicle life).
- Materials that use a greater share of recycled (i.e., secondary) materials achieve greater energy use and GHG savings. The measures of energy use and GHG savings achieved by substituting alternative materials are sensitive to assumptions regarding the recycled content of: (1) the specific alternative material used and (2) the steel that is being replaced.
- In addition to mass reduction by material substitution, improvements in vehicle manufacturing processes and technologies can also help achieve mass reduction. Polymer composites (including those reinforced with glass, carbon fiber, or nanoclays) used in vehicle body panels are more energy- and GHG-intensive to produce in relation to mild steel; however, over the full life cycle, these lightweight, high-strength materials provide lower environmental impacts (e.g., GHG emissions) compared to mild steel. There is a need for additional study of the impacts of composite recycling, reparability, and use of recycled content.
- The substitution of magnesium for conventional steel in vehicles requires more energy use in the vehicle production stage. However, across the full vehicle life cycle, magnesium-substituted vehicles have much higher fuel efficiencies than conventional vehicles due to lighter vehicle weights resulting from the low density of magnesium. This, in turn, lowers the energy use below that of conventional vehicles. However, the environmental impacts in terms of GHG emissions are determined by the manufacturing processes to generate magnesium, the vehicle components substituted with magnesium, and the availability of recycling of magnesium parts at the end-of-life.
- Life-cycle GHG emissions (and most other environmental impacts) on a per-mile-traveled basis across different types of EVs (e.g., BEVs, and PHEVs) are dominated by the use stage (i.e., the impacts associated with electricity generation upstream).
- The environmental impacts associated with Li-ion battery production are small (less than 10 percent of the total life-cycle GHG emissions of EVs).
- There is a potential for EVs to significantly reduce petroleum energy use, GHG emissions, and other environmental impacts associated with reduced petroleum consumption, but the electricity grid mix used to charge EVs will significantly affect the mitigation potential.

- In modeled scenarios in which BEVs and PHEVs charge from a carbon-intensive grid mix (i.e., electricity generation from mostly coal power plants), the vehicle and fuel life-cycle GHG emissions from PHEVs and BEVs are comparable or less than conventional gasoline vehicles.
- Life-cycle GHG emissions from BEVs increase compared to conventional vehicles – and could, in some cases, exceed conventional vehicles[44] – when driven aggressively at high speeds and loads, and when charged using marginal electricity generated from exclusively GHG-intensive power sources, such as coal-fired power plants.
- In general among EVs in the future, PHEVs would cause no more SO_2 emissions, comparable or slightly higher GHG emissions, and limited increases in NO_x emissions than hybrids aggregately throughout the United States if charged during peak electricity generating hours, and would likely cause fewer emissions than hybrids in areas with a low share of coal used to generate electricity, regardless of charging time.

[44] Ma et al. (2012) found that life-cycle GHG emissions from mid-size BEVs driven in the United Kingdom could exceed conventional vehicles in aggressive drive cycles at high speeds and loads, and charged using marginal electricity generated from exclusively GHG-intensive power sources, such as coal-fired power plants.

CHAPTER 7 OTHER IMPACTS

This chapter describes the affected environment and environmental consequences of the Proposed Action and alternatives on land use and development (Section 7.1), hazardous materials and regulated wastes (Section 7.2), historic and cultural resources (Section 7.3), noise (Section 7.4), safety impacts to human health (Section 7.5), and environmental justice (Section 7.6). It also addresses unavoidable adverse impacts (Section 7.7), short-term uses and long-term productivity (Section 7.8), and irreversible and irretrievable commitment of resources (Section 7.9). Due to the uncertainty surrounding how manufacturers would meet the new requirements, many of the potential environmental impacts analyzed below are not quantifiable and have instead been discussed qualitatively.

7.1 Land Use and Development

7.1.1 Affected Environment

Land use and development refers to human activities that alter land (e.g., industrial and residential construction in urban and rural settings, or clearing of natural habitat for agricultural or industrial use). This EIS discusses changes in mining practices, agricultural practices, and development land use patterns that are likely to occur because of shifts toward more efficient vehicles.

7.1.2 Environmental Consequences

Shifts toward more efficient, lighter vehicles, either as a result of consumer preference for fuel-efficient vehicles or mass reduction design decisions by manufacturers, could result in changes in mining land use patterns. Mining for the minerals needed to construct these lighter vehicles (primarily aluminum and magnesium) could shift some metal-extraction activities to areas rich in these resources. Schexnayder et al. (2001) noted that such a shift in materials "could reduce mining for iron ore in the United States, but increase the mining of bauxite [aluminum ore], magnesium, titanium, and other materials in such major countries as Canada, China, and Russia, and in many small, developing countries, such as Guinea, Jamaica, and Sierra Leone."

Relocating mining to new sites for these alternative resources could result in environmental impacts, such as destruction of natural habitat due to altered land cover.

Some of the action alternatives could result in an increased use of biofuels technology in MY 2017–2025 vehicles. The production of biofuels for use in some vehicles could adversely impact land use. Ethanol is the most commonly used biofuel for vehicles and its main source in the United States is corn. Due to increasing gasoline prices and new bioenergy policies, ethanol production in the United States increased by 9 billion gallons and increased corn acreage by 10 percent from 2000 to 2009 (ERS 2011). If the demand for ethanol continues to increase, more corn would need to be harvested to meet ethanol, livestock, and food demands. In 2006, an estimated 71 million acres of corn were harvested. Nearly 137 million acres would be needed to produce enough corn and resulting ethanol (56.4 billion gallons) to substitute for approximately 20 percent of petroleum imports (Yacobucci and Schnepf 2007).

Growing biofuel feedstocks remove carbon dioxide (CO_2) from the atmosphere; therefore biofuels can, in theory, reduce GHG emissions relative to fossil fuels. In practice, however, land use changes resulting from increased ethanol production could increase GHG emissions and cause other environmental impacts. Although most increased corn production for ethanol is from farms previously specializing in soybeans, other land is indirectly affected (ERS 2011). Some farms shift from other crops to produce soybeans in response to the farms that shifted from soybeans to corn. The Economic Research Service (ERS 2011) found that this shift resulted in a reduction in cotton acreage, conversion of land for uncultivated hay to cropland, and the expansion of double cropping. The conversion of previously uncultivated land to cropland, which represents about a third of the average increase in harvested acreage, is an indirect land use change that could accelerate nutrient runoff and soil erosion (ERS 2011). However, ethanol production might not require an equivalent amount of additional crops to be grown for livestock feed, because the ethanol by-product, dry distillers' grains, replaces roughly one-third of the animal feed otherwise diverted (Searchinger et al. 2008).

The conversion from forests or grassland to plowed agricultural land could also reduce carbon storage and sequestration at the time of conversion when much of the carbon previously stored in plants and soils is released into the atmosphere through decomposition or fire. Also, the new planted crops might not be able to store an equivalent amount of carbon (Searchinger et al. 2008).

However, it is important to note that the consequences to land use in this section do not necessarily result directly from the proposed standards. The current production of ethanol is affected primarily by the Renewable Fuel Standard (RFS), which establishes targets for several categories of renewable fuels consumption, including corn based ethanol. The RFS caps the corn ethanol target at 15 billion gallons per year beginning in 2015. It is not expected that the proposed rule will impact the production of corn based ethanol.

By reducing fuel costs per mile, increased fuel economy could provide an incentive for increased driving and lead to higher vehicle miles traveled (VMT). In areas where the highway network, infrastructure availability, and housing market conditions allow, this could increase demand for low-density residential development beyond existing developed areas. Undeveloped land could be converted to support low-density suburban sprawl. Residential communities in such areas are highly dependent on automobiles for travel and are associated with relatively high VMT per household (FHWA 1998). Many agencies are implementing measures, such as funding smart-growth policies, to influence settlement patterns in order to reduce VMT and fuel use to meet climate change goals (Moore et al. 2010). *See* Chapter 2 for more information regarding VMT and Chapter 8 for a discussion of this type of mitigation.

7.2 Hazardous Materials and Regulated Wastes

7.2.1 Affected Environment

For purposes of this analysis, hazardous wastes are defined as any item or agent (biological, chemical, or physical) which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors. Hazardous wastes are generally designated as such by individual states or EPA under the Resource Conservation and Recovery Act of 1976. Additional federal and state legislation and regulations, such as the Federal Insecticide, Fungicide, and Rodenticide Act, determine handling and notification standards for other potentially toxic substances. The relevant sources of impacts of the proposed rule are hazardous materials and wastes generated during the oil-extraction and refining processes, mining activities, and production and disposal of vehicle batteries.

Hazardous wastes produced from oil and gas extraction and refining can present a threat to human and environmental health. Onshore environmental effects result mostly from the improper disposal of saline water produced with oil and gas, from accidental releases of hydrocarbon and produced water, and from oil wells that were improperly sealed when abandoned (Kharaka and Otton 2003). The development of new techniques, such as hydraulic fracturing, has led to vast new reserves of natural gas becoming available in the United States. The extraction of natural gas from shale can impact drinking water quality and has led some states to limit hydraulic fracturing near aquifers (NY DEC). Offshore effects result from improperly treated produced water released into the waters surrounding the oil platform (EPA 1999). Offshore platform spills, while relatively rare,[1] can have devastating environmental impacts. Operation of motor vehicles during the extraction process results in air emissions that affect air quality through combustion of petroleum-based fuels releasing volatile organic compounds (VOCs), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and other air pollutants (EPA 1995a, EPA 2011h). In the atmosphere, SO_2 and NO_x contribute to the formation of acid rain (the wet, dry, or fog deposition of SO_2 and NO_x), which enters waterbodies either directly or as runoff from terrestrial systems (*see* Chapter 4 for more information on air quality) with negative effects on water resources, plants, animals, and cultural resources. Oil extraction activities could also impact biological resources through habitat destruction and encroachment, raising concerns about their effects on the preservation of animal and plant populations and their habitats.

Battery types encompass a broad range of potential battery chemistries, with diverse performance, safety, and toxicity trade-offs. They include advanced lead-acid (PbA), conventional nickel cadmium, nickel-metal hydride (NiMH), and sodium nickel chloride batteries, and multiple options for emerging lighter and higher capacity lithium ion (Li-ion) batteries. Conventional Starting-Lighting-Ignition automotive batteries are based on lead-acid compositions, whereas the two most common types of batteries for hybrid and plug-in electric vehicles (PHEVs) are made from NiMH and Li-ion chemistries.

Wastes produced from the life cycle of vehicle batteries differ depending on material composition. During the life cycle of batteries, there is a potential for resource extraction, production, manufacturing, and disposal to generate wastes, which would contribute to air pollution and landfill waste. In addition, resource extraction to support production of electric motors (mining of rare earth metals, for example), could lead to air pollution, water quality degradation, and other impacts. While effective techniques to recycle electric vehicle batteries have been developed, electric battery recycling is still relatively low given the fact that few electric batteries have neared their end of life and its currently cheaper to mine for new lithium than to extract it from used batteries. If not addressed, increased electric vehicle use combined with the lack of battery recycling could lead to increased waste from batteries.

7.2.2 Environmental Consequences

The projected reduction in fuel production and combustion as a result of the Proposed Action (*see* Section 3.3 for projected fuel consumption and savings under the Proposed Action) could lead to a reduction in the extraction and refining of petroleum for the transportation sector. Wastes produced during the petroleum-refining process are primarily released to the air and water, accounting for 75 percent (air emissions) and 24 percent (wastewater discharges) of the total amount of waste produced during this process (EPA 1995a). EPA defines a release as the “on-site discharge of a toxic chemical to the environment…emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells” (EPA 1995a). EPA reports that 9 of the 10 most common toxic substances released by the petroleum-refining industry are volatile chemicals – highly reactive substances prone to state changes or combustion. These include benzene, toluene, ethylbenzene, xylene, cyclohexane, 1,2,4-trimethylbenzene, and ethylbenze (EPA 1995a). These substances are present in crude oil and in finished petroleum products.

[1] There are typically less than 10 offshore platform spills per year in the United States, amounting to approximately 2 percent of oil pipeline spills (Etkin 2001).

Potential spills of oil or other hazardous materials during oil and gas extraction and refining can lead to contamination of surface water and groundwater, and can result in impacts to drinking water and marine and freshwater ecosystems. EPA estimates that, of the volume of oil spilled in "harmful quantities" (as defined under the Clean Water Act), 83.8 percent was deposited in internal/headland waters and within 3 miles of shore, with 17.5 percent spilled from pipelines, often in inland areas (EPA 2004b). The potential reduction in petroleum extraction and refining that would result from the Proposed Action could also result in a decreased risk of hazardous material spills during the extraction and refining processes.

Several of the produced VOCs emitted through oil and gas extraction and refining contribute to ground-level ozone and smog and are also known or suspected carcinogens, and many others are known to cause respiratory problems and impair internal-organ functions, particularly in the liver and kidneys (EPA 1995a). Potentially dangerous substances commonly released during the refining process include ammonia, gasoline additives (methanol, ethanol, and methyl tertiary butyl ether), and chemical feedstocks (propylene, ethylene, and naphthalene) (EPA 1995a). Spent sulfuric acid is by far the most commonly produced toxic substance; however, it is generally reclaimed instead of released or transferred for disposal (EPA 1995a). Ammonia is a form of nitrogen and can contribute to eutrophication in surface waters. Once present in surface waters, air pollutants can cause acidification of waterbodies, changing the pH of the system and affecting the function of freshwater ecosystems. Plants and animals in a given ecosystem are highly interdependent due to the many connections between them; therefore, changes in pH or aluminum levels can severely affect biodiversity (EPA 2008b). As lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals in these waters could decrease.

Oil exploration and extraction result in intrusions into onshore and offshore natural habitats and can involve construction within natural habitats. There are serious environmental concerns for ecosystems that experience encroachment and chronic effects of drilling for benthic (bottom-dwelling) populations, migratory bird populations, and marine mammals (Borasin et al. 2002).

Acid rain caused from the release of VOCs has been shown to negatively affect forest ecosystems, both directly and indirectly. These impacts include stunted tree growth and increased mortality, primarily as a result of the leaching of soil nutrients (EPA 2007c). Declines in biodiversity of aquatic species and changes in terrestrial habitats likely have ripple effects on other wildlife that depend on these resources. Eutrophication of aquatic systems, which can ultimately result in the death of fish and other aquatic animals, is enhanced by acid rain (Lindberg 2007). Damage from acid rain also substantially reduces the societal value of buildings, bridges, and cultural objects made from materials such as bronze, marble, or limestone (*see* Section 7.3). The projected reduction in fuel production and combustion as a result of the Proposed Action could lead to a reduction in the amount of pollutant emissions that cause acid rain.

Motor vehicles, the motor vehicle equipment industry, and businesses engaged in the manufacture and assembly of cars and trucks produce hazardous materials and toxic substances. EPA reports that solvents (e.g., xylene, methyl ethyl ketone, and acetone) are the most commonly released toxic substances it tracks for this industry (EPA 1995a). These solvents are used to clean metal and in the vehicle-finishing process during assembly and painting (EPA 1995a). Xylene and methyl ethyl ketone act as air pollutants, causing severe damage through inhalation, and are VOCs (EPA 1995a). In addition, xylene has the potential to contaminate soils and groundwater if improperly handled. Other industry wastes include metal paint and component-part scrap.

To comply with the proposed standards, some manufacturers might choose to substitute lighter weight materials (e.g., aluminum, high-strength steel, magnesium, titanium, or plastic) for conventional vehicle materials (e.g., conventional steel and iron). Studies have suggested that the substitution of lighter-weight materials to increase fuel economy could increase the total waste stream resulting from automobile manufacturing (Schexnayder et al. 2001). Mining wastes generated during the extraction of lighter raw materials could increase, primarily due to aluminum mining, and other production wastes (e.g., from refining of aluminum and plastic manufacturing) could also increase because of a greater demand for lightweight vehicles (Schexnayder et al. 2001, Dhingra et al. 1999). The extraction and processing of these metals and the production of man-made fibers and plastics also generate various hazardous wastes (EPA 1995b, EPA 1997a). An assessment of the solid and hazardous wastes generated during the production of three light-weight concept cars concluded the net generation of waste would decrease versus conventional vehicles (Overly et al. 2002). A separate study noted that the generation of most hazardous materials of particular concern to human health (e.g., cadmium, chlorine, and lead) emitted during the production of vehicles appeared to decrease in the new generation vehicle models compared to conventional models (Schexnayder et al. 2001). Recycling vehicles at the end of vehicle life could help offset some of the projected net increase in waste production versus vehicles constructed primarily of steel and iron.

To comply with the proposed standards, some manufacturers might use electric battery technology in addition to or as a substitute for combustion engine technology.

The production, use, and disposal of different types of electric batteries generates different types of waste. Both solid and hazardous wastes are produced through the life-cycle of the batteries, including during production and after their useful life in automobiles. Of the two main materials in electric batteries, nickel is classified as a hazardous air pollutant and hazardous waste, but lithium is not listed in either category (EPA 2010e, 40 CFR §261.33). Disposing of batteries can lead to adverse impacts due to the risk of toxic chemicals being released into the environment.

To mitigate environmental impacts associated with disposal, at the end of the useful life of an electric vehicle (EV) or PHEV, the battery will likely not be fully exhausted and may be useable for other purposes (EPA, NHTSA, and CARB 2010). When these batteries can no longer be reused, most of the materials can then be reprocessed and recycled.

The materials resource and recyclability issues associated with advanced battery chemistries for hybrid-electric vehicles (HEVs) were recently summarized in studies by Argonne National Lab.[2] If NiMH is recycled using the pyro-metallurgical (high temperature smelting) process, only the nickel-rich materials can be recovered, whereas reuse of 86 percent of nickel alloys is possible with the sole use of the physical separation process (Espinosa et al. 2004). Nickel is a valuable metal, which creates an incentive to recycle. Recycling of lead-acid batteries is well established in the United States, recovering about 97 percent of toxic lead metal from the waste stream.[3] Potential benefits of battery recycling and reuse programs also include more efficient resource utilization, energy savings, and economic benefits. NiMH and Li-ion batteries can be recycled, and cost effective recovery and recycling methods are currently in pilot plant test and evaluation phases in the United States.[4]

[2] *See* DOE (2009b) and Gaines and Nelson (2010).
[3] *See* EDF (2003).
[4] *See* DOE (2009b) and DOE (2009c).

Some types of Li-ion batteries have more benign compositions because they use fewer toxic heavy metals and corrosive acids and electrolytes, and are therefore safer for landfill disposal. Furthermore, as Li-ion battery technology continues to develop and mature, the materials-handling industry is developing corresponding recycling and disposal processes. For example, Toxco reports using cryogenic chilling (to slow chemical reactions involving lithium) and remote process control to maintain safety for personnel involved in recycling Li-ion batteries.[5]

A life-cycle assessment[6] of different types of batteries for hybrid and battery-electric vehicles in Europe assigned environmental scores to different battery chemistries, and indicated that NiMH and Li-ion batteries have much lower life-cycle environmental burdens than other battery types. In another study, Schexnayder et al. (2001) concluded that NiMH and Li-ion batteries generate more waste than lead-acid batteries, and Li-ion batteries contribute a slightly higher amount of total waste compared to NiMH throughout their cradle-to-grave life-cycle. However, NiMH batteries generate more hazardous waste than Li-ion batteries. Li-ion batteries are less toxic than lead-acid batteries and NiMH batteries when considering an entire life-cycle.

7.3 Historic and Cultural Resources

7.3.1 Affected Environment

The National Historic Preservation Act of 1966 (16 U.S.C. 470 et seq.), Section 106, states that agencies of the Federal Government must take into account the impacts of their actions to historic properties; the regulations to meet this requirement are provided at 36 CFR Part 800. This process, known as the "Section 106 process," is intended to support historic preservation and mitigate impacts to significant historical or archaeological properties through the coordination of federal agencies, states, and other affected parties. Historic properties are generally identified through the *National Register of Historic Places*, which lists properties of significance to the United States or a particular locale because of their setting or location, contribution to or association with history, or unique craftsmanship or materials.[7]

7.3.2 Environmental Consequences

For this analysis, acid rain, which can be created from processing petroleum products and the combustion of petroleum-based fuels, is the identified relevant impact because of its potential to degrade exposed materials.

Acid rain, the primary source of which is the combustion of fossil fuels, is one cause of degradation to exposed cultural resources and historic sites (EPA 2007d). EPA states that the corrosion of metals and the deterioration of paint and stone can be caused by both acid rain and the dry deposition of pollution, which can reduce the cultural value of buildings, statues, cars, and other historically significant materials (EPA 2007d). The projected reduction in fuel production and combustion as a result of the Proposed

[5] *See* Toxco (2012).
[6] *See* Matheys et al. (2008).
[7] National Register-eligible properties must also be sites that meet one or more of the following criteria (36 CFR 60.4): are associated with events that have made a significant contribution to the broad patterns of our history; are associated with the lives of persons significant in our past; embody the distinctive characteristics of a type, period, or method of construction, or represent the work of a master, or possess high artistic values, or represent a significant and distinguishable entity whose components may lack individual distinction; have yielded, or may be likely to yield, information important in prehistory or history.

Action and alternatives could lead to a reduction in the amount of pollutant emissions that cause acid rain. A decrease in the emissions of such pollutants could result in a corresponding decrease in the amount of damage to historic and other structures caused by acid rain. However, such effects are not quantifiable due to the inability to distinguish between acid rain deterioration and natural weathering (rain, wind, temperature, and humidity) effects on historic buildings and structures, and due to the varying impact for a specific geographic location of any particular historical resource (Striegel et al. 2003).

7.4 Noise

7.4.1 Affected Environment

To comply with the proposed standards, manufacturers could reduce vehicle mass or increase the production of hybrid vehicles, which could lead to some reduction in the amount of exterior noise produced by motor vehicles. Exterior noise, vibration, and harshness (NVH) generated by motor vehicles is produced by three main components: the powertrain (consisting of the engine, transmission, exhaust, axle, radiator, and fuel tank) NVH; road and tire NVH; and wind-related NVH (Qatu et al. 2009). Interior NVH, in contrast, could increase depending on the vehicle mass reduction techniques the manufacturers use to increase vehicle fuel efficiency.

Excessive amounts of noise can present a disturbance and a hazard to human health at certain levels. Potential health hazards from noise range from annoyance (sleep disturbance, lack of concentration, and stress) to hearing loss at high levels (Passchier-Vermeer and Passchier 2000). The noise from motor vehicles has been shown to be one of the primary causes of noise disturbance in homes (Theebe 2004, Ouis 2001). Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property.

Wildlife exposure to chronic noise disturbances from motor vehicles can impair senses, change habitat use and activity patterns, increase stress response, decrease immune response, reduce reproductive success, increase predation risk, degrade conspecific communication, and damage hearing if the sound is sufficiently loud (Barber et al. 2010, Bowles 1995, Larkin et al. 1996). While noise can affect wildlife, it does not mean the effect is always adverse, because wildlife are exposed to many different noises in the environment to which they can adapt. Even without human-generated noise, natural habitats have particular patterns of ambient noise resulting from, among other things, wind, animal and insect sounds, and other noise-producing environmental factors, such as streams and waterfalls (California Department of Transportation 2007).

Various advocacy groups, including the National Federation of the Blind, have expressed concerns regarding HEVs not emitting the sounds that pedestrians and bicyclists rely on as a warning of an approaching vehicle. According to a 2009 NHTSA report, *Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles*, an HEV is twice as likely to be in a crash with a pedestrian or bicycle as an internal combustion engine vehicle (Hanna 2009). The 2011 update to the 2009 NHTSA report had similar crash incidence results (Wu et al. 2011).

7.4.2 Environmental Consequences

As a result of the rebound effect (the increase in VMT as the cost per mile for fuel decreases), NHTSA predicts that there will be increased vehicle use under all of the action alternatives; higher overall VMT could result in increases in vehicle road noise. However, location-specific analysis of noise impacts is not possible based on available data. Noise levels are location-specific, meaning that factors such as the time of day at which increases in traffic occur, existing ambient noise levels, the presence or absence of noise-abatement structures, and the locations of schools, residences, and other sensitive noise receptors all influence whether there will be noise impacts.

However, at the same time, all of the alternatives could lead to an increase in use of hybrid vehicles and EVs, depending on the mix of technologies manufacturers use to meet the proposed standards, economic demands from consumers and manufacturers, and technological developments. An increased percentage of hybrid and electric vehicles could result in reduced vehicle noise at low speeds, potentially offsetting some of the increase in traffic noise that could otherwise result from increased VMT and potential increases to interior NVH due to reductions in vehicle mass.

NHTSA plans to address the issue of potential environmental and safety impacts related to vehicle noise reduction in a future rulemaking. The Pedestrian Safety Enhancement Act of 2010 requires NHTSA to conduct a rulemaking to establish a Federal Motor Vehicle Safety Standard requiring an alert sound for pedestrians to be emitted by electric and hybrid vehicles.[8] On July 12, 2011, NHTSA published a Notice of Intent to Prepare an Environmental Assessment to analyze the potential environmental impacts of that forthcoming rulemaking. NHTSA anticipates publishing a final rule by January 4, 2014. The agency will address the safety and potential environmental impacts of that rulemaking as part of that rulemaking process.

7.5 Safety Impacts to Human Health

In developing the proposed rule analyzed in this EIS, NHTSA analyzed how future improvements in fuel economy might affect human health and welfare through vehicle safety performance and the rate of traffic fatalities. To estimate the possible safety effects of the proposed CAFE standards, NHTSA performed research using statistical analysis of historical crash data and used an engineering approach to investigate the cost and feasibility of mass reduction of vehicles while maintaining safety and other desirable qualities. The mass reduction amounts in NHTSA's analysis were chosen based on both the agency's assumptions about how much is technologically feasible, and finding a way by which manufacturers could comply with the standards in a safety-neutral manner. Using these mass reduction amounts, NHTSA's analysis for the proposed standards projects an approximately neutral effect on fatalities through 2025, although the results are sensitive to decisions made by manufacturers on how they choose to reduce mass. For details about this analysis, *see* Section II.G of the NPRM. The final rule will discuss in detail comments received on the safety analysis in the NPRM.

7.6 Environmental Justice

Executive Order (EO) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*,[9] directs federal agencies to "promote nondiscrimination in federal programs substantially affecting human health and the environment, and provide minority and low-income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment." EO 12898 also directs agencies to identify and consider disproportionately high and adverse human health or environmental effects of their actions on

[8] The Pedestrian Safety Enhancement Act of 2010 is Public Law 111-373, 124 Stat. 4086 (Jan. 4, 2011). 49 U.S.C. 30111 note.
[9] *See* Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, 59 FR 7629 (Feb. 16, 1994).

minority and low-income communities, and provide opportunities for community input in the NEPA process, including input on potential effects and mitigation measures. CEQ has provided agencies with general guidance on how to meet the requirements of the EO as it relates to NEPA (CEQ 1997c).

DOT Order 5610.2(a), *Department of Transportation Actions To Address Environmental Justice in Minority Populations and Low-Income Populations*,[10] describes the process for DOT agencies to incorporate environmental justice principles in programs, policies, and activities. It also defines the terms "minority" and "low-income" in the context of DOT's environmental justice analyses. Minority is defined as a person who is Black, Hispanic or Latino, Asian American, American Indian or Alaskan Native, or Native Hawaiian or Other Pacific Islander. Low-income is defined as a person whose household income is at or below the Department of Health and Human Services poverty guidelines. The term "environmental justice populations" refers to groups composed of minorities and low-income persons who live in proximity or are similarly impacted by DOT programs, policies, or activities.

On August 4, 2011, the Secretary of Transportation, along with heads of other federal agencies, signed a Memorandum of Understanding on Environmental Justice and Executive Order 12898 confirming the continued importance of identifying and addressing environmental justice considerations in agency programs, policies, and activities as required by EO 12898. As part of the Memorandum of Understanding, each federal agency agreed to review and update their existing environmental justice strategy as appropriate, and to publicize the updated strategy. Accordingly, DOT has reviewed and updated its environmental justice strategy as appropriate. The updated strategy continues to reflect DOT's commitment to environmental justice principles and to integrating those principles into DOT programs, policies, and activities.[11]

7.6.1 Affected Environment

The affected environment for this Proposed Action is nationwide, with a focus on areas and groups most exposed to environmental and health effects of oil production, distribution, and consumption, and to the impacts of climate change. Examples are areas where oil production and refining occur, areas in the vicinity of some roadways, and urban areas subject to the heat island effect.[12]

There is evidence that proximity to oil refineries might be correlated with the incidence of cancer and leukemia (Pukkala 1998, Chan et al. 2006). Proximity to high-traffic roadways may result in adverse cardiovascular and respiratory effects, among other possible impacts (HEI 2010, Heinrich and Wichmann 2004, Salam et al. 2008, Samet 2007, Adar and Kaufman 2007). Climate change can affect overall global temperatures, which could affect the number and severity of outbreaks of vector-borne illnesses (CCSP 2008f). Chapters 3, 4, and 5 of this EIS discuss the connections between oil production, distribution, and consumption and their health and environmental impacts. The following paragraphs describe the extent to which minority and low-income populations might be more exposed or vulnerable to such effects.

Existing studies have found mixed evidence on whether there is a correlation between proximity to oil refineries and residence of low-income and minority populations (Fischbeck et al. 2006) or have cited anecdotal evidence (O'Rourke and Connolly 2003). There is some evidence of proximity of low-income

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[10] *See* Department of Transportation Updated Environmental Justice Order 5610.2(a). 77 FR 27534 (May 10, 2012).
[11] DOT accepted public comments on the draft revised strategy until November 30, 2011. *See* <http://www.fhwa.dot.gov/environment/environmental_justice/ej_at_dot/revised_strategy/> (Accessed: November 12, 2011).
[12] The heat island effect refers to developed areas having higher temperatures than surrounding rural areas.

and minority populations to other types of industrial facilities (Mohai et al. 2009, Graham et al. 1999, Jerrett et al. 2001). It is unclear whether any correlation between the location of industrial facilities and the presence of minority and low-income populations is due to the facility siting process or to real-estate market dynamics and migration after facilities are sited (Pastor et al. 2001, Graham et al. 1999, Morello-Frosch 2002). Performing a multivariate statistical analysis, Graham et al. (1999) found little support for the hypothesis that minority or low-income populations are more likely to live near oil refineries.

Whether populations living near mobile sources of pollutants more often have low incomes or are minorities is also often unclear. Although there is some evidence that higher traffic levels depress property values and attract lower income populations, urban development can cause increased traffic in secondary roads and impact relatively expensive housing (O'Neill et al. 2003). Inner-city populations, often low-income and minority, might be more exposed to diesel exhaust emissions from buses and trucks (O'Rourke and Connolly 2003).

Minority and low-income populations tend to be concentrated in areas with a higher risk of adverse climate-related impacts, and this geographic placement might put these communities at higher risk from climate variability and climate-related extreme weather events (CCSP 2008f). For example, urban areas often have relatively large minority and low-income populations, and are subject to the most substantial temperature increase from climate changes due to the urban heat island effect (CCSP 2008f, Knowlton et al. 2007). Low-income populations in coastal urban areas (vulnerable to increases in flooding as a result of projected sea-level rise, larger storm surges, and human settlement in floodplains) are less likely to have the means to quickly evacuate in the event of a natural disaster, and therefore are at greater risk of injury and loss of life (CCSP 2008f, GCRP 2009).

Independent of proximity to sources of pollution or to locations affected by climate change, low-income and minority populations might be more vulnerable to the health impacts of pollutants and climate change. The 2010 National Healthcare Disparities Report stated that minority and low-income populations tend to have less access to health care services, and services received are more likely to suffer in quality (HHS 2010). Increases in heat-related morbidity and mortality as a result of higher overall and extreme temperatures are likely to disproportionately affect minority and low-income populations, partially as a result of limited access to air conditioning and high energy costs (CCSP 2008f, EPA 2009e, O'Neill et al. 2005).

7.6.2 Environmental Consequences

The reduction in fuel production and consumption by passenger cars and light trucks projected as a result of the proposed standards could lead to a minor reduction in the amount of direct land disturbance as a result of oil exploration and extraction, and the amount of air pollution produced by the oil refineries. To the extent that minority and low-income populations live in greater proximity to oil extraction, distribution, and refining, they would be more likely to benefit, but as noted above, there is mixed evidence on whether this is the case.

Under the action alternatives, emissions of criteria and hazardous air pollutants are generally anticipated to decline. However, as discussed in Chapter 4, the overall decrease in emissions predicted to occur as a result of the Proposed Action and alternatives is not evenly distributed due to the increase in VMT from the rebound effect and regional changes in upstream emissions. As a result, emissions of some criteria and hazardous air pollutants are predicted to increase in some air quality nonattainment areas in some years. Although the evidence on the residential proximity of minority and low-income populations to mobile sources of pollutants is unclear, these populations may be more vulnerable to the consequences of adverse impacts from air pollutants, as discussed in Section 7.6.1. Also, to the extent that minority and low-income populations live and circulate in neighborhoods where there is a greater presence of older vehicles, they would could be less affected both by the overall decrease in emissions predicted to occur and by the localized increase due to increased VMT from the rebound effect. Because many of the emissions changes are relatively small, especially under Alternative 2 and the Preferred Alternative, no disproportionately high and adverse impacts on minority and low-income populations would be expected. In areas where larger increases of some air pollutants are expected in some years, minority and low-income populations could be more vulnerable to the consequences of adverse impacts of air pollutants, as discussed in Section 7.6.1.

All action alternatives are expected to result in fewer adverse impacts as a result of climate change compared to the No Action Alternative. Consequently, minority and low-income populations could be expected to benefit from reduced climate change impacts under the action alternatives.

7.7 Unavoidable Adverse Impacts

As demonstrated in Chapters 3, 4, and 5, stricter fuel economy standards under each of the action alternatives are projected to result in a net decrease in energy consumption and in most vehicle emissions compared to the No Action Alternative. Despite these reductions, total energy consumption and total vehicle emissions under all alternatives are currently anticipated to increase overall as a result of projected increases in the number of vehicles in use and the total number of miles they are driven each year (as measured by VMT). Increased VMT, predicted under all of the action alternatives due to the rebound effect, would result in impacts to climate and air quality.

Certain impacts, such as increased global mean surface temperature, sea-level rise, and increased precipitation, are likely to occur as a consequence of accumulated total CO_2 and other GHG emissions in Earth's atmosphere. Neither the Preferred Alternative nor the other action alternatives alone would prevent these emissions and their associated climate change impacts. As described in Section 5.4, each of the action alternatives would reduce GHG emissions compared to projected levels under the No Action Alternative. Although the projected reductions in CO_2 and climate effects are small compared to total projected future climate change, they are quantifiable, directionally consistent, and would be an important contribution to reducing the risks associated with climate change.

Regarding air quality, emissions of certain criteria and toxic air pollutants, such as CO, NO_x, SO_2, acetaldehyde, acrolein, 1,3 butadiene, benzene, diesel particulate matter, and formaldehyde, could increase under certain action alternatives and analysis years compared to levels projected under the No Action Alternative. As described above, this is largely a result of higher VMT under the action alternatives. The results presented in this EIS are based on NHTSA's assumptions regarding the technologies manufacturers will install and how companies will react to increased fuel economy standards. NHTSA's Proposed Action does not mandate specific manufacturer decisions regarding technology applications. Manufacturers could install different technologies or limit harmful emissions through the development of new technologies. Purchasing decisions by individual consumers could also impact individual and fleetwide vehicle emissions. Finally, NHTSA's action does not mandate specific driving behavior. The analysis presented in this EIS 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. It is useful for estimating the costs and benefits of the rule, but NHTSA recognizes that drivers could choose not to alter their behavior in response to higher gas mileage. These factors — changes in manufacturer decisions, consumer purchasing decisions, and driver behavior—among others, could affect the impacts reported in this EIS.

7.8 Short-term Uses and Long-term Productivity

All of the action alternatives would result in a decrease in crude oil consumption and reduced CO_2 emissions (and associated climate change impacts) compared to the No Action Alternative. To meet the proposed standards, manufacturers would need to apply various fuel-saving technologies during the production of passenger cars and light trucks. NHTSA cannot predict with certainty which specific technologies and techniques manufacturers would apply and in what order. Some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the standards. Such short-term uses of resources by vehicle manufacturers to meet the proposed standards would enable the long-term reduction of national energy consumption and could enhance long-term national productivity. For further discussion of the costs and benefits of the proposed rule, *see* NHTSA's Preliminary Regulatory Impact Analysis. NHTSA's Final Regulatory Impact Analysis will be issued with the final rule.

7.9 Irreversible and Irretrievable Commitment of Resources

As noted above, some vehicle manufacturers might need to commit additional resources to existing, redeveloped, or new production facilities to meet the standards. In some cases, this could represent an irreversible and irretrievable commitment of resources. The specific amounts and types of irretrievable resources (such as electricity and other energy consumption) that manufacturers would expend to comply with the proposed standards would depend on the methods and technologies manufacturers select. However, the societal costs of the commitment of resources by manufacturers to comply with the proposed standards would likely be offset by fuel savings generated from implementing the standards.

CHAPTER 8 MITIGATION

CEQ NEPA implementing regulations require that the discussion of alternatives in an EIS "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives." 40 CFR § 1502.14(f). An EIS should discuss the "[m]eans to mitigate adverse environmental impacts." 40 CFR § 1502.16(h). As defined in the CEQ regulations, mitigation includes the following:

- Avoiding the impact altogether by not taking a certain action or parts of an action
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action
- Compensating for the impact by replacing or providing substitute resources or environments

(40 CFR § 1508.20)

Under NEPA, an agency does not have to formulate and adopt a complete mitigation plan,[1] but should analyze possible measures that could be adopted. Generally, an agency does not propose mitigation measures for an action resulting in beneficial effects.

8.1 Overview of Impacts

Compared to the No Action Alternative, each of the three action alternatives would reduce fuel consumption and greenhouse gas (GHG) emissions. The action alternatives would reduce the impacts of climate change that would otherwise occur under the No Action Alternative.

As reported in Chapter 4, emissions of some pollutants would increase under some action alternatives and for some analysis years, while emissions of other pollutants would decline compared to the No Action Alternative. Under the No Action Alternative, neither NHTSA nor EPA would issue a rule regarding fuel economy improvement or GHG emissions for MYs 2017–2025. Compared to the No Action Alternative, health effects are estimated to be reduced and monetized health benefits would occur under all action alternatives, with the exception of Alternative 4 in some analyses and years (*see* Chapter 4).

Nationwide emissions of particulate matter and volatile organic compounds (VOCs) would decrease under all action alternatives for all analysis years, compared to the No Action Alternative. Therefore, any negative health impacts associated with these emissions are similarly expected to be reduced. Nationwide emissions of carbon monoxide, nitrogen oxides, sulfur dioxide, acetaldehyde, acrolein, 1,3-butadiene, benzene, diesel particulate matter, and formaldehyde could increase under certain alternatives and analysis years. Increases in emissions of all pollutants could occur under certain action alternatives and analysis years in some nonattainment areas due to increases in vehicle miles traveled and electric power production. These increases would represent a slight decline in the rate of reduction otherwise achieved by implementation of Clean Air Act (CAA) standards. The potential impacts depend

[1] *Northern Alaska Environmental Center v. Kempthorne*, 457 F.3d 969, 979 (citing *Robertson,* 490 U.S. at 352) (noting that NEPA does not contain a substantive requirement that a complete mitigation plan be actually formulated and adopted). *See* also *Valley Community Preservation Com'n v. Mineta*, 231 F. Supp. 2d 23, 41 (D.D.C. 2002) (noting that NEPA does not require that a complete mitigation plan be formulated and incorporated into an EIS).

on the selection of the final CAFE standards, the magnitude of the emissions increases, and other factors.

8.2 Mitigation Measures

There could be some increases in criteria and hazardous air pollutant emissions as a result of implementing the proposed standards. Notably, however, even if emissions of some pollutants show some level of increase, the associated harm would not necessarily increase concomitantly. As described in Chapter 4, ambient levels of most pollutants are trending generally downward, owing to the success of regulations governing fuel composition and vehicle emissions, as well as stationary sources of emissions. Also, vehicle manufacturers can choose from a suite of technology options to reach the proposed standards, and some technology choices result in higher or lower impacts for these emissions.

A number of federal programs could also result in reductions of criteria and hazardous air pollutant emissions. Federal funds administered by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) could be available to help fund transportation projects that reduce emissions. FHWA provides funding to states and localities for transportation projects that have air quality benefits under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program (FHWA 2011a). FHWA and FTA also provide funds to states and localities under other programs that have multiple objectives, including air quality improvement. For example, the Surface Transportation Program provides flexible funding that states may use for selected projects that could reduce emissions (FHWA 2011b). As state and local agencies conduct their review process and recognize the need to reduce emissions of criteria pollutants such as ozone, carbon monoxide, and particulate matter, they can consider using CMAQ funds to help reduce these impacts. Further, under the CAA, EPA has the authority to continue to improve standards for vehicle emissions, including criteria air pollutants and hazardous air pollutants, which could result in future reductions as EPA promulgates new regulations. For example, the EPA Tier 2 Vehicle & Gasoline Sulfur Program, which went into effect in 2004, established the CAA emissions standards that will apply to MY 2017–2025 passenger cars and light trucks (EPA 2000b). Under the Tier 2 standards, manufacturers of passenger cars and light trucks are required to meet stricter vehicle emissions limits than under the previous Tier 1 standards. Other emissions regulations, such as potential Tier 3 standards, might apply in the future. Under the CAA, EPA also has the authority to regulate stationary sources of air pollution and GHG emissions (e.g., factories and utilities) (EPA 2011h).

Each action alternative would reduce energy consumption and GHG emissions from their levels under the No Action Alternative, resulting in a net beneficial effect. Nonetheless, passenger cars and light trucks are a major contributor to energy consumption, air pollution, and GHG emissions in the United States. The Federal Government is involved in a number of actions, which, together with the Proposed Action, will help reduce GHG emissions from the U.S. transportation sector.

For example, in a joint NHTSA and EPA rulemaking published in September of 2011,[2] NHTSA and EPA established the first national program to improve fuel efficiency and reduce GHG emissions of heavy-duty trucks and buses. The agencies estimate that the combined standards will save approximately 530 million barrels of oil and reduce GHG emissions by approximately 270 million metric tons over the life of vehicles built for MYs 2014–2018. Another example is EPA's collaboration with the freight industry through the SmartWay Transport Partnership. Launched in 2004, the program provides incentives to

[2] *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*, 76 FR 57106 (Sept. 15, 2011).

the freight industry for improved supply chain fuel efficiency through several components, including identification of available technologies and benchmarking. As of 2010, SmartWay Partners report saving 50 million barrels of fuel and eliminating 16.5 million metric tons of CO_2 (EPA 2011i).

Further promoting efforts to reduce fuel consumption, the Federal Aviation Administration is a sponsor of the Commercial Aviation Fuels Initiative, a coalition of the U.S. commercial aviation community that acts as a focal point for engaging the emerging alternative fuels industry (FAA 2009). The initiative seeks to enhance energy security by promoting the development of alternative fuel options for use in aviation, thereby potentially reducing the impacts of GHG emissions from the transportation sector.

The U.S. Department of Energy (DOE) is involved in a number of initiatives that aim to reduce fuel consumption. For example, DOE administers the Vehicle Technologies Program, which creates public-private partnerships that enhance energy efficiency and productivity and bring clean technologies to the marketplace with the potential to reduce GHG emissions (DOE 2012a). Under the American Recovery and Reinvestment Act, $2.4 billion in grants were awarded to accelerate the deployment of electric-drive vehicles, including developing U.S. manufacturing capacity for batteries and electric-drive components, to help establish American leadership in developing the next generation of advanced vehicles (DOE 2010b). DOE also administers programs designed to give consumers and industries information required to make environmentally conscious decisions. Specifically, the DOE Clean Cities Program develops government-industry partnerships designed to reduce petroleum consumption "by advancing the use of alternative fuels and vehicles, idle reduction technologies, hybrid electric vehicles, fuel blends, and fuel economy measures (DOE 2009a)." The focus on urbanized areas overlaps with some of the nonattainment areas identified in Chapter 4 of this EIS.

EPA is also helping to reduce petroleum consumption and GHG emissions by implementing the Renewable Fuel Standards (RFS) under CAA Section 211(o). The RFS program currently requires that 36 billion gallons of renewable fuel be blended into gasoline by 2022. EPA is required to determine the standard applicable to refiners, importers, and certain blenders of gasoline annually. On the basis of this standard, each obligated party determines the volume of renewable fuel that it must ensure is consumed as motor vehicle fuel. The percentage standard represents the ratio of renewable fuel volume to projected non-renewable gasoline and diesel volume. The renewable fuel standard for 2012 is 9.23 percent (EPA 2012g).[3]

Government wide, federal agencies are currently implementing Executive Order (EO) 13514, which sets measurable environmental performance goals for federal agencies and focuses on making improvements in their environmental, energy, and economic performance.[4] EO 13514 requires each federal agency to submit a 2020 GHG emissions reduction target from its estimated 2008 baseline to CEQ and to the Office of Management and Budget by January 4, 2010. On January 29, 2010, President Obama announced that the Federal Government would reduce its GHG emissions from direct sources (e.g., lighting, heating, vehicle fuel, and federal projects) by 28 percent by 2020 (White House 2010a). This federal target is the aggregate of 35 federal agency self-reported targets. On July 20, 2010, an additional target of a 13 percent reduction in GHG emissions from indirect sources (e.g., employee travel and commuting) (White House 2010b) complemented this target. The Federal Government is the single largest energy consumer in the U.S. economy, and the White House estimates that achieving the federal agency GHG emissions reduction target will reduce federal energy use by the equivalent of 646

[3] Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards, 77 FR 1320, 1323 (Jan. 9, 2012).

[4] Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,* 74 FR 52117 (Oct. 8, 2009).

trillion British thermal units, equal to 205 million barrels of oil, and taking 17 million cars off the road for 1 year (White House 2010a).

8.3 Conclusion

Although emissions of many criteria and hazardous air pollutants are generally anticipated to decline, emissions of some pollutants would increase under some alternatives and for some analysis years. Several federal programs are in place that will help reduce such emissions. Regarding energy consumption and climate change, each of the action alternatives would reduce fuel consumption and reduce the impacts of climate change that would otherwise occur.

CHAPTER 9 RESPONSES TO PUBLIC COMMENTS

On November 25, 2011, a Notice of Availability of the Draft EIS appeared in the *Federal Register* (76 FR 72703). In accordance with CEQ NEPA implementing regulations, the Notice of Availability triggered a public comment period. NHTSA invited the public to submit comments on the Draft EIS to Docket No. NHTSA-2011-0056 until January 31, 2012. NHTSA mailed approximately 1,000 copies of the Draft EIS to interested parties, including federal, state, and local officials and agencies; elected officials; environmental and public interest groups; Native American tribes; and other interested individuals, as listed in Chapter 11 of the Draft EIS.

On December 1, 2011, NHTSA and EPA published in the *Federal Register* the proposed rule for 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards (76 FR 74854). Publication of the proposed rule opened a 60-day comment period, and the public was invited to submit comments on or before January 30, 2012, by posting to either the NHTSA or EPA docket (NHTSA-2010-0131 or EPA-HQ-OAR-2010-0799). The comment period for the proposed rulemaking was later extended to February 13, 2012.

NHTSA and EPA also held public hearings on the Draft EIS and the proposed rule on January 17, 2012, in Detroit, Michigan; on January 19, 2012, in Philadelphia, Pennsylvania; and on January 24, 2012, in San Francisco, California. NHTSA received 89 oral statements and 22 written submissions at the hearing in Detroit, 206 oral statements and 68 written submissions at the hearing in Philadelphia, and 107 oral statements and 28 written submissions at the hearing in San Francisco.

In preparing this Final EIS, NHTSA reviewed comments received in EIS Docket No. NHTSA-2011-0056 (a total of 14 public submissions), and comments relevant to the EIS submitted to the NHTSA and EPA rulemaking dockets (NHTSA-2010-0131 and EPA-HQ-OAR-2010-0799). NHTSA considered and evaluated all written and oral comments received during the public comment period in the preparation of this Final EIS. In this chapter of the Final EIS, NHTSA has quoted substantive excerpts from these comments and responded to the comments, as required by NEPA (40 CFR § 1503.4). The agency updated the EIS in response to comments on the rule and Draft EIS and as a result of updated information that became available after the agency issued the Draft EIS. NHTSA also reviewed the testimony transcripts and their associated written submissions for comments relevant to the EIS. NHTSA concluded that all topics in the transcripts and associated written submissions pertaining to the EIS are substantively similar to scoping and Draft EIS comments otherwise received by the agency through its dockets. To avoid repetition, NHTSA only presents the scoping and Draft EIS comments in this chapter.

NHTSA heard from numerous commenters at the public hearings who expressed support for the proposed rule because of the positive impacts they state it will have on the incidence of asthma. Chapter 4 of this Final EIS addresses impacts on air quality and human health. NHTSA also received comments requesting that the agency set standards based on a life-cycle analysis of various technologies. NHTSA discussed how it sets standards in the Notice of Proposed Rulemaking (NPRM) and will address these comments further in the Final Rule. A literature synthesis of life-cycle environmental impacts of certain vehicle materials and technologies appears in Chapter 6 of this Final EIS, which informs the rulemaking process.

NHTSA approached the remainder of the comments it received in both the NHTSA and EPA dockets as follows:

- The agencies received a significant number of comments directly addressing or otherwise related to the proposed rule. This includes comments regarding specific technologies, economic benefits of the rule, including jobs created, and coordination of the Joint National Program. After reviewing all of the comments, NHTSA has addressed in this chapter only comments considered substantive to the EIS. NHTSA will address comments on the proposed rule, but not substantive to the EIS, in the Final Rule and its associated documents.
- The agencies received oral and written comments stating either general support for or general opposition to the proposed rule. NHTSA appreciates those comments, but because they do not raise specific issues or concerns pertaining to the EIS, this chapter does not respond to those comments. This chapter responds to comments specific to the EIS or that substantively addressed EIS analytical methods or approaches.
- NHTSA received multiple comments that were substantively similar or identical. When there were many such comments, NHTSA selected representative comments for presentation.[1] In all cases, these representative comments are considered to comprehensively summarize the issues raised.
- Where the same commenter provided several substantially similar comments on a particular topic, this chapter includes one representative version of the comment.
- Several commenters incorporated by reference comments that they previously submitted to NHTSA in response to previous agency EISs. NHTSA has considered these comments for purposes of this EIS and has already addressed the substantive portions of those comments in responses presented in those previous EISs. To the extent a commenter referenced a previously submitted comment to address a specific substantive issue in the Draft EIS for this rulemaking, NHTSA addresses that comment below. This chapter also specifically addresses comments to the scoping notice that commenters incorporated by reference in their comments to the Draft EIS.

Transcripts from the public hearings and written comments submitted to NHTSA are part of the administrative record and are available on the Federal Docket at: http://www.regulations.gov, Reference Docket No.: NHTSA 2011-0056 (EIS) and NHTSA-2010-0131 or EPA-HQ-OAR-2010-0799 (rulemaking).

Table 9-1 lists the topics addressed in this chapter. Sections 9.1 through 9.4 provide relevant comments on the Draft EIS and the proposed rule and NHTSA's responses to those comments. Draft EIS comment docket numbers in this chapter include only the last four digits of the docket number, excluding the initial "NHTSA-2011-0056," which begins all EIS docket submissions. Comments submitted in response to the agency's scoping notice are listed with "(Scoping)" and appear in the same docket. Rule comment docket numbers in this chapter include only the last four digits of the docket number, but also include either "(EPA Rule Docket)" or "(NHTSA Rule Docket)," indicating whether they were submitted to EPA-HQ-OAR-2010-0799 or NHTSA-2010-0131, respectively.

[1] CEQ regulations permit an agency to attach summaries of substantive comments received on a Draft EIS if the response has been "exceptionally voluminous." *See* 40 CFR § 1503.4(b).

Table 9-1. Outline of Issues Raised in Public Comments on the Draft EIS

9.1	**PURPOSE AND NEED**
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9.4	**OTHER IMPACTS**
9.4.1	National Security Impacts
9.4.2	Economic Impacts
9.4.3	Biological Resource Impacts
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9.1 Purpose and Need

9.1.1 Purpose and Need Statement

Comments

Docket Number: 2075
Commenter: Joe Foss

I support the proposed plans to significantly increase fuel economy standards for cars and light trucks, model years 2017 to 2025. Higher fuel economy standards will help clean the air from toxins, reduce greenhouse gas emissions, and lessen our dependence on oil. Additionally, it will save consumers in the long-term by reducing overall demand for oil. Other industrial countries already have higher fuel economy standards than the United States. We need to do our part to promote conservation.

Response

NHTSA agrees that this rulemaking would lead to a broad range of potential benefits − in terms of economic competitiveness, technological advancement, energy independence, and the environment. As the agencies stated in the Notice of Proposed Rulemaking (NPRM), the proposed rule is part of a strong and comprehensive Joint National Program designed to address the closely intertwined challenges of dependence on oil, energy security, and global climate change. Light-duty vehicles are responsible for approximately 60 percent of all U.S. transportation-related greenhouse gas (GHG) emissions and fuel consumption. All of the action alternatives NHTSA has evaluated for this EIS would result in substantial fuel savings and associated GHG emissions reductions, as well as many of the other benefits highlighted by the commenters. The proposed standards would result in MY 2025 light-duty vehicles with nearly double the fuel economy, and approximately one-half of the GHG emissions, of MY 2010 vehicles.

9.1.2 Statutory Interpretation

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

Although we will comment on this issue in response to the substantive rulemaking, we here note briefly that the Agencies do not have unfettered discretion in how to weigh factors relevant in determining maximum fuel efficiency levels. The Agencies note, correctly, that they must consider the following statutory factors in setting maximum fuel efficiency standards and conserving energy: technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the United States to conserve energy. [Footnote omitted.] We disagree, however, with the Agencies' apparent conclusion that they possess unlimited discretion in what relative weight to assign these factors. That notion was held to be illegal in *Center for Biological Diversity v. NHTSA*, 538 F.3d 1172 (2008).

Such a contention is erroneous for a number of reasons. First, NEPA requires federal agencies to "specify the underlying purpose and need to which the agency is responding in proposing the alternatives." [Footnote omitted.] Here, that purpose is "the need of the United States to conserve energy" in setting CAFE standards. [Footnote omitted.] In other words, the statute requires the Agencies to weigh these factors so as to achieve the statutory mandate of setting truly *maximum feasible* standards that conserve energy, the crucial point of this rulemaking; adoption of an alternative that falls short of this mandate is arbitrary and capricious. *Center for Biological Diversity* held that NHTSA possesses discretion in weighing these factors, but only "as long as NHTSA's balancing does not undermine the fundamental purpose of EPCA [the Energy Policy and Conservation Act of 1975]: energy conservation." [Footnote omitted.] In short, any weighing of factors that undermines the central purpose of the rulemaking is unlawful. Second, the economic practicability factor must be based on a full accounting of the costs and benefits of the alternatives under consideration. That task cannot be accomplished if the social cost of carbon – i.e., the full consequences of climate change – is understated, or if other costs and benefits are excluded or undervalued. It also cannot be accomplished if the Agencies place undue weight on the effect of the rulemaking on the balance sheets of the automotive industry (as they now do) because the inquiry must take into account the enormous external and collateral damages associated with automotive emissions not currently paid for by either the industry or the consumer. [Footnote 29: In any event, the fiscal health of the American auto industry has vastly improved and is no longer at issue.] Third, the Agencies must fulfill the Congressional mandate of setting standards that are truly *technology forcing*. This mandate has become of utmost importance because the next ten years or so constitute a critical decade, and because the Agencies have chosen to set standards over a time frame unprecedented in the history of CAFE (a time frame, as discussed below, which precludes consideration of "lead time," a concept that has inappropriately been used to excuse delay in earlier rulemakings). Standards that are built solely on improvements to technologies already in use today or projected to be in use a few years from today, violate this mandate *per se*. Fourth, the overwhelming evidence of the critical need to stem greenhouse gas emissions now rather than later to avoid the worst effects of climate change renders any balancing of factors that elevates any factor over environmental and energy conservation concerns is unreasonable *per se*.

Response

EPCA, as amended by EISA, requires the Secretary of Transportation to establish average fuel economy standards for each model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." 49 U.S.C. § 32902(a). As the commenter notes, when setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). NHTSA has broad discretion in balancing these factors in determining the average fuel economy level manufacturers can achieve. Congress ''specifically delegated the process of setting . . . fuel economy standards with broad guidelines concerning the factors that the agency must consider.'' *Center for Auto Safety v. NHTSA*, 793 F.2d 1322, 1341 (D.C. Cir. 1986). The breadth of those guidelines, the absence of any statutorily prescribed formula for balancing the factors, the fact that the relative weight to be given to the various factors could change from rulemaking to rulemaking as the underlying facts change, and the fact that the factors could often conflict regarding whether they militate toward higher or lower standards gives NHTSA discretion to decide what weight to give each of the competing policies and concerns and then determine how to balance them — ''as long as NHTSA's balancing does not undermine the fundamental purpose of the EPCA: energy conservation,'' and as long as that balancing reasonably accommodates ''conflicting policies that were committed to the agency's care by the statute.'' *CBD v. NHTSA*, 538 F.3d 1172, 1195 (9th Cir. 2008). Therefore, EPCA does not mandate that any particular number be adopted when NHTSA determines the level of CAFE standards.

NHTSA has carefully balanced all of the statutory factors to derive a range of alternatives (including the Preferred Alternative) analyzed in this EIS. For further explanation of NHTSA's balancing of the statutory factors, including the agency's consideration of technological feasibility and economic practicability, *see* Section IV.F.2 of the NPRM. *See* Section V.G.4 of the NPRM for a discussion of the costs and benefits of the proposed standards.

9.2 Proposed Action and Alternatives

9.2.1 Proposed Action

9.2.1.1 Timing of Standards and Environmental Review

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

In response to the Agencies' proposed decision to conduct an interim review of the rulemaking before 2022, we note that any such review should, at a minimum, include a strong presumption that the stringencies will not decrease, but may very likely increase. There is no reason to use a review to decrease standard stringencies for a number of reasons. First, in each of the prior rulemakings, less stringent alternatives have been adopted because of exaggerated and undue concerns over industry "lead times." But now that standards will be set through 2025, concerns about "lead time" cannot be cited as an excuse for lower stringencies. *The next fourteen years* include not only the statutory lead time of 18 months, but at least two of the oft-cited five-year "redesign" cycles, time periods when manufacturers review and redesign each car model from the ground up. Thus, new technology of every kind can be introduced at least twice from the finalization of this rulemaking until its end in 2025, and manufacturers cannot cite cost concerns arising from "redesign" needs. In today's competitive marketplace, any manufacturer who cannot design and produce completely new products every five years will likely fail; accordingly, the Agencies should give lead time concerns no weight whatever.

Second, the unprecedented length of time covered by the proposed rulemaking cannot be justified unless the resulting standards *exceed* what the automotive industry can produce today based on technology either already on the road, on the shelf, under development, or in the concept stage. Standards set too low mean that available reductions in greenhouse gas emissions and fuel savings will be lost forever, a result the world simply cannot afford.

Third, based on a consistent pattern over the last several decades, we believe that the Agencies' rulemaking will significantly undershoot actual technological developments, and thus we agree that it makes sense to review them to determine whether the standards must be increased. However, any such rulemaking should be strictly limited to determining whether technological advances mandate *higher* standards during the remainder of the rulemaking period; it would be simply irresponsible and contrary to Congressional intent to allow fuel efficiency standards to be reduced. We also note here that the review date suggested by the Agencies has already led to gamesmanship, because fuel efficiency increases for trucks are absurdly back-loaded to occur only *after* that review date when manufacturers undoubtedly hope to be able to influence the Agencies to decrease stringencies. We will comment on this flaw in more detail in connection with the substantive rulemaking. In this regard, we urge the Agencies to give no credence to the predictable reliance by industry on the catchword of the day – "regulatory uncertainty" – as an argument against the possibility of having to meet higher standards. In fact, the duty to comply with the statutory mandate for maximum levels of fuel efficiency achievable at any given time is a key certainty of the automotive business.

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

The effect of allowing minimal efficiency increases early and demanding larger increases only later is to delay efficiency gains that could be achieved much sooner, at a much lower price. As we have frequently stated (see our comments to the DEIS [Draft EIS]), because greenhouse gases remain in the atmosphere for centuries and their warming effect is delayed for decades, it is essential to decrease their emissions as soon as possible; the benefits of avoiding the emission of a ton of carbon today by far exceed the benefits of avoiding the release of the same ton of carbon several years from now. The Agencies recognize this to some extent as they increase the social cost of carbon over time (though insufficiently so). Conversely, remedial efforts get more expensive the longer action is delayed. Even setting aside the triggering of catastrophic events by crossing tipping points and assuming *arguendo* that the social cost of carbon grows by no more than the Agencies currently assume, it is undoubtedly vastly preferable to remove a given ton of carbon in year 1 rather than year 4, when it has wrought that much more damage. From the CAFE perspective, something similar can be said: the longer vehicles retain the same, rather than increased, fuel efficiency standards, the more fuel, a finite commodity that Congress mandates must be conserved, is wasted. Thus, the Agencies' failure to comply with the Congressional mandate to devise *ratable* fuel efficiency increases, and its decision to backload achievable gains instead, has the additional pernicious effect of increasing the rulemaking's cost.

The Agencies seek to justify the anemic annual rate of improvement for trucks by referencing the "unique challenges in improving the fuel economy . . . of full-size pick-up trucks, while preserving the utility of these trucks." [Footnote omitted.] Specifically, they explain that due to characteristics such as 4WD and towing and hauling capacity, "the vehicles in the current light truck fleet are generally less capable of achieving higher fuel economy levels as compared to vehicles in passenger car fleet." [Footnote omitted.] While this reasoning may address the fact that stringency for trucks is currently lower than that of cars, it does nothing to explain the lack of the required ratable annual increases – i.e., increases that are proportional, lead to rapid and consistent progress, and do not create incentives to upsize cars to light trucks and lighter trucks to heavier ones.

In any event, the explanation lacks merit. Studies show that trucks are indeed capable of maintaining towing and hauling capacity with higher fuel economy standards. [Footnote omitted.] The claim that the "unique challenges" faced by trucks justify a slower and disproportional increase in fuel economy standards, or any of the other regulatory leniencies the Agencies provide for them in the NPRM, fails in light of the fact that technologies exist that fully enable trucks to improve fuel efficiency while retaining utilities like hauling and towing.

Response

With regard to the comment about the agency's proposed mid-term review, the values set forth for MYs 2022–2025 represent the agency's current best estimate of what levels of stringency would be maximum feasible in those model years, but for the standards for those model years to be legally

binding, the agency must undertake a subsequent rulemaking. The CAFE standards for MYs 2022–2025 will be determined with finality in a subsequent, de novo notice and comment rulemaking. At that time, the agency will balance the statutory factors in light of then-current conditions.

Regarding the comments about the technological assumptions of the proposal, NHTSA believes that the Preferred Alternative reflects a reasonable and appropriate balancing of the statutory factors in setting maximum feasible fuel economy standards. This Proposed Action affects 9 years of vehicle production – MYs 2017–2025. Given the now-typical 5-year redesign cycle, many vehicles will be redesigned 3 times between MY 2012 and MY 2025, and are expected to be redesigned twice during the 2017–2025 timeframe. Due to the relatively long lead time before 2017, there are fewer lead-time concerns about product redesign in this proposal than with the MY 2012–2016 rule (or the MY 2014–2018 rule for heavy-duty vehicles and engines). However, there are still some technologies that require significant lead time and that are not projected to be heavily utilized in the first years of this proposal. *See* Chapter 3 of the Draft Joint Technical Support Document (TSD). The timeframe and levels for the standards are expected to provide manufacturers the time needed to develop and incorporate technology that will achieve fuel consumption reductions, and to do this as part of the normal vehicle redesign process. The agencies place important weight on the fact that the proposed rule provides a long planning horizon to achieve the very challenging standards being proposed, and provides manufacturers with certainty when planning future products.

Furthermore, as stated above, the agencies recognize that due to the relatively long time between now and 2025, it is very possible that new and innovative technologies will make their way into the fleet, perhaps even in significant numbers that have not been considered in the agencies' analysis. The agencies expect to consider, as appropriate, such technologies as part of the mid-term evaluation discussed in the NPRM. Given the long timeframe at issue in setting standards for MYs 2022–2025, and given NHTSA's obligation to issue a separate rulemaking to establish final standards for vehicles for those model years, NHTSA and EPA have proposed a comprehensive mid-term evaluation and agency decisionmaking process. As part of this undertaking, both agencies will develop and compile up-to-date information for the evaluation through a collaborative, robust, and transparent process, including public notice and comment. The comprehensive evaluation process will lead to final action by both agencies.

Regarding comments about light-truck standards in particular, the agency explained its balancing of the relevant factors in Section IV.F.2 of the NPRM. NHTSA believes that the Preferred Alternative reflects a reasonable and appropriate balancing of the statutory factors for setting maximum feasible fuel economy standards for light trucks through MY 2021. As part of the mid-term evaluation, both agencies will develop and compile up-to-date information, as noted above.

9.2.2 No Action and Action Alternatives

9.2.2.1 Preferred Alternative and Alternative 4

Comments

Docket Number: 9476 (EPA Rule Docket)
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

NESCAUM [Northeast States for Coordinated Air Use Management] strongly encourages the agencies to focus future analysis on the 6% annual improvement rate.

Docket Number: 0775 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

Instead, it is clear that (a) the Agencies can and must reduce emissions from vehicles that will not be built until 14 years from now, (b) technology is presently available to accomplish emission cut-backs at the high end of the Agencies' proposal, and (c) technology innovation must be built into these rules to comply with the Congressional mandate and push the standard even further. Thus, this rulemaking is of critical importance in the quest for a sustainable future.

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

The DEIS' [Draft EIS] failure to meaningfully describe and portray the true results of the choices before us should be remedied in the FEIS [Final EIS], and should lead the Agencies to adopt the most stringent alternative, Alternative 4, as their preferred choice. This is the only alternative that accomplishes what any unbiased environmental analysis would demonstrate is needed: the actual *reduction* of greenhouse gases from the nation's vehicle fleet over the period in question. [Footnote 4: Under Alternative 4, "increases in fuel economy result in projected fuel consumption and CO_2 emission levels through and beyond 2060 that are lower than present annual CO_2 emission levels." DEIS, S-23.]

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

As we pointed out in our comments to the DEIS, only Alternative 4 would actually reduce greenhouse gas emissions from the nation's vehicle fleet; for all of the reasons stated, adopting this standard is a necessity if exceptional damage from climate change is to be avoided.

Cars achieving and even exceeding the fuel economy level of 69 mpg, reached by Alternative 4 by 2025, are already on the road *today*, such as the Toyota Prius and the Nissan Leaf. [Footnote 106: The Prius, for example, achieves 71 mpg in CAFE testing. (Citation omitted.)] Accordingly, it is clear that 69 mpg by 2025 is technically feasible *14 years from now*. Indeed, it is beyond question that a fleet-wide average of 62 mpg (representing approximately a 6% annual increase) can be achieved based mostly on existing, off-the-shelf technologies, such as downsized turbocharged engines, electric power-train design, regenerative breaking, six-and seven-speed transmissions, high strength, high-strength lightweight materials, and enhanced aerodynamic designs. [Footnote omitted.] As stated above, to arrive at a technology-forcing alternative, NHTSA must push beyond existing technologies and include those still in the research and development stage in its modeling assumptions, which can model uncertainties concerning adoption and fleet penetration the Agencies perceive. Doing so demonstrates that Alternative 4 will be technologically feasible in the time provided.

The Agencies in the past have justified decisions not to adopt higher stringency standards because of concerns about economic feasibility. But the economic benefits of the rulemaking here would exceed its costs by more than $300 billion, at a minimum. And, even leaving aside the huge benefits external to the immediate purchase transaction, it is clear that fuel savings alone will more than make up for realistically estimated vehicle cost increases. We note here that the Agencies present no analysis of maximized societal benefits, where the benefits most optimally compare to the anticipated costs. In other words, there is no rigorous analysis of economic feasibility that justifies rejecting Alternative 4 as the appropriate standard for this rulemaking. Energy conservation along with the prevention of extreme climate change damages, however, demands it. Because Alternative 4 is both technological and economic [sic] feasible and best promotes energy conservation, it must be adopted.

The Agencies' preferred alternative of 49.6 mpg clearly does not constitute the maximum feasible fuel economy level because other countries will surpass that number (and in case of the EU [European Union], far surpass it) five years earlier, by 2020: by then, the EU will have achieved 64.8 mpg, Japan 55.1 mpg, and China 50.1 mpg. [Footnote omitted.] [. . .] Given the accelerating rapidity of technical improvements, reaching 69 mpg by 2025, five years after Europe reaches 64.8 mpg, is clearly feasible and is the alternative the Agencies should embrace.

* * * * *

The rulemaking requires insufficiently stringent technological improvements as it does not reflect the historical speed of technological improvements in practically every industry over the last decades, including in the automotive industry, a trend that will undoubtedly continue in the future; as it improperly excludes the impact of technologies under development or in the research stage; and as it does nothing to force technological innovation. The failure to take these developments into account is especially egregious in a rulemaking spanning the next decade and a half. If these factors were properly accounted for, the Agencies would recommend Alternative 4 rather than the preferred alternative.

The Agencies state that with only a few exceptions, the technologies considered here are *the same as those in the MY 2012-2016 rulemaking.* [Footnote omitted.] This approach is completely inadequate for a rulemaking reaching nine years beyond that date. They also state that the technologies they have considered are limited to currently existing technologies and improvements to them that either are or will be available within the rulemaking timeframe. [Footnote omitted.] In fact, they have no such thing, as they admit that that they have only considered technologies "expected to be in production in the next 5-10 years." [Footnote omitted.] Since this rulemaking will extend considerably beyond that time frame, this approach is inadequate. In addition, because the CAFE statutes are technology forcing and the rulemaking period is extraordinarily long, the Agencies must also consider technologies in the research phase.

Defending their refusal to consider research stage technologies, the Agencies point to uncertainties involved in the availability and feasibility of implementing them with significant penetration rates. [Footnote omitted.] But since the Agencies have taken it upon themselves to set standards 14 years into the future, it is their responsibility to assess those uncertainties within reasonable ranges, and include the clearly foreseeable impact of technological innovations rather than to disregard research-stage technology altogether. Moreover, it is certain that the rate of innovation will continue at least at the speed of the last decade, and that technologies now in the research stage and many not yet conceived *will be in existence in 2025* and much before then. In turning a blind eye to research that is sure to bear results 14 years from now, the Agencies ignore their mandate.

Examples of technologies improperly excluded from the rulemaking include but are not limited to higher voltage stop-start/belt integrated starter generators; integrated motor assist/crank integrated starter generators; 2-mode hybrids; and power split hybrids. [Footnote omitted.] As stated below, providing incentive credits instead of setting standards integrating these technologies does not comply with the statute. Among the technologies the Agencies believe are insufficiently developed are fuel cell electric vehicles, HCCI, multi-air, and camless valve actuation and other advanced engines currently under development. [Footnote omitted.] The decision to completely ignore the impact of these highly promising technologies, all clearly far beyond the research stage and already *under development*, is stunning. For example, the Agencies admit both that fuel cell electric vehicles have "the potential of achieving more than twice the efficiency of conventional internal combustion engines" and that "there will be some limited introduction of FCEVs into the market place in the time frame of this rule." [Footnote omitted.] But, because the Agencies "expect this introduction to be relatively small," they have completely *excluded* FCEVs from their modeling analysis. [Footnote omitted.] This approach is clearly wrong.

Response

While each of the action alternatives would avert significant GHG emissions, NEPA does not require that NHTSA develop alternatives designed to achieve specific GHG reduction targets. In addition, "NEPA itself does not mandate particular results." ***Robertson v. Methow Valley Citizens Council*****, 490 U.S. 332, 350 (1989). Instead, NEPA imposes procedural requirements to "ensur[e] that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts." Id. at 349. NHTSA has carefully considered information concerning environmental impacts, and has analyzed a broad range of currently available and soon-to-be in production fuel efficiency technologies, in developing alternatives (including a Preferred Alternative) based on the statutory factors.**

As the agencies stated in the NPRM, for this rulemaking the agencies are considering near-term technologies and other technologies that are not currently in production, but are beyond the initial research phase, are under development, and expected to be in production in the next 5 to 10 years. These are technologies the agencies believe can, for the most part, be applied both to cars and trucks, and that are expected to achieve significant improvements in fuel economy and reductions in carbon dioxide (CO_2) emissions at reasonable costs in the MY 2017–2025 timeframe. The agencies are not considering technologies that are currently in an initial stage of research because of the uncertainty involved in the availability and feasibility of implementing these technologies with significant penetration rates for this analysis. Due to the relatively long timeframe between the date of this proposal and 2025, it is very possible that new and innovative technologies will make their way into the fleet, perhaps even in significant numbers, that the agencies have not considered in this analysis. The agencies expect to consider such technologies as part of the mid-term evaluation, as appropriate.

9.2.2.2 Reasonable Range of Alternatives

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

We have previously commented on the statutory and regulatory requirements governing the forthcoming FEIS and the corporate average fuel efficiency and greenhouse gas rulemaking which it seeks to inform. We have stated that the Agencies must present a full description and quantification of the damages resulting to human health and welfare and the environment from greenhouse gas emissions, including direct, indirect and cumulative effects, to fully account for all reasonably foreseeable costs and benefits of their rulemaking, and to present a meaningful range of alternatives in easily understood terms. We have also commented on why the law requires the Agencies to include a truly maximum feasible alternative among the choices before the decision makers. In the interest of brevity, we do not repeat these comments here.

In 2009, the US and 140 other countries joined the Copenhagen Accord, pledging to reduce greenhouse gas emissions to a level that will maintain global temperature increases *below 2 °C* above pre-industrial levels. The best available science now indicates that temperature increases must be held to, at most, 1.5 °C, corresponding to atmospheric CO_2 concentration levels of 350 ppm, if drastic and unacceptable consequences are to be avoided. [Footnote omitted.] Indeed, a more recent study holds that a margin of safety cannot be reached unless temperature increases are limited to 1 °C. (Citation omitted.)] In fact, however, despite international efforts to reduce greenhouse gas pollution, global energy-related emissions rose to a new record high last year of 30.6 Gigatonnes (Gt), a 5% jump over the previous record year in 2008, when these emissions reached 29.3. [Footnote omitted.] As stated by IEA's [International Energy Agency's] chief economist, it is now "becoming extremely challenging to remain below 2 degrees." [Footnote omitted.] As calculated by the IEA, annual energy-related emissions should be no more than 32 Gt per year by 2020 to avoid exceeding the 2 °C goal; alarmingly, if emissions in 2011 have risen by the same 5% increase experienced in 2010 over 2008, the 32 Gt annual emission level may be reached nine years ahead of schedule. [Footnote omitted.] Because emissions have continued to rise beyond expectations, the time frame for meaningful action has become even shorter. The Agencies cannot issue an adequate DEIS if they fail to portray this highly disturbing reality. Indeed, here we note that, in its discussions of the IPCC's Fourth Annual Assessment Report, the DEIS fails to reveal that worldwide emissions continue on the "worst case" scenario identified in that report. [Footnote omitted.] The so-called "gigaton gap" also is not portrayed anywhere in the DEIS. These facts must be included in the FEIS if it is to fulfill its statutory duty under NEPA.

Expressed in another way, global emissions must be less than 1000 Gt of carbon dioxide between 2000 and 2050 to preserve a 75% chance of meeting the 2 °C goal. [Footnote omitted.] But the global community has already used a substantial portion of this carbon dioxide budget, emitting 305 Gt of CO_2 between 2000 and 2008 alone. [Footnote omitted.] As a result, the years between now and 2020 have been dubbed the "critical decade." [Footnote omitted.] Because carbon emissions must peak soon and decline thereafter, the sooner emissions peak, the less severe the subsequent annual reductions will need to be [footnote omitted]; correspondingly, if emissions are not sufficiently curbed in this decade, avoiding catastrophic damages will require much more drastic, disruptive and costly measures and may no longer be possible at all. Nonetheless, if action is taken immediately, it is both technologically and economically feasible to reduce emissions by 2020 and lay the groundwork for future emissions reductions. [Footnote omitted.] For this reason, it has now become critical to promote the development of advanced clean technology and to implement it immediately. [Footnote omitted.] Reducing greenhouse gases to the maximum feasible extent also goes hand in hand with achieving the maximum fuel efficiency and largest amount of energy conservation feasible, each a statutory goal the Agencies must achieve.

The US vehicle fleet represents the "low hanging fruit" in the effort to reduce global greenhouse gas emissions. The International Energy Agency "has estimated that 80% of projected emissions from the power sector in 2020 are already locked in, as they will come from power plants that are currently in place or under construction today." [Footnote omitted.] That is not the case for our vehicle fleet and its relatively much quicker turnover, which contributes a sizable portion of US greenhouse gas emissions and should lead the charge of producing greenhouse gas emission reductions. [Footnote 18: For this reason, the Agencies' assertion that President Obama's Copenhagen pledge to reduce greenhouse gas emissions 17 percent below 2005 levels by 2020 "does not specify that every emitting sector of the economy must constitute equally proportional emission reductions," DEIS at 5-43, is disingenuous.] In fact, as stated above, the U.S. Department of Energy acknowledges that vehicle efficiency has the greatest short- to mid-term impact on oil consumption. [Footnote omitted.] Thus, it is clear that, if any headway is to be made, the Agencies must *reduce* emissions from vehicles, some of which will not be built until 14 years from now, and the DEIS must show the relationship between what science dictates and the international community agrees must be accomplished, on the one hand, and the effects of the alternatives the Agencies are proposing, on the other. The DEIS does not do so.

As we have explained in earlier comments, in light of the stark scientific necessities, we urge the Agencies to include within the FEIS an analysis of alternative fuel efficiency standards that (a) spells out how far each alternative advances (or falls short of) the goal of limiting temperature increases to below 2 °C; and (b) does so in a context that assumes that other actors also engage in conduct that avoids catastrophic climate change by advancing this goal. We have previously described this approach as a back-casting analysis, but here also express it in terms of the "gigaton gap" – the shortfall between current emissions and emissions levels that must be reached if temperature increases are to be held below 2 °C. In other words, the Agencies should estimate the total amount of GHG emissions from now through 2025 (and beyond) from the light-duty vehicle fleet that would equal the sector's proportionate share of the maximum allowable global emissions necessary to reduce atmospheric GHG concentrations to levels that hold temperature increases below 2 °C, and then present its alternatives in relation to that goal. The presentation should include each alternative's impact on staying within (or exceeding) the allowable global carbon budget for the sector by 2020 and for each decade thereafter through 2100. Only this type of presentation, built on the science of climate change and its consequences, can meet the statutory purpose of this DEIS.

* * * * *

The DEIS considers alternatives resulting in an increase in fuel economy between 2% and 7% per year. As stated above, that range itself is arbitrarily constrained as it is not based on the type of back-casting or "gigaton gap" analysis described above. From the alternatives considered, the Agencies select as "preferred" a mid-point alternative that would arrive at what is described in the MY 2017-2025 Proposed Rule as the "equivalent" of 54.5 mpg in 2025. [Footnote omitted.] Preliminarily, we note that this number is misleading. In fact, when not inflated by air conditioning credits that lower greenhouse gas emissions but do not increase fuel efficiency, the number is reduced to 49.6 mpg if expressed as the "estimated average required fleet-wide fuel economy"; once carmakers' use of various "flexibilities" and credits are accounted for, the "achieved" mileage decreases to just 46.7 mpg. [Footnote omitted.] But the actual real-world fleet-wide fuel efficiency number is even lower, translating to just 40 mpg (and 223 grams per mile). [Footnote omitted.] We urge the Agencies to disclose the estimated achieved mileage of 46.7 mpg prominently as part of the final FEIS, as the higher values, if repeated without adequate explanation, are misleading.

Docket Number: 0775 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

The scoping notice indicates that the Agencies plan to consider alternatives that would result in an increase in fuel economy between 2% and 7% per year. [Footnote omitted.] As stated above, that range is arbitrarily and improperly constrained as it is not based on the type of back-casting analysis described above. In any event, while a 7% annual increase in fuel economy corresponds to a US test-cycle fuel economy of approximately 65 mpg, in actuality it translates to an on-road fuel economy in 2025 of no more than 52 mpg. [Footnote 46: This calculation is based on a 2016 average fleet fuel economy of 35.5 mpg and results in a US test cycle economy of approximately 65 mpg. The Agencies indicated in the NOI that on-road fuel economy is approximately 20% lower than US test cycle measurements [citation omitted]. On the other hand, the discount factor from EPA's 2011 Fuel Economy Guide would be approximately 30%, which would reduce estimated on-road fuel economy to only 45.5 mpg.] We urge the Agencies to disclose this fact prominently as part of the forthcoming EIS, as the higher value, without adequate explanation, is misleading.

Response

NHTSA recognizes the importance of climate change and the necessity of taking action to avert GHG emissions. The agency is acting within its statutory authority to increase average fuel economy and in so doing, to reduce annual U.S. vehicle emissions of CO_2. Emissions from U.S. passenger cars and light trucks constitute roughly 61 percent of total U.S. transportation-sector emissions, which amounts to roughly 3.3 percent of global annual CO_2 emissions. NHTSA recognizes that transportation can play an important role in addressing global climate change.

Regarding the comments about the environmental benefits of the proposal, NHTSA notes that environmental benefits are one consideration in the development of reasonable alternatives analyzed in this EIS. While each of the action alternatives would avert significant GHG emissions, NEPA does not require that NHTSA develop alternatives designed to achieve specific GHG reduction targets. The "rule of reason" guides the choice of alternatives and the extent to which the EIS must discuss each alternative. *See*, e.g., *City of Carmel-by-the-Sea v. U.S. Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997). *See* also *American Rivers v. FERC*, 201 F.3d 1186, 1200 (9th Cir. 2000) (quoting City of Carmel-by-the-Sea, 123 F.3d at 1155). Under the rule of reason, an agency "need not consider an infinite range of alternatives, only reasonable or feasible ones." Id. (citing 40 CFR § 1502.14(a)-(c)).

Under NEPA, agencies are required to examine reasonable alternatives, and not those that are a "worst case scenario." *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 354-55 (1989). An agency is not required to consider alternatives "whose effect cannot be reasonably ascertained, and whose implementation is deemed remote and speculative." *Headwaters, Inc. v. Bureau of Land Mgmt., Medford Dist*, 914 F.2d 1174, 1180 (9th Cir. 1990) (quoting *Life of the Land v. Brinegar*, 485 F.2d 460 (9th Cir. 1973), cert. denied, 416 U.S. 961 (1974)). CEQ guidance on this point is similar. "Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (Mar. 23, 1981). As discussed above, when setting "maximum feasible" fuel economy standards, NHTSA is required to consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy. 49 U.S.C. § 32902(f). NHTSA has carefully balanced the statutory factors to derive a range of reasonable alternatives analyzed in this EIS.

However, NHTSA agrees the current rate of global emissions of GHGs has exceeded that of the Intergovernmental Panel on Climate Change (IPCC) emission scenarios cited by most of the assessments presented in Chapter 5. In response to this comment, NTHSA has added the following text to Chapter 5: "Since 2000, global emissions have been increasing at a growth rate greater than the most fossil-fuel intensive emission scenario (A1Fi) developed by the IPCC (Raupach et al. 2007)."

The commenter requests that NHTSA present each alternative in relation to a goal of limiting temperature increases to below 2 °C (3.6 °F) and does so in a context that assumes that other actors engage in similar conduct. This increase in temperature above the pre-industrial global average would equate to an atmospheric concentration of approximately 450 ppm CO_2e (IPCC 2007a). At the 2010 G8 summit in Muskoka, Canada, the United States and other members of the G8 agreed to a goal of limiting global temperatures to not exceed this 2 °C increase, and further agreed that the G8 nations "support a goal of developed countries reducing emissions of greenhouse gases in aggregate by 80% or more by 2050, compared to 1990 or more recent years." The emission reductions necessary to achieve the climate target of mitigating temperature increase to 2 °C could not be achieved solely with drastic reductions in emissions from the U.S. vehicle fleet, but would also require drastic reductions in all U.S. sectors and from the rest of the developed and developing world. Given that population and vehicle miles traveled (VMT) are likely to increase by 2050, an 80 percent emission reduction for the U.S. passenger car and light-truck fleet would require substantial increases in technology innovation and adoption compared to today's levels and would require an economy and vehicle fleet that has largely moved away from the use of fossil fuels. Under EPCA/EISA, NHTSA must account for technological feasibility and economic practicability when setting CAFE standards. Therefore, NHTSA does not believe this provides a valuable context for evaluating alternatives.

Finally, NHTSA recognizes that on-road fuel economy is approximately 20 percent lower than the test-cycle measurements required by EPCA to be used for standards setting and vehicle compliance purposes. Achieved fuel economy values in Chapter 2 are presented in terms of the test-cycle measurements required by EPCA to facilitate comparison with the proposed fuel economy standards. However, to clarify this issue for the reader, NHTSA has added text to Chapter 2 to explain that on-road fuel economy is expected to be lower than the "estimated achieved" values presented. The environmental analyses presented throughout the EIS are, in fact, based on estimated on-road fuel economy levels and therefore accurately present the agency's forecasts of environmental impacts under the Proposed Action and alternatives.

9.2.2.3 More Aggressive Alternatives

Comments

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

Below we point out the various deficiencies inherent in the rulemaking. Among the most egregious is the laundry list of near-exemptions, credits, and other give-aways that would be provided to the largest and least efficient vehicles covered by the rulemaking: the SUVs, pickup trucks and other "light trucks" that have constituted the most profitable vehicle class, and that have proliferated on America's highways while stymieing real progress on fuel efficiency for decades. Yet, this rulemaking would reintroduce the SUV loophole with a vengeance. We encourage the Agencies to address these deficiencies, abandon the preferred alternative and instead drive industry to use the next 14 years to overhaul, rather than merely tinker with, vehicle technology and achieve the results the statutes demand.

* * * * *

The Agencies cite the fact that the rulemaking's benefits far outweigh their costs as an indication of its reasonableness. [Footnote omitted.] But the opposite is true. In light of the statutory mandate to achieve energy conservation, it is *unreasonable* to design a rulemaking that so obviously undervalues benefits. Here, technologies that can improve fuel efficiency significantly have been ruled out because of alleged cost concerns by manufacturers. [Footnote omitted.] Yet, the rulemaking's benefits exceed its costs by many hundreds of billions of dollars. [Footnote 39: The Agencies state the net benefits of the rulemaking as between $311 billion and $421 billion, at 7 and 3% discount rates, respectively, over the lifetimes of the vehicles sold during MY 2017-2025. (Citation omitted.)] The fuel savings alone pay for the costs of additional technologies many times over, leaving billions of dollars in consumer pockets. The Agencies have thus left substantial, achievable fuel economy improvements and public benefits unrealized due to industry objections. Plainly, a rulemaking that elevates the protection of industry profits over energy conservation is contrary to EPCA and EISA. This calculus underlying the preferred alternative is anything but reasonable.

Response

NHTSA has carefully balanced the statutory factors described above to derive a range of alternatives (including a Preferred Alternative) analyzed in this EIS. The agency believes that considering more aggressive standards beyond what the agency has modeled in for the action alternatives would exceed maximum feasibility. NHTSA also notes that electing to impose more aggressive standards would impose substantial additional costs on the light-duty vehicle industry. Overly aggressive standards would not achieve the result intended by EPCA/EISA (i.e., meeting the overarching goal of energy conservation while also weighing cost-effectiveness and technological feasibility). For more explanation of NHTSA's balancing of the statutory factors, including the agency's consideration of technological feasibility and economic practicability, *see* Section IV.F.2 of the NPRM. In addition, *see* Section V.G.4 of the NPRM for a discussion of the costs and benefits of the proposed standards.

9.2.2.3.1 Maximum Feasible Standards

Comments

Docket Number: 0775 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

In any event, the Agencies' maximum proposed increase of 7% per year in fuel economy is unlikely to represent the maximum fuel economy level technologically (or economically) feasible since the EU has set a target of achieving fuel economy of ~62 mpg by 2020 [footnote omitted], five years earlier than the Agency's highest proposal of ~65 mpg by 2025. [Footnote omitted.] [. . .] In short, previous environmental impact statements have been deficient because they failed to include an alternative that showed the actual maximum feasible mileage standard based on the use of every single technology option presently available, much less one that also included all emerging technologies. The forthcoming EIS, which attempts to span 14 years, must include such an alternative, even if the Agencies do not ultimately choose it.

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

We encourage NHTSA to prepare a final EIS that thoroughly considers the host of societal benefits in order to develop "the maximum feasible average fuel economy level"…"the manufacturers can achieve in that model year," as mandated by the Energy Policy and Conservation Act (EPCA) as amended by the Energy Independence and Security Act of 2007 (EISA). See 49 U.S.C. § 32902(a).

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

After putting more than just a thumb on one side of the scale of the economic analysis, the Agencies have selected as the "preferred alternative" a weak option that fails to represent the "maximum feasible" approach, even though the small incremental costs manufacturers will incur in implementing it in fact are dwarfed by the economic impacts of delayed greenhouse gas emissions reductions, and even though the technology to do much better exists or is under development. This shortcoming is particularly harmful in the instant case because the underlying rulemaking will commence in 2017 and remain in effect through 2025, some 14 years from now. This time span includes and extends beyond the "critical decade" between 2010 and 2020, critical because the failure to actually reduce global warming during that period – rather than just slightly bend the ever upwards-trending curve of emissions – will make it exponentially more difficult and expensive to avoid catastrophic results.

* * * * *

The "preferred alternative" does not, however, constitute the maximum feasible average fuel economy level. Cars achieving and exceeding these fuel economy levels are already on the road *today*, such as the Toyota Prius and the Nissan Leaf. [Footnote omitted.] Accordingly, it strains credibility to assume that even 69 mpg by 2025 (the estimated average required fleet-wide fuel economy level at 7% annual increases examined in Alternative 4) constitutes the maximum feasible standard as a fleet-wide average *14 years from now*. Indeed, at least one study has found that a fleet-wide average of 60 mpg (representing approximately a 6% annual increase) can already be achieved based mostly on existing, off-the-shelf technologies, such as downsized turbocharged engines, electric power-train design, regenerative breaking, six-and seven-speed transmissions, high-strength lightweight materials, and enhanced aerodynamic designs. [Footnote omitted.]

The Agencies' preferred alternative of 49.6 mpg is also highly unlikely to constitute the maximum feasible fuel economy level because other countries will surpass that number (and in case of the EU, far surpass it) five years earlier, by 2020: by then, the EU will have achieved 64.8 mpg, Japan 55.1 mpg, and China 50.1 mpg. [Footnote omitted.]

[See original comment text for figure titled Historical fleet fuel economy performance and current or proposed standards.]

EPCA and Section 202 of the Clean Air Act are "technology-forcing" statutes designed to encourage technological innovation, not just the wider adoption of existing technologies. [Footnote 36: For example, at the time of passage, the Senate Commerce Committee remarked that "[t]he establishment of fuel economy standards for the next 10 years creates the necessary climate for investment in automotive technology leading to substantial energy conservation." (Citation omitted.)] As the court in *Center for Auto Safety v. Thomas* noted, "[t]he experience of a decade leaves little doubt that the congressional scheme in fact induced manufacturers to achieve major technological breakthroughs as they advanced towards the mandated goal." [Footnote omitted.] As explained by the court in *Kennecott Greens Creek Min. Co. v. Mine Safety and Health Admin.*, "when a statute is technology forcing, the agency can impose a standard which only the most technologically advanced plants in an industry have been able to achieve-even if only in some of their operations some of the time." [Footnote omitted.]. The Clean Air Act's legislative history indicates that the primary purpose of the Act was not "to be limited by what is or appears to be technologically or economically feasible," which may mean that "industries will be asked to do what seems impossible at the present time." [Footnote omitted.] To arrive at a technology-forcing alternative, NHTSA must therefore determine what will be "technologically feasible" in 2025 by taking into account *emerging* technologies, including those still in the research and development stage.

The "preferred alternative" does not represent the maximum feasible fuel economy because, with few exceptions, it relies on existing technologies and advances in those technologies, rather than emerging technologies and those that remain in the research stage. ("The list of technologies presented [for MY 2017-2025] is nearly identical to that presented in both the MY 2012-2016 final rule and the 2010 TAR . . ."). [Footnote omitted.] Moreover, even many existing technologies, such as hybrid technologies for trucks, are considered only by means of credits rather than by incorporating them in the stringency of the alternative. We will submit detailed comments on these issues in connection with the substantive rulemaking.

Docket Number: 9472 (EPA Rule Docket)
Commenter: Laurie Johnson, Natural Resources Defense Council

The 54.5 mpg standards are strong but stronger standards are feasible and cost-effective, especially under higher fuel prices predicted by the Energy Information Administration (EIA). To develop an economically feasible and cost-effective standard, the agencies used a projection of fuel prices from the EIA Annual Energy Outlook (AEO) 2011. Since the proposal, the EIA has published AEO 2012 Early Release Reference Case, which projects prices to be $0.24 -$0.34 per gallon higher than the AEO 2011 Reference Case during 2017 to 2035. The higher gasoline prices would increase the fuel-saving technologies that could be applied cost effectively and justify a higher standard.

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

The importance of achieving maximum feasible fuel efficiency, along with maximum feasible greenhouse gas reductions, in the 14 years between now and the end of 2025 cannot be overstated. As the Agencies themselves observe, "DOE has stated that vehicle efficiency has the greatest short-to mid-term impact on oil consumption." [Footnote omitted.] Further, "20% of total U.S. CO_2 emissions come from passenger cars and light trucks," a total that amounts to 4% of global emissions. [Footnote omitted.] But the CAFE rules issued by the Agencies over the years, and therefore their effect on reducing greenhouse gas emissions, has failed to make inroads on the problem: "Passenger cars and light trucks . . . account for more than half of U.S. transportation CO_2 emissions, and CO_2 emissions from these vehicles *have increased by 17 percent since 1990*." [Footnote omitted.] The alternative the Agencies prefer would continue to *increase* greenhouse gas emissions through 2025. The Agencies should, for the first time in their history, reverse this trend and promulgate a rulemaking that reduces rather than increases greenhouse gas emissions.

* * * * *

In enacting EPCA in 1975, shortly after the energy crisis of 1973, Congress observed that "[t]he fundamental reality is that this nation has entered a new era in which energy resources previously abundant, will remain in short supply retarding our economic growth and necessitating an alteration in our life's habitats and expectations." [Footnote omitted.] Among the goals of EPCA are to "'decrease dependence on foreign imports, enhance national security [and to] achieve the efficient utilization of scarce resources . . .'" [Footnote omitted.] The fundamental purpose of EPCA, however, is energy conservation. [Footnote omitted.]

In furtherance of the overarching goal of energy conservation, NHTSA must set fuel economy standards at "*the maximum feasible average fuel economy level* that the Secretary decides the manufacturers can achieve in that model year." [Footnote omitted.] The statute provides that "[w]hen deciding maximum feasible average fuel economy under this section, the Secretary . . . shall consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need for the United States to conserve energy." [Footnote omitted.] But the Agencies' discretion in balancing these factors is significantly limited. It *cannot* balance them in a manner that is contrary to fuel conservation: NHTSA "cannot set fuel economy standards that are contrary to Congress' purpose in enacting the EPCA – energy conservation." [Footnote omitted.] Further, NHTSA cannot give so much weight to any factor, including consumer choice or demand, that the goal of fuel conservation is undercut: "NHTSA may consider consumer demand, but 'it would clearly be impermissible for NHTSA to rely on consumer demand to such an extent that it ignored the overarching goal of fuel conservation.'" [Footnote omitted.] The Agencies also cannot act arbitrarily or capriciously; cannot advance conclusions unsupported by the evidence; if they conduct cost-benefit analyses, they may not assign values of zero to benefits that can be ascertained within a range; and they cannot bias their cost-benefit analysis. [Footnote omitted.]

* * * * *

The Agencies' discussion of the factors that must be considered in setting CAFE standards – and, more importantly, the manner in which the Agencies weigh them – must be corrected in a number of ways. While noting in passing that they cannot undermine energy conservation, the Agencies nonetheless list energy conservation merely as one among many factors to consider, failing to discern that it is the overriding purpose of the statutes. [Footnote omitted.] That energy conservation has been ignored or, at a minimum, arbitrarily relegated to secondary or tertiary importance, is evident from the following statement:

> "While the GHG emissions targets do become more stringent each year, the emissions *targets have been selected to allow compliance by vehicles of all sizes and with current levels of vehicle attributes such as utility, size, safety, and performance*. Accordingly, these proposed standards

are projected to allow consumers to choose from the same mix of vehicles that are currently in the marketplace." [Footnote omitted.]

In other words, the Agencies have selected standards that value purported consumer choice and the continued production of every vehicle in its current form over the need to conserve energy: as soon as increased fuel efficiency begins to affect any attribute of any existing vehicle, stringency increases cease. That is clearly impermissible and contrary to Congressional purpose. [Footnote omitted.] Given this outcome, it is not surprising that, as has been widely reported, the NPRM is the result of an "agreement" between the Agencies and the regulated industries – something that, at a minimum, taints the objectivity of the rulemaking process but instead is touted as an accomplishment. [Footnote omitted.] Protecting "the same mix of vehicles currently on the market" or the "current levels of vehicle attributes" is decidedly not the Agencies' task.

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

There is no doubt that EPCA is a technology-forcing statute. EPCA is meant to encourage technological innovation – meaning *new* technologies, not simply better versions of what exists today. As the court in *Center for Auto Safety v. Thomas* noted, "[t]he experience of a decade leaves little doubt that the congressional scheme in fact induced manufacturers to achieve major technological breakthroughs as they advanced towards the mandated goal." [Footnote omitted.] As explained by the court in *Kennecott Greens Creek Min. Co. v. Mine Safety and Health Admin.*, "when a statute is technology forcing, the agency can impose a standard which only the most technologically advanced plants in an industry have been able to achieve – even if only in some of their operations some of the time." [Footnote omitted.] With regard to a similar technology-forcing statute, the Clean Air Act, legislative history indicates that the primary purpose of the Act was not "to be limited by what is or appears to be technologically or economically feasible," which may mean that "industries will be asked to do what seems impossible at the present time." [Footnote omitted.]

Yet, instead of stressing that EPCA and EISA are technology forcing and intended to create technological innovation, the Agencies discuss "technological feasibility" by remarking that they are "not limited in determining the level of new standards to technology that is already being commercially applied at the time of the rulemaking." [Footnote omitted.] This formulation of the Agencies' duties entirely misconstrues Congressional intent. To be technology forcing, the Agencies *must not* limit themselves to technology already applied at the time of the rulemaking but instead must drive technological innovation. This mandate has become of utmost importance because the next ten years or so constitute a critical decade in which to avert the most dangerous consequences of climate change, and because the Agencies have chosen to set standards over a period spanning that entire decade and the following five years, an unprecedented time frame in the history of CAFE. Standards that are built solely on technologies already in use today or projected to be in use a few years from today, violate this mandate *per se*.

Response

NHTSA recognizes that Congress intended EPCA (and by extension, EISA, which amended EPCA) to be technology forcing. However, it is important to distinguish between setting "maximum feasible"

standards, as EPCA/EISA requires, and standards based in part "on the use of every single technology option presently available," presumably in every vehicle, as a commenter suggests. The agency must weigh all of the statutory factors in setting fuel economy standards, and therefore may not weigh one statutory factor in isolation. Neither EPCA nor EISA define "maximum feasible" in the context of setting fuel economy standards. When setting "maximum feasible" fuel economy standards, the Secretary is required to "consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." 49 U.S.C. § 32902(f). NHTSA has carefully balanced the statutory factors to derive a range of alternatives analyzed in this EIS. It is within the agency's discretion to weigh and balance the factors laid out in 32902(f) in a way that is technology forcing, as evidenced by the alternatives analyzed in this EIS, but that stops short of requiring the application of all available technology or technology not yet in existence, as some commenters suggested.

A commenter suggests that NHTSA's alternatives do not reflect technological feasibility because certain individual vehicle models currently on the road surpass the average fuel economy standards of each of the alternatives. CAFE standards are not measured by the performance of a single vehicle in a manufacturer's fleet. Rather, they are measured as the production-weighted average of the manufacturer's fleet-wide fuel economy. As explained in the NPRM, CAFE standards for each manufacturer are a function of their product mix.

The commenter also suggests that NHTSA's Preferred Alternative is not the maximum feasible because other countries currently have higher fuel economy standards in place than those considered in the Draft EIS for the model years covered by this rulemaking. NHTSA does not believe such a comparison is helpful for the decisionmaker. Setting aside statutory and regulatory differences between these nations (including in standards setting, compliance testing, and the availability of credits or flexibilities), this argument ignores the fact that the United States does not have the same fleet profile – including the distribution of various vehicle footprints – as other countries, and that average fuel economy is strongly dependent on fleet profile. EPCA requires NHTSA to set maximum feasible CAFE standards for passenger cars and light trucks produced for sale in the United States, not to set standards that require manufacturers to replicate the fleet profiles of other countries. NHTSA's determination of maximum feasibility must be applied within the context of the fleet of vehicles to be regulated, which is the projected U.S. fleet.

For a discussion of the alternatives, *see* Chapter 2 of this Final EIS. For more explanation of NHTSA's balancing of the statutory factors, including the agency's consideration of technological feasibility and economic practicability, *see* Section IV.F.2 of the NPRM. In addition, *see* Section V.G.4 of the NPRM for a discussion of the costs and benefits of the proposed standards. NHTSA believes that requiring increased technology penetration beyond what the agency has modeled in the alternatives presented would exceed maximum feasibility.

9.2.2.4 Comparison of Alternatives and Context of Analysis

Comments

Docket Number: 0775 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

We are pleased that the Agencies in a recent EIS included a graph comparing their alternatives to President Obama's Copenhagen pledge of reducing US emissions to 17% below 2005 emissions by 2020. That graph demonstrated the failure of the 2012-2016 CAFE and greenhouse gas rules to reach even that inadequate goal in stark, easily communicable terms. However, the Agencies must also show the impact of their proposed alternatives when measured against the benchmark that actually seeks to avoid catastrophic damage (that is, holding temperature increases below 2 °C). We believe the effects of the Agencies' choices cannot be brought into sharp focus, as the law requires, without this analysis.

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund
In analyzing the proposed alternatives, EDF requests that NHTSA conduct a thorough and transparent analysis that estimates the full suite of benefits, both monetized and non-monetized, associated with the fuel consumption reduction of each alternative. We also ask the Agency to include in the EIS the quantitative value of each economic assumption used in estimating the benefits of each alternative.

* * * * *

The cost/benefit analyses conducted for the EIS must be transparent and thorough to fully reflect the true benefits of each alternative. Because benefits are especially sensitive to economic inputs, it is important for the Agency to conduct a full suite of sensitivity analyses and fully consider their results when choosing a preferred alternative. Indeed, the Agency concluded about the sensitivity analyses presented in the Preliminary Regulatory Impact Analysis (PRIA) that, "The category most affected by variations in the economic parameters considered in these sensitivity analyses is net benefits." (Citation omitted.)

* * * * *

EDF recommends, where feasible, the Agency must estimate the monetized health and environmental benefits of each alternative.

We also recommend that where monetization is not feasible, the Agency must present a qualitative list of benefits and explain why it is not feasible to monetize such benefits. This recommendation is in accordance with a January 2011 Presidential Executive Order [footnote omitted]: "It must take into account benefits and costs, both quantitative and qualitative." "(c) In applying these principles, each agency is directed to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible. Where appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts."

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

The DEIS must permit the environmental impact of the forthcoming rulemaking to be seen in meaningful context and put into sharp focus. The DEIS, however, fails to depict the alternatives it discusses in a manner that allows decision makers to focus on the impact each alternative has on holding global temperatures below 2 °C. The DEIS' failure to evaluate the actions under consideration in this context is compounded by its lack of an adequate cost-benefit analysis.

* * * * *

We appreciate that the Agencies have included a discussion and graph in this DEIS comparing their alternatives to President Obama's Copenhagen pledge of reducing US emissions to 17% below 2005 levels by 2020. [Footnote omitted.] The graph and discussion demonstrate the failure of the 2017-2025 CAFE and greenhouse gas rules to reach even this inadequate goal in easily understood terms: "[T]otal CO_2 emissions from the U.S. passenger car and light tuck sector in 2020 would decrease in the range of 6.7 to . . . 10.2 percent below 2005 levels . . . [but] these reductions in emissions are not sufficient by themselves to reduce total passenger car and light truck missions to the goal of 17 percent below their 2005 levels by 2020." The DEIS' text and graph also show clearly that Alterative 4 – 7% annual stringency increases – will come closest to reaching the stated goal. We also appreciate the DEIS' new section showing the cumulative impact of the alternatives on overall U.S. emissions from all sources because it begins to bring the action's real consequences into focus. [Footnote omitted.] Now, the Agencies must also show the impact of their proposed alternatives when measured against what the U.S. and the vast majority of other nations, in the context of the UNFCCC negotiations, have acknowledged must be achieved - holding temperature increases below 2 °C. In light of the fact that the Agencies were able to accomplish a precise analysis of the effects the alternatives have in reaching the President's Copenhagen pledge, they can clearly complete the same analysis in relation to reaching the overall temperature goal. We believe the effects of the Agencies' choices cannot be brought into sharp focus, as the law requires, without it.

Response

The environmental analysis presented in this EIS is consistent with the requirements of CEQ NEPA implementing regulations. This EIS informs decisionmakers and the public of a range of reasonable alternatives and the environmental impacts associated with each alternative. Under NEPA, agencies are required to examine reasonable alternatives, and not those that are a "worst case scenario." ***Robertson v. Methow Valley Citizens Council*****, 490 U.S. 332, 354-55 (1989). An agency is not required to consider alternatives "whose effect cannot be reasonably ascertained, and whose implementation is deemed remote and speculative."** ***Headwaters, Inc. v. Bureau of Land Mgmt., Medford Dist*****, 914 F.2d 1174, 1180 (9th Cir. 1990) (quoting** ***Life of the Land v. Brinegar*****, 485 F.2d 460 (9th Cir. 1973), cert. denied, 416 U.S. 961 (1974)). CEQ guidance on this point is similar. "Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant." Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027 (Mar. 23, 1981). NHTSA sought to balance EPCA's statutory factors in articulating the range of alternatives analyzed in this EIS.**

Environmental benefits are one consideration in the development of reasonable alternatives analyzed in this EIS. While each of the action alternatives would avert significant GHG emissions compared to the No Action Alternative, NEPA does not require that NHTSA develop alternatives designed to achieve specific GHG reduction targets. The "rule of reason" guides the choice of alternatives and the extent to which the EIS must discuss each alternative. *See*, *e.g.*, *City of Carmel-by-the-Sea v. U.S. Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997). *See also American Rivers v. FERC*, 201 F.3d 1186, 1200 (9th Cir. 2000) (quoting *City of Carmel*-by-the-Sea, 123 F.3d at 1155). Under the rule of reason, an agency "need not consider an infinite range of alternatives, only reasonable or feasible ones." *Id.* (citing 40 CFR § 1502.14(a)-(c)).

NHTSA recognizes the White House goal of reducing U.S. GHG emissions in the range of 17 percent below 2005 levels by 2020, and has included a brief discussion of the magnitude of CO_2 emission reductions under the Proposed Action in terms of the relative contributions of passenger cars and light trucks toward this goal. NHTSA believes that comparing the differences among alternatives against the transportation sector's contribution to a near-term goal for 2020 provides a more meaningful context for this rulemaking than comparisons against longer-term goals (e.g., 2 °C [3.6 °F]). The goal of a 17 percent reduction below 2005 levels by 2020 is an estimate of the reductions that could be achieved with existing technologies, and assumes continued widespread use of fossil fuels. One commenter suggests NHTSA use the goal of reducing emissions such that temperature rise is maintained below 2 °C. The emission reductions necessary to achieve the climate target of mitigating temperature increase to 2 °C could not be achieved solely with drastic reductions in emissions from the U.S. vehicle fleet, but would also require drastic reductions in all U.S. sectors and from the rest of the developed and developing world. Given that population and VMT are likely to increase by 2050, an 80 percent emission reduction for the U.S. passenger car and light-truck fleet would require substantial increases in technology innovation and adoption compared to today's levels and would require an economy and vehicle fleet that has largely moved away from the use of fossil fuels. Under EPCA/EISA, NHTSA must account for technological feasibility and economic practicability when setting CAFE standards. Therefore, NHTSA does not believe this provides a valuable context for evaluating alternatives.

Furthermore, NHTSA has used its judgment to define reasonable alternatives within the requirements of EPCA and NEPA. GHG emissions mitigation is but one dimension in the multi-dimensional balancing act involved in this decision to develop reasonable alternatives. NHTSA is not bound by NEPA to develop alternatives that are predetermined to achieve select policy objectives for GHG reductions. That said, emission reductions under the Preferred Alternative are significant compared to many other actions being considered in other sectors.

9.2.2.4.1 Baselines

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

We also note an additional error in the Agencies' cumulative analysis. Although the Agencies have developed a new "Alternative B" to the "no action" alternative that assumes a small level of fuel efficiency improvement driven solely by market forces, they continue to assume that after 2025, there will be no new regulations that increase fuel efficiency or decrease greenhouse gas emissions.

[Footnote omitted.] (We also note that Alternative B itself suggests a much lower fuel efficiency increase driven solely by market forces than actual experience demonstrates occurs. A University of Michigan study found an average annual increase of 4.2% in an environment of low regulatory pressures. [Footnote omitted.]) The Agencies fail to justify this assumption. In light of the fact that EPCA, EISA, and the Clean Air Act require ongoing rulemaking to increase fuel efficiency and decrease greenhouse gas emissions, that assumption is arbitrary and capricious. The failure to assume continuing regulations requiring increasingly stringent standards also improperly affects the cumulative impact analysis of this rulemaking itself, diminishing its apparent impact. We urge the Agencies to change this erroneous approach.

Docket Number: 9472 (EPA Rule Docket)
Commenter: Laurie Johnson, Natural Resources Defense Council

NHTSA's baseline sensitivities based on voluntary overcompliance should be excluded from the final rule.

* * * * *

NRDC supports the baseline forecast for MY 2017 and beyond that assumes manufacturers meet but do not exceed the MY 2016 standards. Voluntary overcompliance—in which manufacturers apply efficiency technology in excess of what is needed to meet the MY 2016 standard-is possible but too uncertain to be incorporated in a baseline projection. Rapidly rising fuel prices are potentially a reason for overcompliance but during periods of only modest average annual price increases, overcompliance was not widespread. In the 1990's and early 2000's, real motor gasoline prices rose at an average rate of 4 percent per year [footnote omitted] yet full-line manufacturers, such as the GM, Ford and Chrysler, applied just enough technology to meet the standards. [Footnote omitted.] From 2017 to 2035, EIA projects motor gasoline prices that increase at a lower rate of about 1 percent per year. [Footnote omitted.] With the projected low rate of annual price growth, the modification of the 2016 baseline is unjustified.

Further, NRDC disagrees with NHTSA that a sensitivity analysis of voluntary overcompliance is warranted, and we recommend that it be excluded from the final rule. The voluntary overcompliance analysis is counter-productive to the goals of maximizing petroleum reductions as required by EPCA.

If, in future rulemakings, the baseline was altered to account for voluntary overcompliance—assuming it can be reasonably justified as highly likely—NHTSA would be inclined to set a lower standard than what could be achieved with appropriate cost-effective technology application. The achievement of overcompliance assumes that low-cost efficiency technologies are applied by manufacturers first (NHTSA assumes a 1-year payback). The remaining technologies to be driven by the standard would therefore be more expensive, increasing the costs associated with the standards. The standards themselves would also be associated with lower benefits because the savings from lower-cost technologies would be assigned to the market instead of the standard. The resulting reduced benefit-to-cost ratio would be a dampening force on efforts to maximize fuel efficient technology adoption and could push down the standard stringency.

If, during this scenario of a weaker standard, automakers did not overcomply, U.S. petroleum consumption would be higher and counter to the mandate of EPCA. To avoid this situation, NHTSA and EPA should continue to use a baseline that assumes automakers do not overcomply. This ensures that standards are set as strong as possible, and it provides greater certainty that needed oil consumption and GHG emission reductions will be achieved.

Docket Number: 9519 (EPA Rule Docket)
Commenter: Hilary Sinnamon, Environmental Defense Fund

EDF supports EPA's proposal to assume the reference case fleet in MY 2017–2025 would have fleet wide GHG emissions performance no better than that projected to be necessary to meet the MY 2016 standards. Because EPA is using AEO 2011 fuel price forecasts, which project relatively stable fuel prices over the next 15 years, it is reasonable to assume that manufacturers will not overcomply with the 2016 standards and/or consumers will not demand fuel economy greater than the 2016 standard. It is also reasonable to assume that fleetwide overcompliance will not occur because any voluntary over-compliance by one company would generate credits that could be sold to other companies to substitute for their more expensive compliance technologies. Therefore, the ability to buy and sell credits would eliminate any over-compliance for the overall fleet.

Docket Number: 9528 (EPA Rule Docket)
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

The agencies' baseline scenario assumes that fuel economy remains at 2016 levels absent the proposed new standards. However, NHTSA also "examines the impact of an alternative 'market-driven' baseline, which allows for some increases in fuel economy due to 'voluntary overcompliance' beyond the MY 2016 levels" (citation omitted). NHTSA requests comment on this alternative baseline.

There is little historical basis for a scenario in which there is a sustained increase in fuel economy in the absence of increases in standards. Public interest in fuel economy does shift with fuel prices, but even that interest typically has followed from large, rapid changes in price and has been short-lived. The fuel prices on which the various agency analyses are largely based are EIA projections and do not contain dramatic increases in price. Under these conditions, manufacturers not constrained by fuel economy standards historically have employed technological advances to increase vehicle power and acceleration, rather than to improve fuel economy.

Incorrect specification of the baseline scenario will lead to an incorrect valuation of the proposed standards. An alternative baseline such as the one considered by NHTSA will reduce manufacturers' costs to meet the standards, because some of the added technology required to meet the standard will already appear in the baseline. At the same time, the benefits attributable to the standards will decline. The net effect is a reduction in the cost-effectiveness of the standards, because the most cost-effective technologies are the ones that will appear in the alternative baseline scenario, leaving the more expensive technologies for the rule to bring into the market.

The same issue arises from EIA's AEO 2012 Early Release (EIA 2012), which projects an increase in new vehicle fuel economy after 2016 without adoption of the proposed rule, and without major increases in fuel prices. Roughly one-quarter of the reduction in new vehicles' fuel consumption that would result from the proposed standards appears in the AEO 2012 Reference Case. Hence it is all the more important that NHTSA clarify that the baseline scenario used in the NPRM should be the basis for evaluating the benefits of the final rule.

* * * * *

Recommendations

- Clarify that the baseline scenario used to evaluate the benefits of the rule will not assume "voluntary over-compliance" by manufacturers after 2016.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

While the polling and recent study of Gen Y consumers supports consumer interest in fuel efficiency and willingness to pay for the technologies that will reduce oil consumption and emissions, the auto industry has, historically allowed new vehicle fuel consumption to stagnate absent rising standards. This conclusion is supported by the recent study, Automobiles on Steriods which concludes that between 1980 and 2006 (a period that includes increases due to the original CAFE program) average gas mileage increased 15% and application of technologies that could have significantly reduced fuel consumption went to support increased vehicle weight and acceleration. [Footnote omitted.]

* * * * *

Use a flat baseline in assessing post 2016 fuel efficiency: NHTSA is taking comment on the notion that the post-2016 baseline for vehicle standards should assume "market driven" improvements in fuel economy absent standards and account for those improvements in the baseline. [Footnote omitted.] The Knittel study, referenced above, in addition to the historic trend are evidence that absent standards automakers will not increase gas mileage. Leading up to 2008, automakers were not prepared for increasing fuel prices and shifting consumer preferences. The consequences to the auto industry and the economy were devastating.

NHTSA's consideration that new vehicle labels that will provide consumers with more detailed information on mileage and savings and that this will influence consumer choices [footnote omitted] is insufficient basis for using a baseline that presumes automakers will apply technologies to meaningfully improve gas mileage beyond 2016 absent strong final 2017-2025 standards. While some automakers may voluntarily "over-comply" with the 2012-16 program due to market forces, overcompliance in one segment of a fleet (cars for example) could be used to offset lower mileage vehicles such as larger pickups and SUVs. In addition, because the compliance with the program allows for banking, trading and carry-forward and backward credits, any presumption that automakers will improve fuel economy after 2016 could be part of a compliance strategy that includes the 2012-16 model years or planned compliance with these proposed standards. [Footnote omitted.] Over-compliance across the entire fleet heading into the mid-term review included in the NPRM would support strengthening the overall program. The agencies should use a flat baseline beyond 2016. [Footnote omitted.]

Docket Number: 0258 (NHTSA Rule Docket)
Commenter: International Council on Clean Transportation

There is a difference between how EPA and NHTSA handled the modeled Reference Fleet Scenario. EPA projects that in the absence of the proposed GHG and CAFE standards, the reference case fleet in MY 2017-2025 would have fleetwide GHG emissions performance no better than that projected to be necessary to meet the MY 2016 standards. [Footnote omitted.]

While NHTSA used the same baseline assumptions for their primary analyses, they also conducted a sensitivity analysis with an alternative baseline, which assumed that fuel economy would continue to increase after 2016 without regulation. [Footnote omitted.] NHTSA stated:

"The assumption is that the market would drive manufacturers to put technologies into their vehicles that they believe consumers would value and be willing to pay for."

Again, while sensitivity analyses can illuminate the impacts of important uncertainties, there is little or no evidence supporting this particular case. Except during the oil crisis in the 1970s and a brief period for passenger cars in the late 2010s, the market has never driven improvements in vehicle fuel economy. Even these two examples are not relevant to the current situation. The demand for higher fuel economy in the 1970s was driven primarily by fears of oil unavailability and ongoing future increases in fuel price. The modest increase in passenger cars in the late 2010s followed 20 years of unchanging CAFE standards. Thus, NHTSA's sensitivity analysis inappropriately calculates a lower estimate of net benefits of the rule.

The proposed 2017-25 standards follow aggressive increases in standards from 2011 through 2016. Further, the change to a footprint-based standard means that all manufacturers must increase the efficiency of their vehicles to comply, even manufacturers of primarily smaller vehicles. Thus, the 2012-16 standards have already driven the market beyond the level of efficiency it would have demanded in the absence of standards.

The reason why efficiency standards are effective and needed is consumer discounting of uncertain, future fuel savings, as explained above. Efficiency standards move the market from the level of efficiency demanded by loss averse consumers to the level of efficiency desired by society. It will be many years after 2016 before additional technology development and lower cost will finally fall to the level demanded by consumers from the higher level demanded by society through efficiency standards. The historical precedent is that it took 20 years of unchanging CAFE standards combined with high real and nominal fuel prices before the market started to demand additional fuel economy for passenger cars in the late 2000s.

ICCT recommends that the sensitivity analysis for market-driven increases in efficiency after 2016 be removed from the Final Rule.

Response

In its cumulative impacts analysis, NHTSA assumes continuing improvements in the average fuel economy level of light-duty vehicles, but does not explicitly quantify benefits related to potential new fuel economy or GHG regulations for light-duty vehicles after MY 2025. EPCA/EISA do not, in fact, "require ongoing rulemaking to increase fuel efficiency" as the commenter states; rather, they require

NHTSA to set "maximum feasible" standards based on the four statutory factors discussed in Chapter 1 and in comment responses above. Due to considerable uncertainties related to technological feasibility, economic practicability, and the future new vehicle fleet, NHTSA cannot currently predict environmental impacts related to uncertain future regulations. Such impacts would not be reasonably foreseeable, nor could they be accurately quantified.

Several commenters discuss the appropriateness of including a voluntary overcompliance analysis in the EIS. NHTSA recognizes the uncertainty inherent in forecasting whether and to what extent the average fuel economy level of light-duty vehicles will continue to increase beyond the level necessary to meet regulatory standards. However, because market forces could independently result in changes to the future light-duty vehicle fleet even in the absence of agency action, to the extent they can be estimated, those changes should be incorporated into the baseline. As a result, this Final EIS continues to present environmental impacts in terms of two sets of analyses: Analyses A1 and A2 assume that the average fleetwide fuel economy for light-duty vehicles will not exceed the minimum level necessary to comply with CAFE standards, while Analyses B1 and B2 assume continued improvement in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles. Section 2.2 of this Final EIS describes NHTSA's assumptions for these analyses more fully. Analyses C1 and C2 also take these assumptions into account to determine impacts related to past, present, and reasonably foreseeable future actions, as described in Section 2.5 of this Final EIS.

From a market-driven perspective, there is considerable historical evidence that manufacturers have an economic incentive to improve the fuel economy of their fleets beyond the level of the CAFE standards when they are able to do so. Although there was an historical period of stagnation in average fuel economy starting in the 1990s, when manufacturers allocated efficiency improvements to weight and power, it was accompanied by a prolonged period of historically low gasoline prices, where real prices remained below $1.50 per gallon for nearly 15 years. Even during that period, passenger car fuel economy exceeded CAFE standards every year and light-truck fuel economy exceeded standards in most years. This trend supports the proposition that consumers have historically recognized the benefits that accrue from operating vehicles with greater fuel efficiency even in an environment of low fuel prices.

In recent years, overcompliance with standards has increased, likely in response to higher fuel prices, with the market shifting toward more fuel-efficient models and toward passenger cars rather than trucks, even in the absence of regulatory pressure. This suggests that, at the fuel prices that have been prevalent in recent years, consumers are placing a greater value on fuel economy than the longer term historical average. Consumers appear to be recognizing the value of purchases based not only on initial costs but also on the total cost of owning and operating a vehicle over its lifetime. *See* Section 2.2.6, showing that the fuel economy of the combined car and light-truck fleet has increased since 2005, with the largest increase in 2009. NHTSA also expects the new fuel economy labels will increase awareness of the consumer savings that result from purchasing a vehicle with higher fuel economy and will impact consumer demand for more fuel-efficient vehicles. NHTSA discusses how consumers value fuel savings beginning on page 598 of the Preliminary Regulatory Impact Analysis (Preliminary RIA).

Consumer demand for fuel-efficient vehicles is expected to continue in the future. Increasing uncertainty about future fuel prices and growing concern for the energy security and environmental impacts of petroleum use are likely to have an increasing impact on the vehicle market. In response, a

number of manufacturers have announced plans to introduce technology beyond what is necessary to meet the MY 2016 standards. This evidence aligns with the AEO 2012 Early Release, which shows continued fuel economy improvements in the Reference Case through 2035 in the absence of the MY 2017–2025 standards.

As a result of these considerations and comments received both during the scoping process and to previous NHTSA EISs, the agency believes it is appropriate to provide analyses assuming the average fuel economy level of light-duty vehicles will continue to increase beyond the level necessary to meet regulatory standards. More discussion of the agency's rationale appears on pages 768 and 769 of the Peliminary RIA.

9.2.3 Volpe Model

9.2.3.1 Upstream Emissions

Comments

Docket Number: 0775 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

The Agencies requested input on how upstream emissions from electric vehicles and other environmental impacts of batteries should be addressed. The Center believes it is crucial to consider upstream emissions from all vehicles¸ including electric and hybrid vehicles. Thus, while upstream emissions from such vehicles, including their batteries, should be accounted for, upstream emissions of petroleum production and transport must similarly be counted toward the emissions from traditionally powered vehicles. [Footnote omitted.] Similarly, the lifecycle CO_2 emissions of biofuels or other non-conventional fuels must be factored in.

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

The tailpipe emissions of EVs (and PHEVs operating in an all-electric mode) are 0.0 g/mile, for both GHG emissions and criteria pollutant emissions. For purposes of compliance with vehicle emissions or fuel economy standards, any assessment of emissions should be confined to tailpipe emissions (consistent with past EPA practice under CAA Title II) and should not include upstream emissions related to generating the electricity that powers EVs. While compliance should be based on tailpipe emissions, it may be appropriate to assess vehicle emissions more broadly in an EIS, consistent with the goals of NEPA. If NHTSA chooses to address upstream emissions, the Administration should look at increases and decreases of all emissions, including both GHGs and criteria pollutants.

Docket Number: 2078
Commenter: Kenneth Brown, Minnesota Department of Commerce, Division of Energy Resources

- The proposed rule, in effect, selects one technology pathway – vehicles powered by electric motors – as the national powertrain. 1) Due to difficulty anticipated for certifying use of renewable fuels in vehicles under anticipated new Tier III vehicle emission regulations; and 2) the elimination of vehicle use credits until renewable fuel use is increased by RFS2; 3) the opportunity to use renewable fuels as a means to reduce greenhouse gas emissions and reduce consumption of oil may be effectively eliminated.

- The proposed rule provides Electric vehicles (EVs) with preferential treatment compared with conventional or alternative fuel vehicles by means of a “credit” mechanism. The “credit” system proposed in the rule does not use life cycle assessment (LCA) methods commonly used for evaluating greenhouse gas emissions. Absent use of LCA, the proposed rule grants EVs zero greenhouse gas emissions even though U.S. DOE National Energy Technology Laboratory (NETL) studies show that electricity produced from fossil fuel may result in higher LCA vehicle emissions per mile than produced from gasoline (E10) hybrid electric vehicles.

Electric motors have no GHG emissions at point of use. A federal rule that only includes “tail pipe” – rather than life cycle emissions – effectively requires electric vehicles for the U.S. market. Rather than mandating a technology, the rule should motivate all propulsion and fuel technologies to compete to provide diverse, technical and economically optimal solutions for the *Greenhouse Gas Emissions and Corporate Average Fuel Economy Standard.*

Recommendations:

- Use LCA methodology for evaluating greenhouse gas emissions.

Docket Number: 9482 (EPA Rule Docket)
Commenter: Robert Elliot, National Propane Gas Association

We also urge you to evaluate energy efficiency and GHG emission using FFC analysis thereby providing a complete and robust energy consumption and GHG emissions profile for all light-duty vehicles. Limiting emissions analysis to point-of-use metrics (tailgate emissions) ignores the fact that most energy losses associated with non-gaseous fuels, e.g. electricity, occur upstream and ignore greenhouse gas emissions. NPGA urges the EPA/NHTSA to account for upstream production and distribution emissions by applying readily available and scientifically accepted modeling technologies such as GREET and SEEAT.

Response

NHTSA’s EIS considers the environmental benefits of increased electric vehicle (EV) deployment as a result of these regulations and the resulting modernization of the generating fleet. The model used for the EIS analysis was the CAFE Compliance and Effects Modeling System developed by the Volpe National Transportation Systems Center and commonly referred to as “the Volpe model.” The model enables NHTSA to efficiently, systematically, and reproducibly evaluate many regulatory options. The modeling analyzed 16 scenarios – 4 different annual improvement requirements (percent GHG and fuel consumption reduction required in each year), times 2 separate baseline fleets (2008 based and 2010 based), times 2 cases involving voluntary overcompliance (1 without, 1 with). Under the 2008 baseline fleet, EV penetration would increase from 29,000 units under the No Action Alternative to between 40,000 and 306,000 vehicles in the U.S. fleet in 2020 (depending on the annual average rate of fuel-economy improvement required). Under the 2010 baseline fleet, EV penetration remains at zero in 2020 under the No Action Alternative, Preferred Alternative, and Alternative 2 (which assumes

2 percent annual increases in fuel economy), while increasing to between 194,000 to 222,000 under Alternative 4 (which assumes 7 percent annual increases in fuel economy). The resulting change in life-cycle criteria pollutant, air toxic, and GHG emissions from the introduction of these cleaner vehicles has been estimated in the modeling and reported in the results the Final EIS results.

The Volpe model does not provide a forecast of future technology penetration into the vehicle fleet, but evaluates different potential compliance paths manufacturers could take to meet the CAFE requirements. In general, the model chooses lowest cost technologies first and then more expensive technologies if needed to meet the standards. Because EVs are among the more expensive technology options manufacturers could use to comply with the standards, the Volpe model typically chooses other technologies before selecting EVs in compliance scenarios.

The results presented in this EIS account for upstream emissions related to electricity generation and upstream emissions related to the production and transport of petroleum. In response to the comment that NHTSA should account for upstream emissions from all vehicles, NHTSA notes that the EIS includes upstream emissions estimates for conventional gasoline, federal reformulated gasoline, California reformulated gasoline, ethanol-85, conventional diesel, low-sulfur diesel, electricity, and hydrogen. The modeling of upstream emissions for electrical grid generation for EV charging presented in this EIS includes all GHG and criteria pollutants. The pollutants modeled are CO_2, carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur oxides (SO_x), fine particulate matter ($PM_{2.5}$), acetaldehyde,* acrolein,* benzene,* 1,3-butadiene,* formaldehyde,* methane, diesel PM_{10}*** and nitrous oxide***.[2] The Volpe modeling for this analysis assesses the impact of multipliers and upstream emissions resulting from electricity generation to power EVs.**

To estimate upstream emissions, the analysis uses Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (1 2011 version developed by the U.S. Department of Energy [DOE] Argonne National Laboratory). To project the U.S. average electricity generating fuel mix for the reference year 2020, the analysis uses the National Energy Modeling System (NEMS) AEO 2012 Early Release version, an energy-economy modeling system from the Department of Energy. As described in response to comments below, NHTSA also modeled a scenario that accounted for the potential impacts of a cleaner future electrical grid.

Comments

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

Increased deployment of PEVs will increase fuel efficiency and reduce dependence on imported petroleum, consistent with the goals of EISA. Increased PEV deployment also will reduce emissions of GHGs and criteria pollutants from the transportation sector. These environmental benefits will be compounded by the continued reductions in upstream emissions of both GHGs and criteria pollutants related to the generation of the electricity that will fuel PEVs.

[2] *Not applicable to conventional diesel, ethanol-85, electricity, and hydrogen fuel types. **Not applicable to ethanol-85 and hydrogen fuel types. ****Not applicable to ethanol-85, electricity, and hydrogen fuel types. Note: Methyl tertiary butyl ether emissions were examined, but were zero for all fuel cases.

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute

NHTSA states that, unless otherwise noted, projections of energy consumption and supply are based on the 2011 Energy Information Administration (EIA) International Energy Outlook and 2011 EIA Annual Energy Outlook Reference Cases. (Citation omitted.) Reliance on these reference cases, which only consider rules and regulations in force in 2011, is inappropriate for a regulatory action that does not take effect until model year 2017 and covers a time period well over a decade into the future. This is particularly true when assessing the U.S. electric generating fleet. For many reasons, the U.S. electric generating fleet in MY 2017-2025 will be significantly cleaner than the fleet of 2011. NHTSA's Draft EIS must consider the environmental benefits of increased EV deployment as a result of these regulations and the resulting modernization of the generating fleet. These regulations and regulatory responses include:

- Regulation of GHG emissions from new sources and the existing fleet under two separate CAA programs: new source performance standards (NSPS) and the new source review/prevention of significant deterioration (PSD) pre-construction permitting program.
- Increased deployment of highly-efficient natural gas combined cycle units to provide additional generating capacity and replace retired coal units.
- Increased deployment of renewable generation to comply with state renewable portfolio standard or renewable electricity standard requirements.

As a whole, these regulations and regulatory responses – many of which will take effect well before the proposed vehicle standards are in effect – will serve to reduce significantly both criteria air pollutant and GHG emissions related to electricity generation. Given the fact that the proposed vehicle standards do not take effect until more than five years after NHTSA undertook this analysis, the Draft EIS must take into consideration the fact that the current regulatory regime does not provide an appropriate baseline for assessing any upstream emissions related to increased EV deployment. The Draft EIS must recognize and take into account these regulations and their effect on emissions from electricity generation during the period covered by the MY 2017 and later vehicle standards.

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

These trends towards increasingly clean generation are evident in the recent projections from Energy Information Administration (EIA) in its Annual Energy Outlook 2011. In EIA's Reference Case, average emissions intensity, per unit of electricity generated, for the U.S. electric power sector is projected to fall between 2010 and 2020 by 40.4 percent for sulfur dioxide, 26.5 percent for nitrous oxide, 36.9 percent for mercury, and 7.9 percent for carbon dioxide. [Footnote omitted.] And, because EIA's Reference Case generally assumes that current laws and regulations remain unchanged throughout the projections, these calculated improvements would likely be greater should additional proposals become enacted. NHTSA's EIS must consider the environmental benefits of increased PEV deployment as a result of these regulations and the resulting modernization of the generating fleet.

Docket Number: 9584 (EPA Rule Docket)
Commenter: Emily Fisher, Edison Electric Institute

And because EIA's Reference Case generally assumes that current laws and regulations remain unchanged throughout the projections, these calculated improvements would likely be greater if EIA took into consideration all of the air quality rules that have been finalized in recent years and are expected to be finalized in the next several years, as well as clean energy technology improvements and cost reduction.

EPA also states that it is appropriate to consider upstream EV emissions because currently there is no national, comprehensive program addressing GHG emissions from the electric sector. (Citation omitted.) EPA's focus on the existence of a "current" national regulatory program addressing GHGs related to electricity production and distribution is not appropriate in the context of vehicle rules covering MY 2017-2025. But, there are no comprehensive GHG emissions control programs for any fuel sector today.

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

If NHTSA chooses to address upstream emissions related to electricity generation in the EIS, the Administration should look at increases and decreases of all emissions, including both GHGs and criteria pollutants. Moreover, this assessment must be "full and fair," as required by NEPA. At minimum, a "full and fair" analysis of the environmental impacts of increased EV deployment should use the most recent data on projected increases or decreases in electricity demand from all end uses, the expected future makeup of the electric generating fleet, and regional electricity generation information. The analysis also should adopt a fuel-neutral policy that requires that the same type of analysis be performed for all vehicle types and fuels.

To ensure a full and fair EIS, NHTSA must consider the benefits of increased PEV deployment in reducing criteria pollutant emissions from the transportation sector. EPRI and NRDC assessed the air quality impacts of increased PHEV deployment through 2050 in a 2007 report. This report, which was based on 2006 data, concluded that PHEV deployment would result in small but significant improvements in ambient air quality and reductions in the deposition of various pollutants, such as acids and mercury. *See* Electric Power Research Institute (EPRI) and Natural Resources Defense Council (NRDC), *Environmental Assessment of Plug-in Hybrid Vehicles, Vol. 2: United States Air Quality Analysis* (July 2007). [Footnote omitted.]

In the MY 2017-2025 timeframe, the air quality standards applicable to EGUs will be significantly more stringent than they were in 2006, in particular because of the first-ever federal mercury and hazardous pollutant emissions regulations, which will be applicable to all EGUs, new and existing, starting in early 2015. [Footnote 4: (Citation omitted.) Under the terms of the settlement agreement, EPA is required to issue a final rule on November 16, 2011, which would likely result in an effective date sometime in January 2012. EPA also is set to tighten other air quality standards affecting EGUs before 2017, including those regulating sulfur dioxide, nitrogen oxides, particulate matter and ozone emissions.]. As a consequence, it is likely that there will be greater air quality benefits to increased deployment of PEVs going forward. The EIS must include air quality benefits related to increased PEV deployment. In this required discussion of the air quality benefits related to EVs, NHTSA should take into consideration the different emissions patterns between cars and the plants that generate electricity. For example, emissions from electricity are better controlled than those from vehicles because power plants are required to be in near continuous compliance with pollutant emissions limits, whereas vehicles typically only have to pass emissions standards annually or every other year. In 2010, NHTSA and the Environmental EPA issued a joint final rule establishing CAFE and GHG standards for passenger cars and light trucks for MY 2012-2016. [Citation omitted.] [Footnote 5: NHTSA and EPA intend to issue a second joint rule establishing CAFE and GHG standards for MY 2017-2025. (Citation omitted.)].

NHTSA did not address upstream GHG emissions in the Final EIS for the MY 2012-2016 CAFE standards, but the Environmental Protection Agency (EPA or Agency) did consider them in setting GHG emissions standards under the CAA.

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[E]lectric generation in the U.S. has and will continue to become cleaner over time. This results from many factors, including renewable energy policies enacted by many states, more stringent EPA regulations, and even the low cost of natural gas, which has been displacing coal in many markets. EPA's analysis failed to recognize these changes in the fleet.

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[…] EPA's metric failed to use the most recent data on power plant emissions. Given the recent recession, which started in 2008-2009 and which reduced demand for electricity in the United States, using 2005 data quite clearly skewed the national average electricity upstream GHG emissions rate for the period covered by the MY 2012-2016 standards. [Footnote 8: EPA's statement that the Agency chose to use the 2005 national average value "because it is known and documentable" fails to explain why more recent data from 2008 or 2009 was not used for emissions standards that were proposed in 2009 and finalized in 2010. (Citation omitted.)]. For example,according to the Energy Information Agency (EIA), total carbon dioxide emissions from electric generation were 8.6 percent lower in 2009 compared to 2008 (and declined by nearly 10.8 percent between 2005 and 2009) [Footnote omitted.]. Moreover, 2005 data cannot be seen as an appropriate proxy for expected emissions in 2017-2025. It would be highly misleading and inaccurate to fail to use projected emissions data, or at least more recent data. Given that NHTSA's standards will have to rely on projections well into the future to cover MY 2017-2025, NHTSA should document all assumptions and allow for public review and comment on any estimates related to future electricity supply and demand.

Consequently, any static national average estimate of upstream emissions based on annualized data from several years ago cannot provide an accurate picture of the upstream emissions expected when new PEVs will be manufactured and operated, nor can it provide meaningful data on local and regional impacts. [Footnote 10: National data are particularly misleading given recent increases in renewable generation in many states and regions. For example, the Electric Reliability Council of Texas (ERCOT) reported that wind represented 7.8 percent of the total electric energy generated in that region in 2010, compared to 6.2 percent in 2009 and 4.9 percent in 2008 (and 2.1 percent in 2006, according to the ERCOT *2006 Annual Report*). (Citation omitted.)]. If upstream GHG emissions cannot be calculated accurately or estimated with a high degree of confidence, they should not be used in an EIS.

[…] [T]he EIS must recognize that upstream GHG emissions associated with electricity production will be addressed by comprehensive regulatory programs during the period covered by the to-be-proposed CAFE standards. In the final rule for MY 2012-2016, EPA stated that the Agency historically focused on the tailpipe when assessing motor vehicle emissions of criteria pollutants and did not need to look at upstream emissions associated with the production and distribution of conventional fuels because these were addressed by comprehensive regulatory programs aimed at the sources of those emissions. By contrast, EPA noted that "at this time, however, there is no such comprehensive program addressing upstream emissions of GHGs, and the upstream GHG emissions associated with production and distribution of electricity are higher than the corresponding upstream emissions of gasoline." [Footnote 11: EPA provided no support for the assertion that GHG emissions related to electricity production and distribution exceed GHG emissions associated with the production and distribution of gasoline. (Citation omitted.) While it may be true that electricity production contributes a proportionally larger share of overall U.S. GHG emissions than the transportation sector, this does not mean that the GHG emissions associated with the production of a specific MW of electricity fueling an EV always exceed the upstream GHG emissions related to the refining of specific gallon of gasoline, especially if that gallon was produced and refined overseas and then transported to the U.S.] (Citation omitted.)

While this may have been the case when EPA proposed GHG emissions standards for passenger cars and light-duty trucks in 2009, this is clearly not the case in 2011 looking forward to standards covering MY 2017 and on. EPA's GHG permitting program for the largest new and modified sources, which includes electricity generating units (EGUs), went into effect on January 2, 2011. Additional EGUs will become subject to the permitting requirements, which require that the Best Available Control Technology be used to set GHG emissions limits for these facilities, starting on July 1 of this year. [Footnote omitted.] More importantly, on December 23, 2010, EPA announced that, under the terms of a settlement agreement, it will finalize New Source Performance Standards (NSPS) for GHG emissions that eventually will apply not only to new units and major modifications, but also **existing** EGUs via a final rule to be issued by May 2012. [Footnote omitted.] Assistant EPA Administrator for Air and Radiation Regina McCarthy has said that this would mean that compliance would be required for existing EGUs in the 2015-2016 timeframe, before the next set of vehicle standards take effect. Therefore, after 2016, electricity generation in the U.S. will be subject to a"comprehensive program addressing upstream GHG emissions." (Citation omitted.)

If NHTSA chooses to include upstream GHG or criteria pollutant emissions in the draft EIS, the Administration must be fuel neutral in its analytics, assessing the upstream emissions of all fuels, conventional and alternative, and all vehicles, conventional and PEV. Moreover, while NEPA is appropriately focused on environmental impacts in the United States, NHTSA cannot ignore in its analysis that many upstream emissions associated with the production, refining and transportation of gasoline and diesel fuel to ultimate consumers occur outside the U.S. Therefore, in the draft EIS, NHTSA cannot make unqualified direct comparisons of the upstream emissions of various fuels.

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NHTSA should reject the analytical framework used by EPA in assessing upstream emissions from electricity generation. For GHG emissions standards for light-duty vehicles, EPA determined that it would only use the technically correct emissions value of 0.0 grams/mile, but only for a limited number of EVs sold per manufacturer, citing concerns about upstream emissions related to the generation of electricity. Based on outdated data from 2005, EPA calculated a nationwide annual average electricity upstream GHG emissions rate. Using this national annualized average, EPA came to the spurious conclusion that "actual" GHG emissions attributable to EVs exceed the GHG emissions of conventional fuel vehicles. (Citation omitted.)

For many reasons, it would be inappropriate for NHTSA to use EPA's approach to upstream GHG emissions when assessing the environmental impacts of increased PEV deployment in the EIS.

First, EPA's approach to PEV emissions is misguided and contrary to the Agency's goals of promoting the commercialization of a technology that EPA itself calls a "potential game-changer." (Citation omitted.) Expanded introduction of PEVs into all classes and categories of vehicles will serve to significantly reduce GHG emissions from the transportation sector, not "dilute" vehicle emissions standards, as EPA charges. (Citation omitted.) [Footnote 6: (Citation omitted.) It is important to note that the EPRI-NRDC Study focused on PHEVs and did not include EVs.] While the carbon intensity of electricity generation plays a significant role in the GHG emissions of PEVs, increased deployment of PEVs will reduce GHG emissions from the transportation sector, even given the current composition of the generating fleet, as compared to conventional vehicles. (Citation omitted.)

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute

As NHTSA notes in the Draft EIS, the literature review demonstrates that "even in modeled scenarios in which EVs charge from a carbon-intensive grid mix (i.e., electricity generated from mostly coal power plants), the vehicle life-cycle GHG emissions from EVs are less than conventional gasoline vehicles." (Citation omitted.) NHTSA's overall approach to EVs in the Draft EIS must be consistent with this overarching conclusion of the literature review.

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EEI's comments on the Draft EIS focus on identifying instances in which the analysis of EVs is inconsistent with the conclusions of NHTSA's literature review that EVs, even when charging from a carbon-intensive grid mix, have lower life-cycle GHG emissions than conventional gasoline vehicles.

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In the Draft EIS, NHTSA states that "[t]o the extent that any of the action alternatives would lead to an increase in the use of EVs, upstream emissions associated with charging EVs could increase as a result." (Citation omitted.) If NHTSA addresses upstream emissions, it must qualify this statement to recognize, consistent with the findings of its own literature review, that the life-cycle emissions from EVs, even when charging from a generation mix that is mostly coal, are lower than those associated with conventional vehicle. [Footnote 3: In the discussion of EV batteries in the literature review, NHTSA states that "studies agree that the environmental impacts of the upstream production of an EV are higher than a conventional vehicle." (Citation omitted.) (…)]

Docket Number: 9584 (EPA Rule Docket)
Commenter: Emily Fisher, Edison Electric Institute

EEI opposes the use of any upstream GHG emissions factor. EV tailpipe emissions are 0.0 g/mile, and this is the value that should be used for compliance purposes for all time periods covered by the proposed vehicle standards. EPA should not "discount" this compliance value to reflect upstream GHG emissions related to electricity production. After all, EPA does not calculate any value for upstream emissions rates for conventionally fueled vehicles. [Footnote 3: Upstream emissions related to oil production have been a central part of the debate over the Keystone pipeline.]

* * * * *

First, it is inappropriate for EPA, now in 2012, to calculate any upstream electricity GHG emissions rate for 2025, as there is no way that this value could reasonably approximate actual electric generating unit (EGU) emissions 13 years in the future. The current version of EPA's Integrated Planning Model (IPM), which is used to generate electricity generation emissions data, relies on certain assumptions about the current national electric generating unit (EGU) fleet and incorporates some, but not all, regulations affecting EGUs in the near term. The version of IPM used for the proposed vehicle standards does not, for example, include EPA's recently promulgated hazardous air pollutant regulations, nor does it include any regulations that are not currently on the books, but expected to be final and effective well before MY 2025. These include GHG new source performance standards (NSPS) for both new and existing EGUs, new effluent guidelines for EGUs, new regulations for EGU cooling water intake structures and new regulations affecting the disposal of coal combustion residuals. These regulations will dramatically change the makeup of the current EGU fleet, as many coal-based units will retire rather than incur the substantial costs associated with air, water and solid waste pollution control retrofits. If these units are replaced by those using renewable fuels, or even natural gas, their GHG emissions will be much lower than those of existing units. Because no one knows how many units will be retired and replaced by cleaner fuels, it is impossible for the 2012 version of IPM to predict with any accuracy an upstream electricity GHG emissions rate for 2025.

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The Agency would be better served by waiting until MY 2021 to estimate upstream GHG electricity emissions, using actual emissions data and the most up-to-date information about the EGU generating fleet. EPA easily could conduct this analysis concurrently with the planned midterm evaluation of the vehicle standards necessary to support NHTSA's required, separate rulemaking to establish CAFE standards for MY 2022-2025. (Citation omitted.)

* * * * *

Moreover, it appears that the electric sector will become subject to GHG regulations sooner than other fuel sectors. Under the terms of a settlement agreement signed in late 2010, EPA is in the process of designing proposed GHG NSPS for all fossil fuel-based EGUs. These standards will apply to new units and major modifications, as well as the existing fleet. While EPA has missed the original deadline for proposing the GHG NSPS, at least the new and modified source parts of the rule are expected to be released imminently. The entire GHG NSPS program is expected to be in place within the next few years, well before the MY 2017 standards take effect. In the proposed rule, EPA fails to acknowledge these standards and their effect on electricity generation during the time period covered by the proposed MY 2017-2025 standards.

Response

For the analysis of environmental impacts presented in this EIS, NHTSA used the AEO 2012 Early Release data (the most recent available at the time of modeling) on electricity generating mix and estimated the total increase in electricity demand from all end uses. NHTSA assessed the regulatory

programs that will influence the electricity generating mix, including some federal regulatory requirements and state-level renewable portfolio requirements. The agency also estimated the impact that changes in natural gas prices will have on the electricity generating mix. Future demand for electricity was accounted for in the assessment. Specifically, NHTSA's analysis accounts for programs encouraging the use of renewable fuels, implementation of some new environmental rules (Cross-State Air Pollution Rule and state Renewable Portfolio Standards [RPS]), low projected fuel prices for natural gas, and higher assumed prices for construction of coal-fired generating plants. Generation from renewable resources grows in response to state level requirements (RPS), federal tax credits, and the federal renewable fuels standard, which requires greater use of biomass for transportation fuels, some of which can produce electricity as a by-product of the production process. As a result, the share of U.S. generating capacity that comes from renewable sources rises from 10 percent in 2010 to 14 percent in 2020.

The baseline year the Energy Information Administration (EIA) evaluated in the development of the AEO 2012 Early Release is 2010. The projections of future generating mix developed for the AEO 2012 Early Release include regulatory programs that were not included in the 2005 assessment. NHTSA believes that the use of the more updated AEO projections and baseline data significantly updates the analysis. The impact of state and federal electric generation policies such as state-level RPS requirements were accounted for in the Final EIS modeling because the AEO 2012 Early Release estimated the change in generating mix due to implementation of state-level renewable fuel requirements and federal policies such as the Cross-State Air Pollution Rule. However, projected impacts from two federal regulations specific to electricity generation – Mercury and Air Toxics Standards and New Source Performance Standards (NSPS) – were not proposed in time to be included in the AEO 2012 Early Release. The beneficial impacts of these programs were, therefore, not included in NHTSA's analysis.

In analyzing the air quality impacts of the alternatives, NHTSA recognizes that it is important to consider the most recent data on the expected future makeup of the electric generating grid. Due to modeling limitations, the analysis presented throughout this EIS assumes that the future EV fleet would charge from a grid whose mix is similar to today's grid mix and uniform across the country. To estimate upstream emissions, the analysis uses the GREET model (1 2011 version developed by DOE Argonne National Laboratory), whose emissions intensities extend only to 2020. To project the U.S. average electricity generating fuel mix for the reference year 2020, the analysis uses the NEMS AEO 2012 Early Release version, an energy-economy modeling system from the Department of Energy. These modeling tools, which are among the best available, necessarily have limitations when used to predict the state of the electrical grid in the distant future. The assumptions result in a temporally static and geographically homogeneous grid that overstates air quality impacts under alternatives that predict a high level of EV deployment. It is more reasonable to assume steady improvements to the grid during the course of the next several decades — the period during which any EV deployment associated with this program would occur — and, if the current early trends continue, a higher concentration of EVs in areas served by cleaner electrical grids. For this reason, NHTSA reviewed several projections by the EIA, the Federal Government's expert source for forecasting energy use, which show a cleaner grid in future years based on a variety of assumptions and possible scenarios. NHTSA then performed an additional analysis to illustrate the effects of a cleaner future grid on air quality. *See* Sections 2.4.1.2 and 4.1.2.1 of this Final EIS.

Comments

Docket Number: 9472 (EPA Rule Docket)
Commenter: Laurie Johnson, Natural Resources Defense Council

Fuel economy standards under EPCA also do not properly account for the differences in upstream emissions of different types of fuels. Ignoring upstream emissions for fuels such as electricity, hydrogen, biofuels and diesel tend to inflate their GHG benefits in comparison to gasoline. For example, a diesel-fueled vehicle that achieves a fuel economy benefit of 20 percent or more versus a conventional gasoline-fueled vehicle using diesel produced from coal (i.e. coal-to-liquid) could result in almost two times greater GHG life-cycle on a per mile basis due to the inherently higher carbon content of diesel and the extremely high carbon emissions associated with producing a diesel-like fuel from coal.

Response

In its analysis for the Final EIS, NHTSA included upstream emissions for different vehicle and fuel types. NHTSA used the GREET model (1 2011 version developed by DOE Argonne National Laboratory) to determine upstream emissions for eight fuel types (conventional gasoline, federal reformulated gasoline, California reformulated gasoline, conventional diesel fuel, low-sulfur diesel fuel, electricity, ethanol-85, and hydrogen). The analysis accounts for criteria and GHG emissions associated with production, storage, and distribution of the fuels. NHTSA input the generating mix obtained from the AEO 2012 Early Release and AEO 2011 into the GREET model to estimate upstream EV emissions.

Upstream emissions for electrical generation in 2020 for EVs were thus modeled using the same type of analysis as for the seven other fuels evaluated. The GREET model provides life-cycle emissions for approximately 100 fuels. NHTSA recognizes that these different fuels have very different upstream emissions. However, given the uncertainty about the potential future use of fuels (such as Fischer Tropshe fuel derived from coal), the agency modeled only fuels that are currently projected to be in the fleet in 2020 in significant volumes (the eight fuels mentioned above).

Comments

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

[…] EPA's creation and use of a national annualized average electricity upstream GHG emissions rate fails to account for significant regional differences in electricity generation. National averages cannot help NHTSA estimate any localized or regional impacts of potential increased penetration of EVs, a stated goal of the EIS.

Emissions associated with the generation of electricity vary significantly from utility to utility—with nuclear, wind, solar, geothermal, and hydroelectric powered sources emitting low or no GHGs or criteria air pollutants. Any meaningful estimates of upstream emissions associated with electricity as a transportation fuel would need to be tailored not only to reflect regional variations in current electricity baseload (and/or peak load) generation and expectations for marginal electricity generation mix, but also assumptions about usage and recharging of the vehicle, as well as state/federal electric generation policies (such as state RES requirements) [Footnote 7: As of 2011, 29 states and D.C. have RES requirements and seven additional states have nonbinding renewable generation goal. Existing RES requirements applied to 47 percent of U.S. loan in 2010; when these RES requirements are implemented fully, these obligations will apply to 56 percent of load. (Citation omitted.)] and state/regional/federal GHG emissions limits and reductions programs (*e.g.*, California's A.B. 32, the New England Regional Greenhouse Gas Initiative, and the federal CAA).

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute

NHTSA also must address serious flaws in how the Draft EIS estimates and analyzes upstream EV emissions. NHTSA correctly notes that "the amount of emissions created when generating electricity depends on the composition of fuels used for generation, which varies regionally." (Citation omitted.) Despite this, however, NHTSA's analysis does not address regional variation in electricity generation in any meaningful way. This analysis also does not address charging timing patterns and their effect on upstream emissions. These two factors – time of charging and regional variation in electric generation – will have a significant impact on any upstream emissions analysis.

EV charging is likely to take place at night [Footnote 4: Researchers at the Department of Energy's (DOE) Argonne National Laboratory used data from the 2001 National Household Transportation Study to determine likely charging scenarios. They found that more than 60 percent of vehicles end their last trip after 5 p.m. and 70 percent after 4 p.m. Over half of these vehicles begin their first trip between 6 and 9 a.m. (Citation omitted.)], when overall national GHG emissions related to electricity generation are lower because most wind power is generated at night [Footnote 5: (Citation omitted.) Indeed, NHTSA's analysis also fails to consider how EVs, especially PHEVs, can help better integrate more variable resources, like wind, into the grid, further de-carbonizing electricity generation. (Citation omitted.)] and because base load nuclear generating units do not cycle and are always operating. [Footnote 6: Nuclear power plants essentially run continuously. This is because their power output cannot be ramped up and down readily on a daily and weekly basis. As a result, at night, when electric demand is lower, nuclear units continue to run and other forms of generation are backed off. (Citation omitted.)] Electric utilities also are incenting night EV charging through time-of-day electricity rates and separate EV rates, which are significantly lower at night when overall electricity demand is lower. In addition, increased installation and use of smart meters in the coming years, funded in large measure with stimulus funds administered by DOE, also will help to facilitate charging EVs at home at night.

Regional variations in generating resources must be considered, especially with respect to the areas of the country with the highest expected near-term EV deployment rates. For example, California's average upstream GHG electricity emissions rate is significantly lower than that of other parts of the country, as EPA recognizes in the proposed rule. (Citation omitted.) California also is expected to have one of the highest rates of EV adoption. [Footnote 7: (Citation omitted.) EPRI also states that Oregon and Washington, D.C. are expected to have higher EV adoption rates.] In 2011, California residents purchased over 60 percent of the Nissan Leafs and about 30 percent of the Chevrolet Volts sold in the U.S. [Footnote omitted.]. Moreover, California recently adopted aggressive regulations that will put 1.4 million EVs, PHEVs and hydrogen vehicles on the state's road by 2025. [Footnote omitted.] As a result, any analysis that uses national average upstream electricity GHG emissions to estimate the environmental impacts of early EV deployment is, by definition, overestimating these emissions.

NHTSA and EPA use the Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET) model to estimate upstream emissions. (Citation omitted.) The Technical Support Document

(TSD) for the proposed standards notes that all upstream emissions factors for electricity generation came from a version of EPA's Integrated Planning Model (IPM) developed to support the recent Cross-State Air Pollution Rule. (Citation omitted.) Neither IPM nor GREET, however, address EV charging timing patterns or account for regional variability in the sources of electricity generation. [Footnote 10: IPM also does not take into consideration any regulations that take effect in the future, so most regulations affecting power sector criteria air pollutant and GHG emissions that will be in effect in 2017 are not included. As noted, this makes the current version of IPM an inadequate tool to address emissions in MY 2017 and beyond.] Without these refinements, IPM and GREET are blunt instruments at best for estimating upstream GHG emissions related to EVs. NHTSA must revise the modeling conducted to support the Draft EIS to address these issues or note the inherent limitations of its assessments of upstream EV emissions.

Further, it is inappropriate for NHTSA and EPA to assume, with respect to EVs, that it is only the number of EVs included under each action alternative that has any effect on fuel economy or upstream emissions. (Citation omitted.) The upstream implications of increased EV deployment are affected materially by the assumptions made about what grid electricity is used to charge EVs and when EVs are charged, which NHTSA acknowledged in the Draft EIS. (Citation omitted.) Simply looking at the number of EVs included in each action alternative is not sufficient for a full and fair analysis of the environmental impacts, as required by NEPA.

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[NHTSA] must address time-of-day charging and regional variability in electricity generation, which have a significant effect on the grid electricity used to charge a particular EV. In addition, NHTSA's analysis must use data that reflect the expected composition of the generating fleet in MY 2017 and beyond by including all regulations that will be in effect during the period covered by the proposed vehicle standards. Any final EIS that does not address these deficiencies in how the Draft EIS considers EVs and upstream emissions related to the generation of electricity that will power EVs would not satisfy NEPA's requirement that an EIS provide a "full and fair" assessment of the various regulatory alternatives.

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

Under Section 202 of the Clean Air Act, the Agencies' overriding concern must be the reduction of greenhouse gas emissions. *See* 42 U.S.C. §7521. Therefore, the Agencies must assess and count the full lifecycle greenhouse gas emissions of all measures taken in the substantive rulemaking under review, including lifecycle emissions of all fuels and all vehicles under consideration. For electric vehicles, in particular, the FEIS must consider the local upstream emissions generated by electricity providers. The current approach of providing flat credits for electric vehicles without such an examination will allow manufacturers to "offset" these credits against conventional fleet improvements that could easily be implemented, and thus lead to lost opportunities to reduce greenhouse gas emissions.

Docket Number: 9485 (EPA Rule Docket)
Commenter: David Friedman, American Fuel & Petrochemical Manufacturers

Recharging during peak hours could increase peak electricity demand. For example, this could happen if many consumers in an area recharge their plug-in vehicle simultaneously in the early evening of a weekday after returning home from work. It could be necessary to restrict recharging to late-night off-peak hours and this could adversely impact the market penetration of EVs. These potential impacts must be analyzed by the agency and presented for comment. Moreover, if electrification requires additional fossil fuel-generated electricity (whether peak or off-peak), then these technologies will not deliver substantial carbon reductions. The proposed rule does not properly analyze these potential impacts, making it impossible to provide meaningful comment upon the agency's estimates of GHG reductions.

Response

The agency relied on the AEO 2012 Early Release national average generating mix for the analysis used throughout this Final EIS. The AEO 2012 Early Release also published regional generating mixes for different areas of the country. However, using the regional generating mixes in the modeling would have required the agency to project where EVs would be sold in future years. Because the EV industry is in its infancy, little sales data are available to inform assumptions for modeling.

Nonetheless, as noted above, NHTSA recognizes that the modeling tools used for this analysis necessarily have limitations when used to predict the state of the electrical grid in the distant future and in consideration of possible regional implications of EV charging. NHTSA believes it is reasonable to assume steady improvements to the grid during the course of the next several decades — the period during which any EV deployment associated with this program would occur — and, if the current early trends continue, a higher concentration of EVs in areas served by cleaner electrical grids. For this reason, NHTSA reviewed several projections by the EIA, the Federal Government's expert source for forecasting energy use, which show a cleaner grid in future years based on a variety of assumptions and possible scenarios. NHTSA then performed an additional analysis to illustrate the effects of a cleaner future grid on air quality. *See* Sections 2.4.1.2 and 4.1.2.1 and Appendix H for the complete analysis. If, in future years, EVs are sold in greater numbers in the same areas that hybrid vehicles have been sold, upstream emissions would be expected to be somewhat lower than estimated using the national average generating mix that was used for this analysis.

In response to the comment about time-of-use charging, we note that the GREET model used for this analysis assumes charging is averaged over a 24-hour period and therefore assumes the same amount of charging occurs at peak and off-peak times. An approach to estimating peak and off-peak charging was not developed for this analysis given the relative lack of data on recharging behavior to inform the analysis. In addition, such an analysis would have required a detailed evaluation of projected EV sales by region, in conjunction with an analysis of how generating mix changes with seasonal variation, time of day, and different load conditions. To the extent that cleaner energy sources are used to power the grid during the times that EVs are more likely to be charged, it is reasonable to assume that emissions associated with EV charging would be lower.

9.2.3.2 Technological Assumptions

Comments

Docket Number: 9476 (EPA Rule Docket)
Commenter: Arthur Marin, Northeast States for Coordinated Air Use Management

In 2009, nearly 3% of new U.S. light-duty vehicles were gasoline-electric hybrids and thus the assumption that 3% of new vehicles will be gasoline-electric hybrids by 2025 could be considered a "do nothing" scenario.

Response

The model used for the EIS analysis was the CAFE Compliance and Effects Modeling System developed by the Volpe National Transportation Systems Center, and commonly referred to as "the Volpe model." The model enables NHTSA to efficiently, systematically, and reproducibly evaluate many regulatory options. The Volpe model does not provide a forecast of future technology penetration into the vehicle fleet, but evaluates different potential compliance paths manufacturers could take to meet the CAFE requirements. In general, the model chooses lowest-cost technologies first and then more expensive technologies if needed to meet the standards. Because hybrid vehicles are among the more expensive technology options manufacturers could use to comply with the standards, the Volpe model typically chooses other technologies before selecting gasoline-electric hybrids in compliance scenarios. That said, NHTSA added mild hybrid technology (a hybrid which uses its internal combustion engine more often than a strong hybrid) as a technology in the analysis, and in the modeling for the Proposed Action, hybrids (including strong hybrids and mild hybrids) increased 11 to 20 percent under the Preferred Alternative in 2025 from the baseline. Therefore, in the modeling for the EIS, hybrid penetration increased significantly.

9.2.3.3 Economic Assumptions

Comments

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

The DEIS attempts to explain the model used to assess each alternative and the inputs and assumptions used in the model. As explained above, the economic assumptions are incredibly important in thoroughly assessing the benefits of each alternative. While the Agency lists the 12 important economic assumptions used in the model, only two are explained and given quantitative assignments (rebound effect and vehicle survival rates). To learn about the other inputs, the reader is directed to the PRIA, the proposal, and the Draft Joint Technical Support Document. We believe the EIS should at least list the values assigned to each of these economic assumptions, even if the full methodologies are not restated within. The failure to do so reflects a lack of transparency.

Response

NHTSA appreciates the comment and, in response, has added a table in Chapter 2 listing the values assigned to many of the economic assumptions used in the model. To promote further transparency,

NHTSA has added discussion about the Volpe model and the various other modeling software used to prepare this Final EIS.

9.2.3.3.1 Rebound Effect

Comments

Docket Number: 0258 (NHTSA Rule Docket)
Commenter: International Council on Clean Transportation

The agencies used a fixed estimate of 10% for the rebound effect. This estimate was not based upon the latest research, but instead was a compromise between the latest research and outdated historical data:

> "In summary, the 10 percent value was not derived from a single estimate or particular study, but instead represents a compromise between historical estimates and projected future estimates." [Footnote omitted.]
>
> "As we discussed in the 2012-2016 rulemaking and in Chapter 4 of the Joint TSD, this value was not derived from a single point estimate from a particular study, but instead represents a reasonable compromise between the historical estimates and the projected future estimates." [Footnote omitted.]

The agencies quoted the latest research from Small and VanDender and David Greene demonstrating that the rebound effect is linked to personal income and vehicle efficiency, as well as fuel prices, and has been declining over time. EPA also referenced recent work by Kenneth Gillingham, who provides suggestive evidence that consumers may be less responsive to changes in fuel efficiency than to changes in fuel prices. Yet, when it came time to select the number used for the rebound effect, outdated studies with strictly historical effects were given equal weight to the recent studies projecting the future VMT effect.

The proposed rule asks for the submission of new data regarding estimates of the rebound effect and comments on the methodology for applying the rebound effect. Additional data is not needed. The Greene and Small and VanDender work is the proper basis for calculating the rebound effect. They made a major contribution to the field by incorporating economic impacts and the cost of driving into calculations of price elasticity of demand. This is much more appropriate than assuming a fixed 10% rebound effect that does not take into account future changes in vehicle efficiency, fuel prices, and future income. Only future projections of the rebound effect that include the impacts of personal income, vehicle efficiency, and fuel price should be used to calculate the future rebound effect.

Response

NHTSA requires a single-point estimate for the rebound effect as an input to its analysis. However, there is a wide range of estimates for both the historical magnitude of the rebound effect and its projected future value. There is also some evidence that the magnitude of the rebound effect appears to be declining over time. NHTSA and EPA concluded that a value on the low end of the historical estimates is likely to provide a more reliable estimate of its magnitude during the future period spanned by the analysis of the impacts of the Proposed Action. Based on a variety of historical estimates of the rebound effect and more recent analyses by EPA and NHTSA, an estimate of 10 percent for the rebound effect was chosen, with a range of 5 to 20 percent for use in NHTSA's

sensitivity testing. *See* Section IV.G.4 of the NPRM and Chapter X of the Preliminary RIA. This estimate lies within the 10 to 30 percent range of estimates for the historical rebound effect reported in most recent previous research, and at the upper end of the 5 to 10 percent range of estimates for the future rebound effect extrapolated from recent studies by Small (2007) and Greene (2012). It also lies within the 3 to 16 percent range of forecasts of the future magnitude of the rebound effect developed by NHTSA in its recent research. For a more detailed description of NHTSA's rebound estimate, *see* Chapter 4 of the Draft Joint TSD.

9.2.3.3.2 Oil Prices

Comments

Docket Number: 0775 (Scoping)
Organization: Vera Pardee, Center for Biological Diversity

In addition, we urge the Agencies to reconsider their assumptions concerning the retail price of gasoline through the rulemaking period. The Agencies' reliance on a gas retail price in 2025 of $3.49 is based on an Energy Information Agency outlook which used oil and gas predictions from 2009. 2009 was a year constrained by global recession and thus is unlikely to provide meaningful information concerning gas prices in a growing economy. Indeed, oil prices have risen considerably this year, and the Agencies' use of a price of $3.49 is patently unreasonable in light of an ever increasing global energy crunch. [Footnote 69: *See* the 2010 Joint Operating Environmental report of the Joint Forces Command, pp. 28-29, which states that a "severe energy crunch is inevitable without a massive expansion of production and refining capacity:" to meet energy demand by the "2030s would require us to find an additional 1.4 MBD every year until then," but the " discovery rate for new petroleum and gas fields . . . provides little reason for optimism" and by "2012, surplus oil production capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 MBD." (Citation omitted.)] The Agencies' cost-benefit analysis cannot be meaningful if it is based on incorrect data or omits crucial cost-benefit components.

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

NHTSA's choice of fuel price is very important to the cost and thus perceived feasibility of different fuel economy increases in the forthcoming EIS. For CAFE 2012-2016, NHTSA [Footnote omitted.] used the "retail gasoline" price (a 2012-50 average estimated at $ 3.66 per gallon) and "pre-tax gasoline" price (a 2012-50 average estimated at $3.29 per gallon) and used the AEO2009 as its source. While we agree with NHTSA that the AEO is a very credible source for fuel price forecast, it is important to remember that forecasts are based on models, which are not crystal balls. For example, the average (over 6 years) error in the EIA's AEO2005 forecast for fuel prices for 2005 to 2010 was an underestimation of 31%. [Footnote 16: This is based on a comparison of forecasts in the AEO2005 of Motor Gasoline prices (sales weighted-average price for all grades. Includes Federal, State, and local taxes) with the actual motor gasoline retail price of the EIA Short Term Outlook May 2011.] This illustrates the importance of the use of a sensitivity analysis with significantly higher gasoline prices.

Indeed, the Agency conducted a sensitivity analysis examining the effect of using the AEO 2011 High Price Case forecast estimates and found that it increased net benefits by nearly 30 percent. (Citation omitted.)

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

In addition, the Agencies must reconsider their assumptions concerning the retail price of gasoline through the rulemaking period. The U.S. Energy Information Administration (EIA) has released an early overview of its Annual Energy Outlook for 2012, showing that it expects the average price of crude oil in 2035 to rise to approximately $145 per barrel (in 2010 dollars), translating into $4.09 for motor gasoline and $4.49 for diesel per gallon in 2035, "higher levels than the AEO2011 Reference case." [Footnote omitted.] The Agencies' cost-benefit analysis must be based on up to-date information if it is to be meaningful.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

Consider more realistic gas price projections: When considering gas prices, the agencies use AEO's 2011 Reference Case. AEO's forecast assumes that gas prices will average $3.54 per gallon in 2025 (in 2009 dollars). According to EIA's own "This Week in Petroleum," gas prices the week of February 6, 2012 averaged $3.48 per gallon nationwide. [Footnote omitted.] It is shocking to think that gas prices will barely rise from 2012-2025. Although the agencies do consider higher gas prices in sensitivity analyses, when considering setting standards and the benefits derived from those standards, the agencies should place greater emphasis on the high gas price scenarios. We have attached comments submitted to the docket previously by Sierra Club regarding gas price assumptions.

Docket Number: 9567 (EPA Rule Docket)
Commenter: Jim Kliesch, Union of Concerned Scientists

As has been stated in prior comments, UCS objects to the agencies' underestimation of long-term fuel price projections. In this proposed rule, the agencies again rely on the Energy Information Administration's (EIA) Annual Energy Outlook for long-term fuel price projections. We elaborate more on gasoline price projections in Section II(g) below, and thus will only remark here that EIA's core projections have consistently underestimated future fuel prices. Moreover, EIA projects only very modest, steady changes in fuel prices, without any significant volatility. Oil and gasoline price spikes have occurred about twice each decade for the last 30 years and almost every one was followed by a U.S. recession. [Footnote omitted.] Given these facts, the agencies should include such price spikes in their projections. At a minimum, UCS encourages the agencies to continually evaluate projections for future fuel prices and include sensitivity analysis demonstrating potential cost-effectiveness at higher stringency levels under more realistic fuel price scenarios.

* * * * *

As noted above, the Energy Information Administration's Annual Energy Outlook (AEO) has become a common source used in many energy-related projections. However, that fact does not justify applying the AEO "reference case" projection, when there are very clear indications that the price projection is poor at best. According to AEO2011 – the projection used in this proposed rule – gasoline prices will range from $3.25-$3.55 per gasoline (in 2009 dollars) between 2017 and 2025. It is hard to accept this as reasonable, given that the actual 2011 average price was $3.53, a mere two cents per gallon shy of EIA's 2025 gasoline price projection. Further, AEO2011 projects regular gasoline prices will rise to a peak of $3.71 per gallon in 2035, a pump price not infrequently seen across the nation today. Clearly, the use of AEO2011 reference case gasoline price projection is inappropriate and should not be used in the agencies' final rule, as it unfairly diminishes the monetary value of fuel saved under the program.

Within the past few weeks, EIA issued the AEO2012 Early Release, which includes a notable increase in gasoline prices over AEO2011. For the 2017-2035 window, AEO2012 Early Release reflects per-gallon prices $0.24 to $0.34 higher than AEO2011 values (converted to 2010 dollars). EPA and NHTSA should, at a minimum, adopt the higher AEO2012 price projections, and investigate the historical accuracy of AEO's High Price scenarios. If it is deemed that AEO's High Price scenarios have, over the past 15 years, been better predictors of actual pump prices, the agencies should utilize High Price Scenario prices for assessing monetary benefits of fuel savings at the pump.

Finally, as UCS has noted in prior comment submissions, AEO's projection does not account for inevitable price spikes that will occur during the lifetime of the vehicles assessed under this rule. Such spikes are closely tied to our nation's inflation and GDP, and thus can have serious economic consequences. With this in mind, the agencies should attempt to quantify the benefits of reduced susceptibility to such spikes, and incorporate them into the program's benefits writ large.

Response

For the Final EIS, NHTSA has updated the fuel price projections from the Reference Case in EIA's AEO 2011 to the reference case in EIA's AEO 2012 Early Release. It is EIA's policy to perform retrospective analyses to determine the historical accuracy of its fuel price (and other) projections over time. *Available at*: <http://www.eia.gov/oiaf/analysispaper/retrospective/index.html> (Accessed: July 5, 2012) (EIA 2009). For cases where EIA's fuel price forecasts have performed poorly, this is not unusual. Projecting future values of globally traded commodities is difficult and deeply uncertain, and the comment does not explicitly identify more reliable sources of such forecasts for fuel prices.

Using current prices to merely extrapolate future values might not yield accurate predictions, particularly during periods of price volatility (like those accompanying or preceding the global recession). In July of 2008, national average gasoline prices topped $4.00 per gallon. By December of that year, retail gasoline prices were again under $2.50 per gallon. The Volpe model uses an annual time step, meaning that any time series inputs (like fuel prices) should have only annual-level resolution. Although monthly gasoline prices have been historically volatile (especially over the last several years), annual average prices are much less so. Predicting annual price spikes in such a projection is impossible, and the EIA projections appropriately do not attempt to do so. NHTSA believes the EIA price projections to be the best available and used the most current projections (AEO 2012 Early Release) at the time of the Final EIS analysis.

9.2.3.3.3 Payback Period

Comments

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

EDF supports the use of a 5-year payback period as an input to analyze potential economic and environmental impacts of the proposed CAFE alternatives. A payback period of anything less than 5 years would not accurately reflect the current and forecasted buying trends of consumers. In 2010, consumers owned vehicles for an average of 63.9 months, or just over 5 years. [Footnote omitted.] The average length of ownership of new vehicles has been on a steady rise since the economic and auto industry downturn in 2008 and is expected to continue to rise. [Footnote omitted.] Therefore, the period of time that potential vehicle buyers can be assumed to value fuel economy improvements in making their purchasing decisions may also be increasing. For this reason, we strongly urge the Agency to use a payback period that accurately reflects the forecasted purchasing behavior of consumers.

Response

The payback period represents the length of time required for the cost of a technology that improves fuel economy to be offset through savings from reduced fuel use. For manufacturers that have traditionally opted to pay fines in lieu of fully complying with CAFE standards, the Volpe model assumes that manufacturers will make decisions about whether to apply technologies to comply with CAFE standards using a 5-year payback period. In other words, it assumes that those manufacturers will pay fines instead of adding technology to comply with standards when the net cost of new fuel economy technology (technology cost minus 5 years' worth of resulting fuel savings) is higher than the cost of fine payment. This assumption is applied to a small number of manufacturers, because most manufacturers have historically treated the standards as a binding constraint. For the manufacturers that typically comply with the CAFE standards, the model applies technology as necessary to meet the fuel economy standards regardless of the manufacturer's assumptions about consumer valuation of fuel economy. In effect, the payback period is irrelevant for purposes of technology application for these manufacturers.

Different assumptions regarding the payback period also apply in Analyses A and B in this EIS once compliance has been achieved. In Analyses A1 and A2, once a manufacturer is in compliance with the CAFE standards in a particular model year, NHTSA assumes the manufacturer will not add any technology that could improve fuel economy regardless of the payback period for that technology. In contrast, in Analyses B1 and B2, once a manufacturer is in compliance with the CAFE standards in a particular model year, NHTSA assumes the manufacturer will continue to add fuel economy technologies that pay for themselves through fuel savings within 1 year. NHTSA uses 1 year as an estimate of how manufacturers believe consumers value fuel economy improvements.

When determining environmental impacts in this EIS, NHTSA effectively uses a payback period that is the length of the vehicle lifetime. In other words, NHTSA accounts for all of the fuel savings and all of the emissions benefits that occur over the entirety of a vehicle's useful life to determine the environmental impacts reported in this document.

9.2.3.3.4 Discount Rate

Comments

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

EDF commends NHTSA on its use in the model year 2012-2016 CAFE EIS of a 3% discount rate for the main analysis of energy use and emissions resulting from alternative standards [Footnote omitted.]. In accordance with the OMB Guidance [Footnote 14: "For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent," (Citation omitted.)] on the use of discount rates and the previous use by NHTSA of the 3% discount rate, we recommend the use of a discount rate of 3% (with a sensitivity of 7%) be used in the forthcoming EIS.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

It is crucial that the agencies not use inflated and arbitrary discount rates when considering consumer benefits, such as the 25% and 50% discount rates considered in sensitivity analysis for NHTSA's PRIA. [Footnote omitted.] Given the consequences of our oil addiction on our economy, environment, national security and on consumer's individual pocketbooks, the full value of the savings and benefits must be accounted for.

Response

Selecting an appropriate discount rate is a complex issue for estimating benefits associated with the Proposed Action and alternatives. Discounting future benefits and costs is intended to account for the reduction in their value to society when they are deferred until some future date, rather than received immediately. The discount rate expresses the percent decline in the value of these benefits – as viewed from today's perspective – for each year they are deferred into the future. While NHTSA evaluated several sensitivity analyses based on various assumptions in the Preliminary RIA (*see* 67 FR 75306, Dec. 1, 2011), in evaluating the effects of the Proposed Action and alternatives, NHTSA has generally employed discount rates of both 3 percent and 7 percent in this EIS, consistent with Office of Management and Budget Circular A-4.

9.3 Environmental Impacts

9.3.1 Air Quality

Comments

Docket Number: 7821 (EPA Rule Docket)
Commenter: Michael Krancer, PA Department of Environmental Protection

[T]he increase in volatile organic compounds (VOC) emissions needs to be estimated due to the possible increase in Reid vapor pressure in gasoline from the increased use of higher octane gasoline. Higher emissions of VOC can lead to increased ground-level ozone concentrations.

Response

As discussed in Chapter 4 of this Final EIS, VOCs are a chemical precursor to ozone. Tables III-63 and IV-44 in the Preamble to the NPRM and Chapter 4 of this Final EIS list the change in VOC emissions as a result of the program. These show that VOC emissions are projected to decrease under each of the action alternatives as a result of the proposed rule and other EPA regulations.

Comments

Docket Number: 9452 (EPA Rule Docket)
Commenter: Joseph Kubsh, Manufacturers of Emission Controls Association

There is a significant linkage between ground level ozone concentrations and climate change impacts. One example was detailed by a group of researchers from the United Kingdom in a 2007 Nature publication. In this work, ground-level ozone was shown to damage plant photosynthesis resulting in lower carbon dioxide uptake from plants that have been exposed to higher levels of ozone. Other studies have shown that increasing average annual temperatures are likely to result in even higher levels of ozone in the environment. Emission reductions aimed at lowering ambient ozone levels, such as lower emissions of volatile organic compounds (VOCs) and NO_x, will have a positive impact on climate change, as well as human health. Policies that aim to reduce ambient ozone levels may also become more necessary and important to either mitigate the climate change impacts of ground level ozone or to mitigate higher ozone levels that result from climate change.

Response

Chapter 4 of this Final EIS discusses the projected environmental impacts and impacts on human health as a result of ozone, VOCs, and NO_x under the Proposed Action and alternatives. Tables III-63 and IV-44 in the Preamble to the NPRM and Chapter 4 of this Final EIS list the changes in VOC and NO_x emissions as a result of the program. These show that VOC and NO_x emissions are projected to decrease compared to the No Action Alternative and generally, under each action alternative, as a result of the proposed rule and other EPA regulations. NHTSA has also discussed recent findings of the impact of warmer temperatures on ground-level ozone, which can contribute to increased incidence of respiratory ailments and annual air pollution deaths, in the MY 2012–2016 CAFE standards EIS, the MY 2014–2018 HD (medium- and heavy-duty) EIS, and this EIS. While NHTSA will consider environmental effects related to the impact of the proposed rule on VOC and NO_x emissions when setting final CAFE standards, the agency does not have statutory authority to set emissions standards directly for these pollutants.

Comments

Docket Number: 9540 (EPA Rule Docket)
Commenter: Tom Buis, Growth Energy

Despite the evidence that widespread use of GDI [Gasoline Direct Injection] may increase PM emissions, the proposal does not address the issue. The proposal does note that:

> EPA has the discretion under the CAA to consider many related factors, such as the availability of technologies, the appropriate lead time for introduction of technology, and based on this the

> feasibility and practicability of their standards; the impacts of their standards on emissions reductions (of both GHGs and non-GHGs); [Footnote omitted.]

The Joint NPRM considers several impacts of the proposal on non-GHGs, both positive and negative. For example, the analysis evaluates the impact that reductions in domestic fuel refining and distribution due to lower fuel consumption will have on U.S. emissions of various pollutants. In addition, the analysis evaluates the increase in emissions from additional vehicle use associated with the rebound effect from higher fuel economy. As the various positive and negative impacts on non-GHGs and considered, the proposal indicates: [Footnote omitted.]

> Thus the net effect of stricter CAFE standards on emissions of each pollutant depends on the relative magnitudes of its reduced emissions in fuel refining and distribution, and increases in its emissions from vehicle use.

However, there is no discussion in the proposal indicating that EPA considered whether the technologies assumed in the proposal would increase non-GHG emissions. This is an important oversight. Instead, EPA merely assumed that they would not. For example, the proposal indicates: [Footnote omitted.]

> The agencies' analysis assumes that the per-mile emission rates for cars and light trucks produced during the model years affected by the proposed rule will remain constant at the levels resulting from EPA's Tier 2 light duty vehicle emissions standards.

Thus, EPA assumed there would be no impact of the fuel economy technologies on non-GHG or air pollutant emissions. In this regard, it is important to note that NHTSA's draft Environmental Impact Statement (DEIS) does not comply with the National Environmental Policy Act (NEPA). The DEIS notes that "complex" factors determine how the proposed standards will affect criteria or precursor emissions and air toxics. [Footnote 21: The DEIS states: "The increases and decreases in [criteria and toxic air pollutant] emissions reflect the complex interactions among 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, the proportion of electric vehicles in the passenger car and light truck population, and increases in VMT." (Citation omitted.)]

One aspect of these "complex interactions" that certainly merits attention is the potential effect of technological innovation on criteria and toxic pollutants, in the absence of improved in-use fuel standards. As HEI's February 2011 study noted, the use of GDI technology increases some current gasolines' particulate emissions. [Footnote omitted.] Without NHTSA having directly addressed that study in the DEIS, the Agencies simply note in the NPRM that "the net effect of stricter standards on emissions of each criteria pollutant depends on the relative magnitudes of reduced emissions from fuel refining and distribution, and increases in emissions resulting from added vehicle use." 76 Fed. Reg. at 74,933. That cursory observation does not meet the requirements of NEPA for a "thorough investigation" and a "candid acknowledgment" of risks. [Citations omitted.]

Response

Research has shown wall-guided gasoline direct injection (GDI) systems increase PM emissions compared to conventional gasoline engines. Wall-guided GDI is the predominant technology in use at this time; however, spray-guided GDI systems offer improved fuel economy and reduced emissions. Manufacturers have announced production of newer technology GDI systems with significantly

reduced PM emissions. For this reason, in the technical assessment NHTSA and EPA conducted as part of this rulemaking, the agencies assessed the emissions and fuel consumption improvements associated with spray-guided GDI systems.

NHTSA recognizes that, in general, certain fuel economy technologies can impact overall criteria and toxic air pollutant emissions. However, the analysis for this EIS generally assumes that fuel economy technologies alone would not have an impact on emissions at a given engine power output. To the extent that a fuel economy technology allows the engine to provide the same vehicle performance at reduced power output, the Motor Vehicle Emission Simulator (MOVES) model will reflect the change in power output in its emission calculations. Chapter 2 of this Final EIS states:

> **In its emissions calculations, MOVES2010a accounts for the amount of power required of the engine under different operating conditions, such as vehicle weight, speed, and acceleration. Changes to the vehicle that result in reduced engine load, such as from more efficient drivetrain components, improved aerodynamics, and lower rolling-resistance tires, are therefore already reflected in the MOVES2010a calculations of both fuel economy and emissions. Because the proposed standards are not intended to dictate the design and technology choices manufacturers must make to comply, a manufacturer could employ technologies that increase fuel economy (and therefore reduce CO_2 and SO_2 emissions), while at the same time increasing emissions of other criteria pollutants or air toxics, as long as the manufacturer's production still meets both the fuel economy standards and prevailing EPA emission standards. Depending on which strategies are pursued to meet the increased fuel economy standards, emissions of these other pollutants could increase or decrease.**

Wall-guided GDI can increase PM emissions, but the manufacturer remains responsible for ensuring the PM emissions with GDI still meet the EPA emissions standards.

NHTSA has used the most up-to-date information and models available, whenever possible, to provide the agency's best estimates regarding the impact of the proposed standards on fuel economy and criteria and toxic air pollutant emissions. Chapter 4 and Appendix E of this Final EIS provide a thorough analysis of air quality emissions.

Comments

Docket Number: 9541 (EPA Rule Docket)
Commenter: Dave Vander Griend, ICM

We believe the critical health impacts need to be considered as a result of higher octane fuels center around the under-regulated subset of particulates which are ultra-fine particulates (UFPs). They are produced as a result of the fuel combustion process and are not controlled via current vehicle technology, nor are they likely to be. Long thought to be a diesel or stationary source problem, increasing data suggests PM does have a relationship to gasoline, specifically UFPs, which are considerably smaller than the regulatory benchmark of $PM_{2.5}$. They may actually be produced in the combustion process as a result of the higher aromatic content in gasoline, according to recent research by Honda. [Footnote omitted.] These UFPs are suspected of being a much more significant health threat as they can essentially bypass the lungs as a filter system and enter the bloodstream.

Response

Sections III.G.2.a and IV.G.3 of NPRM and Section VIII of the Preliminary RIA discuss particulate matter (PM) and ultra-fine particulates. NHTSA also discusses the environmental and health impacts of PM in Chapter 4 of this Final EIS.

Comments

Docket Number: 9574 (EPA Rule Docket)
Commenter: Clean Fuel Development Coalition

It is especially important to note that, in order to provide an accurate picture of the final rule's health and welfare impacts, the Agencies cannot evaluate emissions results based only on certification fuels and laboratory testing procedures such as the FTP and US06 methods. When real-world fuels containing on average 25% Aromatic Group Compounds are combusted under real-world driving conditions (e.g., stop-start, acceleration and high speeds, heavy loads, etc.), tailpipe emissions of harmful ambient particulate matter increase significantly, as the Aromatic Group Compounds' extraordinary resistance to complete combustion ultimately stymies the best efforts of the vehicles' catalytic converter. Even more worrisome is the fact that some of the more important new advanced engine technologies (e.g., gasoline direct injection) will make these emissions even worse if fuel quality is not improved.

Response

In assessing the environmental impacts of the Proposed Action and alternatives for this EIS, the agencies used criteria pollutant and toxic emission factors from EPA's MOVES2010a model. MOVES2010a significantly improved estimates of emissions over previous versions of mobile source emissions models such as the MOBILE6.2 vehicle emission modeling software. The MOVES2010a emission factors are derived from in-use testing programs. Emissions were collected using continuous monitoring in some testing programs, providing an assessment of emissions under acceleration and high speeds. The vehicles tested in the in-use programs ran on commercially available fuel rather than certification test fuel. Therefore, the emission factors used in this analysis are based on real-world driving conditions using commercially available fuel. Regarding increased emissions associated with GDI, as noted in the response to the previous comment, wall-guided GDI technology has been shown to increase PM emissions compared to conventional gasoline engines. However, newer, more advanced GDI technologies – such as those using spray-guided systems – result in significantly reduced emissions and fuel consumption. It is anticipated that spray-guided GDI will replace wall-guided systems in the 2017–2025 timeframe.

Comments

Docket Number: 9574 (EPA Rule Docket)
Commenter: Clean Fuel Development Coalition

We strongly urge the Agencies to recognize the substantial body of evidence that links gasoline Aromatic Group Compounds to increasing levels of urban PM ($PM_{2.5}$, which includes the UFPs), which are coated with highly toxic polycyclic aromatic hydrocarbons and quinones (PAHQs). Attachment E summarizes and provides cites for just a few of the leading epidemiological and related studies that provide alarming evidence linking gasoline Aromatic Group Compound combustion products to premature births and infant mortality, a wide range of cancers, asthma and other respiratory diseases, cardiovascular and heart conditions, and even brain disorders and autism. Many of the same PAHs found in secondhand cigarette smoke are found in gasoline exhaust [citation omitted], and for the tens of millions of Americans who live within 300 – 2,500 meters of congested roadways, there is no escape from the particle-bound toxics that originate from incomplete combustion of Aromatic Group Compounds. [Footnote 23: "In their research, the investigators focused on a class of cancer-causing culprits found in cigarette smoke called polycyclic aromatic hydrocarbons (PAHs)…The velocity of the cancer-causing process surprised the research team. **They said the speed with which the potentially lethal DNA assault began was comparable to having injected the PAH directly into an individual's bloodstream**." (Emphasis in original.) The PAHs found in cigarette smoke are the same as the PAHs that can coat UFPs, which lodge deeply into humans' lungs, and are carried to the organs by the bloodstream. (Citation omitted.)] As previously discussed, experts warn that advanced engine designs needed for automakers to comply with tighter fuel efficiency rules could lead to a significant increase in the UFP fraction of $PM_{2.5}$ emissions unless fuel composition is upgraded to replace the toxic octane components of Aromatic Group Compounds with Clean Octane components. [Footnote omitted.]

* * * * *

We believe it is critically important for the Agencies to recognize the direct connection between the UFP fraction of $PM_{2.5}$ and the deadly toxics that coat them: the polycyclic aromatic hydrocarbons + quinones (PAHQs). Two of the nation's leading UFP authorities released a 2009 study finding that **"[u]rban UFP contain a higher content per unit mass of polycyclic aromatic hydrocarbons, which are relevant organic constituents since they can induce oxidative stress…in human tissues after conversion to quinones…"** [Emphasis in original.] [Footnote omitted.] Over the past decade, advancing science and measurement techniques have established that the PAHQs—which experts say are carcinogenic, cytotoxic, and genotoxic—"hitchhike" on the tiny particles, which carry them to the bloodstream and throughout the body to the organs. [Footnote 26: UCLA/USC researchers called PAH, etc., coating of UFPs a .Cellular energy crisis: particulate hitchhikers damage mitochondria. They said that one of the body's most important processes—energy production in the cell—can be significantly disrupted by exposure to UFPs…the team isolated organic 'hitchhiker' substances such as PAHs and quinones that had attached to the particle cores. (Citation omitted.)] PAHQs are combustion byproducts and derivatives of Aromatic Group Compounds [citation omitted], and could be inadvertently and substantially increased by this rulemaking in the absence of fuel composition changes.

Response

NHTSA is aware of the findings of recent research that link emissions of aromatics and $PM_{2.5}$ formation in the atmosphere. Outputs from the Volpe model include tons of pollutants for different vehicle types for both upstream and downstream emissions. Some of these emissions are for specific aromatics such as benzene. Other aromatics are contained in the general category of VOCs. In air quality modeling, the VOC emissions are speciated (using EPA [Community Multiscale Air Quality [CMAQ] model] speciation profiles) into the various component species, including aromatic hydrocarbons. The speciation profiles vary according to source type; therefore, the breakdown of VOCs into unique component species, for example, is different for refineries and motor vehicles. Dispersion and geographic concentrations of the gaseous pollutants and conversion of gaseous pollutants to $PM_{2.5}$ and subsequent dispersion and geographic concentrations of $PM_{2.5}$ have been estimated by dispersion and photochemical models for the EIS (*see* Appendix E of this Final EIS). The resulting impacts on health from $PM_{2.5}$ emissions have been estimated as part of this EIS.

Comments

Docket Number: 9574 (EPA Rule Docket)
Commenter: Clean Fuel Development Coalition

We note that EPA states it is currently "conducting a reassessment of cancer risk from inhalation exposure to acetaldehyde," which is the only hazardous air pollutant associated with increased use of E30+ blends. Attachment F provides preliminary details on acetaldehyde's extremely low ranking in terms of Inhalation Risk Factor (IRF), as reported by DOE, CARB, and other experts (1, 3 butadiene = 100; formaldehyde = 4.6; benzene = 3.0; acetaldehyde = 0.8). We will be submitting a more detailed analysis on this subject for the Tier 3 rulemaking, but, in the meantime, we respectfully request that the Agencies take this information into account as they finalize this rule. [Footnote omitted.]

Response

Chapter 4 of this Final EIS contains NHTSA's projections showing that changes in annual acetaldehyde emissions in 2040 are estimated to range from a decrease of 183 tons to an increase of 116 tons, or plus or minus 0.0001 percent of the total U.S. inventory, depending on the analysis and alternative selected. NHTSA believes that the available data on exposure to and health effects of air toxics, including acetaldehyde, is not adequate to quantify the potential health effects of changes in emissions of air toxics under the Proposed Action.

Comments

Docket Number: 9574 (EPA Rule Docket)
Commenter: Clean Fuel Development Coalition

We strongly urge the Agencies to update their database and assumptions with regard to how far mobile source air pollutants can travel at elevated levels. The Agencies, both EPA in the rulemaking, and NHTSA in its EIS, assume populations are exposed only 300 – 500 meters from congested roadways. (Even at this limited range, the Agencies note that 48 million people would be subjected to these elevated pollutant levels.) However, more recent studies (such as 2009 CARB, UCLA, and University of Southern California research) show that mobile source-generated PAHs [polycyclic aromatic hydrocarbons] can be found at elevated levels as far away as 2,500 meters, or more than 1.5 miles. The report states that these findings have significant exposure implications, since most people are in their homes during the hours before sunrise, and outdoor pollutants penetrate into indoor environments. [Footnote 28: A May 2009 UCLA/CARB study found peak levels of ultrafine particles (UFP) immediately adjacent to the freeway, but we found high concentrations persisted for up to 1.5 miles downwind of the freeway during the pre-sunrise hours. Other pollutants, including particle-bound polycyclic aromatic hydrocarbons, also extended far from the freeway during the pre-sunrise hours, which is a time when most people are in their homes. (Citation omitted.)] This means that the vast majority of Americans are exposed to pathogenic PAHs and other particle-bound toxics that this rulemaking does not consider. As the 2007 Tufts University study warned, this oversight represents a major deficiency in transportation fuels regulatory policy, especially since vehicle GHG reduction technologies expected to come into widespread use as a result of this rule are likely to increase these pollutants dramatically. [Footnote 29: The most susceptible (and overlooked) population in the U.S. subject to serious health effects from air pollution may be those who live very near major regional transportation routes, especially highways. Policies that have been technology based and regional in orientation do not efficiently address the very large exposure and health gradients suffered by these populations. This is problematic because even regions that EPA has deemed to be in regional PM "attainment" still include very large numbers of near highway residents who currently are not protected. There is a need for more research, but also a need to begin to explore policy options that would protect the exposed population." (Citation omitted.)]

Response

In this EIS, NHTSA projects national and regional emissions for criteria pollutants and air toxics. However, NHTSA is unable to provide precise exposure impacts for near-road effects. In response to this comment, NHTSA has added the following to Chapter 4: "Concentrations of traffic-generated air pollutants can be elevated for as much as 2,600 meters (8,500 feet) downwind of roads under meteorological conditions that tend to inhibit the dispersion of emissions (Hu et al. 2009b, 2012)."

In estimating localized exposure impacts, NHTSA is constrained by the significant uncertainty associated with the complex interaction between factors such as projected location-specific vehicle deployment and use, deployment of fuel economy improvement technologies, and vehicle sales forecasts. The Federal Highway Administration's Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA Documents (FHWA 2009) notes that for projects that affect highway operations without adding substantial new capacity, localized emissions effects are low. Therefore, "quantitative analysis of these types of projects will not yield credible results that are useful to project-level decision-making due to the limited capabilities of the transportation and emissions forecasting tools." The impacts of the Proposed Action are similar; a quantitative localized analysis would also not be useful to the decisionmaker in this context. Because of the scientific uncertainty and limitations associated with modeling tools, NHTSA has not performed a quantitative near-road impacts analysis. However, the Final EIS continues to present national and regional emissions projections to adequately inform the decisionmaker about the potential environmental and health benefits of the Proposed Action and alternatives.

Comments

Docket Number: 9574 (EPA Rule Docket)
Commenter: Clean Fuel Development Coalition

Update the CMAQ model to ensure full capture of the benefits derived from the significant reductions in urban $PM_{2.5}$ secondary organic aerosol (SOA) that will occur due to the reductions in gasoline "Aromatic Group Compounds" [Footnote 3: Aromatic Group Compounds, commonly known as "aromatics", are derived from crude oil and used to enhance gasoline octane ratings. They span the gasoline distillation curve spectrum, from lower boiling compounds (benzene, toluene) to higher boiling compounds (e.g., multi-substituted alkyl aromatics, MSAAs). In addition to their octane characteristics, Aromatic Group Compounds are typically low volatility, high double bond equivalent (DBE) gasoline components. Their molecular structure makes them difficult to combust, and thus they disproportionately contribute to a wide range of emissions, including VOCs, MSATs, and particulate matter, especially in urban areas near congested roadways.] made possible by E30+ blends' substitution (especially significant for OMB cost – benefit analysis purposes, see discussion on p. 6 and Attachment D).

*** * * * ***

Footnote 9: As will be discussed in more detail below, the Agencies have stated their intention to incorporate more detailed findings in the final rule from new science and model improvements. For example, the EPA says it will use its updated CMAQv.5.0 model to "…analyze the impact of the standards on $PM_{2.5}$, ozone, and selected air toxics." This is potentially significant because EPA has known for years that its CMAQ model was substantially under-reporting the formation of mobile source $PM_{2.5}$ secondary organic aerosols (SOAs). In urban areas, $PM_{2.5}$ SOAs primarily originate from mobile sources, most importantly from toluene within the Aromatic Group Compounds. It must be assumed that incorporation of these new findings will also require NHTSA to make adjustments to its draft EIS, which gives insufficient attention to mobile source $PM_{2.5}$, particularly the future health and welfare costs which will be imposed by increases in gasoline-derived particulate matter emissions, and will most severely impact the nation's highly vulnerable urban population. New science suggests that the particulate bound toxics can be found at elevated levels up to 2,500 meters from congested roadways, thus exposing a vast majority of Americans to these deadly pollutants.

Response

Recent versions (v.4.7 and v.5.0) of the CMAQ model have improved its ability to model the processes that lead to secondary organic aerosols formation and transformation as a result of emissions of aromatics. NHTSA used CMAQ 4.7 to account for the secondary organic aerosols component of $PM_{2.5}$ in the air quality modeling for the Final EIS. (CMAQ 5.0 was released in February 2012, too late to use for the analysis presented in this EIS.) As discussed in the NPRM and the Draft EIS, the agencies recognize that populations near major roads experience elevated exposure to $PM_{2.5}$ from vehicles. NHTSA considered the most recent research on exposure near roadways in preparation of the Final EIS. However, as discussed above, the agency cannot provide precise exposure impacts for near-road effects.

Comments

Docket Number: 9593 (EPA Rule Docket)
Commenter: Bill Holmberg, Biomass Coordinating Council

The continued use of BTX [benzene, toluene, and xylene] as octane enhancers represents a serious health threat according to existing data. BTX group compounds that do not completely combust remain in the air and form fine (known as $PM_{2.5}$, or particulate matter smaller than 2.5 microns in diameter) and ultrafine particulate matter (UFP). There is extensive evidence linking $PM_{2.5}$ and UFP to numerous diseases and conditions, including

- Respiratory diseases such as asthma
- Cardiovascular illness and heart diseases
- A wide range of cancers
- Infant mortality and premature birth

Response

The agencies agree that benzene, toluene, and xylene compounds as components of $PM_{2.5}$ have adverse health effects, as discussed in the NPRM and Chapter 4 of this EIS. Tables 4.2.1-2-A1 through 4.2.1-2-B2 of the Final EIS indicate that annual $PM_{2.5}$ emissions under the Preferred Alternative in 2040 will decrease by up to 5,510 tons. Chapter 4 also discusses changes in emissions of $PM_{2.5}$ and benzene associated with the various alternatives.

9.3.1.1 Health

Comments

Docket Number: 0775.2 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

A new study published by the American Lung Association of California illustrates the massive public health and economic benefits of achieving a fleet average of approximately 74 mpg, or an annual reduction in greenhouse gas emissions of 7.8%. [Footnote omitted.] Conversely, a standard below 7.8% would cause avoidable adverse health effects. Notably, this report indicates that an annual decrease in greenhouse gas emissions of 6% is the minimum necessary to meet California's climate and health goals. Given that the Agencies are working closely with the California Air Resources Board to develop the model year 2017-2025 fuel economy standards, special consideration should be accorded to this report.

Response

NHTSA agrees that increasing the fuel economy of the passenger car and light-truck fleet will result in public health and economic benefits, which are analyzed in this EIS and the rulemaking documents. While NHTSA recognizes the important environmental considerations related to setting fuel economy standards, the agency is required to consider four statutory factors in setting "maximum feasible" fuel economy standards – technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the United States to conserve energy. 49 U.S.C. § 32902(f). NHTSA has accounted for these factors in selecting the range of alternatives analyzed in this EIS.

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

. . .[T]he Agencies should not apply a discount rate to mortality experienced as a result of breathing traditional pollutants emitted by the vehicle fleet. The Agencies justify applying a discount because of the "assumed lag in the occurrence of mortality after exposure." [Footnote omitted.] Applying a discount to the loss of human life because it might be somewhat delayed is a morally dubious if not repugnant idea.

We note that the DEIS fails to quantify the health benefits achieved from reducing ozone and air toxics; but certainly, that value is not zero and can be estimated. [Footnote omitted.]

Response

In this EIS, a discount rate is not applied to a "loss of human life" but rather to the monetary value of statistical life (VSL), a measure of the aggregate estimated value of reducing small risks across a large number of people. VSL is based on how people themselves would value reducing these risks. According to EPA's *Guidelines for Preparing Economic Analyses* (EPA 2010i):

> **VSL is a summary measure for the dollar value of small changes in mortality risk experienced by a large number of people. VSL estimates are derived from aggregated estimates of**

> **individual values for small changes in mortality risks. For example, if 10,000 individuals are each willing to pay $500 for a reduction in risk of 1/10,000, then the value of saving one statistical life equals $500 times 10,000 — or $5 million. Note that this does not mean that any single identifiable life is valued at this amount. Rather, the aggregate value of reducing a collection of small individual risks is, in this case, worth $5 million.**

Discounting reflects the fact that people generally prefer a benefit today to a future benefit. The discount rate applied to VSL reflects the value to people of a small reduction in mortality risk today compared to the value of the same reduction in the future. Here, the discounting reflects that people would place more value on the benefits of the reduction in mortality risk if they occurred today rather than 20 years after the emission reductions.

Regarding the comment about quantifying the health benefits achieved from reducing ozone and air toxics, both the Draft EIS and this Final EIS quantify the health benefits of reductions in emissions of PM, and the monetized values of those health benefits. As discussed in the Preliminary RIA and the Draft EIS, ozone-related benefits-per-ton estimates do not exist due to issues associated with the complexity of the atmospheric air chemistry and nonlinearities associated with ozone formation. The agencies believe that the available data on exposure to and health effects of air toxics is not adequate to make benefits-per-ton estimates for air toxics. As a result, the agencies are not able to quantify the health benefits. In this EIS, NHTSA does provide estimates of toxic air pollutant emissions through 2060 in Chapter 4. In addition, Appendix E to the EIS provides the agency's photochemical air quality modeling and health impacts assessment, providing information on regional and local impacts related to emissions of the criteria air pollutants, including ozone.

9.3.2 Climate

Comments

Docket Number: 0775.2 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

In responding to the Agencies' inquiry, we note that scientific literature has established that current concentrations of approximately 392 parts per million ("ppm") of CO_2 in the atmosphere have already resulted in significant adverse impacts on human health and welfare and the environment, and that present concentrations alone pose unacceptable future risks. Observed current climate impacts include a 0.8°C increase in surface temperature rise, a 30% increase in ocean acidity, increased frequency of floods, droughts and other extreme weather events, tens of thousands of climate-related deaths, declines and population extirpations of numerous species, widespread coral bleaching events, a 50% decline in Arctic summer sea-ice extent and thickness since 1980, the near-global retreat of alpine glaciers and the accelerating mass loss of the Greenland and west Antarctic ice sheets. [Footnote omitted.]

Moreover, the full extent of the temperature rise and associated impacts resulting from current CO_2 concentrations has yet to be experienced due to thermal inertia in the climate system and the effects of identified feedback loops. The additional warming already "in the pipeline" due to this warming commitment has been estimated at 0.6 °C, but could reach 1.6 °C within this century if the cooling effect of aerosols is unmasked, and may reach 2 °C in the long-term. [Footnote omitted.] From a paleoclimatic perspective, today's CO_2 levels were last seen 15 million to 20 million years ago when global surface temperatures were 3 to 6 °C warmer than they are at present [footnote omitted], suggesting that the upper end of the already unavoidable warming commitment estimates are likely.

Response

NHTSA agrees that a number of observed impacts are linked to a changing climate and summarizes these observations in Sections 5.2.2 and 5.5 of the EIS. NHTSA also provides an analysis of the complex and scientifically challenging topics of tipping points, abrupt climate change, and potential thresholds in Section 5.5.1.7 of the EIS. The EIS already included sources cited in the comment, including Stroeve et al. (2008), Kwok and Rothrock (2009), and Meehl et al. (2007). NHTSA has updated the EIS to reflect additional studies suggested by the commenter where relevant.

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

Preliminarily, we note that the DEIS does not list, and may not have taken into account, a number of peer-reviewed, directly applicable articles we have previously submitted to the Agencies. Those articles are listed in Exhibit B attached hereto.

We also submit newly issued and peer-reviewed articles on climate change and ask the Agencies to consider and include them in the FEIS. These articles are listed herein and in Exhibit C attached hereto. The Agencies have already acknowledged that they cannot solely rely on the scientific studies identified in the NOI, such as the Intergovernmental Panel on Climate Change (IPCC) 2007 Fourth Assessment Report and subsequent updates, and other sources they have identified. [Footnote omitted.] Instead, the Agencies' analysis must be informed by the latest scientific studies and findings.

Response

NHTSA recognizes that climate science is rapidly evolving and appreciates the commenter's input to ensure that the most up-to-date and relevant articles are incorporated into the EIS. NHTSA has reviewed the recommended articles and found that a number were already incorporated into the Draft EIS. In this Final EIS, NHTSA has updated the analyses to reflect the remaining suggested studies where relevant and appropriate. For example, this Final EIS incorporates the following studies: Bernstein and Myers (2011), Kwok and Rothrock (2009), Luedeling et al. (2009), Anderson et al. (2010), Friedlingstein et al. (2011), Heberger et al. (2011), Maclean and Wilson (2011), Van Vuuren et al. (2011), Davidson et al. (2012), Koven et al. (2011), Marengo (2011), Notz (2009), Rasmussen and Birk (2012), Serreze (2011), and Carstensen and Weydmann (2012).

Comments

Docket Number: 9567 (EPA Rule Docket)
Commenter: Jim Kliesch, Union of Concerned Scientists

The proposed standards will also deliver significant reductions in the greenhouse gas emissions that cause climate change. Based on UCS analysis, the 2017-2025 standards would reduce global warming pollution by as much as 290 million metric tons (MMT) in 2030 alone. This is equivalent to shutting down 62 (600 megawatt) coal-fired power plants for an entire year. When combined with the final standards for MYs 2012-2016, the National Program will reduce U.S. greenhouse gas emissions by more than 630 MMT in 2030.

Response

NHTSA agrees that the National Program, including the MY 2012–2016 CAFE standards, the MY 2014–2018 HD vehicle standards, and the Proposed Action, if adopted, will significantly reduce the GHG emissions that cause climate change. Under the Preferred Alternative, GHG emissions in 2030 are expected to be reduced by 159 to 225 million metric tons of carbon dioxide equivalent. Chapter 5 of this Final EIS provides more information about these GHG emissions reductions and the potential impact on the environment as a result.

9.3.2.1 Methodology

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

The purpose of a NEPA analysis is to inform the public of the potential impacts of a federal action. As such, it is crucial that the analysis present information in an accessible and relevant manner. As we pointed out in our June 2010 comments, with regard to climate change, regional impacts are likely to be particularly relevant to the public. Most states and/or regions of the United States have undertaken assessments of the local consequences of climate change. [Footnote omitted.] We are disappointed to note that the DEIS fails to present the regional models and information contained in these assessments for each region of the U.S. to illustrate how changes in transportation-related greenhouse emissions can influence regional climate impacts. We urge the Agencies to address this defect in the FEIS, and we encourage the use of color-coded maps for graphic illustration.

Response

To address this comment, NHTSA added Section 5.5.2 to the EIS to provide a discussion for regions across the United States, informed largely by panel-reviewed synthesis and assessment reports from the IPCC, the U.S. Climate Change Science Program, and the U.S. Global Change Research Program (GCRP). In particular, the discussion cites the regional divisions as outlined in the GCRP (2009) report, and focuses on the main impacts that affect each region.

Notwithstanding the addition of this section to the EIS, in the NEPA context there are limits to the utility of drawing from assessments summarized in local, state, and regional reports to characterize the benefits of the alternatives in terms of regional climate impacts. The existing assessment reports do not have the resolution necessary to illustrate the effects of this action, because they typically assess climate change impacts associated with emission scenarios that have much larger differences in emissions – often between one and two orders of magnitude greater than the difference between the No Action Alternative and the emissions reductions associated with all action alternatives. Therefore, NHTSA has not included color-coded maps in the EIS, as suggested by the commenter, because they would not shed additional light on climate impacts related to this action that would be meaningful for the decisionmaker. CEQ's Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions emphasizes that agencies consider presenting GHG impacts information that would be useful and relevant to the decision, and meaningful to decisionmakers and the public;

the global-scale Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) modeling reported in the EIS complies with this guidance.[3]

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

The Agencies also fail to adjust the GCAMReference scenario used to calculate cumulative impacts by including in the data base the MY 2012-2016 vehicle rules and the MY 2014-2018 heavy duty rules. The proffered justification is that this adjustment would “undermine the integrity of a well-established reference point and would have little effect on the magnitude of the impacts attributed to the rule in terms of climate parameters” [Footnote omitted.] To claim that the integrity of a factual reference point would be undermined by accurately updating those facts to include the effects of two known and extremely relevant rulemakings is nonsensical – the opposite is true. To assert that the adjustment would have little effect in terms of climate parameters simply underscores what has been wrong all along: as presently structured, the DEIS shows all climate-change related rulemaking impacts as de minimis for numerous reasons set forth above. The Agencies must update the GCAMReference as part of this FEIS.

*** * * * ***

The United Kingdom and Denmark have recently announced new plans to rapidly reduce their greenhouse gas emissions. These and other international efforts to reduce greenhouse gases must be reflected in the baseline emissions level and the reasonably anticipated future actions of third parties used for modeling the impact of the proposed regulations. Denmark recently joined Germany in its commitment to be independent from fossil fuels by 2050. [Footnote omitted.] While this is an ambitious goal, Denmark has achieved a large increase in renewable energy in the last decades while sustaining economic growth, and the Danish government views the transition to 100% renewable energy as a decision that will protect the future economy in Denmark. [Footnote omitted.] Transportation is currently one of the prime consumers of fossil fuel in Denmark, but the Danish government intends to foster a rapid transition to alternative, green vehicles by 2050. [Footnote omitted.]

The United Kingdom also recently announced that it will cut its greenhouse gas emissions 50% below 1990 levels by 2025. This is an ambitious goal that is based in part on ensuring long-term economic prosperity and that the government has determined will also be achieved without economic harm in the short-term. [Footnote omitted.]

Perhaps most astounding is the fact that to date, developing nations have pledged deeper cuts in total greenhouse gas emissions than the combined developed nations. [Footnote omitted.] If nations who are struggling with basic human necessities can pledge deep cuts in emissions, a developed nation such as the United States should be able to do better.

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[3] Memorandum from Nancy Sutley, Chair, White House Council on Environmental Quality at 1-2 (Feb. 18, 2010), *Available at*: <http://www.whitehouse.gov/sites/default/files/microsites/ceq/20100218-nepa-consideration-effects-ghg-draft-guidance.pdf>. (Accessed: July 2, 2012) (CEQ 2010).

These examples of international leadership in reducing greenhouse gas emissions are important for two reasons. First, these intentions indicate that there will be a robust and thriving international market for advanced automotive design that reduce or eliminate fossil fuel usage. If the United States wishes to compete and profit in this market, it must commit to reduced emissions and consequently to alternative vehicles and technology. Second, these international reductions are important to understanding how the proposed emissions reductions compare to global emissions. As other nations reduce their emissions, emissions from the U.S. transportation sector will constitute a correspondingly larger percentage of global emissions.

One option for quantifying the impact of U.S. transportation emissions on a global scale is to employ the freely-available C-Roads climate modeling software recently released by Climate Interactive. [Footnote omitted.] This software allows rapid assessment of emissions scenarios taking into account all international pledges.

The DEIS does not sufficiently take international greenhouse gas reduction efforts into account. In using the GCAM6.0 scenario to evaluate cumulative impacts of international initiatives, the DEIS considers only three international actions: proceedings under the UNFCCC, the European Union Emissions Trading System, and support for the Copenhagen Accords expressed during the G8 Summit in June 2010. [Footnote omitted.] As shown above, many other efforts are underway and must be accounted for. Even as to the efforts considered, NHTSA "has not attempted to quantify the precise benefits associated with these programs." [Footnote omitted.] Instead, the DEIS states that "some reduction in the rate of global GHG emissions is reasonably foreseeable in the future," and assigns "moderate reductions in the rate of global GHG emissions." [Footnote omitted.] Because the Agencies provide no justification for the amount of reductions the Agencies assume, they are arbitrary and capricious. Instead, as we have argued previously and herein, the Agencies should model the effects of the alternatives they discuss in the context of global scenarios where other nations (a) fulfill their Copenhagen pledges, and (b) reduce greenhouse gases sufficiently to comply with the adopted goal of keeping temperatures below 2 °C. Both scenarios are more reasonably foreseeable to occur in the future than the "moderate" but entirely insufficient reductions arbitrarily chosen by the Agencies. This is particularly so since, as the Agencies note, "at COP 16, in December 2010, a draft accord pledged to limit global temperature increase to less than 2 °C . . . above pre-industrial global average temperature." [Footnote omitted.] Under either of these scenarios, differences between the alternatives discussed in the DEIS will become meaningful rather than apparently futile. We urge the Agencies to perform cumulative analyses as described herein.

* * * * *

To be effective, as we have also previously suggested, the presentation must show the effect of this rulemaking in a context that does not incorrectly portray the impact of reducing greenhouse gases from the US vehicle fleet as de minimis (i.e., as affecting no more than a tiny fraction of a percentage in global temperature rise and other climate change effects) by assuming that other nations will not take adequate measures to reach the internationally agreed-to temperature goals. The Agencies' failure to provide such an analysis is unreasonable in light of their acknowledgment that "[t]he G8 summit [of 2010] officially recognized a goal that the global temperature should not increase by more than 2 °C," and that "[a]t COP-16, in December 2010, a draft accord pledged to limit global temperature increase to less than 2 °C . . . above preindustrial global average temperature." [Footnote omitted.] Despite this acknowledgment, the "cumulative impact" analysis in the DEIS proceeds on the assumption that these pledges will not be fulfilled – a choice that directly leads to an environmental impact report creating the false impression that the rulemaking's impact on climate change is minimal, regardless of what is done.

Response

For the analysis presented in this EIS, NHTSA chose to use GCAM climate scenarios because they are widely available, have been subject to public and expert scrutiny, and have been accepted by the climate change modeling community as reasonable representations of plausible future scenarios. The GCAM scenarios do not account for specific climate actions by specific nations, but instead account for a number of different global factors and targets. NHTSA has chosen not to adjust the GCAM scenarios because adjusting them would require: (1) selecting which additional climate actions should or should not be included and accounted for under the EIS No Action Alternative and (2) modifying them to account for the latest trends in economic and population growth, fossil-fuel development, and other factors that are constantly changing.

The scenarios already include several that represent significant changes in global emission levels to meet various stabilization targets. Moreover, trying to adjust the scenarios for individual actions in individual countries would be extremely complex. For example, CAFE standards affect GHG emissions from transportation CO_2, so they influence part of the emissions in 1 entry from among more than 50 in the annual series of Inventory of U.S. Greenhouse Gas Emissions and Sinks. To try to make similar adjustments for various sectors from among all countries would be extremely complicated and the resulting emission scenarios would depart from those currently accepted in the scientific community.

The cumulative impacts analysis presents the action alternatives compared to a baseline that assumes significant global actions to address climate change. GCAM6.0 is a scenario that incorporates declines in overall energy use, including fossil-fuel use, compared to the reference case. In addition, GCAM6.0 includes increases in renewable energy and nuclear energy, with the proportion of electricity-supplied total final energy increasing due to fuel switching in the end-use sectors. CO_2 capture and storage also plays an important role that allows for continued use of fossil fuels for electricity generation and cement manufacture while limiting CO_2 emissions. Although GCAM6.0 does not explicitly include specific climate change mitigation policies, it does represent a reasonably foreseeable future pathway of global emissions in response to significant global action to mitigate climate change. Therefore, NHTSA's cumulative impacts analysis illustrates the benefits of the rulemaking in conjunction with other reasonably foreseeable actions.

NHTSA performed a sensitivity analysis using the Representative Concentration Pathway (RCP4.5), GCAM6.0, and GCAMReference scenarios in part to account for the uncertainty of possible future climate actions (*see* Section 5.4.2.3.5 in the EIS). The sensitivity analysis uses the RCP4.5 scenario to represent a more aggressive series of climate actions than GCAM6.0 provides for. As the sensitivity analysis demonstrates, the choice of baseline has very little influence on the magnitude of the benefits (as measured by incremental reductions in temperature and sea-level rise or in terms of the social cost of carbon). Under the direct and indirect and the cumulative impacts analyses, the incremental benefits of this rulemaking, in isolation, might appear low regarding specified climate endpoints. However, the cumulative impacts analysis presents climate endpoints based on NHTSA's Proposed Action in addition to significant global efforts to address climate change. Taken together, these global actions can significantly reduce GHG emissions. Readers who wish to know more about the impacts on climate endpoints of the various action alternatives in addition to a moderate level of global GHG reductions based on the assumptions outlined in Section 5.3.3.2.2 can compare the No Action Alternative under the direct and indirect impacts analysis to the action alternatives in the

cumulative impacts analysis. ***See*** **Section 5.3.3.2 for a more in-depth discussion of the global emission scenarios.**

NHTSA appreciates the commenter's suggestion to consider the C-Roads emissions modeling software from Climate Interactive. While the agency acknowledges the additional efforts to create modeling software intended for policymakers, the software does not currently suit the needs of this EIS. NHTSA believes that the models used for this EIS, such as MAGICC, have received more scientific scrutiny in the climate science field and already provide the information necessary to perform a complete environmental analysis as required by NEPA.

9.3.2.2 Social Cost of Carbon

Comments

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

In addition, we recommend improvements to the methodology for determining the Social Cost of Carbon that do not unduly discount the threat to future generations and that do not fail to account transparently for non-monetized benefits.

* * * * *

It is critical that NHTSA collaborate with other agencies and carry out its responsibilities to accurately account for the Social Cost of Carbon (SCC). Cf. Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.,538 F.3d 1172, 1185 (9^{th} Cir. 2008) (finding a NHTSA fuel economy rule arbitrary and capricious where "[t]he value of carbon emissions reduction [was] nowhere accounted for in the agency's analysis, whether quantitatively or qualitatively"). The social cost of carbon is a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions. The SCC assigns a net present value to the marginal impact of one additional ton of carbon dioxide-equivalent emissions released at a specific point in time. EDF commented extensively on the consideration of the SCC in the first light-duty greenhouse gas rulemaking, the heavy-duty greenhouse gas rulemaking, and the Notice of Intent for this Draft EIS. Those comments are hereby incorporated. It is imperative that NHTSA rigorously and transparently account for the SCC in carrying out its responsibilities under NEPA, EISA, and EPCA. In the DEIS, it is noted that NHTSA adopted an approach that relies on estimates of the social cost of carbon (SCC) developed by the Interagency Working Group on Social Cost of Carbon. While we support the collaboration and work of the Group, we make suggestions below as to how the approach can and should be improved.

Lower Range of Discount Rates: In light of significant economic and ethical challenges raised by discounting, and the lack of consensus around a single number or even a single conceptual approach to choosing a discount rate, the only appropriate course of action is a fully transparent, exhaustive and rigorous process to determine a range of appropriate discount rates. As described in the DEIS, and based on the Interagency Working Group on Social Cost of Carbon, NHTSA uses discount rates of 5%, 3% and 2.5%. We believe it is not appropriate to include a 5% discount rate and we encourage NHTSA to use a range of discount rates of 3% and below in its SCC analysis, including 1% and 2% discount values, as some analysts suggest values as low as 1.4%. [Footnote omitted.] These lower values reflect the scientific, economic, and ethical complexities inherent in inter-generational discounting. We also reiterate our recommendation to use declining discount rates.

Analyzing Burdens on Future Generations: Discount rates are traditionally applied to account for a general preference for immediate benefits as opposed to benefits realized in the future. In the context of climate change, however, benefits accrue not just in the future but to future generations of people. Such intergenerational discounting is more problematic and controversial because it requires us to compare risks faced by different individuals and choose to place more value on one individual's preferences simply because he or she is alive first. Given these issues associated with inter-generational equity, we encourage NHTSA to explore other available analytical tools for defining our moral obligations to future generations. Sustainable development, utilitarianism, corrective-justice, and other ethical theories all offer social decision-makers a model for how to treat future costs and benefits. Choosing among these options is difficult but underscores the fact that our obligation to future generations is fundamentally an ethical question that cannot be resolved by economic analysis alone.

Evaluating Non-Monetized Benefits: GHG reduction policies can significantly undervalue benefits simply because some of these benefits are not easily quantifiable. The White House Office of Management and Budget recognizes that some costs and benefits will be difficult to monetize, but directs agencies to consider other means of quantification. [Footnote omitted.] We request that climate impacts omitted from the models should be identified explicitly. A table should be provided that lists, for each economic model, what impacts were not included in the model's estimate of monetized damages. Accompanying text should serve to explain and complement the table entries but not be a substitute for them. Below, we have provided an example table listing impacts typically omitted from SCC models.

List of Impacts Typically Omitted from SCC Models [Footnote omitted.]

Agriculture

- Reduction in growing season (e.g. in Sahel/southern Africa)
- Increase in growing season in moderate climates
- Impact of precipitation changes on agriculture
- Impact of weather variability on crop production

Biomes/Ecosystems

- Reverse of carbon uptake amplification of climate change
- Thresholds or "tipping points" associated with species loss, ecosystem collapse, and long-term catastrophic risk (e.g. Antarctica ice sheet collapse)
- Species existence value and the value of having the option for future use
- Earlier timing of spring events; longer growing season
- Poleward and upward shift in habitats; species migration
- Shifts in ranges of ocean life
- Increases in algae and zooplankton
- Range changes/earlier migration of fish in rivers
- Impact on coral reefs
- Ecosystem service disruption (e.g. loss of cold water fish habitat in the U.S.)
- Coral bleaching due to ocean warming

Energy

- Energy production/infrastructure
- Water temperature/supply impacts on energy production

Foreign Affairs

- Social and political unrest abroad that affects U.S. national security (e.g. violent conflict or humanitarian crisis)
- Damage to foreign economies that affects the U.S. economy
- Domestic valuation of international impacts

Forest

- Longer fire seasons, longer burning fires, and increased burn area
- Disappearance of alpine habitat in the United States
- Tropical forest dieback in the Amazon

GDP/Economy

- Insurance costs with changes in extreme weather, flooding, sea level rise
- Global transportation and trade impacts from Arctic sea ice melt
- Distributional effects within regions
- Vulnerability of societies highly dependent on climate-sensitive resources
- Infrastructure costs (roads, bridges)
- Extreme weather events (droughts, floods, fires, and heavy winds)

Health

- Increased deaths, injuries, infectious diseases, stress-related disorders with more frequent extreme weather (droughts, floods, fires, and heavy winds)
- Increases in malnutrition, food-borne illnesses
- Air quality interactions (e.g. ozone effects, including premature mortality)

Snow/Glacier

- Changes in Arctic/Antarctic ecosystems
- Enlargement and increased numbers of glacial lakes; increased flooding
- Snow pack in southeastern United States

Tourism

- Changes in tourism revenues due to ecosystems and weather events
- Arctic hunting/travel/mountain sports

Water

- River flooding
- Infrastructure, water supply
- Precipitation changes on water supply; increased runoff in snow-fed rivers
- Increasing ground instability and avalanches

* * * * *

To fully estimate the suite of benefits of the proposed standards and the alternatives, we request the final EIS provide a quantitative value for the social cost of non-CO_2 GHG emissions. While we recognize that the interagency group that developed the TSD on SCC did not decide on a methodology for estimating the costs of non-CO_2 GHG emissions, we do not believe this is a reason to assign those costs a value of zero. The DEIS discusses the idea of using GWP as a proxy but determines, "…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, omitting the other GHGs is not a barrier to distinguishing among alternatives." (DEIS, Page 5-24) We do not believe the Agency should omit benefits simply because when looked at alone they may not be a significant factor in distinguishing between alternatives. All benefits should be presented so they can be looked at and analyzed cumulatively. Indeed, in the proposed rule, EPA characterizes the failure to monetize non-CO_2 GHG emissions as a limitation: "Another limitation of the GHG benefits analysis in this proposed rule is that it does not monetize the impacts associated with the non-CO_2 GHG reductions expected under the proposed standards." (Proposal preamble, page 75,127) We therefore request that the Agencies work together to determine the most appropriate methodology for estimating the social costs of non-CO_2 GHG emissions, and include those estimates in the final EIS.

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

In our comments dated June 9, 2011 on the Notice of Intent to Prepare an Environmental Impact Statement for the MY 2017-2025 Proposed Rules, filed in this docket, we commented on the Agencies' failure to properly account for the ever increasing social cost of carbon, including the potentially calamitous costs of delaying greenhouse gas reductions to some point in the future. We submitted scientific articles demonstrating that both the current social cost of carbon ranges used by the Agencies and the slow increase in that cost are erroneous and must be revised. However, the Agencies have failed to change their assumptions and continue to use flawed data for their assessment. This FEIS must correct these shortcomings.

As we have pointed out, the world is currently heading toward a 6° C temperature increase by 2050. [Footnote omitted.] In a business-as-usual trajectory – a trajectory from which the world has not deviated and which represents the worst case scenario under the ICCP's Fourth Assessment Report – global annual CO_2 emissions will rise from approximately 30.6 Gt in 2011 up to 62 Gt/year in 2050. [Footnote omitted.] This trajectory runs completely counter to the emissions reduction needed to stabilize atmospheric CO_2 concentrations at 450 ppm, which corresponds roughly to a 2° C temperature increase: under one scenario representing an emissions peak in 2020 slightly above 32 Gt per year and a relatively gentle downwards slope thereafter, global annual emissions would need to fall to a level of 14 Gt/year by 2050 to limit global CO_2 concentrations to 450 ppm. [Footnote omitted.]

Every year that the world delays its efforts to reach sustainable levels of greenhouse gas emissions represents a lost opportunity of tremendous economic significance. McKinsey & Company estimated in 2009 that for every year of delay, 1.8 Gt of potential CO_2 abatement is foregone. [Footnote omitted.] This delay, and the accompanying Gts of lost CO_2 abatement, has a price tag, as the damage caused by CO_2 emissions accelerate while the cumulative amount of greenhouse gases in the atmosphere rises, both because of the increasingly dire damages wrought by rising temperatures and other greenhouse gas effects, and because of the delay factor itself. If governments delay mitigation in the present, the emissions reduction curve in future years necessarily becomes much steeper, requiring much more drastic and costly emission reduction mechanisms with tremendous economy-wide disruptions, just to "catch up" with the lost opportunities from prior years to reach a sustainable emissions trajectory—or risk undergoing unsustainable climatic extremes.

Economists have sought to quantify the costs of waiting to embark upon an emissions reduction path. In 2007, researchers used the DICE model [footnote omitted] to estimate the cost of delaying mitigation for a given period of time and then switching to an optimal abatement trajectory. According to their findings, the global cost of ten years of delay, relative to starting on an optimal trajectory in the present, ranges from hundreds of billions to several trillion dollars. [Footnote omitted.] For instance, this study estimates that it would cost somewhere between $200 and $400 billion dollars to delay action for ten years and then embark upon a mitigation strategy that would result in stabilization at 3 °C (a level now universally understood to far exceed the dangerous). The cost of delaying mitigation soars into the trillions of dollars as the delay continues, until it ultimately becomes impossible to achieve a certain level of temperature stabilization. According to this study, more than thirty years' delay of changing the current course would make it impossible – no matter what the expense – to stabilize temperature rises at 2° C above preindustrial levels.

The Agencies' methodology for setting a price for the social cost of carbon ("SCC"), based on the work of the Interagency Working Group of [sic] the Social Cost of Carbon, falls far short of adequately accounting for these facts or for the true SCC. The Working Group combined three existing climate models to yield its estimates: the DICE, FUND, and PAGE models. [Footnote omitted.] The Working Group's "central value" for the SCC is $23/ton in 2011 (in 2009 dollars), growing to only approximately $46/ton in 2050. [Footnote 48: (Citation omitted.) The DEIS states but rejects other values of $5, $23, $37 and $69 per metric ton of CO_2 based on discount rates of 5, 3, and 2.5 percent and, for the last number, based on the 95th percentile of the social cost of carbon from all three models at a 3 percent discount rate. (Citation omitted.)] However, these values vastly understate the economic costs of climate change. Among the many criticisms that have been leveled against the Working Group's work are the following. First, the FUND model used in the Working Group's analysis wholly excludes consideration of climate-induced catastrophic events. But the Working Group weighs the values generated by each of the three models equally, even though the FUND model's values is significantly lower [footnote omitted] than the others, and consequently pulls down the final value of the SCC. The potential for catastrophic climate events, and the increasing likelihood that tipping points will be reached even sooner than anticipated, are increasingly serious risks, however, and, despite the associated uncertainties, must be fully represented in any evaluation of the SCC. Instead, the Working Group employed a risk-neutral approach, clearly inappropriate in light of the vast majority of scientific studies. The Working Group also adopted a median temperature increase of 3 °C, which is an optimistic measure of central tendency considering the world's current emissions path. Furthermore, the Working Group decided not to include equity weighting in its calculation. Equity weighting adjusts the SCC to account for the different welfare losses associated with a given loss in income across both poor and rich nations: the loss of $1 represents a far greater loss in a poor country than a wealthy one. The Working Group's approach is seriously deficient because it understates the full cost that CO_2 emissions will have on the world's most vulnerable. All of the above choices serve to underestimate the true value of the SCC. [Footnote 50: The DEIS also asserts that many climate change effects cannot be quantified but can only be described in a qualitative fashion. E.g., DEIS, Section 5.5. Because each such decision effectively assigns zero value to real world damages, we urge the Agencies to substitute dollar figures instead.]

Other evaluations of the SCC attempt to account for these omitted factors. The Stern Review, in particular, reaches a SCC of $85/ton of CO_2 (in 2000 dollars). [Footnote omitted.] For comparison purposes with a Working Group value of $21 in 2005 dollars, this amount is equivalent to $96.25/ton in 2005. The Stern Review uses the PAGE model, which explicitly models for the risk of catastrophic climate change. [Footnote 52: According to the Working Group itself, DICE "offers the best insight into the SCC if the world were to experience catastrophic climate change." (Citation omitted.)] In contrast with the Working Group, the Stern Review uses a mean temperature increase of 3.9 °C for its baseline scenario (consistent with the Third IPCC Report) and a 4.3 °C increase for its higher climate scenario. The resulting higher value of the SCC is thus very likely to be a closer approximation of the real cost of CO_2.

The recent developments in climate science indicate both that our current emissions trajectory is higher than current models anticipated by the scenarios developed for the IPC for the use in climate models, and that the maximum temperature to avoid irreversible and calamitous climate change is lower than previously acknowledged. As discussed above, the International Energy Agency ("IEA") found that the year 2010, producing an unexpectedly high 30.6 Gt of emissions, broke all CO_2 emissions records despite the global recession that commenced in 2008. [Footnote omitted.] The IEA's chief economist interprets this development as an alarming setback, with the possibility of limiting temperature increases to 2 °C becoming extremely difficult. [Footnote omitted.] Just two days after the IEA's announcement, the head of the UNFCCC, Christiana Figueres, called for the adoption of a 1.5 °C target. [Footnote omitted.] These developments underscore the fact that existing climate cost models underestimated both the emissions trajectory and climate sensitivity to GHG emissions. In short, existing climate models are too conservative in their assumptions, and the cost of climate change – whether measured as a percentage of GDP or as a cost per ton emitted – is much higher than estimated.

As has been pointed out by us and many others, the values developed by the Working Group suffer from other, highly significant defects. The models used fail to account fully or even partially for certain highly complex aspects of climate change, including the possibility of interrelations between different sectors and accelerating damage feedback loops, non-CO_2 emissions, [Footnote 56: For instance, the estimated social cost of methane and SF6, are, respectively, $105/tonne and $200,000/tonne. (Citation omitted.)] and social and political instability. Moreover, the valuation techniques and discount rates used to reach these values are inherently problematic and fail to represent the full value of all losses from climate change, in significant part because some cannot be reduced to monetary terms. The use of discount rates in intergenerational transfer situations raises not only economic, but also ethical and moral questions. The use of any discount coupled with the under-valuation of the exponential increase in damages caused by delayed mitigation efforts distorts the value even further. Yet, the DEIS fails to present the decision maker with any calculation showing the SCC without a discount. In addition, these values represent a global average and thus likely mask much higher costs to vulnerable populations. In sum, the social cost of carbon is certainly much larger than the estimates previously used by the Agencies.

The Agencies are performing a cost-benefit analysis and have based their selection of the "preferred alternative" on that analysis, but they have not corrected what is understood to be flawed data in arriving at the SCC. They themselves note that their current SCC values are subject to serious questions. [Footnote 57: The DEIS states that the SCC calculation raises "serious questions of science, economics, and ethics, and should be viewed as provisional." DEIS at 5-23. It also notes "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." Id.] Yet, they shirk responsibility for correcting these flaws: "The interagency group hopes that over time researchers and modelers will work to fill these gaps and that the SCC estimates the Federal Government uses for regulatory analysis will continue to evolve with improvement in modeling." [Footnote omitted.] Vague hopes of future improvements in the light of acknowledged deficiencies are insufficient. The Agencies are the Federal Government for purposes of this rulemaking, and it is incumbent upon them to rectify errors in the cost-benefit analysis upon which they rely to arrive at their conclusions. We urge them to correct the data and methodology they employ to calculate the SCC in the final FEIS.

When the magnitude of the cost of carbon is juxtaposed with the lost abatement opportunity of each year of delay, the total costs of procrastinating on mitigation assume great economic significance. The time frame in question is very short: as discussed above, it is becoming increasingly obvious that a ten year global delay in mitigation (starting in 2010) will make an at least 2 °C increase all but inevitable. [Footnote omitted.] Maximally improved vehicle emissions standards are an indispensable part of the mitigation strategy, as emissions from personal vehicle use in the US alone accounted for approximately 20% of national CO_2 emissions and slightly below 4% of global emissions in 2009. [Footnote 60: (Citations omitted.) Personal vehicle use accounted for 65% of the emissions from the transportation sector, which constituted 33% of CO_2 emissions from fossil fuel combustion in 2009. CO_2 emissions from fossil fuel combustion contributed, in turn, to about 95% of total US CO_2 emissions in 2009. In 2009, the US contributed about 18% of global emissions. (Citations omitted.)] Low CAFE standards for the 2017-2025 period, on the other hand, would entail a disastrous foregone abatement opportunity.

Docket Number: 9472 (EPA Rule Docket)
Commenter: Laurie Johnson, Natural Resources Defense Council

The centuries-long impacts of greenhouse gases emitted today make the choice of the discount rate particularly contentious, because the farther into the future climate damages occur, the smaller the weight assigned to them as a result of discounting. Discounting at too great a rate could result in a heavy bias toward favoring the current generation and ignoring catastrophic damage several generations hence. Greenhouse gas emissions also affect the entire earth's atmosphere regardless of where the emissions occur. A perverse consequence of this is that many of the world's poor, who neither emitted the gases nor benefited from the economic growth that ensued, will be disproportionately impacted. This makes decisions about "equity weighting" important and controversial. [Footnote 3: Equity weighting refers to weighing damages to poor countries more heavily than those to wealthy countries in any given time period. This is distinct from weighting damages over time. To the extent that developing countries become wealthier in the future from current high emission levels (e.g. China), the resulting growth in income over time is partially canceled out by discounting damages. More precisely, the more a country's income is assumed to grow (which is assumed to increase with increasing emission levels), the lower the present value of climate damages. In this sense, discounting "equity weighs" damages over time by counting damages to richer future generations less the richer they become (See Section II.a).]

Many of the problems associated with IAMs can be avoided, at least in theory, by using a "shadow price of carbon" (SPC) approach to assess climate change mitigation policies, which is distinctly different from cost benefit analysis. Under the SPC approach, society determines a mitigation target based upon science (rather than upon piecemeal marginal cost benefit analysis regulation by regulation), estimates the marginal abatement cost of that target, and then pursues mitigation policies whose costs are less than or equal to that value—essentially a cost effectiveness framework. This approach more closely follows an insurance perspective than does the social cost of carbon approach—and is better suited for the kind of non-marginal changes in emissions that would be prescribed by comprehensive climate legislation NRDC supports (rather than estimating the marginal damage of one extra ton of CO_2, the SPC is based upon a large change in emission levels and a defined target). But the SPC also has its drawbacks—the largest one being that politics rather than science could dominate the choice of the target, producing a target that falls short of what is needed to minimize catastrophic risks. Indeed, with Congress's failure to pass comprehensive climate legislation, the U.S. effectively has no target.

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GWP Method. Because models directly estimating climate mitigation benefits for other gases are still in their early stages of development, GWPs should be used to calculate climate benefits from reducing non-CO_2 greenhouse gases (Recommendation #1). In so doing, 100 year GWPs should be used, following domestic and international conventions. Further, the most recent GWP estimates from the IPCC's Fourth Assessment Report should be used (rather than GWP estimates from the Second Assessment Report, as was recently used in the proposed oil and gas new source performance standards for methane). For methane calculations and carbon monoxide, EPA should do a sensitivity analysis using the most recently published GWP estimates. [Citation and footnote omitted.] (Recommendation #2); in addition, CO_2 fertilization benefits need to be adjusted to reflect non-CO_2 gases actual contribution of CO_2 to the atmosphere, which is less than direct CO_2 emissions (Recommendation #3).

Improved SCC. a. Use the updated versions of the social cost of carbon models that were used for the 2010 estimates to re-estimate the SCC for this rulemaking (Recommendation #4).

b. Use a lower discount rate. We recommend 0.7%, the average return on 6 month U.S. Treasury Notes (Recommendation #5), for several reasons (see discussions in Section I.2. and d) and e) in Section II. At a minimum, whatever discount rates the agencies adopt, it needs to include an estimate of the SCC using the government's own recommended lower bound sensitivity value for intergenerational discounting, of 1% (OMB, Circular A-4). [Footnote 5: In 2008, EPA suggested an even lower bound of 0.5%.Technical Support Document on Benefits of Reducing GHG Emissions. U.S. Environmental Protection Agency, June 12, 2008. As EPA notes in the beginning of the document, it began developing most of the information in the report in support of the Executive Order 13432 for developing CAA (Clean Air Act) regulations that would reduce GHG emissions from motor vehicles.] The choice by the Working Group not to use the lower bound was not justified, and should not be continued. If the agencies elect not implement this recommendation, we request it provide a justification (Recommendation #6).

c. Short of our preferred 0.7% rate, the agencies should at least use a more representative set of discount rates that take into account long run uncertainty in interest rates. The range should include Weitzman [Footnote 6: Weitzman, M (2001). Gamma Discounting. American Economic Review, American Economic Association, vol. 91(1): 260-271.] and UK Greenbook [Footnote 7: Lowe, J (2008). Intergenerational wealth transfers and social discounting: supplementary greenbook guidance. UK Treasury. http://www.hm-treasury.gov.uk/d/4(5).pdf. Note that the schedule in this supplement to the greenbook subtracts out an implicit positive value for the pure rate of time preference, appropriate for intergenerational discounting.] declining discount rate schedules, not just the Newell-Pizer estimate already used by the Working Group (Recommendation #7). If the agencies elect not implement this recommendation, we request it provide a justification.

Transparency of SCC. EPA should provide a more transparent presentation of the social cost of carbon used in the calculations, such that it better conveys the limitations of the models to handle catastrophic risks and many damage categories, by

a. Providing a detailed list of damages included and excluded from the models in tabular format (Recommendation #8). If the agencies elect not implement this recommendation, we request it provide a justification.

b. Providing the 99th percentile social cost of carbon estimates (Recommendation #9). If the agencies elect not implement this recommendation, we request it provide a justification.

Recommendations for the Interagency Working Group. The agencies should recommend to the Interagency Working Group, along with Recommendations above, that the Group:

a. Incorporate risk aversion according to different available methodologies as summarized in Kosky and Kopp (2011) [Footnote 8: Kousky, C, and Kopp, RE (2011). Risk Premia and the Social Cost of Carbon: A Review. Economics: The Open-Access, Open-Assessment E-Journal. Discussion Paper No. 2011-19. http://www.economics-ejournal.org/economics/discussionpapers/2011-19.] (Recommendation #10).

b. In addition to incorporating risk aversion, better integrate the very high and catastrophic damages to which individuals are risk averse into all three models. Specifically, the Working Group should 1) use Weitzman's analysis (2009) [Footnote 9: Weitzman, M (2009). On Modeling and Interpreting the Economics of Catastrophic Climate Change. Review of Economics and Statistics 9(1): 1-19.] to "extend the grid" in the Monte Carlo simulations; 2) for catastrophic outcomes, consider using as an estimate of damages Weitzman's implied "value of statistical life on Earth as we know it," the VSL (value-of-a-statistical life), multiplied by world population; 3) reduce the amount of low cost adaptation assumed in the models; and 4) modify damage functions to reflect cross-sectoral damages (Recommendations #11, 12, 13, 14).

c. Conduct sensitivity analyses equity weighting the SCC according to different available methods (Recommendations #15, 16).

d. Review the literature for estimates of the ratio between non-use and use values, and develop a methodology to apply a multiplication factor (or factors) to relevant use values included in the models (Recommendation #17).

e. Dedicate full time staff to collecting and reviewing new climate science and economic modeling on an ongoing basis, and regularly incorporate these developments into the SCC models. As they become available, post findings on a public website with links to sources (Recommendations #18, 19).

f. Update the models to reflect recent research on agricultural changes, which suggest the CO_2 fertilization is overestimated in the FUND model, and that much, if not all, fertilization benefits may be cancelled out by negative impacts on agriculture (e.g. extreme heat, pests, and weeds) (Recommendation #20).

g. Examine whether the upper ends of the 612 to 889 ppm of CO_2 in the four business-as-usual scenarios used by the Working Group reflect current worse-case estimates (Recommendation #21).

Docket Number: 9519 (EPA Rule Docket)
Commenter: Hilary Sinnamon, Environmental Defense Fund

While we support the collaboration and work of the Group, the SCC used should always be based on models reflecting the latest science, as the Agency has itself committed to do. All three modeling teams, whose work led to the report by the Interagency Working Group, have since updated their models to reflect the latest research and methodological developments. At the very least, the SCC used should be updated using the current versions of the models.

We make additional suggestions below as to how current modeling approaches can and should be improved in order to meet the Agency's commitment to update the social cost of carbon as the underlying models and methodologies are improved [footnote omitted]:

Declining discount rate over time: In assigning a dollar value to reductions in CO_2 emissions, the Agencies use the social cost of carbon and the discount rates included in the Interagency Working Group on Social Cost of Carbon. This includes the use of 5 percent, 3 percent and 2.5 percent discount rates. Recent advances in economic theory indicate that it is not appropriate to use such high and constant discount rates in the context of the social cost of carbon analysis, with a constant 5 percent discount rate being particularly inappropriate. A certainty-equivalent approach, for example, would yield much lower constant discount rates than those currently used. At the very least, we encourage the Agency to use a range of discount rates of 3 percent and below in its SCC analysis. We strongly recommend, however, that the Agency move as soon as possible to the use of a declining social discount rate. Appropriately accounting for uncertainty around the discount rate over long time horizons generates a discount rate that declines over time. As demonstrated at an academic workshop convened by Resources for the Future on Intergenerational Discounting, September 22-23, 2011, there is broad support for the use of declining discount rates within the relevant community of experts. [Footnote omitted.] These declining rates reflect the scientific, economic, and ethical complexities and uncertainties inherent in intergenerational discounting.

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Evaluating catastrophic risks: The SCC numbers currently used seriously undervalue low-probability/high-consequence climate impacts. Functional form assumptions in the models used in the Interagency Report misrepresent these risks and lead to inaccurately-low SCC numbers. In particular, they cut off the tails of distribution functions too quickly, ignoring potentially catastrophic climate risks.

[Footnote omitted.] The SCC numbers used should reflect the uncertainty range around different functional forms and standard assumptions around risk aversion in order to more accurately value potentially catastrophic climate impacts. [Footnote omitted.]

Docket Number: 0775.2 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

A 2010 study converted planetary warming caused by changes in sea and land albedo (reflectivity) and changes in methane emissions into annual CO_2 equivalents, and then calculated the costs incurred by that additional warming using various estimates of the per-ton social cost of carbon estimates. Estimated costs in 2010 from the decline in albedo and increase in methane emissions alone range from $61 billion to $371 billion. By 2050, this number rises to a cumulative range of $2.4 trillion to $24.1 trillion. Over the remainder of the century, cumulative costs could range from $4.9 trillion to $91.2 trillion. [Footnote omitted.] Models of future ocean and weather patterns are likely to bring longer seasons of Harmful Algal Bloom (HAB) outbreaks in Puget Sound, which could translate to longer shellfishery closings and threaten the state's $108 million annual shellfish industry. [Footnote omitted.]

Response

NHTSA appreciates the commenters' recommendations about the social cost of carbon (SCC) estimates, which were developed through an interagency process that included NHTSA, EPA, and other executive branch entities, and concluded in February 2010. NHTSA and other federal agencies have since used these estimates to calculate the potential social costs and benefits of various regulatory actions that have impacts on cumulative global emissions. NHTSA recognizes and acknowledges that the SCC estimates are not exhaustive and would benefit from further analysis. The U.S. Government is working on revising these estimates, considering new research findings that were not included in the first round. To help inform this process, DOE and EPA hosted a series of workshops. The first workshop focused on conceptual and methodological issues related to integrated assessment modeling and valuing climate change impacts, along with methods of incorporating these estimates into policy analysis. The second workshop reviewed research on estimating impacts and valuing damages on a sectoral basis *See* EPA website *available at*: <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwRepNumLookup/EE-0564?OpenDocument> (Accessed: July 2, 2012) for details about the workshop series (EPA 2010g).

The interagency group committed to update the SCC estimates as the science and economic understanding of climate change and its impacts on society improves over time. The group set a preliminary goal to revisit the SCC values within 2 years, or at such time as substantially updated models become available, and to continue to support research in this area.

NHTSA has reviewed the commenters' specific comments about discount-rate selection and analyzing effects on future generations, and will continue to consider these comments as the current SCC estimates are updated. In the meantime, NHTSA used the discount rates selected by the interagency group; the basis for this approach is discussed in detail in the SCC TSD (EPA 2010b). In sum, the interagency group applied three constant certainty-equivalent discount rates (2.5, 3, and 5 percent) to the SCC estimates. These values are within the range provided by empirical applications of different approaches to identifying a discount rate, accounting for the ethics of inter-generational issues,

investment risk, and uncertainty. The discount rates of 3 and 5 percent are consistent with after-tax returns on riskless and risky investments, respectively, and also with other perspectives on identifying a discount rate. The discount rate of 2.5 percent reflects the additional impact of uncertainty over time on the discount rate, and also responds to concerns that rates lower than 3 percent be used for normative reasons in an inter-generational context. NHTSA recognizes the limitations of the discounting approach used in the interagency modeling, but finds it to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of cost-benefit analysis and with the approach outlined in existing Office of Management and Budget guidance.

Regarding the comment about the SCC values used in the analysis, the interagency group did not obtain its range of SCC values by sampling the breadth of published SCC values; rather it used a series of model runs with parameters described in the SCC TSD. The Stern review, cited by the commenter, and many other papers were considered in the choice of the range of parameters to use. *See* page 22 of the SCC TSD for more discussion.

Regarding the recommendation to identify non-monetized benefits, it is not possible at this time to provide a precise list of each model's treatment of (i.e., included or excluded) climate impacts. Instead, the SCC TSD presents a robust discussion of this key analytical issue (e.g., how each model estimates climate impacts, the known parameters and assumptions underlying those models, and the implications of incomplete impacts [catastrophic and non-catastrophic] for the SCC estimates). NHTSA notes that the commenter does not provide a complete list for all three models used to estimate the SCC. Moreover, the discussion in the SCC TSD underscores the difficulty in accurately distilling the models' treatment of impacts in tabular form. Most notably, the use of aggregate damage functions – which consolidate information about impacts from multiple studies – in two of the models poses a challenge in listing included impacts. For example, within the broad agricultural impacts category, some of the sub-grouped impacts are not explicitly modeled, but are highly correlated to other subcategories that are explicitly modeled. Therefore, it could be misleading to identify these kinds of impacts as either "included" or "omitted" from the model. Along those lines, impacts might be included in models, but not directly; the Dynamic Integrated Climate and Economy (DICE) model represents adaptation implicitly through the choice of studies used to calibrate the aggregate damage function, and the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model includes adaptation both implicitly and explicitly (*see* the SCC TSD for details). Accordingly, NHTSA recognizes the need for a thorough review of damage functions – in particular, how the models incorporate adaptation, technological change, and catastrophic damages. As noted above, DOE and EPA are exploring the treatment of impacts in the models.

Finally, commenters state that the SCC analysis omits the damages caused by emissions of gases other than CO_2 and recommend that this be corrected. The interagency group did not estimate the social cost of non-CO_2 GHG emissions, and hopes to develop methods to value GHGs other than CO_2 in the next round of SCC estimation. However, in response to the commenter, NHTSA has updated the SCC analysis to include the GWP-weighted CO_2e values for non-CO_2 GHGs to approximate the impacts of each alternative. This addition of non-CO_2 GHGs had a very minor impact on the overall SCC results.

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

We note that the DEIS arbitrarily selects different cut-off dates for various calculations without providing any justification therefor. For example, the DEIS cuts off the calculation of the SCC in 2050, even though it calculates greenhouse gas emissions through 2100 and the health impacts of criteria pollutants through 2060. [Footnote omitted.] A cost-benefit analysis that performs calculations of relevant costs and benefits over different time periods cannot but result in skewed results. We urge the Agencies to compete the calculations – which obviously can be performed – through 2100 for every input they are considering, unless they provide a reasonable justification for doing otherwise.

Response

One of the reasons for truncating the SCC analysis in the Draft EIS at 2050 is that 2050 is the time horizon of the SCC values reported by the interagency group. As the interagency group acknowledged, the uncertainties associated with the SCC rise dramatically beyond that point. In addition, the net present value of impacts associated with emissions beyond 2050 is quite low, as measured using the SCC and a range of discount rates. For example, the net present value of a dollar at a 3 percent discount rate is only 5 cents 100 years from now. However, in response to a similar comment on a previous NHTSA EIS (for HD vehicles), we added an analysis examining the sensitivity of the results to extrapolating the SCC to 2100. In this simple sensitivity analysis, we found that the net present value of impacts associated with emissions out to 2100 increases, depending on the discount rate, by 19 to 79 percent in the analysis of direct impacts (as discussed in EIS Section 3.5), and 65 to 119 percent in the emissions scenario incorporating other foreseeable actions (as discussed in EIS Section 4.4). Using this simple analysis, we can see that total benefits from GHG emissions reductions increase by extending the analysis to 2100; however, the relative effectiveness of the alternatives does not change, so a full analysis through 2100 is not warranted. NHTSA did not assess health impacts of criteria pollutants beyond 2060, because there is a high level of uncertainty regarding not only the actual levels of criteria pollutant emissions even beyond 2040, but also uncertainty in the growth and distribution of population (which affects exposure levels) and changes in incomes (which affect monetized values of health benefits).

9.3.2.3 Tipping Points/Abrupt Climate Change

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

The DEIS devotes space to the discussion of tipping points but opines that damages from such tipping points cannot be quantified. [Footnote omitted.] As a result, the DEIS' cost-benefit analysis attaches a value of zero to these damages. This approach is certainly in error. [Footnote 62: (Citation omitted.) We have cited recent peer-reviewed scientific articles discussing the occurrence of and damages wrought by exceeding tipping points in Exhibit C, attached hereto, and request that the Agencies consider them when quantifying tipping point damages.]

The DEIS begins this discussion by defining climate tipping points as situations in which the climate system (the atmosphere, oceans, land, cryosphere 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" . . . could result in abrupt changes in the climate . . . [that] could occur so quickly and unexpectedly that human systems would have difficulty adapting to them. [Footnote omitted.]

Despite the clear danger posed by and high likelihood of tripping climate tipping points, the Agencies state that they have not quantified these risks (under either the direct-indirect or the cumulative analysis) because "the current state of science does not allow for quantification of how emission reductions from a specific policy or action might affect the probability and timing of abrupt climate change." [Footnote omitted.] This justification cannot withstand scrutiny: under the cumulative impacts analysis, the Agencies need not quantify how increasing U.S. mileage standards alone would affect tipping points (indeed, no individual action by itself can halt GHG emissions sufficiently to avoid tipping points), when it can quantify the damages likely to arise from crossing them as a result of cumulative impacts. Indeed, for 2100 the DEIS depicts global CO_2 concentrations exceeding 780 ppm, and temperature increases well above 3 °C under all of its scenarios, conditions under which tipping points are very likely to have been exceeded. Certainly, the Agencies must account for tipping point damages in these scenarios.

We note that the qualitative survey of tipping points provided in the DEIS as well as the FEIS accompanying the MY 2012-2016 vehicle rules relied upon here [footnote omitted] contain ample information to begin quantification of the tipping point risk. The MY 2012-2016 FEIS described continental, sub-continental, regional and local effects of crossing tipping points, including dramatic alteration of the Asian monsoon; overturning of the circulation system in the Atlantic Ocean; the collapse of the West Antarctic ice sheet; the loss of the Greenland ice sheet; drying in the southwestern United States leading to drought and increases in fire frequencies; and loss of the Sierra Nevada snow pack. The FEIS noted that such tipping points are characterized by rates of change sharply greater than what has prevailed over previous decades and change acceleration at a pace that exceeds the resources and ability of nations to respond to it. [Footnote omitted.] The MY 2012-2016 FEIS further pointed out that tipping points can occur at levels "exceeding 450 ppm" and that, while "future abrupt changes cannot be predicted with confidence, . . . climate surprises are to be expected." [Footnote omitted.] The MY 2012-2016 FEIS also noted that, based on "'growing evidence that even modest increases in [global mean temperature] could commit the climate system to the risk of very large impacts on multiple-century time scales,' the risks of large-scale discontinuities were expertly judged to begin being a source of substantial risk around 1 °C (around 2 °F). Smith et al. (2008) projected 2.5 °C (4.5 °F) . . . to be the 'possible trigger for commitment to large-scale global impacts over multiple-century time scales.'" [Footnote omitted.]

In other words, the best outcome the DEIS (and the MY 2012-2016 FEIS before it) describes as resulting from its most stringent alternative and the "reasonably foreseeable" actions of other parties virtually commits the environment to massive, large-scale trigger points that cause changes to which we can no longer adapt. The economic value of such damages is neither zero nor unquantifiable. Indeed, the DICE and PAGE models used to assess the SCC, discussed above, include a tipping point valuation. We urge the Agencies to complete a valuation of the economic effects of tipping points, at least on a cumulative basis, and include that valuation in the cost-benefit analysis of the underlying rulemaking.

Response

NHTSA appreciates the discussion of tipping points and citations provided. Many scientists assert that if thresholds related to the climate system are exceeded, there could be severe and abrupt climate changes and impacts. For this reason, this EIS discusses the potential impacts of reaching or passing various climate tipping points (*see* Section 5.5.1.7) and applies SCC estimates that incorporate models accounting for the damages associated with crossing tipping points. There are three things in particular that NHTSA would like to clarify in response to this comment.

First, the commenter incorrectly states that the Draft EIS attaches a value of zero to the damages resulting from climate change tipping points. The EIS incorporates the latest technical findings from the Interagency Working Group on the Social Cost of Carbon, which include model results that quantify tipping-point risk in SCC estimates. The interagency group was established by the White House to develop SCC estimates that federal agencies could use to quantify the benefits of reducing CO_2 emissions in cost-benefit analyses of regulatory actions that have marginal impacts on cumulative global emissions (EPA 2009d, p. 2). Estimating the SCC challenges the state of the art in climate science and economics, and the SCC estimates NHTSA used in the EIS represent the interagency group's latest technical support on this issue. The interagency group is committed to updating the SCC estimates as the science and economic understanding of climate change impacts on society improves over time. Reports from workshops EPA convened to provide input to subsequent analyses of SCC are *available at*: <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwRepNumLookup/EE-0564?OpenDocument> (Accessed: July 2, 2012) (EPA 2010g); <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwRepNumLookup/EE-0566?OpenDocument> (Accessed: July 2, 2012) (EPA 2010h).

Two of the three integrated assessment models the interagency group applied in developing SCC estimates for the cost-benefit analysis (i.e., Policy Analysis for the Greenhouse Effect [PAGE] 2002, DICE, and FUND) incorporate the costs from climate change tipping points or large-scale "discontinuities," as follows:

- **PAGE2002 includes the costs of catastrophic, discontinuous tipping points in a damage sub-function, modeled probabilistically (EPA 2010d, p. 7). Above a threshold global average temperature increase, the probability of a large-scale discontinuity increases for every 1° C (1.8 °F) rise in global average temperature. The damage associated with a large-scale discontinuity is characterized by the percent loss of gross domestic product (GDP) in the European Union; this is scaled to other regions by weighting factors (Hope 2006, p. 24). To capture uncertainty, these parameters are modeled as random variables in a probabilistic Monte Carlo analysis, each with a triangular distribution characterized by mean, minimum, mode, and maximum values. For example, the modal parameter values used to characterize the risk of a large-scale discontinuity specify that, above a global average temperature increase of 5 °C (9 °F), the probability of a large-scale discontinuity increases by 10 percent, and that the loss in the European Union, if a discontinuity occurs, would be 10 percent of GDP (Hope 2006, p. 25). Accounting for large-scale discontinuities increases the mean marginal impact of a metric ton of CO_2 by 16 percent compared to an earlier version of PAGE (Hope 2006, p. 30).**
- **DICE includes the expected value of damages from climate change tipping points. The expected value of damages from low-probability, high-consequence tipping points is based on a survey of experts (EPA 2010d, p. 6). The damages are incorporated as expected values based on the probability and consequence of abrupt, catastrophic changes. The probability of catastrophic damages increases with increased warming; the expected value is applied deterministically, added**

to other market and non-market impacts calculated by the model (EPA 2010d, p.6; Ackerman et al. 2010, p. 1658).

- **FUND does not consider damages from low-probability, catastrophic impacts (EPA 2010d, p. 8).**

Second, the commenter states that the qualitative survey of tipping points contains "ample information to begin quantification of the tipping point risk." The scientific literature describes potential tipping points, but the qualitative nature of this information does not enable quantification beyond what is already incorporated into the SCC analysis. NHTSA has qualitatively summarized the current state of scientific knowledge concerning low-probability, catastrophic events in Section 5.5.1.7 of the EIS.

There remains substantial uncertainty surrounding the existence of various tipping points, and their triggering at a specific CO_2 concentration (e.g., 450 parts per million [ppm]) or increase in global mean temperature (e.g., 2 °C [3.6 °F] above pre-industrial levels). Although Section 5.5.1.7 discusses many of these tipping points, the current scientific literature generally discusses their occurrence using broad ranges of CO_2 concentrations or projected increases in global mean temperature.

PAGE and DICE incorporate estimates of the timing and consequence of tipping-point risk using approaches that – while subject to modeling limitations and uncertainty associated with the timing and consequence of possible tipping points – are consistent with approaches advanced in the scientific literature regarding tipping-point risks. For example, Lenton and Schellnuber (2011, p. 186) provide an initial "straw man" tipping-point risk assessment that assigns likelihoods and relative impacts to different tipping points on a five-point scale (i.e., low, low-medium, medium, medium-high, high). Likelihood is determined based on scientific literature and expert judgment, while relative impacts are assigned based on "initial subjective judgment." As explained above, to account for the uncertain impacts of crossing tipping-point thresholds, DICE and PAGE incorporate similar parameters to estimate the probability and consequence of catastrophic changes in climate. DICE uses parameters of the likelihood and consequence of a catastrophic event to apply an expected value of the risk (Nordhaus 2008, p. 27–28), whereas PAGE applies these parameters probabilistically to calculate a probability distribution of the risk rather than a single estimate (Hope 2006, p. 21).

Given the limitations and uncertainty associated with these approaches, NHTSA stated in the Draft EIS that "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" (Draft EIS, p. 5-35). We have expanded the discussion in this Final EIS to clarify how the DICE and PAGE models consider tipping-point risk through parameters related to the likelihood and consequence of abrupt climate change, and that these estimates are included in the SCC estimates.

Third, NHTSA's action is one of several federal programs that, together, could make substantial contributions to averting levels of abrupt and severe climate change. To the degree that the action in this rulemaking reduces the rate of CO_2 emissions growth, the rule contributes to the general reduction or delay of reaching these tipping-point thresholds. Addressing abrupt and severe climate-change tipping points requires a global effort, including CO_2-reduction initiatives beyond the scope of the current rulemaking. NHTSA recognizes the potential severity of the consequences and the desire for unified action to avert possible impacts of abrupt climate change. The EIS discussions of tipping points and abrupt climate change therefore include discussions of potential impacts and the possible severity of those impacts. *See* Section 5.5.1.7.

In response to this comment, NHTSA added to the EIS information extracted from the following peer-reviewed studies cited by the commenter: Friedlingstein et al. (2011), Lenton (2011), UNEP (2011), Van Vuuren et al. (2011), Lenton (2012), Marengo (2011), Notz (2009), Rasmussen and Birk (2012), Serreze (2011), Carstensen and Weydmann (2012), and Friedrich et al. (2012).

9.3.2.4 Cumulative Climate Impacts

Comments

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute

NHTSA also must account for these regulations affecting emissions from electricity generation in the cumulative impacts analysis. See Draft EIS chapter 5. In the cumulative impacts analysis, NHTSA includes initiatives and programs that it "has tentatively concluded are past, present, or reasonably foreseeable future actions to reduce GHG emissions." See id. at 5-29. Under federal actions, NHTSA included only EPA's GHG PSD permitting program, but not the GHG NSPS regulations for electric generating units (EGUs) that EPA plans to propose this year and are required as part of settlement agreement entered into by EPA at the end of 2010. [Footnote 2: EPA entered into a settlement agreement to address GHG emissions from EGUs and refineries on December 23, 2010. See EPA's website for more information: http://www.epa.gov/airquality/ghgsettlement.html. EPA has failed to meet some of the deadlines in the settlement agreement, but any near-term delay in the proposal or finalization of the EGU GHG NPSP is not a valid reason for excluding these regulation and their impacts from NHTSA's Draft EIS for vehicle standards that will not take effect until MY 2017].

Given that the proposed standards are part of a joint rulemaking with EPA, the GHG NSPS for EGUs – which will affect both new and existing EGU GHG emissions – is more than reasonably foreseeable. It must be included in NHTSA's cumulative impacts analysis.

Response

In response to this comment, NHTSA has added a discussion of EPA's proposed carbon pollution standard for new power plants as part of NSPS to Section 5.3.3.2.3 of the Final EIS. As stated in Chapter 5, the GCAM 6.0 scenario used in the cumulative impacts analysis does not account for any specific domestic or international climate actions, such as the NSPS. GCAM6.0 represents a global emissions scenario that assumes a moderate level of global GHG reductions.

9.3.2.5 Health, Society, and Environmental Impacts of Climate Change

Comments

Docket Number: 0775.2 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

Climate change is expected to increase ozone pollution and its health and economic burdens across large parts of the US. An analysis of future climate-induced temperature increases and their relationship to ozone formation found that expected increases in ground-level ozone concentrations in 2020 could lead to an average of 2.8 million more occurrences of acute respiratory symptoms, 944,000 more missed school days, and over 5,000 more hospitalizations for respiratory-related problems. In 2020, the continental U.S. could pay an average of $5.4 billion (2008$) in health impact costs associated with the climate penalty on ozone, with California experiencing the greatest estimated impacts averaged at $729 million. [Footnote omitted.]

Americans today experience climate-induced health effects in the form of illness, injury and death from extreme heat, extreme precipitation, and vector-, food-, and water-borne disease. Extreme precipitation in the Midwest, South and other regions has increased by 50%, most of it over the last few decades. The US experienced more than 3,400 deaths between 1999 and 2003 that were reported as resulting from exposure to excessive heat. There are an estimated 38 million cases of food- and water-borne illness in the US each year, caused in part by an increasing number of pathogens in the wake of extreme weather events such as droughts, flooding, and hurricanes. [Footnote omitted.]

Heat is already the leading cause of weather-related deaths in the United States, and more frequent extreme heat waves will increase the risk of illness and death. Projections for Chicago suggest that the average number of deaths due to heat waves would more than double by 2050 under a lower emissions scenario and quadruple under a high emissions scenario. In Los Angeles, annual heat-related deaths are projected to increase by two to three times by the end of the century under a lower emissions scenario and by five to seven times under a higher emissions scenario, compared to a 1990s baseline. The number and intensity of some extreme weather events are already increasing and are projected to increase further in the future, leading to increases in associated injury, illness, emotional trauma, and death. For example, over 2,000 Americans were killed in the 2005 hurricane season, more than double the average number of lives lost to hurricanes in the United States over the previous 65 years. Groups including children, the elderly, and the poor are particularly vulnerable to climate-related health effects. [Footnote omitted.]

Climate change represents a major threat to children's health. Climate change is increasing the global disease mortality, and in the year 2000 was responsible for more than 150,000 deaths worldwide, 88% of which were children. Documented health effects of climate change on children include changing ranges of vector-borne diseases; increased diarrheal and respiratory disease; increased morbidity and mortality from extreme weather; changed exposures to toxic chemicals; worsened poverty; food and physical insecurity; and threats to habitation. [Footnote omitted.]

In the United States, climate change poses a threat to children's health by placing additional stress upon the availability of clean air, food, and clean water, and by increasing the spread of some vector-borne diseases. Lyme disease is the most common vector-borne disease in the United States, with 25,000–30,000 cases reported to the CDC per year, with the highest incidence among children between ages 5 and 9. Warming is thought to be promoting the spread of the Lyme disease to new regions. Asthma remains a leading cause of morbidity and school absenteeism in the United States. Air pollution constituents that trigger asthma attacks, specifically air particulates and ozone, are expected to increase with climate change. [Footnote omitted.]

* * * * *

Models show that projected climatic conditions by the middle to end of the 21st century will no longer support some of the main tree crops currently grown in California. Winter chill, one of the defining characteristics of a location's suitability for the production of many tree crops, was modeled for two past temperature scenarios (1950 and 2000), and 18 future scenarios (2041– 2069 and 2080-2099 under three different greenhouse gas emissions scenarios). For all emissions scenarios, the area of safe winter chill for many tree species is predicted to decrease 50-75% by mid-21st century, and 90 – 100% by late century. [Footnote omitted.]

* * * * *

Climate change threatens food security in the United States. Higher levels of warming and extreme weather events such as droughts and flooding are expected to negatively affect crop growth and yields. Warming will benefit weeds, diseases, and insect pests, increasing stress on crop plants and requiring more pest and weed control. Increasing CO_2 concentrations are expected to lead to declines in forage quality in pastures and rangelands for livestock, while increased heat, disease, and weather extremes will increase livestock mortality. [Footnote omitted.]

Climate change, including temperature increases, changes in rainfall, and extreme weather events, are expected to increase the incidence and intensity of food-borne diseases and food contamination, jeopardizing food security. Ocean warming and ocean acidification are expected to threaten marine food resources by disrupting marine communities, promoting harmful algal blooms and the spread of some diseases, and increasing contaminants in fish and shellfish. [Footnote omitted.]

* * * * *

Climate change, which is bringing more extreme weather to the United States, is resulting in increased power outages nationwide, increased vulnerability of oil and gas infrastructure in the Gulf region, more frequent disruptions of coal transport in the Midwest and Northeast, and limited electricity generation in the Southwest. Major weather-related power outages have increased from 5 to 20 each year in the mid-1990s to 50 to 100 each year during the last five years. Oil and gas infrastructure in the Gulf region is unprepared to meet the predicted hurricane wind increases of 2 to 13% and the increased rainfall totals of 10 – 31%. Heavy precipitation events are projected to cause major disruption to rail and barge transportation which will hamper the distribution of coal around the country. In one weather-related disruption in 2005, disrupted coal deliveries are estimated to have cost $228 million nationwide. [Footnote omitted.]

In the Southwestern United States, reductions in precipitation coupled with rises in temperatures could result in an increase in evaporation such that average soil moisture conditions in the Southwest may be lower than any previously experienced severe droughts of this century, including the 1930's Dustbowl. By 2100, reductions in precipitation coupled with rises in temperatures as much as 5 °F, could result in changes in water runoff in the Colorado River Basin of up to 20%. [Footnote omitted.]

* * * * *

The ecological effects of climate change are already being observed on a wide range of ecosystems and species in all regions of the world, including changes in distribution, phenology, physiology, demographic rates, genetics, ecosystem services, as well as climate-related population declines and extinctions. [Footnote omitted.]

A comprehensive literature review found that significant species range losses and extinctions are projected to occur at global mean temperature rises below 2 °C in some biodiversity hotspots (e.g. amphibian extinctions in tropical forests) and globally for coral reef ecosystems. At a 2 °C temperature rise, projected impacts increased in magnitude, numbers and geographic spread, while beyond a 2 °C temperature rise, the level of impacts and the transformation of the Earth's ecosystems will become steadily more severe, with the potential collapse of some entire ecosystems, and extinction risks accelerating and becoming widespread. Coral reef, Arctic, Mediterranean, and mountain ecosystems including many biodiversity hotspots are particularly at risk. [Footnote omitted.]

* * * * *

Projections of future precipitation indicate that the Northwestern and north-central portions of the United States may gradually become wetter while the Southwestern and South-central portions gradually become drier. [Footnote omitted.]

Increases and decreases in precipitation have the capacity to affect hydroelectric generation, populations of fish and wildlife, surface water ecosystems and their ability to remove pollutants, ground water supplies, and water demands. [Footnote omitted.]

Climate change has already altered the water supply in the United States, and the impacts on water resources will become increasingly more severe. In the United States, climate change is projected to results in more common and intense floods and droughts, with rainfall becoming concentrated into fewer, heavier events; precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer; and in areas where snow pack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer. Climate change will place additional burdens on already stressed water systems. [Footnote omitted.]

Climate change has already profoundly affected water resources in the western United States, including a decrease in total precipitation, a decline in mountain snow pack, an advance in the timing of spring snowmelt, the most severe drought observed since 1900, and steep declines in Colorado River reservoir storage. The biggest regional water reservoirs—Lake Powell and Lake Mead—declined from nearly full in 1999 to about 50% full in 2004, and they have not yet recovered. These changes are disrupting the region's water supply system. [Footnote omitted.]

Climate models robustly project that the Southwestern United States will become drier and experience increasingly severe droughts in this century, posing a major threat to water supplies. Dry events are expected to increase from a historical range of 4 to 10 years to 12 years or more. Severe future droughts will be aggravated by lower spring snow pack and reduced spring and summer soil moisture. [Footnote omitted.]

* * * * *

A new operational hurricane-prediction model that produces a realistic distribution of intense hurricane activity for present-day conditions projects a near doubling of the frequency of category 4 and 5 storms by the end of the 21st century, with the largest increase projected to occur in the Western Atlantic, north of 20º North. [Footnote omitted.]

Although the IPCC Fourth Assessment Report projected a global mean sea-level rise in the 21st century of 18–59 cm, the IPCC acknowledged that this estimate did not represent a "best estimate" or "upper bound" for sea-level rise because it assumed a negligible contribution from the melting of the Greenland and west Antarctic ice sheets. [Footnote omitted.]

Recent studies documenting the accelerating ice discharge from the Greenland and Antarctic ice sheets indicate that the IPCC projections are a substantial underestimate. [Footnote omitted.] Studies that have attempted to improve upon the IPCC estimates have found that a mean global sea-level rise of at least 1 to 2 meters is highly likely within this century. [Footnote omitted.] Studies that have reconstructed sea-level rise based on the geological record, including oxygen isotope and coral records, have found that larger rates of sea-level rise of 2.4 to 4 meters per century are possible. [Footnote omitted.]

Although the IPCC AR4 provides an important synthesis of the climate change science, numerous studies published since the AR4 indicate that many climate change risks are substantially greater than assessed in the AR4. These studies have found that climatic indices are changing more quickly than projected by earlier IPCC reports; climate impacts are occurring at lower surface temperatures than previously estimated; temperature change and sea level rise during this century will be greater than previously projected; the climate is approaching tipping points beyond which the climate system is expected to switch to a different state; and impacts associated with 2 °C temperature rise have been "revised upwards, sufficiently so that 2 °C now more appropriately represents the threshold between 'dangerous' and 'extremely dangerous' climate change." [Footnote omitted.]

Docket Number: 9519 (EPA Rule Docket)
Commenter: Hilary Sinnamon, Environmental Defense Fund

The U.S. Global Change Research Program has found that climate changes "are already affecting water, energy, transportation, agriculture, ecosystems, and health." [Footnote omitted.] Its 2009 Assessment predicts that water resources will be further stressed, crop and livestock production will be increasingly challenged, coastal areas will be increasingly threatened, and human health will be impacted due to heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents.

The number of people at risk due to droughts will increase because many low-rainfall areas are projected to receive less rain and because rising temperatures and evaporation will cause soils to dry. Seasonal snow packs in the Western United States will shrink, endangering water supplies relied upon by Western communities. The number and extent of wildfires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska will likely expand. And damaging impacts outside of the United States may harm our trade, humanitarian, and national security interests.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

Our addiction to oil feeds dangerous climate change. Last year was the ninth warmest year on record with the 10 warmest years all occurring since 2000. [Footnote omitted.] In 2011 we saw an unprecedented number of extreme weather events, most occurring within in the U.S. The 12 month period from September 2010 to August 2011 was the driest on record for Texas, where a severe drought still persists. The estimated cost of $10 billion will continue to rise until the drought ends. While Texas was experiencing historic dryness and extreme heat, other parts of the U.S. were flooded with rainfall. Levees were breached along the Missouri and Mississippi river flooding farmland and damaging thousands of homes. The estimated costs in damages were greater than $5 billion. Parts of the Northeast suffered from Hurricane Irene, with damage to hundreds of roads and bridges in New Jersey, New York and Vermont. [Footnote omitted.]

Response

NHTSA recognizes that climate change has broad implications both regarding human health and for a wide range of natural resources. Regarding the comment about health impacts, NHTSA agrees there is significant evidence linking observed changes in climate to adverse impacts on human health, which includes the harmful impacts of extreme events; aeroallergens; water-, food-, and vector-borne diseases; and skin cancer. Section 5.5.1.6 of the Final EIS summarizes these findings. In response to that comment, NHTSA has incorporated into this Final EIS information excerpted from the peer-reviewed studies Bernstein and Myers (2011) and Sheffield and Landrigan (2011), cited by the commenter. The Draft EIS included Karl et al. (2009, cited as GCRP 2009), as does this Final EIS.

NHTSA summarizes the impacts of climate change on the agriculture sector in Section 5.5.1.4 of this Final EIS. In response to the comment regarding the agricultural sector, NHTSA added to the EIS information excerpted from the peer-reviewed study Luedeling et al. (2009).

NHTSA agrees with the comment indicating that climate change impacts are projected to be widespread and detrimental to food security. NHTSA discusses aspects of climate change impacts on food security in several sections in this Final EIS, including Sections 5.5, 5.5.1.4, and 5.5.1.6. In response to this comment, NHTSA added to the EIS information excerpted from the peer-reviewed study Tirado et al. (2010). The EIS already included Karl et al. (2009; cited as GCRP 2009).

Regarding impacts to freshwater resources, NHTSA agrees that climate change has been observed and is projected to impact freshwater resources, which will have implications for energy, ecosystems, and human health (*see* Section 5.5.2 in this Final EIS). In response to this comment, NHTSA added information to the EIS excerpted from the peer-reviewed study Cayan et al. (2010). The EIS already included Karl et al. (2009; cited as GCRP 2009) and the Bureau of Reclamation (2011a).

Regarding the impact of climate change on extreme weather, NHTSA agrees that climate change science suggests weather extremes have become more frequent (*see* Sections 5.1 and 5.2.2 in this Final EIS), which could adversely impact many sectors in the United States (*see* Section 5.5). NHTSA recognizes the potential harmful impact of climate change on ecosystems (*see* Section 5.5.1.2 in this Final EIS). The EIS already included information excerpted from the peer-reviewed studies Leadley et al. (2010) and Warren et al. (2011).

NHTSA discusses projected changes of hurricanes and tropical storms, and sea-level rise in the context of climate change in this Final EIS (*see* Sections 5.2.2 and 5.2.2.4). NHTSA acknowledges that the sea-level rise projections estimated by the IPCC (2007) are conservative and had provided recent studies that account for the additional contribution to sea-level rise by the melting of ice sheets. NHTSA also recognizes the scientific community concern of tipping points and discusses these dangers in Section 5.5.1.7 of this Final EIS. The EIS already included IPCC (2007), Bender (2010), Pfeffer et al. (2008), Vermeer and Rahmstorf (2009), Grinsted and Jevrejeva (2010), Milne et al. (2009), and Anderson and Bows (2011).

9.3.2.6 Non-climate CO_2 Impacts

Comments

Docket Number: 0775.2 (Scoping)
Commenter: Vera Pardee, Center for Biological Diversity

The ocean's absorption of anthropogenic CO_2 has already resulted in more than a 30% increase in ocean acidity, a rate 100 times anything seen in hundreds of millennia, and ocean acidity is projected to increase by 100 to 150% by the end of this century if CO_2 emissions remain unabated. [Footnote omitted.] Numerous U.S. and international scientific and policy bodies have identified ocean acidification as an urgent, significant, and long-term threat to ocean ecosystems, food security, and society. [Footnote omitted.]

Coral reef ecosystems, on which a half a billion people directly depend for their livelihoods, are particularly threatened by ocean acidification. Coral erosion is projected to exceed calcification rates at atmospheric CO_2 concentrations between 450 to 500 ppm [footnote omitted], and all coral reefs will begin to dissolve at CO_2 concentrations of 560 ppm. [Footnote omitted.] Due to the synergistic impacts of ocean acidification, mass bleaching, and other impacts, reefs are projected to experience "rapid and terminal" declines worldwide at atmospheric CO_2 concentrations of 450 ppm. [Footnote omitted.]

Response

Section 5.6 of this Final EIS summarizes observed and projected climate change impacts on oceans, and includes a discussion of ocean acidification. NHTSA added to this EIS information from the panel-reviewed study United Nations Environmental Programme (UNEP 2010), cited by the commenter.

9.3.3 Life-cycle Assessment

Comments

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute

NHTSA's assessment of EV batteries must include robust assumptions about the likelihood of recycling, which will significantly mitigate the environmental impact of producing EV batteries.

Docket Number: 0762 (Scoping)
Commenter: Edison Electric Institute

In the NOI, NHTSA asked for comments about the "impacts regarding waste and disposal of advanced batteries." (Citation omitted.) It is likely that the batteries used for PEVs will be reused in secondary markets or recycled at rates that are similar to the recycling rate of lead-acid batteries. According to an August 2009 report for the Battery Council International (BCI), the recycling rate for lead-acid batteries during the period from 2004-2008 was 96 percent. [Footnote omitted.] It should be noted that the typical market price of automobile batteries is around $100, while the battery packs for PEVs will have an estimated market value in the thousands of dollars. As a higher-value product, there will be a much higher likelihood that these batteries will be recycled or re-used, rather than disposed.

There are several possible uses for disposed PEV batteries:

- Renewable energy storage: Power generated by wind power and solar energy can be stored in EV battery systems and used when demand warrants. This will also allow for the greater integration into the grid of intermittent renewable resources that tend to generate electricity during "off peak" periods. [Footnote 15: For example, Southern California Edison and DTE Energy are participating in a demonstration program to use huge battery packs built by A123Systems (up to 2 MegaWatts (MW), the equivalent of about 80 all-electric car batteries integrated into a shipping container) to store energy at large wind power and solar power generating sites.]
- Grid load management: Utilities will be able to use the PEV batteries to store electricity generated during "off-peak" periods to supplement demand during high-peak operation. This will help utilities to better manage the grid, improving reliability and efficiency.
- Back-up power supplies for communities: PEV battery systems can store electricity that can be used by communities during power outages caused by storms or other natural disasters.
- Time of use management: Industrial customers can store off-peak, lower-priced electrical power in PEV batteries for use during peak demand for cost savings.

Given these opportunities for secondary uses and the likelihood of a high rate of recycling, NHTSA's analysis of the environmental impacts of PEV batteries should not assume that a high percent of batteries enter the waste stream. Moreover, to ensure a fair and balanced EIS, NHTSA must consider the possible environmental impacts of conventional vehicle batteries if it decides to include an assessment of the environmental impacts of PEV batteries.

Response

NHTSA agrees that the environmental benefits of recycling EV batteries are an important consideration in discussing the life-cycle impacts of EVs as a whole. The modeling included in this EIS relied on the GREET Fuel-Cycle model. The GREET Vehicle-Cycle model calculates life-cycle energy use and emissions from battery production, but does not yet estimate emissions and energy savings from battery recycling. The GREET model documentation notes there are still many challenges associated with recycling advanced batteries, including a lack of information about the exact material composition of each battery. In addition, some battery manufacturers might be reluctant to reuse battery components after they have been separated and cleaned because the level of impurities in reclaimed battery materials that can be tolerated is not necessarily clear. For these reasons, an estimate of emissions and energy savings resulting from battery recycling has not been developed to date.

Although NHTSA did not quantitatively assess the recycling and disposal impacts of lithium-ion (Li-ion) batteries from a life-cycle perspective, this EIS does present a qualitative review of battery end-of-life treatment in Chapter 6. That chapter contains a literature synthesis of studies on EV batteries that span production through the entire battery life cycle, including studies speaking to the potential to reduce life-cycle energy implications (and therefore the associated GHG emissions) through recycling of battery components at end of life.

One of the life-cycle assessment (LCA) studies NHTSA examined, Gaines et al. (2011), quantitatively describes the additional environmental benefits of recycling Li-ion batteries at end-of-life. The study determined through scenario analysis that recycling heavy metals, including aluminum, steel, nickel, and copper, and other battery components, could reduce energy consumption of batteries by 30 percent compared to a base-case scenario of no recycling. Several of the LCA studies NHTSA examined explicitly excluded end-of-life impacts of Li-ion batteries, including Samaras and Meisterling (2008), Majeau-Bettez et al. (2011), and Notter et al. (2010).

It is important to note that lead-acid batteries are significantly different from batteries used in EVs (usually Li-ion batteries). Li-ion batteries have a different chemical structure, are manufactured differently, are much more complex, and have different end-of-life options. In addition, there have been robust state-level policies in the United States since the early 1990s for most states to manage lead-acid battery recycling processes (Battery Council International 2010). At present, there are no similar policies for other battery types (including Li-ion batteries), and the recycling market for Li-ion batteries is still in its infancy. At the same time, however, NHTSA recognizes that public and private efforts are underway to advance and implement Li-ion battery recycling. We have included information on these efforts in Chapter 6 of the Final EIS. For example, Tesla motors, a manufacturer of electric vehicles, launched a Li-ion battery recycling program in 2011 to recover metals from their vehicles' battery packs in Europe (Tesla Motors 2011). Research and development initiatives have also been launched by the U.S. Department of Energy's Argonne National Laboratory[4] and at academic and research facilities in Germany through the LithoRec (Kwade 2010) and LiBRi (Elwert 2011) projects.

Comments

Docket Number: 9478 (EPA Rule Docket)
Commenter: Motor & Equipment Manufacturers Association

Benefits of ["game changing"] technologies should be considered from a well-to-wheel, fuel lifecycle perspective. Without this type of comprehensive assessment, the agencies consequently improperly favor preferred technologies rather than providing truly technology-neutral standards. MEMA would recommend using the existing well-to-wheel assessment of the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model) that is used by the U.S. Department of Energy. GREET has been used to shape policy choices that impact emissions and evaluates the well-to-wheel impact of various technologies.

Docket Number: 2080
Commenter: Emily Sanford Fisher, Edison Electric Institute
[Footnote 3: […] In the proposed rule, EPA states that it cannot and will not assess the life-cycle emissions of vehicle production for a variety of reasons, including because this raises complex accounting issues that go beyond vehicle testing and fuel cycle analyses. (Citation omitted.) If EPA and NHTSA do not believe that emissions related to vehicle production can be appropriately accounted for in the context of the proposed standards, it is unreasonable for NHTSA to discuss the life-cycle emissions

[4] *Available at:* <http://www.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2009/propulsion_materials/pmp_05_gaines.pdf>. (Accessed: July 6, 2012) and <http://www.transportation.anl.gov/pdfs/B/626.PDF> (Accessed: July 2, 2012) (Gaines and Nelson 2010).

of EV production, including battery production, in the Draft EIS. If NHTSA wants to discuss vehicle production emissions, it should address all vehicle types and all battery types and not single out EVs.]

Docket Number: 9482 (EPA Rule Docket)
Commenter: Robert Elliot, National Propane Gas Association

NPGA believes it is imperative that the EPA/NHTSA establish principles implementing full fuel-cycle (FFC) analysis consistent with accepted scientific findings and other government agencies. Evaluating GHG emissions from the vehicle's tailpipe is consistent with current evaluation methodologies, but does little to accurately measure consumption of primary energy resources, emission of GHGs or smog forming pollutants attributable to the production of gasoline or the generation of electricity. Full-fuel-cycle measurement (well-to-wheels) captures the additional energy consumption and emissions derived from the extraction, processing, transportation, conversion, and distribution of energy to the vehicle. For electric and plug-in hybrid electric vehicles (EV and PHEV) that re-charge their batteries using power from the utility grid, point-of-use measurement such as a vehicle's tailpipe misleads the consumer to believe the tailpipe is the only source of emissions and engine efficiency is the only source of energy consumption when, in fact, they are not.

* * * * *

NPGA supports the use of the Source Energy and Emissions Analysis Tool [footnote omitted] (SEEAT) developed by the Gas Technology Institute (GTI). This computer modeling tool calculates source energy and GHG emissions attributable to point-of-use energy consumption by vehicle fuel type. SEEAT includes a source energy and carbon emission calculation methodology that accounts for primary energy consumption and related emissions for the full-fuel-cycle of extraction, processing, transportation, conversion, distribution, and consumption of energy. GTI researchers have calculated source-based fuel economies for various vehicle options and found more rational comparisons of vehicle efficiencies using 'Source Fuel Economies' than point-of-use fuel economies.

Another scientifically accepted modeling tool is the Greenhouse Gas, Regulated Emissions and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory. [Footnote omitted.] The GREET model estimates the upstream portion of the life-cycle GHG emissions of various vehicle fuels. This model calculates emissions in grams per million Btu, of multiple pollutants, including CO_2, CH_4, and N_2O to derive a total CO_2 equivalent.

NPGA supports the Department of Energy's intended use of the GREET model to perform the national impact analyses and environmental assessments included in the review of proposed energy conservation appliance standards. Further affirming our support of the GREET model, the Propane Educational Research Council (PERC) conducted a study using the GREET model (version 1.8c) comparing autogas to other fuel sources. The study, titled "Propane Reduces Greenhouse Gas Emissions: A Comparative Analysis 2009" looked at thirteen (13) different applications where autogas was used including a GM 6.0L engine, Ford 150, Ford 250, school buses, forklifts, and commercial mowers. The comparisons looked at energy end-use and annual life-cycle GHG emissions for a variety of fuel sources.

A comparison by GTI found that the GREET and SEEAT vehicle source energy factors indicate excellent agreement between the two methodologies for both full-fuel-cycle efficiency factors and GHG emission factors. Minor differences appear to be based on underlying data sources and default values. Based on the national average fuel mix for electricity calculated using GTI's SEEAT, the source energy conversion factor for electricity is 3.29 Btu/Btu. Conversion factors for fossil fuels directly consumed at the point-of-use are as follows: Natural gas: 1.09 Btu/Btu; Autogas: 1.12 Btu/Btu; Fuel oil: 1.13 Btu/Btu.

Docket Number: 9493 (EPA Rule Docket)
Commenter: Nathan MacPherson, Univ. Mich. Center for Sustainable Systems

We recognize that electrified vehicles, including battery electrics (EVs), and plug-in hybrids (PHEVs), have the potential to reduce GHG emissions from the light-duty vehicle fleet. In low carbon grid scenarios electrified vehicles have been shown to have a lower emissions profile than conventional gasoline and diesel powered vehicles (CVs). [Footnote omitted.] However, the GHG emissions attributable to electrified vehicles charged on the current U.S. electric grid, are significant. [Footnote omitted.] The proposed 2017-2025 GHG emission standards neglect to count these important upstream sources. This may result in unintended consequence by incentivizing electrified vehicles which may be charged in regional grids of high carbon intensity. Vehicles charged in these grids may do little to reduce the total new vehicle fleet GHG emissions, without a significant change in the electric grid.

Due to the various sources of GHG emissions from electrified vehicles, we feel that a life-cycle approach should be considered in order to best evaluate and set standards for all vehicle technologies. This is particularly important for EVs since the GHG emissions are upstream, while the majority of the emissions for CVs is due to combustion of fuel during vehicle operation. A life-cycle approach, to evaluating vehicle emissions, would fully account for emission sources due to upstream, vehicle operation and vehicle production life-cycle phases. Furthermore, life-cycle analysis would allow for analogous comparisons between vehicle technologies to ensure that the overall light-duty vehicle GHG emission reductions are realized.

Regional variation in GHG intensity of electricity, as pointed out in Section III-C-2 of the proposed 2017-2025 rule, is also an important consideration which should be addressed in vehicle standards. As part of the U.S.-China Clean Energy Research Center for Clean Vehicles, we have conducted research on the total life-cycle GHG emissions from conventional and electrified vehicles using a total vehicle life-cycle (or cradle-to-grave) approach, the results of which are currently in review. [Footnote omitted.] Our analysis of a representative midsize plug-in hybrid vehicle has shown that there is over a 100 gram per mile GHG emissions variation between vehicles charged in the lowest and highest GHG intensive North American Electric Reliability Council (NERC) regions (based on an assumption of 63.5% utilization of electric mode). Our analysis showed that the Midwest Reliability Council and Southwest Power Pool North American Reliability Council (NERC) regions showed higher life-cycle GHG emissions in electric mode than for gasoline mode. Our results further showed that this difference is even greater for a representative battery electric vehicle, with a difference of over 150 life-cycle GHG grams per mile. These results highlight the importance of a life-cycle approach.

We recognize the difficulty in instituting a life-cycle framework into the proposed GHG standards since this type of analysis has not been applied to vehicle standards in past rules. To account for the difficulty in incorporating all vehicle life-cycle stages in the standards we recommend incorporating life-cycle stages as reliable data and methodology becomes available. For instance, data on the upstream GHG emissions from electric power plants is available from sources such as EPA's eGrid database. [Footnote omitted.] Vehicle production life-cycle data for specific vehicles is less established, although frameworks such as Argonne National Laboratory's GREET Vehicle Cycle model, do exist. [Footnote omitted.] By adding in these other emission sources, which result from a significant portion of vehicle emissions shifting upstream, an inclusive approach will result in a more complete and robust standard.

Since the contribution of GHG emissions to climate change is the same regardless of the source location, we feel that only a complete vehicle life-cycle regulatory approach will result in the necessary emissions reductions from the U.S. vehicle fleet.

Response

NHTSA recognizes that understanding the life-cycle implications of vehicles is important, particularly the upstream emissions associated with electricity generation for electric vehicles and potential changes in types of materials and processes used in an effort to reduce vehicle weight. NHTSA has used the GREET Fuel-Cycle model (1 2011 version) to estimate the upstream emissions for eight types of fuels (reformulated gasoline, conventional gasoline, California reformulated gasoline, conventional diesel, low sulfur diesel, hydrogen, electricity, and ethanol-85). The GREET Fuel-Cycle model provides estimates of fuel-related upstream emissions resulting from production, transportation, and storage of fuels. The model also provides estimates of emissions associated with generation of electricity, which NHTSA has used to develop upstream emissions estimates for electric vehicles.

As explained above and in Chapter 4, NHTSA believes that, because of likely improvements in the U.S. electrical grid in future years, GHG and criteria air pollutant emissions from the electricity sector are likely to decrease in future years. The agency reviewed several projections by the EIA, the Federal Government's expert source for forecasting energy use, which show a cleaner grid in future years based on a variety of assumptions and possible scenarios. NHTSA then performed an additional analysis to illustrate the effects of a cleaner future grid on air quality. *See* Chapter 4 for more detail on this analysis.

NHTSA did not use the GREET Vehicle-Cycle model in this EIS analysis; therefore, upstream emissions associated with vehicle and battery production have not been estimated for this analysis. Such an assessment would require extensive information on many variables that are highly uncertain, including the future behavior of automobile manufacturers in response to the proposed standards – what technologies they would apply to each future vehicle and how many vehicles they would manufacture. CAFE standards are performance-based rather than technology-mandating, so NHTSA does not attempt to predict or analyze exactly how manufacturers will respond to the proposed standards. In the absence of any precise forecast about the specific technology choices of individual manufacturers, NHTSA has performed a literature synthesis of studies that have analyzed the life-cycle environmental implications of producing certain materials and technologies the agency expects will be employed in the light-duty vehicle sector in the future. That literature synthesis appears as Chapter 6 of this EIS and is intended to inform the decisionmaker about certain broader environmental implications of the Proposed Action.

9.4 Other Impacts

9.4.1 National Security Impacts

Comments

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

Our nation's dependence on oil is also a threat to national security. The U.S. consumes nearly 25 percent of the world's oil production, but controls less than 2 percent of the supply. [Footnote omitted.] And over half of the oil we use each day is imported from foreign countries, many of which do not like us. In 2008, we sent over $1 billion a day overseas to pay for oil, the majority of it going to nations deemed "dangerous or unstable." [Footnote 6: (Citation omitted.) "The United States imported 4 million barrels of oil a day—or 1.5 billion barrels total—from "dangerous or unstable" countries in 2008 at a cost of about $150 billion. This estimate excludes Venezuela, which is not on the State Department's "dangerous or unstable" list but has maintained a distinctly anti-American foreign and energy policy. Venezuela is one of the top five oil exporters to the United States, and we imported 435 million barrels of oil from them in 2008." (Citation omitted.)] The rate at which we consume oil helps our enemies by paying to finance and sustain their unfriendly regimes. And the longer the U.S. remains dependent on petroleum, the more the U.S. will have to engage in tough fights just to protect our energy supplies.

Additionally, the high price of oil threatens our fragile economy. Gasoline and diesel fuel prices remain high, leaving consumers with less money to spend elsewhere. More than 70 percent of the oil we consume is for transportation, and more than 60 percent of that is used to fuel passenger cars and light trucks. [Footnote omitted.] If we want to reduce our dependence on oil, we must address fuel consumption from our fleet of highway cars and trucks.

* * * * *

Oil dependence has serious consequences. The US consumes nearly 19 million barrels of oil a day, which is nearly a quarter of the oil consumed in the entire world, and more than all EU nations combined. Over half of the oil we use each day is imported from foreign countries, many of which do not like us. And more than 70 percent of the oil we consume is used for transportation. Our addiction to oil threatens our national security and puts our service men and women at risk.

Our petroleum addiction also has significant environmental consequences. Extracting oil fouls land and water, kills wildlife, and destroys habitat. Refining oil creates air pollution and water pollution. Combustion of oil—burning oil and oil-based fuels in engines—releases CO_2, which causes global warming (about 42 percent of the world's energy-related CO_2 emissions come from oil). Emissions from oil refining and combustion also contribute to ozone, which worsens asthma, causes premature death and contributes to other health problems. [Footnote omitted.]

In addition, oil dependence makes the U.S. economy vulnerable to short-and long-term increases in energy costs. In terms of imported oil, an increase in the price of imported oil could lead to 'imported inflation' and vulnerability of the local manufacturers and consumers alike.

We commend the Administration for recognizing the importance of U.S. energy security and the positive impact more efficient use of transportation rules would have. However, we do not fully agree with the approach to valuation of these effects that have been used in past rulemakings. Therefore, we recommend that the upcoming EIS include the following additional inputs.

EDF recommends that the Agency include the monopsony effect in the energy security benefits. OMB's Circular A–4 clearly states [footnote omitted]: "analysis should focus on benefits and costs that accrue to citizens and residents of the United States." (Emphasis added.) The PRIA explains that the Agency uses information from the Oakridge National Laboratory (ORNL) to "estimate the value of reduced economic externalities from petroleum consumption and imports." (PRIA, Page 646). The PRIA also states that the ORNL recently updated its estimates of external costs from U.S. oil imports resulting in an increase in estimated monopsony costs associated with U.S. oil imports. Therefore, ORNL assigns the value of reducing U.S. oil imports to about $0.308 per gallon saved. Yet despite this recommendation, NHTSA fails to include a monopsony value in its analysis, stating "Consistency with NHTSA's use of estimates of the global benefits from reducing emissions of CO_2 and other greenhouse gases in this analysis, however, requires the use of a global perspective for assessing their net value" (PRIA, Page 647).

We request that the EIS include the monopsony effects as a true benefit to the "citizens and residents of the United States" per OMB guidance. This will more realistically reflect the energy security benefits of the proposed alternatives.

In determining the full benefits of fuel consumption reduction and energy security, it is also worth considering cost estimation proposals such as that included in Sen. Richard Lugar's (R-Ind.) Practical Energy and Climate Plan, S. 3464. (Citation omitted.) This proposed legislation included both an extensive list of potential impacts to be considered and an alternative approximation valuation methodology for the "external cost of petroleum use" (i.e. this does not include the actual fuel savings).

Docket Number: 9519 (EPA Rule Docket)
Commenter: Hilary Sinnamon, Environmental Defense Fund

In determining the full benefits of fuel consumption reduction and energy security, the Agencies did not attempt to quantify the reduction in U.S. military spending associated with the reduction in U.S. oil imports. The Agencies state in the proposal that "attributing military spending to particular missions or activities is difficult." (Citation omitted.) While we agree that such a quantitative analysis would result in uncertainties, that is not a reason to assign the benefits a zero value. It is important the Agencies develop a methodology to value the benefits of reduced oil imports on U.S. military spending for this rule, and future rules that reduce our dependence on foreign oil. We request that the Agencies at least report a range of estimates for these benefits.

Docket Number: 9548 (EPA Rule Docket)
Commenter: America's Natural Gas Alliance

In response to the agencies' request for comment on whether to include costs of the relevant U.S. overseas military presence in the energy security benefits analysis (citation omitted), AGA and ANGA strongly support doing so. To include only "the macroeconomic disruption and adjustment costs portion of the energy security benefits to estimate the monetary value of the total energy security benefits of this program" (citation omitted) ignores enormous costs that are directly attributable to U.S. dependence on overseas oil supplies. A single example should suffice: the express purpose of the Navy's Fifth Fleet – reestablished in 1995 and based in Bahrain – is to secure the Persian Gulf sea-lanes, and the annual cost of maintaining this force is in the billions of dollars.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

Cars and light trucks fuel our dangerous addiction to oil. They consume more than 8 million barrels of oil every day and spew nearly 20% of US carbon pollution into our air. Our oil addiction threatens our environment and drains our economy by forcing us to send as much as $1 billion overseas every day, costing jobs and putting our national security in danger. Much of our oil comes from countries "at high risk of instability, and several of which actively work against U.S. interests." [Footnote omitted.] Our oil dependence both complicates our foreign policy and embroils the United States in conflicts abroad, and funds many of our own adversaries. Recent developments with Iran are yet another reminder of this fact.

Docket Number: 9567 (EPA Rule Docket)
Commenter: Jim Kliesch, Union of Concerned Scientists

The proposed standards will also dramatically reduce U.S. oil consumption by as much as 1.5 million barrels per day (mbd) – roughly 23 billion gallons of gasoline annually – in 2030 alone. This is equivalent to 2010 U.S. imports from Saudi Arabia and Iraq combined. And the cumulative oil savings of the National Program (MYs 2012-2025) could result in a total reduction in U.S. oil consumption of nearly 3.5 mbd in 2030, nearly double the amount the U.S. currently imports from the entire Persian Gulf. No other federal policy has delivered greater oil savings, energy security benefits, or greenhouse gas emissions reductions to the country.

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

Similarly, the Agencies exclude the costs of maintaining a U.S. military presence to secure imported oil supplies from unstable regions "because their attribution to particular missions or activities is difficult." [Footnote omitted.] "Difficulty" does not justify conducting a cost-benefit analysis that improperly puts a thumb on one side of the scale. [Footnote omitted.]

Response

NHTSA agrees that dependence on foreign sources of oil has national security implications. The fundamental purpose of this EIS is to evaluate the environmental impacts of the alternatives to inform the decisionmaker. NHTSA does not quantify monetary costs and benefits related to national security

in the EIS because that information is included in the RIA. However, Section 5.5.1.5.1 of the EIS discusses the potential national security impacts of climate change. That section incorporates Sections 4.5.7.2 and 5.5 of the MY 2014–2018 HD Final EIS by reference.

One of the stated purposes of EISA, which restructured the CAFE program, is to move "the United States toward greater energy independence and security." Reducing dependence on energy imports is a key component of the President's March 30, 2011, *Blueprint for a Secure Energy Future*, which states that increasing transportation efficiency is an essential step toward that goal (White House 2011b). The Blueprint Progress Report notes that in the last year alone, the United States has cut net imports by 10 percent, a reduction of 1 million barrels a day (White House 2012). This reduction has been due in part to booming United States oil and gas production, more efficient cars and trucks, and a refining sector that last year was a net exporter for the first time in 60 years. The Blueprint Progress Report also notes that, taking into account the CAFE standards set forth under the Proposed Action, the United States is on pace to meet its goal of reducing oil imports by a third over the next decade. Similarly, DOE acknowledges that vehicle efficiency has the greatest short- to mid-term impact on oil consumption (DOE 2011c). NHTSA believes that stronger fuel economy standards for light-duty vehicles have the potential to further increase U.S. energy efficiency in the transportation sector and reduce U.S. dependence on petroleum.

NHTSA recognizes the potential for national and energy security risks due to the possibility of tension over oil supplies. Much of the world's oil and gas supplies are in countries facing social, economic, and demographic challenges, making them even more vulnerable to the potential local instability associated with the impacts of climate change. Because of U.S. dependence on oil, the military could be called on to protect energy resources through such measures as securing shipping lanes from foreign oil fields. To maintain such military effectiveness and flexibility, the U.S. Department of Defense stated in the Quadrennial Defense Review that it is "increasing its use of renewable energy supplies and reducing energy demand to improve operational effectiveness, reduce greenhouse gas emissions in support of U.S. climate change initiatives, and protect the Department from energy price fluctuations (DOD 2010)." The U.S. Department of the Navy has also stated that the Navy and Marine Corps are too reliant on petroleum, which "degrades the strategic position of our country and the tactical performance of our forces. The global supply of oil is finite, it is becoming increasingly difficult to find and exploit, and over time cost continues to rise" (U.S. Department of the Navy 2011). In its report *Ensuring America's Freedom of Movement: A National Security Imperative to Reduce U.S. Oil Dependence*, the Center for Naval Analyses Military Advisory Board found that: (1) U.S. dependence on petroleum constitutes a national security threat, (2) a 30 percent reduction in petroleum use over the next 10 years would significantly reduce U.S. vulnerability to global supply disruptions, (3) using less petroleum and improving fuel efficiency are critical parts of a comprehensive energy security strategy, and (4) developing and deploying alternative transportation fuels should also be part of such a strategy. In remarks given to the White House Energy Security Summit on April 26, 2011, Deputy Secretary of Defense William J. Lynn, III, noted the direct impact of energy security on military readiness and flexibility: "Today, energy technology remains a critical element of our military superiority. Addressing energy needs must be a fundamental part of our military planning" (DOD 2011). To the degree the Proposed Action reduces reliance on imported energy supplies or promotes the development of technologies that can be deployed by either consumers or the military, the United States could expect benefits related to national security, reduced energy costs, and increased energy supply.

9.4.2 Economic Impacts

Comments

Docket Number: 2083
Commenter: Vera Pardee, Center for Biological Diversity

We further note that giving undue weight to how many jobs may or may not be created as a result of the mileage and greenhouse gas emission standards the Agencies select would exceed the Agencies' discretion, as their goal is not to generate new jobs but to set maximum feasible mileage standards. But in any case, the assumption that increased stringency in efficiency standards results in job losses is incorrect. A recent study unbiased by decades-old industry rhetoric uncovered basic technical errors in industry assertions that strong mileage standards will result in substantially lower levels of production and employment in 2025; instead, the opposite is true: strong fuel efficiency standards lead to positive impacts on industry and growth in US automobile sales, production, and unemployment. [Footnote omitted.] For instance, creating more fuel efficient cars for the US market could generate more than 190,000 new jobs. [Footnote omitted.] The US fuel economy standards are currently among the least stringent in the world [footnote omitted], and even a 6% annual increase between model years 2017 and 2025 will leave the United States straggling behind. If the United States wishes to reap the benefits of job creation and innovation related to more efficient vehicles, along with a healthy, prospering automotive industry, it is essential that standards more stringent than the current 7% increase per year be considered.

Docket Number: 2082
Commenter: Hilary Sinnamon, Environmental Defense Fund

EDF believes the DEIS lacks transparency by failing to present the estimated quantitative impacts of the preferred and alternative standards on vehicle sales and employment. EPA and NHTSA conducted quantitative vehicle sales and employment analyses in previous rulemakings and used the same methodologies to estimate quantitative impacts for the current proposed rulemaking. However, the results of these analyses were not included in the published proposal, PRIA or DEIS.

EPA and NHTSA conducted a vehicle sales analysis in previous rulemakings by comparing the up-front costs of the vehicles with the present value of five years' worth of fuel savings. The Agencies used the same methodology to quantify vehicle sales impacts for the current proposed standards (preferred alternative), finding that in 2025, combined new car and light truck sales could increase by an estimated 644,000 vehicles. [Footnote omitted.] However, these results were not included in the PRIA, DEIS or final proposed rulemaking. The DEIS refers readers to the PRIA, which refers to the inherent uncertainties in estimating values as far out as 2025 and concludes, "In light of the relevant uncertainties, the agency therefore decided not to include a quantitative sales estimate…" (PRIA, page 598) While we agree that uncertainties indeed exist in such an analysis, we strongly believe that a quantitative analysis should at the very least be presented for the public to review and comment on. We strongly encourage NHTSA to include quantitative vehicle sales estimates in the final EIS to reflect full transparency and the true estimated benefits of the proposed standards.

Additionally, the proposal fails to include the Agencies' results of the quantitative employment analysis, which found that at a 3 percent discount rate, the proposed standards could add more than 65,000 jobs by 2025. [Footnote omitted.] While the PRIA acknowledges, "…this program is expected to affect employment in the regulated sector (auto manufacturing) and other sectors directly affected by the proposal…" the PRIA also states, "Since the impact of this proposal on sales is unknown, and sales have the largest potential effect on employment, the impact of this proposal on employment is also unknown." (PRIA, page 610-611) Again, we recognize the inherent uncertainties in estimating these impacts, but believe the public should have the opportunity to comment on the analysis and request the Agency include the results of the analysis in the final EIS.

Response

NHTSA recognizes that the proposed CAFE standards could impact vehicle sales and employment. In its Preliminary RIA, the agency acknowledged the difficulty of estimating the impact of the proposal on sales and employment. The fundamental purpose of this EIS is to evaluate the environmental impacts of the alternatives to inform the decisionmaker so that these impacts can be taken into account. Because sales and employment are not "environmental" impacts, but rather economic impacts, those issues are better addressed in the RIA. NHTSA will continue to consider these comments in the course of preparing its Final RIA and Final Rule.

9.4.3 Biological Resource Impacts

Comments

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

To our knowledge the Agencies have not initiated consultation with the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries Service under Section 7 of the federal Endangered Species Act to ensure that this action will not jeopardize or adversely modify the critical habitat of any species listed as "threatened" or "endangered."

Congress enacted the Endangered Species Act ("ESA") to conserve endangered and threatened species and the ecosystems upon which they depend. [Footnote omitted.] The Supreme Court's review of the ESA's "language, history, and structure" convinced the Court "beyond a doubt" that "Congress intended endangered species to be afforded the highest of priorities." [Footnote omitted.] As the Court found, "the plain intent of Congress in enacting this statute was to halt and reverse the trend toward species extinction, whatever the cost." [Footnote omitted.] Species are added to the lists of endangered and threatened species by the U.S. Fish and Wildlife Service (with jurisdiction over most terrestrial and freshwater species) and the National Marine Fisheries Service (with jurisdiction over most marine species) (collectively, the "Services"). A species is "endangered" if it "is in danger of extinction throughout all or a significant portion of its range." [Footnote omitted.] A species is "threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." [Footnote omitted.] Once a species is listed under the ESA, Section 7 requires all federal agencies to "insure" that their actions neither "jeopardize the continued existence" of any listed species nor "result in the destruction or adverse modification" of its "critical habitat." [Footnote omitted.] In addition, the "take" of listed species is generally prohibited. [Footnote omitted]. "Take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." [Footnote omitted.] The Services may, however, permit "incidental" take on a case-by-case basis if it finds, among other things, that such take will be minimized and mitigated and that such take will not "appreciably reduce the likelihood of survival and recovery of the species."

[Footnote omitted.]

Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." [Footnote omitted.] Agency "action" is defined in the ESA's implementing regulations to include "all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. Examples include, but are not limited to: (a) actions intended to conserve listed species or their habitat; (b) the promulgation of regulations; (c) the granting of licenses, contracts, leases, easements, rights-of-way, permits, or grants-in-aid; or (d) actions directly or indirectly causing modifications to the land, water, or air." [Footnote omitted.] This regulatory definition of "action" clearly encompasses the Agencies' rulemaking, since the emissions from the regulated vehicles unquestionably will cause "modification to the land, water, or air." The U.S. Fish and Wildlife Service's and National Marine Fisheries Service's Consultation Handbook, Procedures for Conducting Consultation and Conference Activities under Section 7 of the Endangered Species Act (March 1998,) explains the above terms and definitions. There can also be no question that the enormous volume of direct, indirect, and cumulative emissions from the regulated vehicles "may affect" listed species, and therefore the Agencies must consult.

The rulemaking will impact species listed as threatened and endangered in several ways, yet the Agencies have failed to initiate the required Section 7 consultations with the Services on its impact. If the Agencies fail to initiate and complete the required Section 7 consultations on the rulemaking, they may be held liable for take of listed species caused by the impacts of their action, including increased greenhouse gas emissions and other emissions such as NO_x. On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species throughout i[t]s range due to global warming. [Footnote omitted.] The Agencies must consult on the impact of the rulemaking on the polar bear.

On May 9, 2006, the National Marine Fisheries Service listed the staghorn and elkhorn corals as threatened due in part to increasing ocean temperature and ocean acidification due to anthropogenic greenhouse emissions. [Footnote omitted.] The Agencies must consult on the impact of the rulemaking on these coral species. The Agencies must also consult on the impact of the rulemaking on the polar bear's and the corals' critical habitat, once such habitat is designated.

Global warming was cited by the U.S. Fish and Wildlife Service in its critical habitat rulemakings for the Quino Checkerspot and Bay Checkerspot butterflies. [Footnote omitted.] The Agencies must consult on the impact of the rulemaking on these species and their critical habitat as well.

The Agencies must not limit their consultation, however, to species like the polar bear, corals, and checkerspot butterflies for which anthropogenic greenhouse emissions were cited as a reason for listing or as an impact in the listing or critical habitat rules. Numerous species are affected by climate change as reflected in the recovery plans for those species and other documents.

There [are] at least 124 listed species for which a recovery plan has been adopted that specifically identifies climate change or a projected impact of climate change as a direct or indirect threat to the species, as a critical impact to be mitigated, as a critical issue to be monitored, and/or as a component of the recovery criteria. [Footnote omitted.] These findings constitute clear evidence that the Agencies' rulemaking "may affect" these species, and that they must consult on the impact of this action on all listed species which may be affected.

The rulemaking will impact listed species in ways beyond global warming and ocean acidification. For example, vehicles are a primary source of excess nitrogen in the environment. Excess nitrogen contributes to major environmental problems including reduced water quality, eutrophication of estuaries, nitrate-induced toxic effects on freshwater biota, changes in plant community composition, disruptions in nutrient cycling, and increased emissions from soil of nitrogenous greenhouse gases. [Footnote omitted.] Nitrogen deposition therefore impacts species listed under the Endangered Species Act in a number of ways.

The direct, indirect, and cumulative impacts of setting fuel economy standards for all passenger vehicles and light trucks nationally are extraordinarily significant, and therefore a large number of species may be implicated. Where, as here, the Agencies' rulemaking is national in scope, they should conduct a nationally focused consultation. The agencies must not attempt to use the large scale of the rulemaking as an excuse for ignoring its environmental review duties; instead, the scope of the action only makes it more important to thoroughly review its impacts under all applicable laws. Nor can the mere fact that a large geographical area or large number of species will be affected be used as an excuse for inaction. [Footnote omitted.] If anything, a nationally focused consultation will provide the opportunity to most efficiently analyze the impact of the rulemaking on species and groups of species.

Response

Section 7(a)(2) of the Endangered Species Act (ESA) requires federal agencies, in consultation with the National Oceanic and Atmospheric Administration Fisheries Service and/or the U.S. Fish and Wildlife Service (FWS), to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of federally listed threatened or endangered species, or result in the destruction or adverse modification of designated critical habitat of such species. 16 U.S.C. § 1536(a)(2). Under relevant implementing regulations, consultation is required for actions that "may affect" listed species or critical habitat. 50 CFR § 402.14. Consultation is not required where the action has "no effect" on such listed species or critical habitat. Under this standard, it is the federal agency taking the action that evaluates the action and determines whether consultation is required. *See* 51 FR 19926, 19949 (June 3, 1986). The effects of the action are defined by regulation to include both the direct and indirect effects on species or critical habitat. 50 CFR § 402.02. Indirect effects are those that are caused by the action and are later in time, but still are reasonably certain to occur. *Id.*; *See also*, 51 FR at 19932-19933 (discussing "reasonably certain to occur" in the context of cumulative effects analysis and noting that only matters that are likely to occur – and not speculative matters – are included in the standard).

Pursuant to Section 7(a)(2) of the ESA, NHTSA has considered the effects of the proposed CAFE standards and has reviewed applicable ESA regulations, case law, and guidance to determine what, if any, impact there might be to listed species or designated critical habitat. NHTSA has considered issues related to emissions of CO_2 and other GHGs, and issues related to non-GHG emissions. Based on this assessment, NHTSA has determined that the agency's action of setting CAFE standards, which will result in nationwide fuel savings and which, consequently, will generally result in emissions reductions from what would otherwise occur in the absence of the CAFE standards, does not require consultation under Section 7(a)(2) of the ESA.

NHTSA notes that the commenter generally misunderstands the effect of the Proposed Action and appears to attribute the entire volume of emissions from the regulated sector – including a reference at one point to "increased greenhouse gas emissions" – to NHTSA's action. The Proposed Action

would generally reduce the impacts of climate change and would, therefore, have a beneficial effect with respect to global climate change compared to the No Action Alternative.

NHTSA believes that any potential for a specific impact to particular listed species and their habitats associated with emissions changes achieved by this rulemaking is too uncertain and remote to trigger the threshold for ESA Section 7(a)(2) consultation. 16 U.S.C. § 1536(a)(2). NHTSA's analysis under ESA Section 7(a)(2) is substantially similar to the analysis of this issue provided in Appendix G of the MY 2012–2016 CAFE standards EIS. That analysis relied on the significant legal and technical analysis undertaken by the FWS and EPA regarding GHG emissions and the ESA. NHTSA believes that changes in GHG emissions associated with this rulemaking are within the framework of the FWS analysis discussed in that appendix, which concluded that Section 7(a)(2) consultation was not required because of the absence of reasonably certain effects on listed species.

One of the analytical bases for this determination extends from the FWS Interim Final Special Rule for the Polar Bear (73 FR 28212, May 15, 2008) and Final Special Rule for the Polar Bear (73 FR 76249, Dec. 16, 2008). In these rules, FWS determined that it is impossible, for ESA purposes, to trace a causal link between a single stationary source's GHG emissions and any reasonably certain effect on a specific species in a specific habitat. Although the Proposed Action involves GHG reductions from mobile sources rather than emissions from a single stationary source, NHTSA believes that the analysis regarding causation is applicable here.[5] NHTSA agrees that there must be a causal connection between a federal action and a potential effect on listed species or critical habitat for Section 7(a)(2) consultation requirements to apply, and that the potential effect must be reasonably certain to occur.

NHTSA has also considered GHG emissions reductions under the Proposed Action in light of a modeling analysis undertaken by EPA and described in Appendix G of the MY 2012–2016 CAFE standards EIS. As described there, EPA attempted to analyze the impacts on temperature and tropical ocean pH of emissions from a single large stationary source. EPA concluded that any such potential effects would be so small as to be beyond physical measurement or detection in the habitats of listed species, and would be outside the scope of any potential effect on such species or habitat identified in the scientific literature the agency reviewed. For the same reasons outlined in Appendix G of the MY 2012–2016 CAFE standards EIS, NHTSA has determined that the same conclusion applies to changes in GHG emissions associated with the Proposed Action.

For more discussion of NHTSA's analysis regarding CAFE standards and ESA Section 7(a)(2) consultation, *see* Appendix G of the MY 2012–2016 CAFE standards Final EIS.

[5] While the Final Special Rule was recently vacated pending NEPA review, the case turned on FWS's NEPA determination rather than the ESA analysis, which the court determined had a rational basis. *See In re Polar Bear Endangered Species Act Listing and § 4(d) Rule Litigation*, No. 08-764 (D.D.C. issued Oct. 17, 2011). Accordingly, NHTSA continues to rely on the reasoning behind the FWS ESA analysis as a basis for its approach here.

9.4.4 Safety Impacts

Comments

Docket Number: 9528 (EPA Rule Docket)
Commenter: Therese Langer, American Council for an Energy-Efficient Economy

The weakness of the standards at the large footprint end of the light truck spectrum not only will result in a direct loss in GHG reductions relative to what would have been saved with a uniform five percent annual emissions reduction across all classes, but also runs the risk of pushing production towards that larger end. Such a shift raises safety concerns as well.

Docket Number: 9549 (EPA Rule Docket)
Commenter: Sierra Club

Smart fuel economy improvements deliver safety, as well as better mileage and lower emissions: Advanced high strength and light weight materials and other recent technological and design breakthroughs—along with well-engineered weight reduction—give us the ability to travel safely and save money in cars that cut the emission of global warming pollution by 5% and, at 54.5 mpg, ease our oil addiction.

Docket Number: 0255 (NHTSA Rule Docket)
Commenter: Vera Pardee, Center for Biological Diversity

Because light weight material can improve vehicle efficiency by 20%, its use must be encouraged.

* * * * *

Because of its large impact on fuel efficiency, we urge the Agencies to require significant weight reduction among the vehicle fleet as part of its standards; failure to implement light-weighting across the fleet because of alleged safety concerns would be contrary to the evidence and arbitrary and capricious. These revisions must not simply lead to corrections in the text of the final rule, but also to significant increases in fuel efficiency standards in the final rulemaking.

Response

NHTSA agrees that advances in high-strength and light-weight materials have the potential to improve vehicle fuel economy. The Proposed Action, as performance-based standards rather than a technology mandate, allows manufacturers flexibility in terms of what technologies they employ to achieve compliance, and NHTSA expects manufacturers to include some amount of lightweighting in their future fleets in response to the standards. Regarding concerns that the footprint-based standards might create an incentive for manufacturers to build larger trucks, which could in turn decrease overall fleet safety, the agency does not think this is likely. The target curves were designed to be challenging, and the fact that the targets for the very largest light trucks remain static for several years reflects the significant challenges faced by manufacturers in improving fuel economy levels for

those vehicles while continuing to provide the levels of performance demanded by the marketplace. NHTSA does not believe that the target curves will incentivize production of any particular vehicles beyond what the market itself will demand. Moreover, one of the benefits of setting footprint-based standards is the incentive they create to use advanced light-weight materials and structures, because manufacturers can use them to improve a vehicle's fuel economy without necessarily causing a change in the vehicle's footprint, and therefore, target level of fuel economy.

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CHAPTER 12 DISTRIBUTION LIST

CEQ NEPA implementing regulations (40 CFR 1501.19) specify requirements for circulating an EIS. In accordance with those requirements, NHTSA has notified the agencies, officials, and other interested persons listed in this chapter of the availability of this EIS.

12.1 Federal Agencies

- Access Board, Office of the General Counsel
- Advisory Council on Historic Preservation
- Argonne National Laboratory
- Armed Forces Retirement Home
- Board of Governors of the Federal Reserve System, Engineering and Facilities
- Committee for Purchase From People Who Are Blind or Severely Disabled
- Consumer Product Safety Commission, Directorate for Economic Analysis
- Delaware River Basin Commission
- Denali Commission
- Executive Office of the President, Council on Environmental Quality
- Executive Office of the President, Office of Science and Technology Policy
- Export-Import Bank of the United States, Office of the General Counsel
- Farm Credit Administration, Office of Regulatory Policy
- Federal Communications Commission, Administrative Law Division
- Federal Communications Commission, Mass Media Bureau
- Federal Communications Commission, Wireless Telecommunications Bureau
- Federal Deposit Insurance Corporation, Facilities Operations Section
- Federal Energy Regulatory Commission, Division of Environmental and Engineering Review, Office of Energy Projects
- Federal Energy Regulatory Commission, Office of External Affairs
- Federal Energy Regulatory Commission, Office of Pipeline Regulation
- Federal Maritime Commission, Office of the Chairman
- Federal Trade Commission, Litigation
- General Services Administration, Public Buildings Service, Office of Applied Science
- Government of Canada, The Department of Natural Resources, Natural Resources Canada
- International Boundary and Water Commission, United States & Mexico, Engineering Department, United States Section
- Marine Mammal Commission
- Millennium Challenge Corporation
- National Aeronautics and Space Administration, Environmental Management Division
- National Capital Planning Commission, Office of Urban Design and Plan Review
- National Credit Union Administration, Office of General Counsel, Division of Operations

- National Endowment for the Arts
- National Indian Gaming Commission, Contracts Division
- National Institutes of Health, Division of Environmental Protection
- National Science Foundation, Office of the General Counsel
- Nuclear Regulatory Commission, Division of Intergovernmental Liaison and Rulemaking
- Oak Ridge National Laboratory
- Office of the Federal Coordinator, Alaska Natural Gas Transportation Projects
- Office of Management and Budget
- Overseas Private Investment Corporation, Environmental Affairs Department
- Presidio Trust
- Securities and Exchange Commission, Office of Public Utility Regulation
- Small Business Administration, Office of Management & Administration - Office of the Associate Administrator
- Social Security Administration
- Susquehanna River Basin Commission
- Tennessee Valley Authority, Environmental Policy and Planning
- U.S. Agency for International Development
- U.S. Agency for International Development, Bureau for Economic Growth, Agriculture, and Trade
- U.S. Department of Agriculture, Agriculture Research Service, Natural Resources and Sustainable Agricultural Systems
- U.S. Department of Agriculture, Animal and Plant Health Inspection Service - Environmental Services
- U.S. Department of Agriculture, Farm Service Agency
- U.S. Department of Agriculture, National Institute of Food and Agriculture - Natural Resources and Environmental Unit
- U.S. Department of Agriculture, Natural Resources Conservation Service - Ecological Services Division
- U.S. Department of Agriculture, Office of the Secretary
- U.S. Department of Agriculture, Rural Business Cooperative Service
- U.S. Department of Agriculture, Rural Housing Service
- U.S. Department of Agriculture, Rural Utilities Service, Engineering and Environmental Staff
- U.S. Department of Agriculture, U.S. Forest Service - Ecosystem Management Coordination
- U.S. Department of Commerce, Economic Development Administration
- U.S. Department of Commerce, National Marine Fisheries Service
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration Planning and Integration Office
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Fisheries Service
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service

- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of General Counsel for Fisheries
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of the General Counsel
- U.S. Department of Commerce, National Telecommunications and Information Administration
- U.S. Department of Commerce, Office of the Secretary
- U.S. Department of Defense, Defense Logistics Agency, Environment, Safety and Occupational Health
- U.S. Department of Defense, Defense Threat Reduction Agency
- U.S. Department of Defense, Department of Air Force, United States Air Force Basing and Units
- U.S. Department of Defense, Department of Army, Office of Deputy Assistant Secretary of the Army, Environment Safety and Occupational Health
- U.S. Department of Defense, Department of Navy, Office of the Deputy Assistant Secretary of the Navy (Environment)
- U.S. Department of Defense, National Guard Bureau, Office of General Counsel
- U.S. Department of Defense, Office of Deputy Undersecretary of Defense (Installations and Environment)
- U.S. Department of Defense, Office of the Secretary
- U.S. Department of Defense, U.S. Army Corps of Engineers, Headquarters, Environmental Community of Practice
- U.S. Department of Defense, U.S. Army Corps of Engineers, Planning and Policy Division
- U.S. Department of Defense, United States Marine Corps, Natural and Cultural Resources Division
- U.S. Department of Defense, United States Navy, Office of the Chief of Naval Operations (CNO-N45)
- U.S. Department of Energy, Bonneville Power Administration
- U.S. Department of Energy, Energy Efficiency and Renewable Energy Office of Vehicle Technologies
- U.S. Department of Energy, Office of the General Counsel - Office of NEPA Policy and Compliance
- U.S. Department of Energy, Office of the Secretary
- U.S. Department of Energy, Western Area Power Administration
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Office of the Director
- U.S. Department of Health and Human Services, Food and Drug Administration, Center for Drug Evaluation and Research
- U.S. Department of Health and Human Services, Food and Drug Administration, Center for Veterinary Medicine - Office of New Animal Drug Evaluation
- U.S. Department of Health and Human Services, Food and Drug Administration, Center for Food Safety and Applied Nutrition
- U.S. Department of Health and Human Services, Food and Drug Administration - Office of the Commissioner
- U.S. Department of Health and Human Services, Health Resources Services Administration, Office of Federal Assistance Management
- U.S. Department of Health and Human Services, Indian Health Service

- U.S. Department of Health and Human Services, National Institutes of Health, Division of Environmental Protection
- U.S. Department of Health and Human Services, Office for Facilities Management and Policy - Division of Programs
- U.S. Department of Health and Human Services, Office of the Secretary
- U.S. Department of Homeland Security, Federal Emergency Management Agency, Office of Environmental Planning and Historic Preservation
- U.S. Department of Homeland Security, Federal Law Enforcement Training Center
- U.S. Department of Homeland Security, Office of the Secretary
- U.S. Department of Homeland Security, Transportation Security Administration
- U.S. Department of Homeland Security, U.S. Coast Guard
- U.S. Department of Homeland Security, U.S. Customs and Border Protection - Environmental Programs Branch
- U.S. Department of Housing and Urban Development, Environmental Planning Division, Office of Environment and Energy
- U.S. Department of Housing and Urban Development, Office of the Secretary
- U.S. Department of Interior, Bureau of Indian Affairs
- U.S. Department of Interior, Bureau of Land Management - Division of Decision Support, Planning, and NEPA
- U.S. Department of Interior, Bureau of Ocean Energy Management, Environmental Assessment Branch
- U.S. Department of Interior, Bureau of Ocean Energy, Management, Regulation and Enforcement
- U.S. Department of Interior, Bureau of Reclamation - Office of Program and Policy Services - Water & Environmental Resources Office
- U.S. Department of Interior, National Park Service - Environmental Planning and Compliance Branch
- U.S. Department of Interior, Office of Environmental Policy and Compliance
- U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement
- U.S. Department of Interior, Office of the Secretary
- U.S. Department of Interior, U.S. Geological Survey - Environmental Management Branch
- U.S. Department of Interior, United States Fish and Wildlife Service
- U.S. Department of Interior, United States Geological Survey
- U.S. Department of Justice, Community Oriented Policing Services, Office of General Counsel
- U.S. Department of Justice, Drug Enforcement Administration, Civil Litigation Section
- U.S. Department of Justice, Environment and Natural Resources Division, General Litigation Section
- U.S. Department of Justice, Facilities and Administration Services
- U.S. Department of Justice, Federal Bureau of Investigation
- U.S. Department of Justice, Federal Bureau of Prisons, Site Selection and Environmental Review Branch
- U.S. Department of Justice, Justice Management Division, Facilities and Administrative Services
- U.S. Department of Justice, National Institute of Justice

- U.S. Department of Justice, Office of Attorney General
- U.S. Department of Justice, Office of Justice Programs, Office of General Counsel
- U.S. Department of Labor, Employment and Training Administration, Job Corps
- U.S. Department of Labor, Mine Safety and Health Administration, Office of Standards, Regulations & Variances
- U.S. Department of Labor, Occupational Safety and Health Administration
- U.S. Department of Labor, Office of the Secretary
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs, Office of Multilateral Affairs and Sustainable Development
- U.S. Department of State, Office of the Secretary
- U.S. Department of Transportation, Federal Highway Administration
- U.S. Department of Transportation, Federal Highway Administration, Office of Project Development and Environmental Review
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Office of the Chief Counsel
- U.S. Department of Transportation, Federal Railroad Administration, Office of Policy and Development
- U.S. Department of Transportation, Federal Railroad Administration, Office of Railroad Development
- U.S. Department of Transportation, Federal Transit Administration, Office of Planning and Environment
- U.S. Department of Transportation, Office of Assistant Secretary for Transportation Policy, Office of Safety, Energy, and Environment
- U.S. Department of Transportation, Research and Innovative Technology Administration
- U.S. Department of Transportation, Saint Lawrence Seaway Development Corporation
- U.S. Department of Transportation, Surface Transportation Board, Section of Environmental Analysis
- U.S. Department of Treasury, Office of Environment, Safety, and Health
- U.S. Department of Veterans Affairs, Veterans Health Administration, Office of General Counsel
- U.S. Environmental Protection Agency, Office of Federal Activities, EIS Filing Section
- U.S. Environmental Protection Agency, Office of Transportation and Air Quality
- U.S. Institute for Environmental Conflict Resolution
- United States Postal Service, USPS Law Department
- Valles Caldera Trust

12.2 State And Local Government Organizations

- American Samoa Office of Grants Policy/Office of the Governor, Department of Commerce, American Samoa Government
- Arkansas Office of Intergovernmental Services, Department of Finance and Administration

- Connecticut Department of Environmental Protection, Bureau of Air Management, Planning and Standards Division
- Delaware Office of Management and Budget, Budget Development, Planning & Administration
- Department of Administration, Nevada State Clearinghouse, Coordinator/SPOC
- District of Columbia Office of the City Administrator
- Federal Assistance Clearinghouse, Missouri Office of Administration, Commissioner's Office
- Florida State Clearinghouse, Florida Department of Environmental Protection
- Georgia State Clearinghouse
- Grants Coordination, California State Clearinghouse, Office of Planning and Research
- Guam State Clearinghouse, Office of I Segundo na Maga'lahen Guahan, Office of the Governor
- Iowa Department of Management
- Maine State Planning Office
- Maryland Department of Planning
- Maryland Department of Transportation
- Maryland State Clearinghouse for Intergovernmental Assistance
- Massachusetts Office of the Attorney General
- Minnesota Department of Commerce, Division of Energy Resources
- Minnesota Department of Environmental Protection
- New Hampshire Office of Energy and Planning, Attn: Intergovernmental Review Process
- North Dakota Department of Commerce
- North Mariana Islands Office of Management and Budget, Office of the Governor
- Pennsylvania Department of Environmental Protection
- Puerto Rico Highway and Transportation Authority
- Puerto Rico Planning Board, Federal Proposals Review Office
- Rhode Island Division of Planning
- South Carolina Office of State Budget
- Southeast Michigan Council of Governments
- State of Connecticut, Department of Transportation
- The Governor's Office for Local Development
- Utah State Clearinghouse, Governor's Office of Planning and Budget Utah State
- West Virginia Development Office

12.3 Elected Officials

- The Honorable Robert Bentley, Governor of Alabama
- The Honorable Sean Parnell, Governor of Alaska
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa
- The Honorable Jan Brewer, Governor of Arizona
- The Honorable Mike Beebe, Governor of Arkansas

- The Honorable Edmund G. Brown, Governor of California
- The Honorable John Hickenlooper, Governor of Colorado
- The Honorable Dan Malloy, Governor of Connecticut
- The Honorable Jack Markell, Governor of Delaware
- The Honorable Rick Scott, Governor of Florida
- The Honorable Nathan Deal, Governor of Georgia
- The Honorable Eddie Calvo, Governor of Guam
- The Honorable Neil Abercrombie, Governor of Hawaii
- The Honorable C.L. "Butch" Otter, Governor of Idaho
- The Honorable Pat Quinn, Governor of Illinois
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Terry Branstad, Governor of Iowa
- The Honorable Sam Brownback, Governor of Kansas
- The Honorable Steve Beshear, Governor of Kentucky
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable Paul LePage, Governor of Maine
- The Honorable Martin O'Malley, Governor of Maryland
- The Honorable Deval Patrick, Governor of Massachusetts
- The Honorable Rick Snyder, Governor of Michigan
- The Honorable Mark Dayton, Governor of Minnesota
- The Honorable Phil Bryant, Governor of Mississippi
- The Honorable Jeremiah W. Nixon, Governor of Missouri
- The Honorable Brian Schweitzer, Governor of Montana
- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable Brian Sandoval, Governor of Nevada
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable Chris Christie, Governor of New Jersey
- The Honorable Susana Martinez, Governor of New Mexico
- The Honorable Andrew Cuomo, Governor of New York
- The Honorable Beverly Perdue, Governor of North Carolina
- The Honorable Jack Dalrymple, Governor of North Dakota
- The Honorable John Kasich, Governor of Ohio
- The Honorable Mary Fallin, Governor of Oklahoma
- The Honorable John Kitzhaber, Governor of Oregon
- The Honorable Tom Corbett, Governor of Pennsylvania
- The Honorable Luis G. Fortuño, Governor of Puerto Rico
- The Honorable Lincoln Chafee, Governor of Rhode Island
- The Honorable Nikki R. Haley, Governor of South Carolina

- The Honorable Dennis Daugaard, Governor of South Dakota
- The Honorable Bill Haslam, Governor of Tennessee
- The Honorable Rick Perry, Governor of Texas
- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable John P. de Jongh, Jr., Governor of the United States Virgin Islands
- The Honorable Gary Herbert, Governor of Utah
- The Honorable Peter Shumlin, Governor of Vermont
- The Honorable Bob McDonnell, Governor of Virginia
- The Honorable Chris Gregoire, Governor of Washington
- The Honorable Earl Ray Tomblin, Governor of West Virginia
- The Honorable Scott Walker, Governor of Wisconsin
- The Honorable Matthew Mead, Governor of Wyoming
- The Honorable Vincent C. Gray, Mayor of the District of Columbia

12.4 Native American Tribes

- Absentee-Shawnee Tribe of Indians of Oklahoma
- Agdaagux Tribe of King Cove
- Agua Caliente Band of Cahuilla Indians
- Ahtna, Inc.
- Ak Chin Indian Community
- Akiachak Native Community (Indian Reorganization Act [IRA])
- Akiak Native Community (IRA)
- Alabama-Coushatta Tribes of Texas
- Alabama-Quassarte Tribal Town
- Alatna Village
- Aleut Community of St. Paul Island
- Aleut Corporation
- Algaaciq Native Village (St. Mary's)
- Allakaket Village
- Alturas Indian Rancheria
- Angoon Community Association (IRA)
- Anvik Village
- Apache Tribe of Oklahoma
- Arapahoe Tribe
- Arctic Slope Regional Corp.
- Arctic Village Council
- Aroostook Band of Micmac Indians
- Asa'carsarmiut Tribe

- Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation
- Atqasuk Village
- Augustine Band of Cahuilla Indians
- Bad River Band of Lake Superior Tribe of Chippewa Indians
- Barona Band of Mission Indians
- Battle Mountain Band Council
- Bay Mills Indian Community
- Bear River Band of Rohnerville Rancheria
- Beaver Village Council
- Bering Straits Native Corp.
- Berry Creek Rancheria of Maidu Indians
- Big Lagoon Rancheria
- Big Pine Paiute Tribe of the Owens Valley Paiute Shoshone Indians
- Big Sandy Rancheria of Mono Indians
- Big Valley Rancheria of Pomo Indians
- Birch Creek Tribal Council
- Bishop Paiute Tribe
- Blackfeet Tribe of the Blackfeet Indian
- Blue Lake Rancheria
- Board of Directors, Trenton Indian Service Area
- Bois Forte Reservation Business Committee
- Bridgeport Indian Colony
- Bristol Bay Native Corp.
- Buena Vista Rancheria of Me-wuk Indians
- Burns Paiute Tribe of the Burns Paiute Indian Colony
- Cabazon Band of Mission Indians
- Cachil DeHe Band of Wintun Indians (Colusa Rancheria)
- Caddo Nation of Oklahoma
- Cahto Indian Tribe of Laytonville Rancheria
- Cahuilla Band of Mission Indians
- California Valley Miwok Tribe
- Calista Corporation
- Campo Band of Diegueno Mission Indians
- Carson Community Council
- Catawba Indian Nation
- Cayuga Nation of New York
- Cedarville Rancheria
- Central Council Tlingit & Haida Indian Tribes of Alaska

- Chalkyitsik Village
- Cheesh-Na Tribal Council
- Chemehuevi Indian Tribe
- Chenega IRA Council
- Cher-Ae Heights Indian Community of the Trinidad Rancheria
- Cherokee Nation
- Chevak Native Village
- Cheyenne River Sioux Tribe
- Cheyenne-Aprapaho Tribes
- Chickaloon Native Village
- Chickasaw Nation
- Chicken Ranch Rancheria of Me-wuk Indians
- Chignik Lagoon Council
- Chignik Lake Village Council
- Chilkat Indian Village (Klukwan) (IRA)
- Chilkoot Indian Association (IRA)
- Chinik Eskimo Community
- Chippewa-Cree Indians
- Chitimacha Tribe of Louisiana
- Chitina Traditional Indian Village Council
- Choctaw Nation of Oklahoma
- Chugach Alaska Corp.
- Chuloonawick Native Village
- Circle Native Community (IRA)
- Citizen Potawatomi Nation
- Cloverdale Rancheria of Pomo Indians
- Cocopah Tribe of Arizona
- Coeur D'Alene Tribe
- Cold Springs Rancheria of Mono Indians
- Colorado River Indian Tribe
- Comanche Nation
- Confederated Salish & Kootenai Tribes of the Flathead Reservation
- Confederated Tribes and Bands of the Yakama Nation
- Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians
- Confederated Tribes of Siletz Indians of Oregon
- Confederated Tribes of the Chehalis Reservation
- Confederated Tribes of the Colville Reservation
- Confederated Tribes of the Goshute Reservation, Nevada and Utah

- Confederated Tribes of the Grand Ronde Community of Oregon
- Confederated Tribes of the Umatilla Indian Reservation
- Confederated Tribes of the Warm Springs Reservation
- Cook Inlet Region, Inc.
- Coquille Tribe of Oregon
- Cortina Indian Rancheria of Wintun Indians
- Coushatta Tribe of Louisiana
- Cow Creek Band of Umpqua Indians
- Cowlitz Indian Tribe
- Coyote Valley Band of Pomo Indians
- Craig Community Association (IRA)
- Crow Creek Sioux Tribe
- Crow Tribe of Montana
- Curyung Tribal Council
- Delaware Nation
- Delaware Tribe of Indians
- Douglas Indian Association (IRA)
- Doyon Ltd.
- Dresslerville Colony (Washoe Tribe of Nevada & California)
- Dry Creek Rancheria of Pomo Indians
- Duckwater Shoshone Tribe
- Eastern Band of Cherokee Indians
- Eastern Shawnee Tribe of Oklahoma
- Egegik Village
- Eklutna Native Village
- Ekwok Village
- Elem Indian Colony of Pomo Indians of the Sulphur Bank Rancheria
- Elim IRA Council
- Elk Valley Rancheria
- Elko Band (Te-Moak Tribe of Western Shoshone Indians of Nevada)
- Ely Shoshone Tribe of Nevada
- Emmonak Village
- Enterprise Rancheria of Maidu Indians
- Evansville Village
- Ewiiaapaayp Band of Kumeyaay Indians
- Fallon Paiute Shoshone Tribal Business Council
- Federated Indians of Graton Rancheria
- Flandreau Santee Sioux Tribe of South Dakota

- Fond du Lac Reservation Business Committee
- Forest County Potawatomi Community
- Fort Belknap Indian Community
- Fort Bidwell Indian Community
- Fort Independence Indian Community of Paiute Indians
- Fort McDermitt Paiute and Shoshone Tribes of Fort McDermitt Indian Reservation
- Fort McDowell Yavapai Nation
- Fort Mojave Indian Tribe of Arizona, California & Nevada
- Fort Sill Apache Tribe of Oklahoma
- Gambell IRA Council
- Gila River Indian Community
- Grand Portage Band (Minnesota Chippewa Tribe)
- Grand Traverse Band of Ottawa and Chippewa Indians
- Greenville Rancheria of Maidu Indians
- Grindstone Rancheria of Wintun-Wailaki Indians
- Guidiville Rancheria of California
- Gulkana Village
- Habematolel Pomo of Upper Lake
- Hannahville Indian Community
- Havasupai Tribe
- Healy Lake Village
- Ho-Chunk Nation of Wisconsin
- Hoh Indian Tribe
- Holy Cross Village
- Hoonah Indian Association (IRA)
- Hoopa Valley Tribe
- Hopi Tribe of Arizona
- Hopland Band of Pomo Indians
- Houlton Band of Maliseet Indians
- Hualapai Indian Tribe
- Hughes Village
- Huslia Village Council
- Hydaburg Cooperative Association (IRA)
- Igiugig Village
- Iipay Nation of Santa Ysabel
- Inaja Band of Diegueno Mission Indians of the Inaja and Cosmit Reservation
- Inupiat Community of Arctic Slope (IRA)
- Ione Band of Miwok Indians

- Iowa Tribe of Kansas & Nebraska
- Iowa Tribe of Oklahoma
- Iqurmiut Traditional Council
- Jackson Rancheria of Me-Wuk Indians
- Jamestown S'Klallam Tribe of Washington
- Jamul Indian Village of California
- Jena Band of Choctaw Indians
- Jicarilla Apache Nation
- Kaguyak Village
- Kaibab Band of Paiute Indians of the Kaibab Indian Reservation
- Kaktovik Village
- Kalispel Indian Community of Kalispel Reservation
- Kaltag Tribal Council
- Karuk Tribe of California
- Kashia Band of Pomo Indians of the Stewarts Point Rancheria
- Kaw Nation
- Kenaitze Indian Tribe (IRA)
- Ketchikan Indian Community Tribal Council
- Keweenaw Bay Indian Community
- Kialegee Tribal Town
- Kickapoo Traditional Tribe of Texas
- Kickapoo Tribe of Indians of the Kickapoo Reservation in Kansas
- Kickapoo Tribe of Oklahoma
- King Island Native Community (IRA)
- King Salmon Tribe
- Kiowa Indian Tribe of Oklahoma
- Klamath Tribe
- Klawock Cooperative Association
- Knik Village
- Kobuk Traditional Council
- Kokhanok Village
- Kongiganak Traditional Council
- Koniag, Inc.
- Kootenai Tribe of Idaho
- Koyukuk Native Village
- La Jolla Band of Luiseno Mission Indians of the La Jolla Reservation
- La Posta Band of Diegueno Mission Indians of the La Posta Indian Reservation
- Lac Courte Oreilles Band of Lake Superior Chippewa Indians of Wisconsin

- Lac du Flambeau Band of Lake Superior Chippewa Indians of Wisconsin
- Lac Vieux Desert Band of Lake Superior Chippewa Indians
- Larsen Bay Tribal Council
- Las Vegas Tribe of Paiute Indians of the Las Vegas Indian Colony
- Leech Lake Band (Minnesota Chippewa Tribe)
- Lesnoi Village
- Levelock Village
- Lime Village Traditional Council (LVTC)
- Little River Band of Ottawa Indians
- Little Traverse Bay Bands of Odawa Indians
- Los Coyotes Band of Cahuilla & Cupeno Indians
- Louden Tribal Council
- Lovelock Paiute Tribe of the Lovelock Indian Colony
- Lower Brule Sioux Tribe
- Lower Elwha Tribal Community
- Lower Lake Rancheria
- Lower Sioux Indian Community in the State of Minnesota
- Lummi Tribe
- Lytton Rancheria of California
- Makah Indian Tribe
- Manchester Band of Pomo Indians of the Manchester-Point Arena Rancheria
- Manley Hot Springs Village
- Manokotak Village
- Manzanita Band of Diegueno Mission Indians
- Mary's Igloo Traditional Council
- Mashantucket Pequot Tribe of Connecticut
- Mashpee Wampanoag Tribal Council
- Match-e-be-nash-she-wish Band of Pottawatomi Indians of Michigan
- McGrath Native Village Council
- Mechoopda Indian Tribe of Chico Rancheria
- Menominee Indian Tribe of Wisconsin
- Mentasta Lake Tribal Council
- Mesa Grande Band of Diegueno Mission Indians
- Mescalero Apache Tribe
- Metlakatla Indian Community
- Miami Tribe of Oklahoma
- Miccosukee Indian Tribe of Florida
- Middletown Rancheria of Pomo Indians of California

- Mille Lacs Band Assembly
- Minnesota Chippewa Tribe
- Mississippi Band of Choctaw Indians
- Moapa Band of Paiute Indians
- Modoc Tribe of Oklahoma
- Mohegan Indian Tribe of Connecticut
- Mooretown Rancheria of Maidu Indians of California
- Morongo Band of Mission Indians
- Muckleshoot Indian Tribe
- Muscogee (Creek) Nation
- Naknek Native Village
- Nana Corporation
- Narragansett Indian Tribe of Rhode Island
- Native Village of Afognak
- Native Village of Akhiok
- Native Village of Akutan
- Native Village of Aleknagik
- Native Village of Ambler
- Native Village of Atka
- Native Village of Barrow Inupiat Traditional Government
- Native Village of Belkofski
- Native Village of Bill Moore's Slough
- Native Village of Brevig Mission
- Native Village of Buckland (IRA)
- Native Village of Cantwell
- Native Village of Chuathbaluk
- Native Village of Council
- Native Village of Crooked Creek
- Native Village of Deering (IRA)
- Native Village of Diomede (IRA) (aka Inalik)
- Native Village of Eagle (IRA)
- Native Village of Eek
- Native Village of Ekuk
- Native Village of Eyak
- Native Village of False Pass
- Native Village of Fort Yukon (IRA)
- Native Village of Gakona
- Native Village of Georgetown

- Native Village of Goodnews Bay
- Native Village of Hamilton
- Native Village of Hooper Bay
- Native Village of Kanatak (IRA)
- Native Village of Karluk (IRA)
- Native Village of Kasigluk
- Native Village of Kiana
- Native Village of Kipnuk
- Native Village of Kivalina (IRA)
- Native Village of Kluti-Kaah (aka Copper Center)
- Native Village of Kotzebue (IRA)
- Native Village of Koyuk (IRA)
- Native Village of Kwigillingok
- Native Village of Kwinhagak (IRA)
- Native Village of Marshall
- Native Village of Mekoryuk (IRA)
- Native Village of Minto (IRA)
- Native Village of Nanwalek (aka English Bay)
- Native Village of Napaimute
- Native Village of Napakiak (IRA)
- Native Village of Napaskiak
- Native Village of Nikolski (IRA)
- Native Village of Noatak (IRA)
- Native Village of Nuiqsut
- Native Village of Nunam Iqua
- Native Village of Nunapitchuk (IRA)
- Native Village of Ouzinkie
- Native Village of Paimiut
- Native Village of Perryville Tribal Council
- Native Village of Pitka's Point
- Native Village of Point Hope (IRA)
- Native Village of Point Lay (IRA)
- Native Village of Port Heiden
- Native Village of Port Lions
- Native Village of Savoonga (IRA)
- Native Village of Shaktoolik (IRA)
- Native Village of Shishmaref (IRA)
- Native Village of Shungnak (IRA)

- Native Village of South Naknek
- Native Village of St. Michael (IRA)
- Native Village of Stevens (IRA)
- Native Village of Tanana (IRA)
- Native Village of Tatitlek (IRA)
- Native Village of Tazlina
- Native Village of Tetlin (IRA)
- Native Village of Tyonek (IRA)
- Native Village of Unalakleet (IRA)
- Native Village of Venetie Tribal Government (IRA)
- Native Village of Wales (IRA)
- Native Village of White Mountain (IRA)
- Navajo Nation
- Nelson Lagoon Tribal Council
- Nenana Native Association
- New Koliganek Village Council
- New Stuyahok Village
- Newhalen Village
- Newtok Traditional Council
- Nez Perce Tribe
- Nightmute Traditional Council
- Nikolai Village
- Ninilchik Traditional Council
- Nisqually Indian Tribe
- Nome Eskimo Community
- Nondalton Village
- Nooksack Indian Tribe of Washington
- Noorvik Native Community (IRA)
- Northern Cheyenne Tribe
- Northfork Rancheria of Mono Indians of California
- Northway Village
- Northwestern Band of Shoshoni Nation of Utah (Washakie)
- Nottawaseppi Huron Band of Pottawatomi
- Nulato Tribal Council
- Nunakauyarmiut Tribe
- Oglala Sioux Tribe
- Ohkay Owingeh
- Ohogamuit Traditional Council

- Omaha Tribe of Nebraska
- Oneida Nation of New York
- Oneida Tribe of Indians of Wisconsin
- Onondaga Nation of New York
- Organized Village of Grayling (IRA)
- Organized Village of Kake (IRA)
- Organized Village of Kasaan (IRA)
- Organized Village of Kwethluk (IRA)
- Organized Village of Saxman (IRA)
- Orutsararmuit Native Council
- Osage Nation
- Oscarville Tribal Council
- Otoe-Missouria Tribe of Indians
- Ottawa Tribe of Oklahoma
- Paiute Indian Tribe of Utah
- Paiute-Shoshone Indians of the Lone Pine Community of the Lone Pine Reservation
- Pala Band of Luiseno Mission Indians
- Pascua Yaqui Tribe of Arizona
- Paskenta Band of Nomlaki Indians of California
- Passamaquoddy Tribe - Indian Township Reservation
- Passamaquoddy Tribe - Pleasant Point Reservation
- Pauloff Harbor Village
- Pauma Band of Luiseno Mission Indians of the Pauma & Yuima Reservation
- Pawnee Nation of Oklahoma
- Pechanga Band of Luiseno Mission Indians
- Pedro Bay Village Council
- Penobscot Tribe of Maine
- Peoria Tribe of Indians of Oklahoma
- Petersburg Indian Association (IRA)
- Picayune Rancheria of Chukchansi Indians of California
- Pilot Point Tribal Council
- Pilot Station Traditional Village
- Pinoleville Pomo Nation
- Pit River Tribe
- Platinum Traditional Village Council
- Poarch Band of Creek Indians of Alabama
- Pokagon Band of Potawatomi Indians
- Ponca Tribe of Indians of Oklahoma

- Ponca Tribe of Nebraska
- Port Gamble Indian Community
- Port Graham Village Council
- Portage Creek Village Council
- Potter Valley Tribe
- Prairie Band of Potawatomi Nation
- Prairie Island Indian Community in the State of Minnesota
- Pueblo of Acoma
- Pueblo of Cochiti
- Pueblo of Isleta
- Pueblo of Jemez
- Pueblo of Laguna
- Pueblo of Nambe
- Pueblo of Picuris
- Pueblo of Pojoaque
- Pueblo of San Felipe
- Pueblo of San Ildefonso
- Pueblo of Sandia
- Pueblo of Santa Ana
- Pueblo of Santa Clara
- Pueblo of Santo Domingo
- Pueblo of Taos
- Pueblo of Tesuque
- Pueblo of Zia
- Pueblo of Zuni
- Puyallup Tribe
- Pyramid Lake Paiute Tribe
- Qagan Tayagungin Tribe of Sand Point Village
- Qawalangin Tribe of Unalaska
- Quapaw Tribe of Indians
- Quartz Valley Indian Community
- Quechan Tribe
- Quileute Tribe
- Quinault Tribe
- Ramah Navajo Chapter
- Ramona Band of Cahuilla Mission Indians
- Rampart Village
- Red Cliff Band of Lake Superior Chippewa Indians of Wisconsin

- Red Lake Band of Chippewa Indians
- Redding Rancheria
- Redwood Valley Rancheria of Pomo Indians
- Reno-Sparks Indian Colony
- Resighini Rancheria
- Rincon Band of Luiseno Mission Indians
- Robinson Rancheria of Pomo Indians of California
- Rosebud Sioux Tribe
- Round Valley Indian Tribe
- Ruby Tribal Council
- Rumsey Indian Rancheria of Wintun Indians of California (Yocha Dehe Wintun Nation)
- Sac & Fox Tribe of the Mississippi in Iowa
- Sac and Fox Nation
- Sac and Fox Nation of Missouri in Kansas and Nebraska
- Saginaw Chippewa Indian Tribe of Michigan
- Saint Regis Mohawk Tribe
- Salt River Pima-Maricopa Indian Community
- Samish Indian Tribe
- San Carlos Apache Tribe
- San Juan Southern Paiute Tribe of Arizona
- San Manuel Band of Mission Indians
- San Pasqual Band of Diegueno Mission Indians of California
- Santa Rosa Band of Cahuilla Indians
- Santa Rosa Indian Community
- Santa Ynez Band of Chumash Mission Indians
- Santee Sioux Nation
- Sauk-Suiattle Indian Tribe
- Sault Ste. Marie Tribe of Chippewa Indians of Michigan
- Scammon Bay Traditional Council
- Scotts Valley Band of Pomo Indians of California
- Sealaska Corporation
- Selawik IRA Council
- Seldovia Village Tribe (IRA)
- Seminole Nation of Oklahoma
- Seminole Tribe of Florida
- Seneca Nation of New York
- Seneca-Cayuga Tribe of Oklahoma
- Shageluk Native Village (IRA)

- Shakopee Mdewakanton Sioux Community of Minnesota
- Shawnee Tribe
- Sherwood Valley Rancheria of Pomo Indians of California
- Shingle Springs Band of Miwok Indians
- Shoalwater Bay Tribe
- Shoshone Business Committee
- Shoshone-Bannock Tribes of the Fort Hall Reservation of Idaho
- Shoshone-Paiute Tribes of the Duck Valley Reservation
- Sisseton-Wahpeton Oyate of the Lake Traverse Reservation
- Sitka Tribe of Alaska (IRA)
- Skagway Village
- Skokomish Indian Tribe
- Skull Valley Band of Goshute Indians of Utah
- Sleetmute Traditional Council
- Smith River Rancheria
- Snoqualmie Tribe
- Soboba Band of Luiseno Indians
- Sokaogon Chippewa Community
- Solomon Traditional Council
- South Fork Band (Te-Moak Tribe of Western Shoshone Indians of Nevada)
- Southern Ute Indian Tribe
- Spirit Lake Tribe
- Spokane Tribe
- Squaxin Island Tribe
- St. Croix Chippewa Indians of Wisconsin
- St. George Traditional Council
- Standing Rock Sioux Tribe of North & South Dakota
- Stebbins Community Association (IRA)
- Stewart Community (Washoe Tribe of Nevada & California)
- Stillaguamish Tribe of Washington
- Stockbridge Munsee Community of Wisconsin
- Summit Lake Paiute Tribe
- Sun'aq Tribe of Kodiak
- Suquamish Indian Tribe
- Susanville Indian Rancheria
- Swinomish Indians of the Swinomish Reservation
- Sycuan Band of the Kumeyaay Nation
- Table Mountain Rancheria of California

- Takotna Village
- Tanacross Village Council
- Telida Village
- Teller Traditional Council
- Te-Moak Tribe of Western Shoshone Indians of Nevada
- Thlopthlocco Tribal Town
- Three Affiliated Tribe
- Timbi-sha Shoshone Tribe
- Tohono O'odham Nation of Arizona
- Tonawanda Band of Seneca Indians of New York
- Tonkawa Tribe of Indians of Oklahoma
- Tonto Apache Tribe of Arizona
- Torres Martinez Desert Cahuilla Indians
- Traditional Village of Togiak
- Tulalip Tribes of the Tulalip Reservation
- Tule River Indian Tribe
- Tuluksak Native Community (IRA)
- Tunica-Biloxi Indian Tribe of Louisiana
- Tuntutuliak Traditional Council
- Tununak IRA Council
- Tuolumne Band of Me-Wuck Indians
- Turtle Mountain Band of Chippewa Indians of North Dakota
- Tuscarora Nation of New York
- Twenty-Nine Palms Band of Mission Indians of California
- Twin Hills Village Council
- Ugashik Traditional Village Council
- Umkumiut Native Village
- Unga Tribal Council
- United Auburn Indian Community of the Auburn Rancheria of California
- United Keetoowah Band of Cherokee Indians in Oklahoma
- Upper Sioux Community
- Upper Skagit Indian Tribe
- Ute Business Committee
- Ute Mountain Ute Tribe
- Utu Utu Gwaitu Paiute Tribe of the Benton Paiute
- Venetie Village Council
- Viejas Band of Capitan Grande Band of Mission Indians of the Viejas Reservation
- Village of Alakanuk

- Village of Anaktuvuk Pass
- Village of Aniak
- Village of Atmautluak
- Village of Chefornak
- Village of Clarks Point
- Village of Dot Lake
- Village of Iliamna
- Village of Kalskag
- Village of Kotlik
- Village of Lower Kalskag
- Village of Old Harbor
- Village of Red Devil
- Village of Salamatoff
- Village of Stony River
- Village of Wainwright
- Walker River Paiute Tribe
- Wanpanoag Tribe of Gay Head (Aquinnah) of Massachusetts
- Washoe Tribe of Nevada and California
- Wells Indian Colony Band Council
- White Earth Band (Minnesota Chippewa Tribe)
- White Mountain Apache Tribe
- Wichita and Affiliated Tribes
- Wilton Rancheria
- Winnebago Tribe of Nebraska
- Winnemucca Indian Colony of Nevada
- Wiyot Tribe
- Woodfords Community (Washoe Tribe of Nevada & California)
- Wrangell Cooperative Association (IRA)
- Wyandotte Nation
- Yakutat Tlingit Tribe
- Yankton Sioux Tribe of South Dakota
- Yavapai-Apache Nation
- Yavapai-Prescott Tribe
- Yerington Paiute Tribe
- Yomba Shoshone Tribe
- Ysleta Del Sur Pueblo of Texas
- Yupiit of Andreafski
- Yurok Tribe

12.5 Stakeholders

- AAA Mid-Atlantic, Public and Government Relations
- Alaska Public Interest Research Group
- Alliance of Automobile Manufacturers, Environmental Affairs
- Alliance to Save Energy
- Aluminum Association
- American Association of Blacks in Energy
- American Automotive Policy Council
- American Chemistry Council, Plastics
- American Council for an Energy Efficient Economy
- American Council on Renewable Energy, Biomass Coordinating Council
- American Fuel & Petrochemical Manufacturers, Regulatory Affairs
- American Gas Association
- American Indian Science and Engineering Society
- American International Automobile Dealers Association
- American Iron and Steel Institute
- American Jewish Committee
- American Lung Association
- American Natural Gas Alliance
- American Powersports Mfg. Co. Inc.
- American Road & Transportation Builders Association (American Suzuki Motor Corporation, President
- Appalachian Mountain Club
- Arizona Public Interest Research Group
- Association of International Automobile Manufacturers, Inc.
- Association of Metropolitan Planning Organizations
- Auto Research Center, LLC
- Better Place, North America Market Development
- BlueGreen Alliance
- BMW of North America, LLC, President
- Border Valley Trading, LTD
- Boyden Gray & Associates PLLC
- Bridgestone Americas Tire Operations Product Development Group, Technical Standards and Regulations
- California Air Pollution Control Officers Association
- CALPIRG (Public Interest Research Group)
- CALSTART

- Center for Auto Safety
- Center for Biological Diversity, Climate Law Institute
- Central States Air Resources Agencies
- Ceres and the Investor Network on Climate Risk
- Chrysler Group, LLC, Vice President, Regulatory Affairs
- Citizens' Utility Board of Oregon
- Clean Air Task Force
- Clean Energy
- Clean Fuel Development Coalition
- Columbian Justice Peace and Integrity of Creation Office
- Commission for Environmental Cooperation
- Competitive Enterprise Institute
- Conservation Law Foundation
- Consumer Action
- Consumer Assistance Council of Cape Cod
- Consumer Federation of America
- Consumer Federation of the Southeast
- Consumers for Auto Reliability and Safety
- Consumers Union
- Con-way, Inc
- Coulomb Technologies, Inc.
- Criterion Economics, LLC
- Crowell Moring
- Daimler AG, c/o President, Mercedes-Benz USA, LLC
- Daimler Vans USA, LLC
- Dale Kardos & Associates, Inc.
- Dana Holding Corporation
- Defenders of Wildlife
- Democratic Processes Center
- Ecology Center
- Edison Electric Institute
- Electric Power Research Institute, Electric Transportation & Energy Storage
- Empire State Consumer Association
- Engine Manufacturers Association
- Environment America
- Environment Illinois
- Environmental Defense Fund
- ETEC

- Evangelical Environmental Network, Climate Campaign
- Evangelical Lutheran Church in America
- FedEx Corporation
- Florida Consumer Action Network
- Florida Power & Light Co.
- Florida Public Interest Research Group
- Ford Motor Company, Group Vice President, Sustainability, Environment and Safety Engineering
- Friends Committee on National Legislation
- General Motors, Vice President, Environment, Energy and Safety Policy
- Gibson, Dunn & Crutcher, LLP
- Greater Washington Interfaith Power and Light c/o Interfaith Conference of Metropolitan Washington
- Growth Energy
- HayDay Farms, Inc
- Honda North America, Inc., Vice President, Government and Industry Relations
- Hyundai Kia America Technical Center Inc. (HATCI), Regulation & Certification Department
- ICM, Inc.
- Illinois Trucking Association
- Illinois Public Interest Research Group
- Insurance Institute for Highway Safety, VRC Operations
- International Council on Clean Transportation
- Jaguar Land Rover North America LLC, President
- Jewish Community Relations Council
- Joe Foss
- Justice and Witness Ministries
- Kirkland & Ellis, LLP
- Mack and Volvo Trucks
- Manufacturers of Emission Controls Association
- Marcy Ruth Reed
- Maryknoll Office of Global Concerns
- Maryland Consumer Rights Coalition
- Maryland Public Interest Research Group
- Massachusetts Consumers Council
- Massachusetts Public Interest Research Group, Transportation
- Mazda North American Operations, Director, Government & Public Affairs
- Mercatus Center, George Mason University
- Metro 4, Inc. - Southeastern States Air Resource Managers, Inc.
- Michelin North America, Inc., President

- Michigan Tech University, ME-EM Department
- Mid-Atlantic Regional Air Management Association, Inc.
- Mitsubishi Motors North America, Inc., Director and General Manager, Regulatory Affairs and Certification
- Motor & Equipment Manufacturers Association
- National Alliance of Forest Owners
- National Association of Attorneys General
- National Association of Clean Air Agencies (NACAA), NACAA Mobile Sources and Fuels Committee (Massachusetts)
- National Association of Counties
- National Association of Regional Councils
- National Association of Regulatory Utility Commissioners
- National Association of State Energy Officials
- National Automobile Dealers Association
- National Caucus of Environmental Legislators
- National Conference of State Legislatures
- National Council of Churches USA
- National Governors Association
- National Groundwater Association
- National League of Cities
- National Propane Gas Association, Regulatory Affairs
- National Truck Equipment Association
- National Wildlife Federation, National Advocacy Center
- Natural Gas Vehicles (NGV) America
- Natural Resources Canada
- Natural Resources Defense Council, Climate Center
- New Jersey Citizen Action
- New Mexico Public Interest Research Group
- Nissan North America, Inc., Director, Government Affairs
- Northeast States for Coordinated Air Use Management
- NY Public Interest Research Group
- Ozone Transport Commission
- Pew Environment Group, Climate and Energy Programs
- Pierobon & Partners
- Podesta GROUP
- Pollution Probe
- Porsche Cars North America, Inc., Regulatory Affairs
- Presbyterian Church (USA)

- Public Citizen
- Recreation Vehicle Industry Association
- Renewable Fuels Association
- Republicans for Environmental Protection
- Road Safe America
- Rocky Mountain Institute
- Rubber Manufacturers Association
- Saab Cars North America, Inc., President
- Safe Climate Campaign
- Santa Clara Pueblo
- SaviCorp, Inc.
- Securing America's Future Energy
- Sentech, Inc.
- Sierra Club
- Single Springs Rancheria, Band of Miwok Indians
- Socially Responsible Investing, General Board of Pension and Health Benefits of The United Methodist Church
- Society of Plastics, Inc., Industry Affairs - Environment & Health
- Sport Utility Vehicle Owners of America
- Subaru of America, Government Relations
- SUN DAY Campaign
- Teamsters Joint Council 25
- Tesla Motors, Inc., Director of Public Policy and Associate General Counsel
- Tetlin Village Council
- The Accord Group
- The Consumer Alliance
- The Council of State Governments
- The Environmental Council of the States
- The Episcopal Church
- The Hertz Corporation
- The Lee Auto Malls
- The Pew Charitable Trusts, Pew Environment Group
- The United Methodist Church General, Board of Church and Society
- TIAX, LLC
- ToChi Technologies, Inc.
- Toyota Motor North America, Inc., Senior Vice President, Technical and Regulatory Affairs
- Trillium Asset Management Corporation
- Truck Manufacturer's Association

- Truman Project
- Tufts University, The Fletcher School of Law and Diplomacy
- U.S. Chamber of Commerce
- U.S. Conference of Mayors
- Union for Reform Judaism
- Union of Concerned Scientists, Washington Office, Clean Vehicles Program
- United Auto Workers
- United Automobile, Aerospace and Agricultural Workers of America (UAW)
- United Church of Christ
- United Steelworkers
- University of Colorado School of Law
- University of Michigan Center for Sustainable Systems
- University of Michigan Transportation Research Institute
- U.S. Public Interest Research Group
- Utility Consumers Action Network
- Vermont Public Interest Research Group
- Victims Committee for Recall of Defective Vehicles
- Virginia Citizens Consumer Council
- Volkswagen Group of America, Inc., Executive Vice President, Public Affairs & General Counsel
- Volvo Group North America, Vice President, Government and Industry Relations
- West Virginia University
- Western Governors' Association
- Western Regional Air Partnership
- Western States Air Resources Council
- Wisconsin Consumers League
- World Auto Steel
- World Resources Institute, Greenhouse Gas Protocol Team

CHAPTER 13 PREPARERS/REVIEWERS

13.1 United States Department of Transportation

Name/Role	Qualifications/Experience
James D. MacIsaac Jr., General Engineer, Contracting Officer's Technical Representative, NHTSA	
	B.S., Mechanical Engineering with minor in Economics, The Ohio State University
	11 years of experience in vehicle and tire safety, fuel efficiency, and regulatory development
Angel Jackson, General Engineer, Contracting Officer's Technical Representative, NHTSA	
	J.D., University of Cincinnati College of Law; M.S., Mechanical Engineering; B.S., Mechanical Engineering, Florida Agricultural and Mechanical University
	8 years of engineering experience; 5 years of experience in regulatory analysis and drafting; 4 years of legal experience
Coralie Cooper, Environmental Protection Specialist, Volpe Center	
	M.C.P., Environmental Policy and Planning, Massachusetts Institute of Technology; B.A., French Literature, Boston University
	16 years of experience in transportation policy, with a focus on state and federal policies to reduce transportation related emissions and fuel consumption
John Donaldson, Assistant Chief Counsel, Legislation and General Law, NHTSA	
	J.D., Boston College Law School; B.A., Economics, Cornell University
	28 years of experience in vehicle safety issues, including environmental impact assessments
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	J.D., University of Washington School of Law; B.A., Psychology, Whitman College
	3 years of legal experience; 2 years of policy/legislative experience
Kevin Green, Chief, CAFE Program Office, Volpe Center	
	M.Eng., Applied & Engineering Physics, Cornell University; B.S., Applied & Engineering Physics, Cornell University
	21 years of experience in transportation energy and emissions analysis and rulemaking; 10 years of experience in fuel economy rulemaking
Ryan Keefe, Operations Research Analyst, Volpe Center	
	Ph.D., Public Policy Analysis, Pardee RAND Graduate School, Santa Monica, CA; M.S., B.S., Mathematics (summa cum laude), University of Vermont–Burlington
	8 years of experience analyzing transportation, security, energy and environmental policies
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	J.D., University of California, Los Angeles School of Law; B.A., Sociology, Harvard University
	1 year of legal experience
Analiese Marchesseault, Attorney Advisor, NHTSA	
	J.D., Brooklyn Law School; B.A., Art History, University of Chicago
	1 year of legal experience

Name/Role	Qualifications/Experience
Don H. Pickrell, Chief Economist, Volpe Center	
	Ph.D., Urban Planning; M.A., Urban Planning, University of California–Los Angeles; B.A. (with high honors), Economics and Mathematics, University of California–San Diego
	34 years of experience in applied transportation economics; 19 years of experience in analysis of environmental impacts of transportation activity
Helen L. Serassio, Senior Attorney Advisor, Office of the Secretary of Transportation	
	J.D., S.J. Quinney College of Law, University of Utah; B.S., Political Science, University of Utah
	11 years of legal experience in NEPA and environmental issues
James Tamm, Chief, Fuel Economy Division, NHTSA	
	M.S., Mechanical Engineering, University of Michigan; B.S., Mechanical Engineering, Pennsylvania State University
	31 years of experience in automotive engineering related to fuel economy and emissions development; 2 years of experience in vehicle fuel economy rulemaking
O. Kevin Vincent, Chief Counsel, NHTSA	
	J.D., University of Alabama School of Law; B.S., Electrical Engineering, University of Alabama
	26 years of legal experience in contracts and administrative law issues
John Wood, Honors Attorney, NHTSA (DEIS)	
	J.D., University of Mississippi School of Law; B.B.A., Finance, Southern Methodist University
	Less than 1 year of legal experience
Stephen P. Wood, Assistant Chief Counsel, Vehicle Safety Standards and Harmonization, NHTSA	
	J.D., Columbia Law School; B.A., Political Science, Williams College
	43 years of experience in vehicle safety rulemaking; 37 years of experience in fuel economy rulemaking

13.2 Consultant Team

ICF International supported NHTSA in preparing its environmental analyses and in preparing this EIS.

Name/Role	Qualifications/Experience
PROJECT MANAGEMENT	
Alan Summerville, Officer in Charge	
	M.A., City Planning, University of Pennsylvania; B.A., Economics and Political Science, University of Vermont – Burlington
	20 years of experience participating in and managing the preparation of NEPA documents
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	B.S., Environmental Science, University of Ulster
	12 years of environmental consulting experience; 10 years of experience in environmental impact assessment

Name/Role	Qualifications/Experience
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	Ph.D., Sociology, Utah State University; M.A., Geography, University of Wyoming; B.A., Environmental Studies, University of California – Santa Cruz
	19 years of experience in environmental impact assessment
TECHNICAL AND OTHER EXPERTISE (alphabetically)	
Sarah Alexander, Life-cycle Assessment Analyst	
	B.A., Environmental Studies, Dartmouth College
	1 year of experience in life-cycle assessment and alternative fuels
Sarah Alves, EIS Reviewer	
	J.D., Boston University School of Law; B.A., Astronomy and Physics, Boston University
	5 years of legal and regulatory experience; 2 years of experience in macroeconomic analysis
Adam Brundage, Climate Change Analyst, Life-cycle Assessment Lead	
	M.E.M., Environmental Management, Duke University; B.S., Atmospheric Science, McGill University
	5 years of experience assessing and analyzing climate change issues
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	M.P.P., Environmental Policy; B.S., Ecology, The Ohio State University
	2 years of experience in energy and climate policy analysis
Joseph Casola, Climate Change Analyst	
	Ph.D., Atmospheric Sciences, University of Washington; M.S., Atmospheric Sciences, University of Washington; B.S., Chemistry, Duke University
	11 years of experience in issues related to climate science and policy
Michelle Cawley, Librarian	
	M.L.S., Library Science, North Carolina Central University; M.A., Ecology, University of North Carolina; B.A., Political Science, San Diego State University
	11 years of experience in consulting, education, and library settings
Sharon Douglas, Photochemical Modeling Analysis Lead	
	M.S., Meteorology, Pennsylvania State University; B.A., Earth and Planetary Science, Johns Hopkins University
	25 years of experience in meteorological, air quality, and health effects modeling
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	M.C.R.P., Environmental Policy, Harvard University; B.S., Urban Systems Engineering; B.A., Ethics and Politics, Brown University
	31 years of experience preparing air quality analysis for NEPA documents

Name/Role	Qualifications/Experience
Lizelle Espinosa, Reference Manager	
	B.S., Government Administration, Christopher Newport University
	8 years of experience in environmental impact assessment, policy analysis, and regulatory compliance
Christopher Evans, Life-cycle Assessment Analyst	
	M.S., Technology and Policy, Massachusetts Institute of Technology; B.S., Mechanical Engineering, University of Manitoba
	6 years of experience in policy analysis of climate change issues, life-cycle assessment of energy and greenhouse gas (GHG) emissions
Rebecca Ferenchiak, Climate Change Analyst	
	B.S., Chemical Engineering, Villanova University
	2 years of experience in climate change and sustainability consulting
Randall Freed, Senior Climate Change Advisor	
	M.S., Water Resource Management, University of Maryland; B.S., Zoology, University of Maryland
	37 years of experience in assessing and managing environmental risk; 16 years of experience assessing climate change issues
Jay Haney, Photochemical Modeling Analysis Reviewer	
	M.S., Meteorology, Saint Louis University; B.S., Meteorology, Saint Louis University
	32 years of experience in air quality modeling
Christine Hartmann, EIS Reviewer	
	M.Eng., Environmental Engineering, University of Maryland; B.S., Civil Engineering - Environmental Core, University of Maryland
	18 years of experience in environmental engineering and regulatory compliance; 7 years of experience in NEPA project management
Christopher Holder, Air Quality Analyst	
	M.S., Meteorology, North Carolina State University; B.A., Meteorology, North Carolina State University
	6 years of experience in hazardous air pollutant risk assessment, climate change impacts, GHG emission estimation, and renewable energy technologies and policy
Belle Hudischewskyj Guelden, Photochemical and Health Effects Modeler	
	B.S., Meteorology, California State University; A.S., Mathematics, Sierra Junior College
	32 years of experience in meteorological and air quality data analysis and modeling
Brad Hurley, Climate Change Analyst	
	B.A., Environmental Science, State University of New York College at Purchase
	22 years of experience in writing and editing reports, articles, Web content, and other publications on climate change and other environmental topics for a variety of audiences

Todd Jones, NEPA Analyst	
	M.S., Environmental Resource Management, Florida Institute of Technology; B.A., Environmental Studies, University of Central Florida
	2 years of NEPA experience
Nisha Krishnan, Climate Change Analyst	
	M.A., Applied Economics, Johns Hopkins University; B.A., Economics and Political Science, Macalester College
	5 years of experience in researching, analyzing, and designing policies and projects on international and domestic climate change impacts and adaptation
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	M.S., Environmental Science, Indiana University; Master of Public Affairs, Indiana University; B.S., Life Sciences - Biotechnology, St. Xavier's College, Mumbai University
	6 years of experience in environmental impact assessment
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	B.S., Meteorology, Lyndon State College; B.A., Global Studies, Lyndon State College
	1 year of experience in climate change and sustainability consulting
Amy Latella, NEPA Analyst	
	B.S., Resource Economics and Commerce, University of Rhode Island
	1 year of experience in environmental and regulatory analysis
Sheri Lausin, Life-cycle Assessment Analyst	
	B.A., Environmental Science, University of California–Santa Barbara
	13 years of experience with alternative fuels and vehicles and environmental issues
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	M.E.M., Environmental Management, Yale School of Forestry and Environmental Studies; B.S., Environmental Science & Sociology, University of Michigan
	7 years of experience in analysis of climate change issues and life-cycle energy and GHG emissions
Charlotte Mack, Climate Change Analyst	
	M.S., Natural Resources and Environment, University of Michigan; M.P.P., Public Policy, University of Michigan; B.S., Environmental Science, University of Delaware
	5 years of experience working on climate change issues
Kristen Marin, Air Quality Analyst	
	M.E.M., Environmental Health and Security, Duke University; B.S., Atmospheric Science, Cornell University
	4 years of experience in air quality analysis
Lindsey McAlpine, Life-cycle Assessment Analyst	
	B.S., Environmental Science, Brown University
	2 years of experience in waste management and climate change consulting

Rawlings Miller, Climate Change Analyst	
	Ph.D., Atmospheric Sciences, University of Arizona; M.S., Aerospace Engineering, Boston University; B.S., Physics, Union College
	13 years of experience with climate change modeling, air quality research, and impacts analysis; 7 years of experience on environmental issues; 3 years of NEPA experience
Sarah Mulligan, Air Quality Analyst	
	M.P.P., Environmental Policy, University of Maryland–College Park; B.A., Physical Geography with a minor in Atmospheric and Oceanic Sciences, University of Colorado- Boulder
	2 years of experience in environmental impact assessment and policy analysis
Thomas C. Myers, Photochemical Modeler	
	M.A., Physics, University of California–Davis; B.S., Physics, University of the Pacific
	32 years of experience in the development and application of air quality models
Rick Nevin, Energy Lead and Data Manager	
	M.B.A., Finance, Managerial Economics, and Strategy, Northwestern University; M.A., Economics, Boston University; B.A., Economics and Mathematics, Boston University
	29 years of experience managing and preparing environmental, energy, and economic analyses
Jamie O'Malley, NEPA Analyst, Climate Change Analyst	
	B.A., Global Change and Sociology, University of Michigan
	2 years of experience in NEPA
Andrew Papson, Air Quality Analyst	
	M.Eng., Transportation Engineering, University of California – Berkeley; B.S., Materials Science, Stanford University
	4 years of experience analyzing vehicle emissions and fuel efficiency
Annah Peterson, NEPA Analyst, Energy Analyst	
	M.E.M., Environmental Economics and Policy, Duke University; B.S., Biology, Reed College
	4 years of experience in environmental consulting; 3 years of experience in NEPA
Thuy Phung, Climate Change Analyst	
	B.A., Economics and Environmental Policy, Williams College
	1 year of experience in climate change and sustainability issues
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	B.S., Environmental Studies, Keene State College
	2 years of experience in NEPA
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	B.S., Mechanical Engineering, University of Virginia
	3 years of experience in life-cycle assessment and climate change

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	M.S., Atmospheric Science, Cornell University; B.S., Earth and Planetary Sciences, University of New Mexico
	7 years of experience in analysis of climate change impacts to water resources, terrestrial and marine ecosystems, transportation infrastructure, and human health
Emily Rowan, Climate Change Analyst	
	B.A., Science in Society, Wesleyan University
	4 years of experience in climate change impacts and adaptation
Michael Savonis, Senior Climate Change Advisor	
	M.R.P., Regional Planning, Cornell University; B.S. Chemistry, State University of New York at Buffalo
	25 years of experience in transportation policy, climate change, air quality, and emerging environmental issues
Peter Schultz, Senior Climate Change Advisor	
	Ph.D., Geosciences, Pennsylvania State University; M.S., Geosciences, Pennsylvania State University; B.S., Geology, Virginia Polytechnic Institute and State University
	21 years of experience in climate and global change research, management, decision support, and communication
Judith Shipman, Technical Editor	
	A.A., General Studies, University of South Carolina
	34 years of experience producing and editing NEPA documents
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	B.S., Biology, Metropolitan State College of Denver
	1 year of experience in environmental impact assessment
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	B.A., Environmental Science and Public Policy, Harvard University
	2 years of experience in climate change impacts and adaptation
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	M.E.S.M., Environmental Science and Management, University of California – Santa Barbara; B.S., Geographic Science, James Madison University
	2 years of experience in climate change and sustainability
Dana Spindler, Climate Change Analyst	
	M.A., Environmental and Urban Planning, University of Washington; Certificate, Sustainable Business, Bainbridge Graduate Institute; B.S., Environmental and Natural Resources, University of Michigan
	7 years of experience in sustainable management, community outreach, and assessing climate change issues

Elizabeth Strange, Climate Change Analyst	
	Ph.D., Ecology, University of California – Davis; M.S., Ecology, University of California – Davis; B.A., Biology, San Francisco State University
	16 years of experience in climate change impacts and adaptations and analyzing impacts on ecosystems and water resources
Ken Theodos, NEPA Analyst	
	B.S., Environmental Science and Policy, University of Maryland
	1 year of experience in environmental and regulatory analysis
Victoria Thompson, Life-cycle Assessment Analyst	
	M.E.M., Environmental Management, Yale School of Forestry and Environmental Studies; B.A., Biology, Amherst College
	6 years of experience in life cycle assessment, agricultural GHG emission sources, and industrial materials recycling
Alex Uriarte, Environmental Justice and Mitigation Analyst	
	Ph.D., Development Studies, University of Wisconsin–Madison; M.S., Economics, University of Wisconsin–Madison
	13 years of experience in socioeconomic impact assessment, international development projects and economic research and teaching
John Venezia, Climate Change Lead	
	M.S., Environmental Science and Policy, Johns Hopkins University; B.S., Biology and Environmental Science & Policy, Duke University
	13 years of experience analyzing climate change, GHG emission sources, and options for reducing emissions, focusing on the energy sector
Nicole Vetter, Librarian	
	M.L.S., Library Science, Simmons College; B.A., Women's Studies, University of Minnesota
	3 years of library experience; 1 year consulting experience
Yihua Wei, Photochemical Modeling Emission Inventory Preparation Lead	
	M.S., Atmospheric Science, State University of New York at Albany; M.S., Physics, Indiana State University; B.S., Physics, Nanjing University
	21 years of experience in emission inventory processing for air quality modeling