# Draft Environmental Impact Statement

## Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015

June 2008

NHTSA

www.nhtsa.gov

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

Deputy Administrator

1200 New Jersey Avenue SE.
Washington, DC 20590

JUN 24 2008

In Reply Refer To:
Draft Environmental Impact Statement for
New Corporate Average Fuel Economy
Standards, Passenger Cars and Light Trucks,
MY 2011-2015
Docket No. NHTSA-2008-0060

TO THE PARTY ADDRESSED:

I am pleased to enclose for your review a copy of the National Highway Traffic Safety Administration's (NHTSA's) Draft Environmental Impact Statement (DEIS) for new Corporate Average Fuel Economy (CAFE) standards required by the Energy Independence and Security Act of 2007. NHTSA recently proposed standards for model year 2011-2015 passenger cars and light trucks at 73 Fed. Reg. 24,352 (May 2, 2008). I invite you to submit written comments on the DEIS using the instructions below. For your convenience, NHTSA's DEIS and Notice of Proposed Rulemaking (NPRM) are also available at http://www.nhtsa.dot.gov/.

Overview

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

Among other potential impacts, NHTSA has analyzed the direct and indirect impacts related to fuel and energy use, emissions including carbon dioxide ($CO_2$) and its effects on temperature and climate change, air quality, natural resources, and the human environment. NHTSA also considered the cumulative impacts of the proposed standards for MY 2011-2015 automobiles together with estimated impacts of NHTSA's implementation of the CAFE program through MY 2010 and NHTSA's future CAFE rulemaking for MYs 2016-2020, as prescribed by the Energy Policy and Conservation Act, as amended by EISA.

In developing the proposed standards and possible alternatives, NHTSA considered the four EPCA factors underlying maximum feasibility (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy) as well as relevant environmental and safety considerations. NHTSA used a computer model (known as the "Volpe model") that, for any given model year, applies technologies to a manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration. In light of the

EPCA factors, the agency placed monetary values on relevant externalities (both energy security and environmental externalities, including the benefits of reductions in $CO_2$ emissions).

Under the proposed standard for passenger cars, the average fuel economy (in miles per gallon, or mpg) would range from 31.2 mpg in MY 2011 to 35.7 mpg in MY 2015. Under the proposed standard for light trucks, the average fuel economy would range from 25.0 mpg in MY 2011 to 28.6 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks under the proposed standard would range from 27.8 mpg in MY 2011 to 31.6 mpg in MY 2015, if each manufacturer exactly met its obligations under the standards proposed.

Invitation to Comment

I invite your organization to submit written comments or participate in a public hearing on the DEIS during the upcoming 45-day public comment period. In addition, please share this letter and the enclosed DEIS with interested parties within your organization. To ensure consideration, it is important that NHTSA receives your comments before the date specified below. All comments and materials received, including the names and addresses of the commenters who submit them, will become part of the administrative record and will be posted on the web at http://www.regulations.gov. Please carefully follow these instructions to ensure that your comments are received and properly recorded:

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

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

- Reference Docket No. **NHTSA-2008-0060**.

- **Mail your comments so that they will be received in Washington, DC on or before August 18, 2008.**

**NHTSA encourages electronic filing of any comments.** To submit comments electronically, go to http://www.regulations.gov and follow the online instructions for submitting comments. **Comments submitted electronically must be submitted by August 18, 2008.**

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

**NHTSA also will hold a public hearing on the DEIS on Monday, August 4, 2008**, at the National Transportation Safety Board Conference Center, 429 L'Enfant Plaza, SW, Washington, DC 20594. NHTSA will publish a *Federal Register* notice in the near future providing details on the public hearing and instructions for participating.

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

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

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

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

Additional information about the project is available from NHTSA's Fuel Economy Division, Office of International Vehicle, Fuel Economy and Consumer Standards, at 1-202-366-5206 or on the NHTSA CAFE Internet Website identified above. For assistance, please contact NHTSA though the following website https://www.nhtsa.dot.gov/email.cfm or toll free at 1-888-327-4236 (for TTY, contact 1-800-424-9153). The NHTSA CAFE Internet Website also provides access to the texts of formal documents issued by the NHTSA, such as orders, notices, and rulemakings.

Thank you for your continued cooperation.

Sincerely yours,

James F. Ports, Jr.

# SUMMARY

## FOREWORD

The National Highway Traffic Safety Administration (NHTSA) has prepared this Draft Environmental Impact Statement (DEIS) to disclose and analyze the potential environmental impacts of the proposed new  Corporate Average Fuel Economy (CAFE) standards and reasonable alternative standards in the context of NHTSA's CAFE program pursuant to the National Environmental Policy Act (NEPA) implementing regulations issued by the Council on Environmental Quality (CEQ), U.S. Department of Transportation (DOT) Order 5610.1C, and NHTSA regulations.[1] This DEIS compares the potential environmental impacts of the NHTSA's proposed standards and reasonable alternatives, including a No Action Alternative. It also analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance.

## BACKGROUND

The Energy Policy and Conservation Act of 1975 (EPCA) established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and separate standards for light trucks. As part of that Act, the CAFE program was established to reduce national energy consumption by increasing the fuel economy of cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for cars and light trucks sold in the United States.

NHTSA is delegated responsibility for implementing the EPCA fuel economy requirements assigned to the Secretary of Transportation. In December 2007, the Energy Independence and Security Act of 2007 (EISA) amended EPCA's CAFE program requirements and granted DOT additional rulemaking authority. Pursuant to EISA, NHTSA recently proposed CAFE standards for model year (MY) 2011-2015 passenger cars and light trucks in a Notice of Proposed Rulemaking (NPRM).

## PURPOSE AND NEED FOR THE PROPOSED ACTION

EISA sets forth extensive requirements for the proposed rulemaking and these requirements form the purpose of and need for the proposed standards. These requirements also serve as the basis for establishing a range of alternatives to be considered in this DEIS. Specifically, EPCA requires the Secretary of Transportation to establish average fuel economy standards for each model year at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." 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." NHTSA construes the statutory factors as including environmental issues and permitting the consideration of other relevant societal issues such as safety. The purpose of this DEIS, is to analyze the potential environmental impacts of the proposed action and its alternatives.

EPCA further directs the Secretary, after consultation with the Secretary of Energy and the Administrator of the Environmental Protection Agency (EPA), to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with MY 2011, "to achieve a combined fuel economy average for MY 2020 of at least 35 miles per gallon for the

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[1] NEPA is codified at 42 U.S.C. § 4321-4347. CEQ's NEPA implementing regulations are codified at 40 C.F.R. Pts. 1500-1508, and NHTSA's NEPA implementing regulations are codified at 49 C.F.R. Part 520.

total fleet of passenger  and non-passenger automobiles manufactured for sale in the United States for that model year."  In doing so, the Secretary of Transportation is to adopt "annual fuel economy standard increases," but in any single rulemaking, standards may be established for not more than five model years.  This DEIS covers the initial 5-year rulemaking and also considers the cumulative impacts of reaching the 35 miles per gallon (mpg) total fleet requirement during the second 5-year period, MY 2015-2020.

## ALTERNATIVES

NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives.  EPCA's fuel economy requirements, including the four EPCA factors, NHTSA must consider in determining "maximum feasible" CAFE levels – technological feasibility, economic practicability, the need to conserve energy, and the effect of other standards of the Government on fuel economy – from the purpose of and need for the proposed MY 2011-2015 CAFE standards and therefore inform the range of alternatives for consideration in NHTSA's NEPA analysis. NHTSA recognized that a very large number of alternative CAFE levels are potentially conceivable and that the alternatives represent several points on a continuum of alternatives. NHTSA must balance several factors in weighting each of four EPCA factors and other considerations slightly differently in relation to one another.  In developing its reasonable range of alternatives, NHTSA identified alternative stringencies that represent the full spectrum of potential environmental impacts and safety considerations.  This DEIS analyzes the impacts of six alternative actions as well as those impacts that would be expected to occur if NHTSA imposed no new requirements and adopted a rule allowing the current MY 2010 standards to remain in place (the No Action Alternative).

NHTSA's preferred alternative establishes optimized mpg standards that yield the greatest net benefits of any of the feasible alternatives.  As mpg standards are increased beyond this optimized level, manufacturers would be forced to apply technologies that entail higher incremental costs than benefits, thereby, reducing total net benefits.

One of the specific alternatives examined, and the most stringent, is the Technology Exhaustion Alternative, which represents the level at which vehicle manufacturers apply all feasible technologies without regard to costs.  Another specific alternative is the total costs (TC) equal total benefits (TB) level (Total Costs Equal Total Benefits Alternative), at which manufacturers are forced to apply technologies until total costs equal total benefits, yielding zero net benefits.  The Total Costs Equal Total Benefits Alternative is the second most stringent set of mpg standards examined, after the Technology Exhaustion Alternative (which yields negative net benefits).  Three other alternatives that were analyzed illustrate how costs, benefits, and net benefits vary across other possible CAFE standards between the No Action and the Total Costs Equal Total Benefits Alternatives.

As shown in Table S-1, the 50 Percent Above Optimized Alternative would impose a 2015 mpg standard halfway between the Optimized and Total Costs Equal Total Benefits Alternatives.  The 25 Percent Above Optimized Alternative would impose a 2015 mpg standard halfway between the Optimized and 50 Percent Above Optimized Alternatives, and the 25 Percent Below Optimized Alternative would impose a 2015 standard that falls below the Optimized Alternative by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds the Optimized scenario.

**TABLE S-1**

**MY 2015 Required Miles Per Gallon (mpg) by Alternative**

| | No Action | 25% Below Optimized | Optimized (Preferred) | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| Cars | 27.5 | 33.9 | 35.7 | 37.5 | 39.5 | 43.3 | 52.6 |
| Trucks | 23.5 | 27.5 | 28.6 | 29.8 | 30.9 | 33.1 | 34.7 |

## POTENTIAL ENVIRONMENTAL CONSEQUENCES

The DEIS describes potential environmental impacts to a variety of resources. The impact areas that warrant the most detailed analysis are energy resources, air quality, and climate – as well as resources that may be impacted by changes in climate. Tables S-2 through S-14 and Figures S-1 through S-6 below summarize the direct, indirect, and cumulative effects of the CAFE alternatives on energy, air quality, and climate. In regard to global climate change issues, NHTSA recognizes the national interest in global climate change issues, particularly as they relate to the country's use of automobiles and light trucks. "Global climate change" refers to long-term fluctuations in global surface temperatures, precipitation, sea levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, the earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) (0.74 °Celsius [C]) and sea levels have risen 6.7 inches (0.17 meters).

Most scientists now agree that this climate change is largely a result of greenhouse gas (GHG) emissions from human activities. Most GHGs are naturally occurring, including carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), water vapor, and ozone ($O_3$). Human activities such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees can contribute to increased concentrations of these gases in the atmosphere.

Contributions to the build-up of GHG in the atmosphere vary greatly from country to country, and depend heavily on the level of industrial and economic activity. Emissions from the United States accounted for approximately 15 to 20 percent of global GHG emissions in the year 2000. With over one-quarter of these United States emissions due to the combustion of petroleum fuels in the transportation sector, $CO_2$ emissions from the United States transportation sector represent about 4 percent of all global GHG emissions.

Throughout this DEIS NHTSA has relied extensively on findings of the United Nations' Intergovernmental Panel on Climate Change (IPCC) and the U.S. Climate Change Science Program (USCCSP). Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global climate change and its impact on the United States: the IPCC Fourth Assessment (AR4) Working Group I[2] and II[3] Reports,[4] and reports by the USCCSP that include the *Scientific*

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[2] *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.* ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7. See http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

[3] *Climate Change 2007 – Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.* (978 0521 88010-7 Hardback; 978 0521 70597-4 Paperback). See http://www.ipcc.ch/ipccreports/ar4-wg2.htm.

[4] *See generally* http://www.ipcc.ch/ipccreports/assessments-reports.htm.

*Assessments of the Effects of Global Change on the United States* and Synthesis and Assessment Products.[5] These sources and the studies they review are frequently cited throughout the DEIS. For these reasons, we encourage readers to read the Synthesis Report: Summary for Policymakers of the IPCC Fourth Assessment Report before reading this document.[6] This relatively short document summarizes the key findings of the IPCC Fourth Assessment Report.

Because of the link between the transportation sector and GHG emissions, NHTSA recognizes the need to consider the possible impacts on climate and global climate change in the analysis of this proposed action. We also recognize the difficulties and uncertainties involved in such an impact analysis. Accordingly, NHTSA has reviewed existing credible scientific evidence which is relevant to this analysis and summarized it in this DEIS consistent with Council on Environmental Quality regulations on addressing incomplete or unavailable information in environmental impact analyses. NHTSA has also employed and summarized the results of research models generally accepted in the scientific community.

However, NHTSA emphasizes to the reader of this DEIS that the proposed action does not directly regulate the emissions from passenger cars and light trucks. NHTSA does not have that authority. The proposed action before NHTSA is to establish the CAFE standards for MY 2011-2015 passenger cars and light trucks. Among its goals is energy conservation. At the same time, the reduction of $CO_2$ emissions is a substantial and direct by-product of that conservation. Further, the stringency of the fuel economy standards is based on the valuation of both direct (fuel savings) and indirect (e.g., the reduction of $CO_2$ emissions) benefits.

In order to establish these new standards, NSHTA must evaluate and take into account a variety of factors, projections, and trends occurring in the transportation sector of the economy as well as in society's driving habits and driving decisions. NHTSA's authority to promulgate new fuel economy standards is a limited authority and does not allow it to regulate these factors, e.g., driving habits and decisions stemming from the projected number of vehicle miles to be driven. Rather, NHTSA's authority is focused on adopting fuel economy standards so that the projected number of miles to be driven occurs under appropriate fuel conservation practices, taking into account other statutory concerns. To the extent that these conservation measures reduce fuel consumption, they play a role in reducing vehicle emissions that would have occurred absent such conservation. Consequently, as discussed in the DEIS, this proposed action will indirectly contribute to reducing impacts on and associated with the ongoing process of global climate change.

Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring, but only result in small reductions in the anticipated increases in $CO_2$ concentrations, temperature, precipitation, and sea level. They would also to a small degree delay the point at which certain temperature increases and other physical effects stemming from increased GHG emissions would occur. As discussed below, NHTSA's presumption is that these reductions in climate effects will be reflected in reduced impacts on affected resources.

NHTSA informed the public through notices in the *Federal Register* (FR) of its intent to prepare this DEIS. The purpose of these notices was to request from the public its views and comments on the scope of the agency's NEPA analysis, including the impacts and alternatives that the DEIS should address, as well as to inform NHTSA of any available studies that would assist in the impact analysis for

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[5] *See generally* http://www.climatescience.gov/.

[6] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf.

global climate change issues.  NHTSA has reviewed and considered the public comments that were provided as well as the suggested studies.  The predominant request by commenters was that NHTSA focus this DEIS on the proposed action's possible impacts on both air quality and global climate change.

Commenters urged NHTSA to consider standards that would go beyond the 35 mpg requirements in EISA for the year 2020.  NHTSA has examined a full range of alternatives, the most stringent of which exceed the 35 mpg target in 2020.  Commenters also noted that environmental impacts may depend on the choice of economic inputs and the extent to which manufacturers take advantage of credits and flexibilities allowed under the law.  NHTSA has addressed these concerns in Chapter 3, "Sensitivity Analyses."  Finally, commenters requested that human health impacts be addressed in the DEIS which NHTSA has included.

NHTSA consulted with various federal agencies in the development of this DEIS.  These include: EPA, Centers for Disease Control and Prevention (CDC), National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (USFWS), the National Park Service, and the U.S. Forest Service.

While the main focus of this DEIS is on the quantification of impacts to energy, air quality, and climate, as well as qualitative cumulative impacts resulting from climate change, the DEIS also addressed other potentially affected resources.  NHTSA conducted a qualitative review of the non-climate change related direct, indirect, cumulative effects, either positive or negative, of the alternatives on other potentially affected resources.  These resource areas included:  water resources, biological resources, land use, hazardous materials, safety, noise, historic and cultural resources, and environmental justice.  Effects of the alternatives on these resources were too small to address quantitatively.  Impacts to biological resources could include:  reductions in habitat disturbance, decreased impacts from acid rain on water and terrestrial habitats from decreases in petroleum production as well as increased agricultural-related disturbances and runoff due to biofuel production.  Impacts to land use and development could include increased agricultural land use.  Impacts to safety could include downweighting of vehicles and increased vehicle miles traveled, resulting in increased traffic injuries and fatalities.  Impacts to hazardous materials could include, overall reductions in the generation of air and oil production related wastes, and increases in agricultural wastes due to biofuel production.  Impacts to historic and cultural resources could include reductions in acid rain related damage.  Noise impacts could include increased noise levels in some areas due to higher vehicle miles traveled.  Impacts to environmental justice populations could include, increased air toxics in some areas as a result of higher vehicle miles traveled.  No impacts are expected to natural areas protected under Section 4(f).

The effects of the alternatives on climate – $CO_2$ concentrations, temperature, precipitation, and sea level rise – can translate into impacts on key resources, including freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, human health, and environmental justice.  Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring.  However, the magnitudes of the changes in these climate effects that the alternatives produce – a few parts per million (ppm) of $CO_2$, a hundredth of a degree C difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2 millimeter (mm) of sea level change – are too small to meaningfully address quantitatively in terms of their impacts on resources.  Given the enormous resource values at stake, these distinctions may be important – very small percentages of huge numbers can still yield substantial results – but they are too small for current quantitative techniques to resolve.  Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.[7]

These impacts were examined on the United States and global scale. Impacts to freshwater resources could include changes in precipitation patterns, decreasing aquifer recharge in some locations, changes in snowpack and time of snowmelt, salt water intrusion from ocean rise, changes in weather patterns resulting in flooding or drought in certain regions, increased water temperature, and numerous other changes to freshwater systems that disrupt human use and natural aquatic habitats. Impacts to terrestrial ecosystems could include shifts in species range and migration patterns, potential extinctions of sensitive species unable to adapt to changing conditions, increases in forest fire and pest infestation occurrence and intensity, and changes in habitat productivity because of increased atmospheric $CO_2$. Impacts to coastal ecosystems, primarily from predicted sea level rises, could include the loss of coastal areas due to submersion and erosion, additional severe weather and storm surge impacts, and increased salinization of estuaries and freshwater aquifers. Impacts to land use could include flooding and severe weather impacts to coastal, floodplain and island settlements, extreme heat and cold waves, increases in drought in some locations, and weather/sea level related disruptions of service, agricultural and transportation sectors. Impacts to human health could include increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water and food-borne diseases, changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition. Impacts to environmental justice populations could come from any of the above, especially where these effects would occur in developing nations.

## Direct and Indirect Effects

### Energy

Table S-2 shows the impact on fuel consumption for passenger cars and light trucks from 2020 through 2060[8], a period in which an increasing volume of the fleet will be MY 2011-2015 vehicles. The table shows total fuel consumption (both gasoline and diesel) under the No Action Alternative and the six action alternative scenarios. Fuel consumption under the No Action Alternative is 256.9 billion gallons in 2060. Consumption falls under to 228.5 billion gallons under the Optimized Alternative and would fall to 208.1 billion gallons under the Technology Exhaustion Alternative.

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[7] *See* 42 U.S.C. § 4332 (requiring federal agencies to “identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration”); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited June 20, 2008) (recognizing that agencies are sometimes “limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood” or cannot be quantified).

[8] 2060 is used as the end point for the analysis as it is the time at which 98 percent or more of the operating fleet would be made up of MY 2011-2016 or newer, thus achieving the maximum fuel savings under this rule.

**TABLE S-2**

**Comparison of Direct and Indirect Energy Consequences for Action Alternatives to the CAFE Standard for MY 2011 to MY 2015 and No Action Alternative**

| | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Passenger Cars and Light Trucks Fuel Consumption (billions of gallons) by Calendar Year** | | | | | | | |
| 2020 | 148.0 | 140.7 | 138.3 | 135.9 | 134.3 | 132.8 | 131.3 |
| 2030 | 176.8 | 163.0 | 158.5 | 153.9 | 150.9 | 148.2 | 145.3 |
| 2040 | 213.9 | 196.1 | 190.3 | 184.5 | 180.6 | 177.3 | 173.5 |
| 2050 | 256.9 | 235.5 | 228.5 | 221.5 | 216.7 | 212.5 | 208.1 |
| 2060 | 307.8 | 282.3 | 273.9 | 265.4 | 259.5 | 254.5 | 249.2 |

## Air Quality

Table S-3 summarizes the total national criteria and air toxic pollutant emissions in 2035 for the seven alternatives, presented in left-to-right order of increasing fuel economy requirements. The No Action Alternative has the highest emissions of all the alternatives for all air pollutants except acrolein, which increases with the action alternatives because upstream emissions data were not available (emissions for acrolein reflect only increases due to the rebound effect). Localized increases in criteria and toxic air pollutant emissions could occur in some non-attainment areas as a result of implementation of the CAFE standards under the alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. Under the No Action alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect that would not need mitigation. The Federal Highway Administration (FHWA) has funds dedicated to the reduction of air pollutants in nonattainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in nonattainment areas that would be observed under the proposed standard. Further, EPA has authority to continue to improve vehicle emissions standards.

## TABLE S-3

## Comparison of Direct and Indirect Air Quality Consequences for Action Alternatives to the CAFE Standard for MY 2011-2015 and No Action Alternative

| | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Carbon Monoxide (CO) | 26,446,292 | 26,158,046 | 26,044,977 | 24,159,436 | 23,111,813 | 22,362,860 | 21,927,726 |
| Nitrogen Oxides (NOx) | 2,720,799 | 2,590,414 | 2,547,317 | 2,340,656 | 2,222,744 | 2,136,859 | 2,080,801 |
| Particulate Matter (PM) | 583,318 | 568,326 | 564,238 | 524,529 | 500,769 | 483,889 | 473,062 |
| Sulfur Oxides (SOx) | 603,991 | 543,259 | 523,947 | 467,569 | 434,523 | 410,207 | 392,441 |
| Volatile Organic Compounds (VOC) | 2,477,999 | 2,399,287 | 2,372,905 | 2,203,377 | 2,105,993 | 2,034,852 | 1,990,799 |
| **Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Acetaldehyde | 14,354 | 14,198 | 14,137 | 13,360 | 12,931 | 12,622 | 12,447 |
| Acrolein | 663 | 676 | 677 | 677 | 685 | 690 | 696 |
| Benzene | 76,355 | 74,969 | 74,430 | 69,017 | 66,025 | 63,857 | 62,591 |
| 1,3-Butadiene | 8,062 | 7,991 | 7,949 | 7,463 | 7,216 | 7,038 | 6,941 |
| Diesel Particulate Matter (DPM) | 265,474 | 238,004 | 229,040 | 205,151 | 191,609 | 181,604 | 174,200 |
| Formaldehyde | 19,851 | 19,486 | 19,356 | 18,628 | 18,241 | 17,963 | 17,798 |

## Climate: GHG emissions

Table S-4 shows total GHG emissions and emission reductions from new passenger cars and light trucks from 2010-2100[9] for each of the seven alternatives. While GHG emissions from this sector will continue to rise over the time period (absent other reduction efforts), the effect of the alternatives is to slow this increase by varying amounts. Compared to the No Action Alternative, projections of emission reductions over the 2010 to 2100 timeframe due to other MY 2011-2015 CAFE standard alternatives ranged from 18,333 to 35,378 million metric tons of $CO_2$ ($MMTCO_2$).[10] Over this period, this range of alternatives would reduce global $CO_2$ emissions (from all sources) by about 0.4 to 0.7 percent (based on global emissions of 4,850,000 $MMTCO_2$).

**TABLE S-4**

**Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard, from 2010-2100 ($MMTCO_2$)**

| Alternative | Emissions | Emission Reductions Compared to No Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 229,558 | 18,333 |
| Optimized | 223,795 | 24,096 |
| 25 Percent Above Optimized | 221,003 | 26,887 |
| 50 Percent Above Optimized | 218,548 | 29,342 |
| Total Costs Equal Total Benefits | 215,714 | 32,176 |
| Technology Exhaustion | 212,512 | 35,378 |

## Climate: $CO_2$ Concentration and Global Mean Surface Temperature

Table S-5 shows mid-range estimated $CO_2$ concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 for the No Action Alternative and the six alternative CAFE levels. There is a fairly narrow band of estimated $CO_2$ concentrations as of 2100, from 705.4 ppm for Technology Exhaustion to 708.6 ppm for the No Action Alternative. As $CO_2$ concentrations are the key driver of climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. These estimates include considerable uncertainty due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid point to 3.0 degrees C which directly relates to the uncertainty in the estimated global mean surface temperature

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[9] The global climate change models used in the analysis conducted for this DEIS use the year 2100 because NHTSA believes that given the current state-of-the-science the year 2100 is a practical maximum for impacts of climate change to be considered reasonably foreseeable rather than speculative.

[10] The values here are summed from 2010 through 2100, and are thus considerably higher than the value of 520 MMTCO2 that is cited in the NPRM for the "Optimized" alternative. The latter value is the reduction in CO2 emissions by only MY 2011-15 cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the NPRM baseline of extending the CAFE standards for MY 2010 to apply to 2011-15.

**TABLE S-5**

**MY 2011-2015 CAFE Alternatives Impact on $CO_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC**

| | $CO_2$ Concentration (ppm) | | | Global Mean Surface Temperature Increase (°C) | | |
|---|---|---|---|---|---|---|
| | **2030** | **2060** | **2100** | **2030** | **2060** | **2100** |
| **Totals by Alternative** | | | | | | |
| No Action (A1B – AIM[11]) | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.3 | 574.4 | 706.9 | 0.788 | 1.835 | 2.757 |
| Optimized | 458.2 | 574.2 | 706.4 | 0.788 | 1.834 | 2.755 |
| 25 Percent Above Optimized | 458.2 | 574.1 | 706.1 | 0.788 | 1.833 | 2.754 |
| 50 Percent Above Optimized | 458.2 | 574.0 | 705.9 | 0.788 | 1.832 | 2.753 |
| Total Costs Equal Total Benefits | 458.1 | 573.9 | 705.6 | 0.788 | 1.832 | 2.752 |
| Technology Exhaustion | 458.1 | 573.7 | 705.4 | 0.788 | 1.831 | 2.751 |
| **Reduction from No Action to CAFE Alternatives** | | | | | | |
| 25 Percent Below Optimized | 0.1 | 0.8 | 1.7 | 0.001 | 0.002 | 0.006 |
| Optimized | 0.2 | 1.0 | 2.2 | 0.001 | 0.003 | 0.008 |
| 25 Percent Above Optimized | 0.2 | 1.1 | 2.5 | 0.001 | 0.004 | 0.009 |
| 50 Percent Above Optimized | 0.2 | 1.2 | 2.7 | 0.001 | 0.005 | 0.010 |
| Total Costs Equal Total Benefits | 0.3 | 1.3 | 3.0 | 0.001 | 0.005 | 0.011 |
| Technology Exhaustion | 0.3 | 1.5 | 3.2 | 0.001 | 0.006 | 0.012 |

To supplement the modeled estimates in Table S-5 generated by applying the Model for Assessment of Greenhouse gas-Induced Climate Change (MAGICC)[12], a scaling approach was used to (1) validate that the modeled estimates are consistent with recent IPCC (2007) estimates and (2) characterize the sensitivity of the $CO_2$ and temperature estimates to different assumptions about (a) global emissions from sources other than United States passenger cars and light trucks and (b) climate sensitivity (i.e., the equilibrium warming associated with a doubling of atmospheric $CO_2$ concentrations compared to pre-industrial levels). The scaling analysis showed that the results for $CO_2$ concentration and temperature are in good agreement with recent estimates from IPCC (2007). The analysis also indicates that the estimates for $CO_2$ concentrations and global mean surface temperature vary considerably, depending on which global emissions scenario is used as a reference case. Furthermore, temperature increases are sensitive to climate sensitivity. Regardless of the choice of reference case or climate sensitivity, the differences among CAFE alternatives are small: $CO_2$ concentrations as of 2100 are within 2 ppm across alternatives, and temperatures are within 0.02°C across alternatives (consistent with the MAGICC modeling results). The scaling results illustrate the uncertainty in $CO_2$ concentrations and temperatures related to reference case global emissions and climate sensitivity.

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[11] The AIB-AIM scenario is the Special Report on Emissions Scenarios (SRES) marker scenario used by the IPCC WG1 to represent the SRES A1B storyline. The A1B scenario is regarded as a moderate emissions case and has been widely used in climate models. For more information on SRES, the future emission scenarios developed by the IPCC to drive global circulation models, see http://www.grida.no/climate/ipcc/emission/. See Chapter 3 for a more complete discussion of NHTSA's modeling approach.

[12] NHTSA employed a simple climate model, MAGICC version 4.1, to estimate changes in key direct and indirect effects from reductions in GHG emissions.

## Climate: Global Mean Rainfall

The CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, and thus reduce increases in precipitation slightly, as shown in Table S-6.  As shown in the table and figures, there is a fairly narrow band of estimated precipitation increase reductions in the mid-range estimates as of 2090, from 4.30 percent to 4.32 percent, and there is very little difference between the alternatives.  Uncertainty in these results from uncertainty in the increase in the global mean surface temperature and uncertainty from the global mean rainfall change.

## TABLE S-6

## MY 2011-2015 CAFE Alternatives: Impact on Reductions in Global Mean Rainfall based on A1B SRES Scenario (percent change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC

| Scenario | 2020 | 2055 | 2090 |
|---|---|---|---|
| **Global Mean Rainfall Change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature above Average 1980-1999 Levels ($^{o}$C) for the A1B Scenario and CAFE Alternatives, Mid-level Results** | | | |
| No Action | 0.69 | 1.750 | 2.650 |
| 25 Percent Below Optimized | 0.690 | 1.747 | 2.645 |
| Optimized | 0.690 | 1.747 | 2.643 |
| 25 Percent Above Optimized | 0.690 | 1.746 | 2.642 |
| 50 Percent Above Optimized | 0.690 | 1.746 | 2.641 |
| Total Costs Equal Total Benefits | 0.690 | 1.745 | 2.640 |
| Technology Exhaustion | 0.690 | 1.745 | 2.639 |
| **Reduction in Global Temperature ($^{o}$C) for CAFE Alternatives, Mid-level Results (Compared to No Action Alternative)** | | | |
| 25 Percent Below Optimized | 0.000 | 0.003 | 0.005 |
| Optimized | 0.000 | 0.003 | 0.007 |
| 25 Percent Above Optimized | 0.000 | 0.004 | 0.008 |
| 50 Percent Above Optimized | 0.000 | 0.004 | 0.009 |
| Total Costs Equal Total Benefits | 0.000 | 0.005 | 0.010 |
| Technology Exhaustion | 0.000 | 0.005 | 0.011 |
| **Mid Level Global Mean Rainfall Change (%)** | | | |
| No Action | 1.00 | 2.64 | 4.32 |
| 25 Percent Below Optimized | 1.00 | 2.64 | 4.31 |
| Optimized | 1.00 | 2.64 | 4.31 |
| 25 Percent Above Optimized | 1.00 | 2.64 | 4.31 |
| 50 Percent Above Optimized | 1.00 | 2.64 | 4.30 |
| Total Costs Equal Total Benefits | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion | 1.00 | 2.63 | 4.30 |
| **Reduction in Global Mean Rainfall Change for CAFE Alternatives (% Compared to No Action Alternative)** | | | |
| 25 Percent Below Optimized | 0.00 | 0.00 | 0.01 |
| Optimized | 0.00 | 0.00 | 0.01 |
| 25 Percent Above Optimized | 0.00 | 0.01 | 0.01 |
| 50 Percent Above Optimized | 0.00 | 0.01 | 0.0 |
| Total Costs Equal Total Benefits | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion | 0.00 | 0.01 | 0.02 |

## Climate: Impact on Sea Level Rise

IPCC AR4 identifies four primary components to sea level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland. Ice sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise, using a non-linear temperature- and pressure-dependent expansion coefficient. It also addresses the other three primary components through ice-melt models for small glaciers, and the Greenland and Antarctic ice sheets.

Table S-7 shows that the impact on mid-range estimates of sea level rise from the scenarios is at the threshold of the MAGICC model's reporting: the alternatives reduce sea level rise by 0.1 centimeter (cm). Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above), and the lower the sea level. hus, the more stringent alternatives are likely to result in slightly less sea level rise.

**TABLE S-7**

**MY 2011-2015 CAFE Alternatives: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level (cm) |
|---|---|
| No Action | 37.9 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.8 |
| Total Costs Equal Total Benefits | 37.8 |
| Technology Exhaustion | 37.8 |
| **Reduction in Sea Level Rise for the CAFE alternatives (% compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.1 |
| Technology Exhaustion | 0.1 |

One of the areas of climate change research where there have been many recent developments is the science underlying the projection of sea level rise. As noted above, there are four key components of sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-the-science, so the scaling approach is an important supplement. The scaling approach applied in the DEIS captures two effects which could overstate the impacts by just scaling the sea level rise by changes in global temperature. The first effect is the current "commitment" (i.e., the inertia in the climate system that would result in climate change even if concentrations did not increase in the future) to global warming, which will occur despite the emission reduction from the CAFE alternatives. The second is the current commitment to sea level rise similar to the current "commitment" to global warming. By examining the difference between the low (B1) scenario[13] and the mid-level (A1B) scenario, these terms, which will be the same in both scenarios, are eliminated.

The results are shown above Table S-8 for scenario A1B (medium) and the 3 degrees C climate sensitivity. Across the CAFE alternatives, the mean change in the global mean surface temperature, as a ratio of the increase in warming between the B1 (low) to A1B (medium) scenarios, ranges from 0.5 percent to 1.1 percent. The resulting change in sea level rise (compared to the No Action Alternative) ranges, across the alternatives, from 0.04 cm to 0.07 cm. This compares well to the MAGICC results of about 0.1 cm. Thus, despite the fact that MAGICC does not reflect some of the more recent developments in the state-of-the-science, the results are of the same magnitude.

**TABLE S-8**

**The Estimated Impact on Sea Level Rise in 2100 From the 2011-2015 CAFE Alternatives for SRES Scenario A1B; Scaling Approach**

| | Reduction in Equilibrium Warming for the 3.0 °C Climate Sensitivity (°C) | Reduction in Global Mean Surface Temperature for the 3.0 °C Climate Sensitivity (°C) | Reduction in Global Mean Warming as Share of B1 - A1B Increase in Warming (%) | Mid Range of Sea Level Rise (cm) |
|---|---|---|---|---|
| **Totals by Alternative** | | | | |
| No Action | NA | 2.650 | 0.00 | 28.00 |
| 25 Percent Below Optimized | NA | 2.645 | 0.50 | 27.96 |
| Optimized | NA | 2.643 | 0.80 | 27.95 |
| 25 Percent Above Optimized | NA | 2.643 | 0.90 | 27.94 |
| 50 Percent Above Optimized | NA | 2.642 | 0.90 | 27.94 |
| Total Costs Equal Total Benefits | NA | 2.641 | 1.00 | 27.93 |
| Technology Exhaustion | NA | 2.640 | 1.10 | 27.93 |
| **Reduction from the CAFE Alternatives** | | | | |
| 25 Percent Below Optimized | 0.007 | 0.005 | 0.5 | 0.04 |
| Optimized | 0.010 | 0.007 | 0.8 | 0.05 |
| 25 Percent Above Optimized | 0.011 | 0.007 | 0.9 | 0.06 |
| 50 Percent Above Optimized | 0.012 | 0.008 | 0.9 | 0.06 |
| Total Costs Equal Total Benefits | 0.013 | 0.009 | 1.0 | 0.07 |
| Technology Exhaustion | 0.014 | 0.009 | 1.1 | 0.07 |

## Cumulative Effects

### Energy

The seven alternatives examined for CAFE standards will result in different future levels of fuel use, total energy, and petroleum consumption, which will in turn have an impact on emissions of GHG and criteria air pollutants. Figure S-1 shows the estimated lifetime fuel consumption of passenger cars

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[13] The B1 storyline from IPCC SRES represents a low scenario of global GHG emissions, due largely to the following assumptions: rapid changes toward a service and information economy, reductions in material intensity, and cleaner and more efficient technologies.

and light trucks under the various CAFE standards. Figure S-1 shows the savings in lifetime fuel consumption for passenger cars and light trucks depending on the CAFE alternative examined.

**Figure S-1: Lifetime Fuel Consumption of Light Trucks and Passenger Cars under Alternative CAFE Standard**

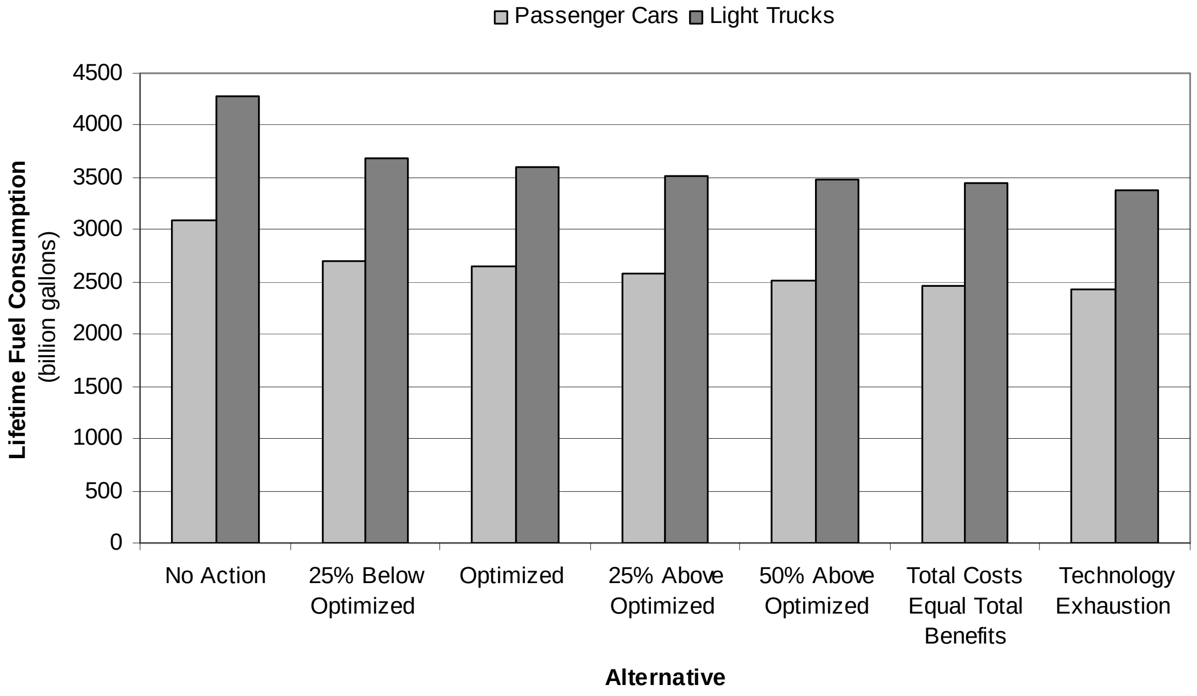
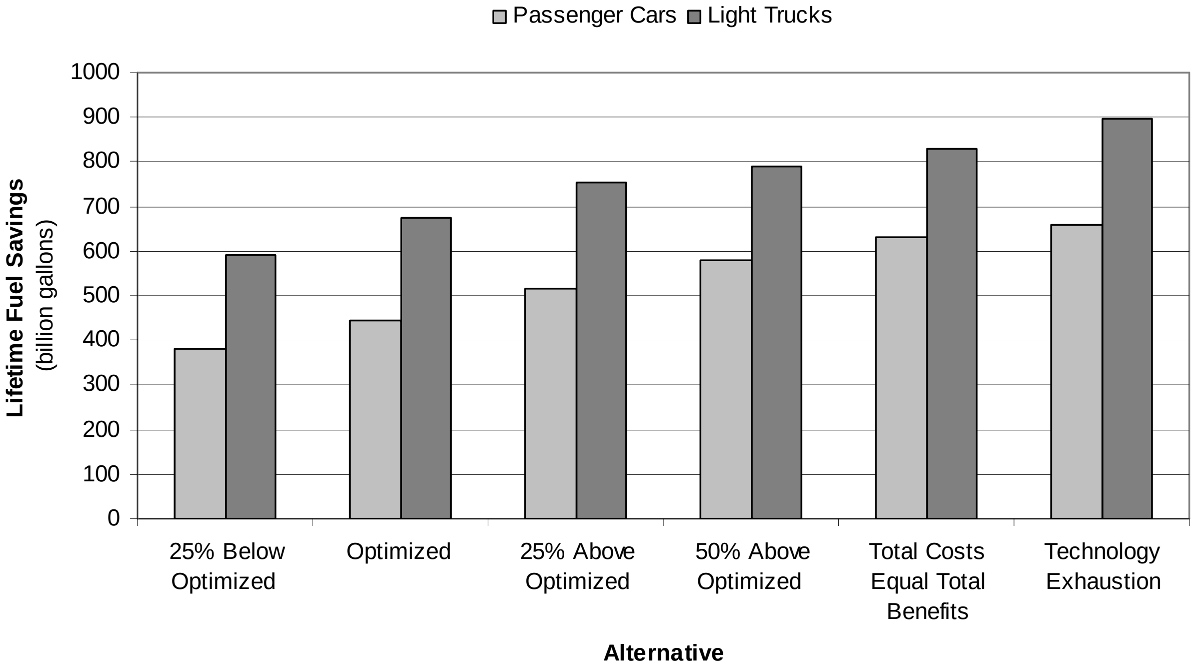


**Figure S-2: Savings in Lifetime Fuel Consumption by Light Trucks and Passenger Cars under Alternative CAFE Standard**



## Air Quality

Table S-9 summarizes the cumulative national toxic and criteria pollutants, showing that the No Action Alternative has the highest emissions of all the alternatives for all pollutants except acrolein, which increases with the action alternatives because upstream emissions data were not available (emissions for acrolein reflect only increases due to the rebound effect). Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act (CAA) standards. Under the No Action Alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect and would not need mitigation. FHWA has funds dedicated to the reduction of air pollutants in non-attainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in non-attainment areas that would be observed under the proposed standard. Further, EPA has authority to continue to improve vehicle emissions standards.

## TABLE S-9

### Comparison of Cumulative Air Quality Consequences for Six Action Alternatives to the CAFE Standard for MY 2011 to MY 2020 and No Action Alternative

| | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Carbon Monoxide (CO) | 26,446,292 | 26,392,554 | 25,928,187 | 22,327,626 | 20,563,462 | 19,584,601 | 18,665,921 |
| Nitrogen Oxides (NOx) | 2,720,799 | 2,508,200 | 2,437,802 | 2,093,950 | 1,921,291 | 1,822,258 | 1,730,923 |
| Particulate Matter (PM) | 583,318 | 565,632 | 554,564 | 481,268 | 441,564 | 419,680 | 398,490 |
| Sulfur Oxides (SOx) | 603,991 | 493,989 | 469,439 | 385,825 | 342,328 | 316,867 | 292,926 |
| Volatile Organic Compounds (VOC) | 2,477,999 | 2,362,124 | 2,311,540 | 2,022,160 | 1,874,970 | 1,790,100 | 1,713,463 |
| **Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Acetaldehyde | 14,354 | 14,252 | 14,063 | 12,646 | 11,959 | 11,573 | 11,225 |
| Acrolein | 663 | 687 | 688 | 687 | 702 | 712 | 722 |
| Benzene | 76,355 | 74,938 | 73,498 | 63,637 | 58,866 | 56,161 | 53,696 |
| 1,3-Butadiene | 8,062 | 8,034 | 7,911 | 7,008 | 6,619 | 6,400 | 6,204 |
| Diesel particulate Matter (DPM) | 265,474 | 214,961 | 204,045 | 169,501 | 152,605 | 142,653 | 133,315 |
| Formaldehyde | 19,851 | 19,312 | 19,098 | 17,904 | 17,363 | 17,060 | 16,796 |

## Climate: Cumulative GHG emissions

Total emission reductions from 2010-2100 new passenger cars and light trucks for each of the seven alternatives are shown below in Table S-10. Projections of emission reductions over the 2010 to 2100 timeframe due to the MY 2011-2020 CAFE standards ranged from 38,294 to 53,365 MMTCO2. Compared against global emissions of 4,850,000 MMTCO2 over this period (projected by the IPCC A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global CO2 emissions by about 0.8 to 1.1 percent.

**TABLE S-10**

**$CO_2$ Emissions and Emission Reductions (Compared to the No Action Alternative) Due to the MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard, from 2010-2100 ($MMTCO_2$)**

| Alternative | Emissions | Emission Reductions Compared to No Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 209,596 | 38,294 |
| Optimized | 204,487 | 43,403 |
| 25 Percent Above Optimized | 202,075 | 45,815 |
| 50 Percent Above Optimized | 199,933 | 47,958 |
| Total Costs Equal Total Benefits | 197,434 | 50,456 |
| Technology Exhaustion | 194,525 | 53,365 |

## Climate: $CO_2$ Concentration and Global Mean Surface Temperature

The mid-range results of MAGICC model simulations for the No Action Alternative and the six alternative CAFE levels, in terms of $CO_2$ concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table S-11 and Figures S-3 to S-6. As Figures S-3 and S-4 show, the impact on the growth in $CO_2$ concentrations and temperature is just a fraction of the total growth in $CO_2$ concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both $CO_2$ concentrations and temperature in the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures S-5 to S-6.

As shown in the table and figures, there is a fairly narrow band of estimated $CO_2$ concentrations as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. As $CO_2$ concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global surface air temperature increases are also shown below in Table S-11. For all alternatives, the temperature increase is about 0.8°C as of 2030, 1.8°C as of 2060, and 2.8°C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.012°C to 0.018°C. These estimates include considerable uncertainty due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid-point of 3.0 degrees C which directly relates to the uncertainty in the estimated global mean surface temperature.

To supplement the modeled estimates (generated by applying MAGICC) in Table S-11, a scaling approach was used to (1) validate that the modeled estimates are consistent with recent IPCC AR4 estimates and (2) characterize the sensitivity of the $CO_2$ and temperature estimates to different assumptions about (a) global emissions from sources other than United States passenger cars and light trucks and (b) climate sensitivity (i.e., the equilibrium warming associated with a doubling of atmospheric $CO_2$ concentrations compared to pre-industrial levels). The scaling analysis showed that the results for $CO_2$ concentration and temperature are in good agreement with recent estimates from IPCC AR4. The analysis also indicates that the estimates for $CO_2$ concentrations and global mean surface temperature vary considerably, depending on which global emissions scenario is used as a reference case. Furthermore, temperature increases are sensitive to climate sensitivity. Regardless of the choice of reference case or climate sensitivity, the differences among CAFE alternatives are small in the context of global emission estimates: $CO_2$ concentrations as of 2100 are within 4 ppm across alternatives, and temperatures are within 0.03°C across alternatives (consistent with the MAGICC modeling results). The scaling results illustrate the uncertainty in $CO_2$ concentrations and temperatures related to reference case global emissions and climate sensitivity.

**TABLE S-11**

**MY 2011-2020 CAFE Alternatives Impact on $CO_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC**

| | **$CO_2$ Concentration (ppm)** | | | **Global Mean Surface Temperature Increase ($^oC$)** | | |
|---|---|---|---|---|---|---|
| | **2030** | **2060** | **2100** | **2030** | **2060** | **2100** |
| **Totals by Alternative** | | | | | | |
| No Action (A1B – AIM)[14] | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.2 | 573.7 | 705.1 | 0.788 | 1.832 | 2.751 |
| Optimized | 458.1 | 573.4 | 704.6 | 0.788 | 1.831 | 2.749 |
| 25 Percent Above Optimized | 458.1 | 573.3 | 704.4 | 0.788 | 1.83 | 2.748 |
| 50 Percent Above Optimized | 458.1 | 573.3 | 704.2 | 0.787 | 1.829 | 2.747 |
| Total Costs Equal Total Benefits | 458.0 | 573.2 | 703.9 | 0.787 | 1.829 | 2.746 |
| Technology Exhaustion | 458.0 | 573.0 | 703.7 | 0.787 | 1.828 | 2.745 |
| **Reduction from CAFE Alternatives** | | | | | | |
| 25 Percent Below Optimized | 0.2 | 1.5 | 3.5 | 0.001 | 0.005 | 0.012 |
| Optimized | 0.3 | 1.8 | 4.0 | 0.001 | 0.006 | 0.014 |
| 25 Percent Above Optimized | 0.3 | 1.9 | 4.2 | 0.001 | 0.007 | 0.015 |
| 50 Percent Above Optimized | 0.3 | 1.9 | 4.4 | 0.002 | 0.008 | 0.016 |
| Total Costs Equal Total Benefits | 0.4 | 2.0 | 4.7 | 0.002 | 0.008 | 0.017 |
| Technology Exhaustion | 0.4 | 2.2 | 4.9 | 0.002 | 0.009 | 0.018 |

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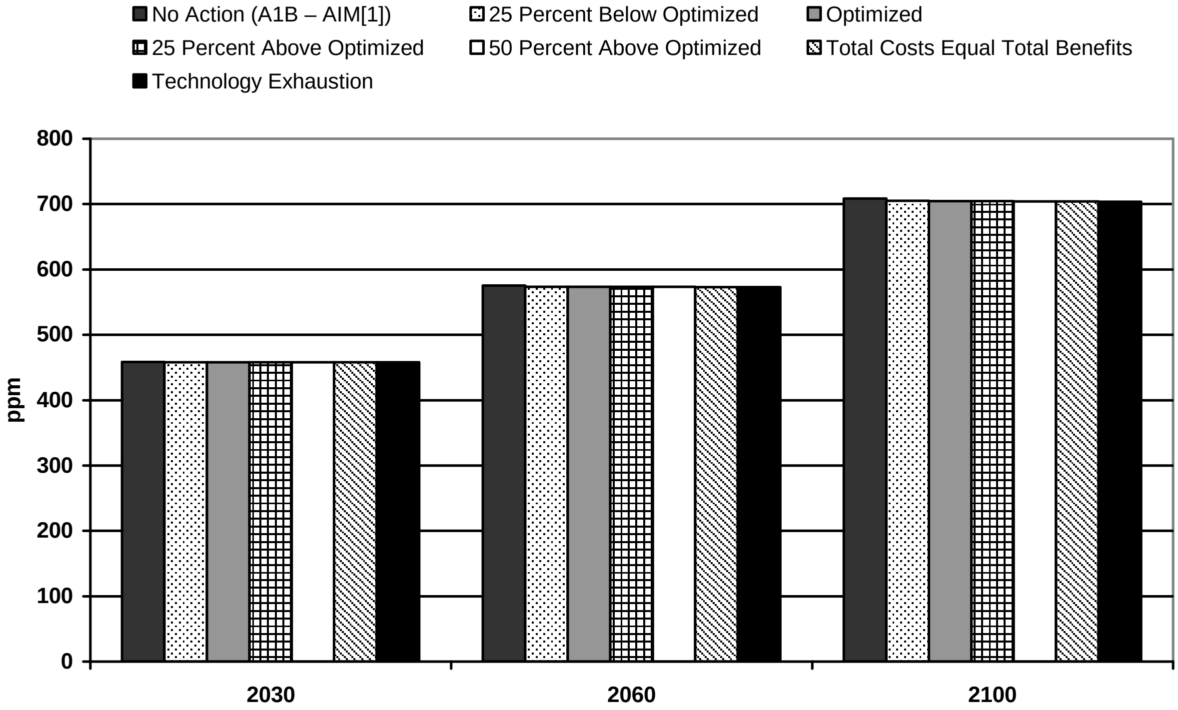
[14] The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

## Figure S-3: CO2 Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020



## Figure S-4: Increase in Global Mean Surface Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020

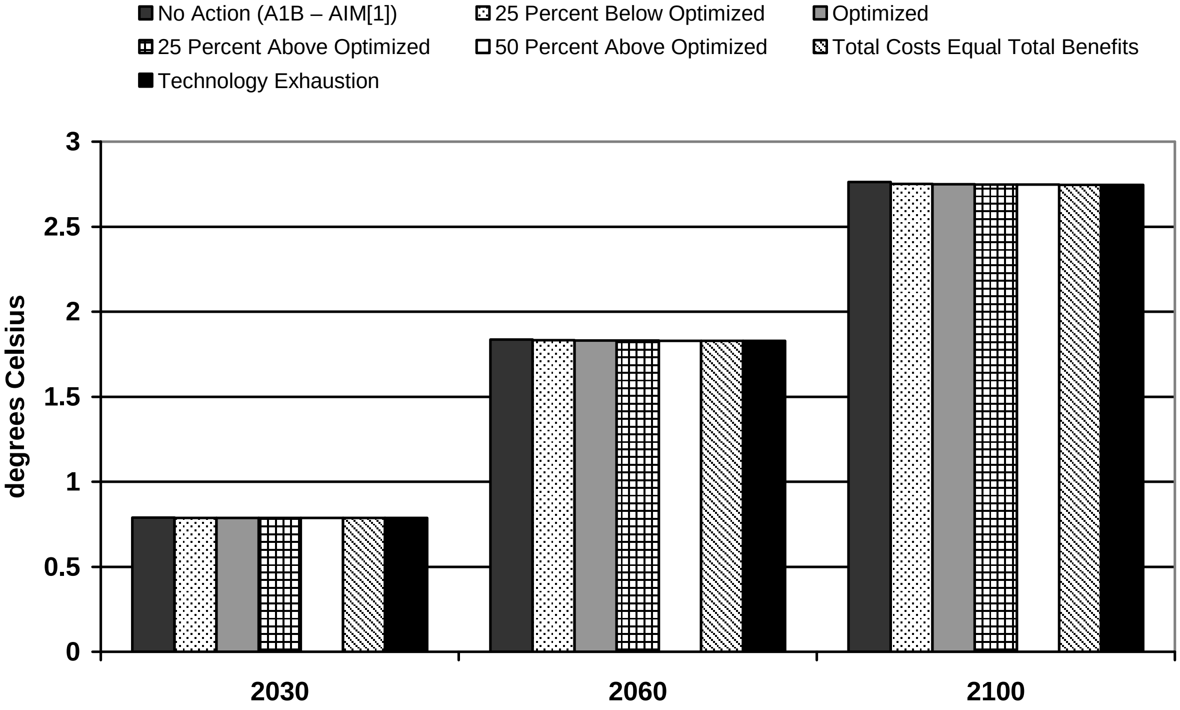


**Figure S-5: Reduction in the Growth of CO2 Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020**

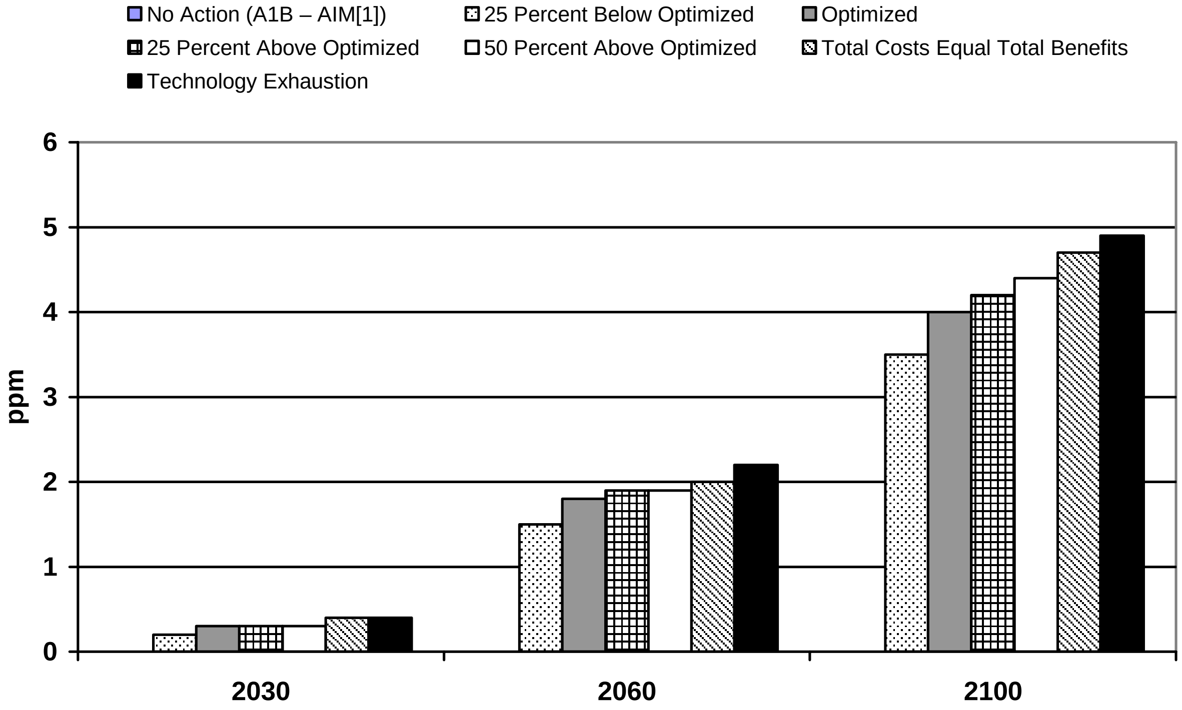
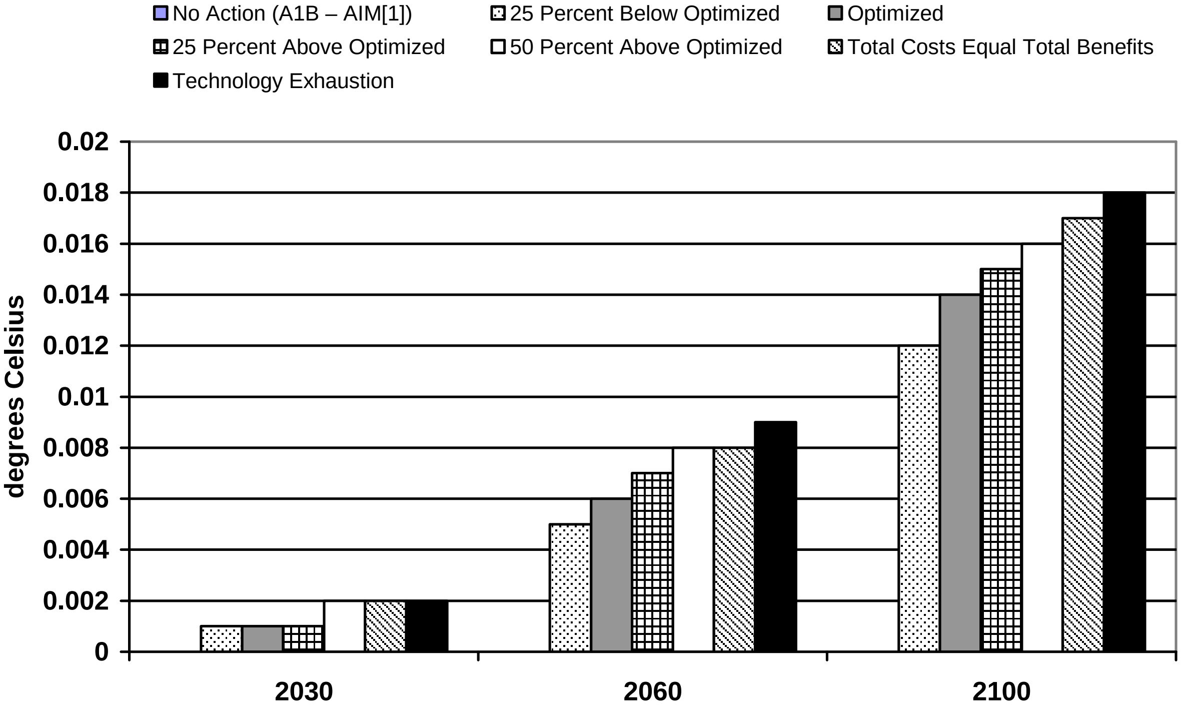


**Figure S-6: Reduction in the Growth of Global Mean Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020**



### Climate: Global Mean Rainfall

The CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, thus they also reduce predicted increases in precipitation slightly, as shown in Table S-12. As shown in the table and figures, there is a fairly narrow band of mid-range estimated precipitation increase reductions as of 2100, from 4.29 percent to 4.32 percent, and there is very little difference between the alternatives. Uncertainty in these results from uncertainty in the increase in the global mean surface temperature and uncertainty from the global mean rainfall change.

**TABLE S-12**

**MY 2011-2020 CAFE Alternatives: Impact on Reductions in Global Mean Rainfall based on A1B SRES Scenario (% change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2011–2030/2020 | 2046–2065/2055 | 2080–2099/2090 |
|---|---|---|---|
| **Global Mean Rainfall Change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature Above Average 1980-1999 Levels ($^{o}$C) for the A1B Scenario by 2100, Mid-level Results** | | | |
| No Action | 0.690 | 1.750 | 2.650 |
| 25 Percent Below Optimized | 0.690 | 1.745 | 2.639 |
| Optimized | 0.690 | 1.744 | 2.638 |
| 25 Percent Above Optimized | 0.690 | 1.744 | 2.636 |
| 50 Percent Above Optimized | 0.690 | 1.743 | 2.636 |
| Total Costs Equal Total Benefits | 0.690 | 1.743 | 2.635 |
| Technology Exhaustion | 0.690 | 1.742 | 2.634 |
| **Reduction in Global Temperature ($^{o}$C) for the A1B Scenario, Mid-level Results** | | | |
| 25 Percent Below Optimized | 0.000 | 0.005 | 0.011 |
| Optimized | 0.000 | 0.006 | 0.012 |
| 25 Percent Above Optimized | 0.000 | 0.006 | 0.014 |
| 50 Percent Above Optimized | 0.000 | 0.007 | 0.014 |
| Total Costs Equal Total Benefits | 0.000 | 0.007 | 0.015 |
| Technology Exhaustion | 0.000 | 0.008 | 0.016 |
| **Mid-level Global Mean Rainfall Change by 2100 (%)** | | | |
| No Action | 1.00 | 2.64 | 4.32 |
| 25 Percent Below Optimized | 1.00 | 2.63 | 4.30 |
| Optimized | 1.00 | 2.63 | 4.30 |
| 25 Percent Above Optimized | 1.00 | 2.63 | 4.30 |
| 50 Percent Above Optimized | 1.00 | 2.63 | 4.30 |
| Total Costs Equal Total Benefits | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion | 1.00 | 2.63 | 4.29 |
| **Reduction in Global Mean Rainfall (%)** | | | |
| 25 Percent Below Optimized | 0.00 | 0.01 | 0.02 |
| Optimized | 0.00 | 0.01 | 0.02 |
| 25 Percent Above Optimized | 0.00 | 0.01 | 0.02 |
| 50 Percent Above Optimized | 0.00 | 0.01 | 0.02 |
| Total Costs Equal Total Benefits | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion | 0.00 | 0.01 | 0.03 |

## Climate: Impact on Sea Level Rise

IPCC AR4 identifies four primary components to sea level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland. Ice sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise, using a non-linear temperature- and pressure-dependent expansion coefficient. It also addresses the other three primary components through ice-melt models for small glaciers, and the Greenland and Antarctic ice sheets.

The mid-range estimate of the impact on sea level rise from the alternatives is near the threshold of the MAGICC model's reporting capabilities: the alternatives reduce sea level rise by 0.1 to 0.2 cm (Table S-13). Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above); and the lower the temperature, the lower the sea level. hus, the more stringent alternatives are likely to result in slightly less sea level rise.

**TABLE S-13**

**MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level (cm) |
|---|---|
| No Action | 37.9 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.8 |
| Total Costs Equal Total Benefits | 37.7 |
| Technology Exhaustion | 37.7 |
| **Reduction in Sea Level Rise for the CAFE alternatives (% compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.2 |
| Technology Exhaustion | 0.2 |

One of the areas of climate change research where there have been many recent developments is the science underlying the projection of sea level rise. As noted above, there are four key components of sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-the-science, so the scaling approach is an important supplement. The scaling approach applied in the DEIS captures two effects which could overstate the impacts by just scaling the sea level rise by changes in global temperature. The first effect is the current "commitment" (i.e., the inertia in the climate system that would result in climate change even if concentrations did not increase in the future) to global warming, which will occur despite the emission reduction from the CAFE alternatives. The second is the current commitment to sea level rise similar to the current “commitment” to global warming. By examining the difference between the low (B1) scenario and the mid-level (A1B) scenario, these terms, which will be the same in both scenarios, are eliminated.

The results are shown above Table S-14 for scenario A1B (medium). Across the CAFE alternatives, the mean change in the global mean surface temperature, as a ratio of the increase in warming between the B1 (low) to A1B (medium) scenarios, ranges from 1.2 percent to 1.7 percent. The resulting change in sea level rise (compared to the No Action Alternative) ranges across the alternatives from 0.08 cm to 0.11 cm. This compares well, but is less, than the MAGICC results of 0.1-0.2 cm. Thus, despite the fact that MAGICC does not reflect some of the more recent developments in the state-of-the-science, the results are of the same magnitude.

**TABLE S-14**

**The Estimated Impact on Sea Level Rise in 2100 From the MY 2011-2015 Standard and Potential 2016-2020 CAFE Standard for SRES Scenario A1B; Scaling Approach**

| Alternative | Reduction in Equilibrium Warming for the 3.0 $^{o}$C Climate Sensitivity ($^{o}$C) | Reduction in Global Mean Surface Temperature for the 3.0 $^{o}$C Climate Sensitivity ($^{o}$C) | Reduction in Global Mean Warming as Share of B1 - A1B Increase in Warming (%) | Mid Range of Sea Level Rise (cm) |
|---|---|---|---|---|
| **Totals by Alternative** | | | | |
| No Action | NA | 2.650 | 0.00 | 28.00 |
| 25 Percent Below Optimized | NA | 2.640 | 0.50 | 27.92 |
| Optimized | NA | 2.638 | 0.80 | 27.91 |
| 25 Percent Above Optimized | NA | 2.637 | 0.90 | 27.90 |
| 50 Percent Above Optimized | NA | 2.637 | 0.90 | 27.90 |
| Total Costs Equal Total Benefits | NA | 2.636 | 1.00 | 27.90 |
| Technology Exhaustion | NA | 2.635 | 1.10 | 27.89 |
| **Reduction from CAFE Alternatives** | | | | |
| 25 Percent Below Optimized | 0.015 | 0.010 | 1.2 | 0.08 |
| Optimized | 0.017 | 0.012 | 1.4 | 0.09 |
| 25 Percent Above Optimized | 0.019 | 0.013 | 1.5 | 0.10 |
| 50 Percent Above Optimized | 0.019 | 0.013 | 1.5 | 0.10 |
| Total Costs Equal Total Benefits | 0.020 | 0.014 | 1.6 | 0.10 |
| Technology Exhaustion | 0.022 | 0.015 | 1.7 | 0.11 |

In summary, the impacts of the MY 2011-2020 CAFE alternatives on global mean surface temperature, sea level rise, and precipitation are relatively small in the context of the expected changes associated with the emission trajectories in the Special Report on Emission Scenarios (SRES) scenarios. This is due primarily to the global and multi-sectoral nature of the climate problem. Emissions of $CO_2$, the primary gas driving the climate effects, from the United States automobile and light truck fleet represented about 2.5 percent of total global emissions of GHGs in the year 2000.[15] While a significant source, this is a still small percentage of global emissions, and the relative contribution of $CO_2$ emissions from the United States passenger car and light truck fleet is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions).

## OTHER POTENTIAL ENVIRONMENTAL CONSEQUENCES

While the main focus of this DEIS is on the quantification of impacts to energy, air quality, and climate, as well as qualitative cumulative impacts resulting from climate change, the DEIS also addressed other potentially affected resources. NHTSA conducted a qualitative review of the non-climate change related direct, indirect, cumulative effects, either positive or negative, of the alternatives on other potentially affected resources. These resource areas included water resources, biological resources, land use, hazardous materials, safety, noise, historic and cultural resources, and environmental justice. Effects of the alternatives on these resources were too small to address quantitatively. Impacts to biological resources could include reductions in habitat disturbance, decreased impacts from acid rain on water and terrestrial habitats from decreases in petroleum production as well as increased agricultural-related disturbances and runoff due to biofuel production. Impacts to land use and development could include increased agricultural land use. Impacts to safety could include downweighting of vehicles and increased vehicle miles traveled, resulting in increased traffic injuries and fatalities. Impacts to hazardous materials could include, overall reductions in the generation of air and oil production related wastes, and increases in agricultural wastes due to biofuel production. Impacts to historic and cultural resources could include reductions in acid rain related damage. Noise impacts could include increased noise levels in some areas due to higher vehicle miles traveled. The non-climate related impact from increased atmospheric $CO_2$ could potentially in conjunction with other environmental factors and changes in plant communities, alter growth, abundance, and respiration rates of some soil microbes.

Impacts to environmental justice populations could include, increased air toxics in some areas as a result of higher vehicle miles traveled. No impacts are expected to natural areas protected under Section 4(f).

The effects of the alternatives on climate – $CO_2$ concentrations, temperature, precipitation, and sea level rise – can translate into impacts on key resources, including freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, human health, and environmental justice. Although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring. However, the magnitudes of the changes in these climate effects that the alternatives produce – a few ppm of $CO_2$, a hundredth of a degree C difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2 mm of sea level – are too small to meaningfully address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions may be important – very small percentages of huge numbers can still yield significant results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.

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[15] $CO_2$ emissions from passenger cars and light trucks were obtained from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks. 1990–2006*, which can be found at http://www.epa.gov/climatechange/emissions/usinventoryreport.html. Global GHG emissions were obtained from the World Resources Institute's Climate Analysis Indicators Tool (CAIT) Version 5.0. http://cait.wri.org.

These impacts were examined on the U.S. and global scale. Impacts to freshwater resources could include changes in precipitation patterns, decreasing aquifer recharge in some locations, changes in snowpack and time of snowmelt, salt water intrusion from ocean rise, changes in weather patterns resulting in flooding or drought in certain regions, increased water temperature, and numerous other changes to freshwater systems that disrupt human use and natural aquatic habitats. Impacts to terrestrial ecosystems could include shifts in species range and migration patterns, potential extinctions of sensitive species unable to adapt to changing conditions, increases in forest fire and pest infestation occurrence and intensity, and changes in habitat productivity because of increased atmospheric $CO_2$. Impacts to coastal ecosystems, primarily from predicted sea level rises, could include loss of coastal areas due to submersion and erosion, additional severe weather and storm surge impacts, and increased salinization of estuaries and freshwater aquifers. Impacts to land use could include flooding and severe weather impacts to coastal, floodplain and island settlements, extreme heat and cold waves, increases in drought in some locations, and weather/sea level related disruptions of service, agricultural and transportation sectors. Impacts to human health could include increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water and food-borne diseases, changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition. Impacts to environmental justice populations could come from any of the above, especially where these effects would occur in developing nations.

## MITIGATION MEASURES AND UNAVOIDABLE ADVERSE IMPACTS

Each of the six action alternatives, when compared to the No Action Alternative, would result in a decrease in $CO_2$ emissions and associated climate change impacts, an overall decrease in criteria air pollutant emissions and toxic air pollutant emissions, and a decrease in energy consumption as compared to the No Action Alternative. Based on our current understanding of global climate change, certain effects are likely to occur due to the sum total of GHG emissions entering the atmosphere. This proposed action or its alternatives would not prevent these effects. It may diminish the effects of climate change and contribute to global GHG reductions. Under the No Action alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect that would not need mitigation.

Localized increases in criteria and toxic air pollutant emissions could occur in some non-attainment areas as a result of implementation of the CAFE standards under the alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of CAA standards. FHWA has funds dedicated to the reduction of air pollutants in nonattainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in nonattainment areas that would be observed under the proposed standard. Further, EPA has authority to continue to improve vehicle emissions standards for criteria and toxic air pollutant emissions.

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# List of Acronyms and Abbreviations

| | |
|---|---|
| $\mu g/m^3$ | micrograms per cubic meter of air |
| 42V | Forty-Two Volt |
| AEO | Annual Energy Outlook |
| AER | Annual Energy Review |
| Alliance | Alliance of Automobile Manufacturers |
| AMFA | Alternative Motor Fuels Act |
| AMT | Automated Shift Manual Transmission |
| AOGCM | atmospheric-ocean general circulation models |
| BTU | British thermal unit |
| CAA | Clean Air Act |
| CAFE | Corporate Average Fuel Economy |
| CAI | controlled auto ignition |
| CBD | Center for Biological Diversity |
| CDC | Centers for Disease Control and Prevention |
| CEQ | Council on Environmental Quality |
| CFR | Code of Federal Regulations |
| $CH_4$ | methane |
| cm | centimeter |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| CVT | Continuously Variable Transmission |
| DEIS | Draft Environmental Impact Statement |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| DPM | diesel particulate matter |
| EA | environmental assessment |
| EIA | Energy Information Administration |
| EIS | Environmental Impact Statement |
| EISA | Energy Independence and Security Act |
| ENSO | El Niño Southern Oscillation |
| EO | Executive Order |
| EPA | U.S. Environmental Protection Agency |
| EPCA | Energy Policy and Conservation Act |
| EPS | Electric Power Steering |
| FAO | United Nations Food and Agriculture Organization |
| FEIS | Final Environmental Impact Statement |
| FFV | flexible fuel vehicle |
| FHWA | Federal Highway Administration |
| FR | Federal Register |
| FRIA | Final Regulatory Impact Analysis |
| FTA | Federal Transit Administration |
| GHG | greenhouse gases |
| GMSTE | global mean surface temperature at equilibrium |
| GREET | Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation |
| Gt | gigaton |
| GWP | global warming potential |
| HCCI | Homogeneous charge compression ignition |
| HFC | hydrofluorocarbons |

| | |
|---|---|
| IEO | International Energy Outlook |
| IMA | Integrated Motor Assist |
| IPCC | Intergovernmental Panel on Climate Change |
| ISAD | Integrated Starter-Alternator-Dampener |
| ISG | Integrated Starter-Generator with Idle-Off |
| LDV | light-duty vehicles |
| LTV | light trucks and vans |
| MAGICC | Model for Assessment of Greenhouse Gas-induced Climate Change |
| mg/L | milligrams per liter |
| $mg/m^3$ | milligrams per cubic meter of air |
| mm | millimeter |
| $MMTCO_2$ | million metric tons of carbon dioxide |
| MOC | Meridional Overturning Circulation |
| mpg | miles per gallon |
| MSAT | mobile source air toxic |
| MTBE | methyl tertiary butyl ether |
| MY | model year |
| $N_2$ | nitrogen |
| $N_2O$ | nitrous oxide |
| NAA | nonattainment areas |
| NAAQS | National Ambient Air Quality Standards |
| NADA | National Automobile Dealers Association |
| NCD | National County Database |
| NEPA | National Environmental Policy Act |
| NGO | non-government organization |
| NHTS | National Household Transportation Survey |
| NHTSA | National Highway Traffic Safety Administration |
| NMIM | National Mobile Inventory Model |
| NO | nitric oxide |
| $NO_2$ | nitrogen dioxide |
| NOI | Notice of Intent |
| NOx | nitrogen oxides |
| NPRM | Notice of Proposed Rulemaking |
| NRDC | Natural Resources Defense Council |
| OECD | Organization for Economic Cooperation and Development |
| PFC | perfluorocarbons |
| PHEV | Plug-In Hybrid Electric Vehicle |
| PM | particulate matter |
| PM10 | particulate matter10 microns diameter or less |
| PM2.5 | particulate matter 2.5 microns diameter or less |
| ppm | parts per million |
| PRIA | Preliminary Regulatory Impact Analysis |
| RFS | Renewable Fuels Standard |
| RGGI | Regional Greenhouse Gas Initiative |
| RIA | Regulatory Impact Analysis |
| ROD | Record of Decision |
| RPE | retail price equivalent |
| SAP | Synthesis and Assessment Product |
| SCR | Selective Catalytic Reduction |
| $SF_6$ | sulfur hexafluoride |
| SIP | State Implementation Plan |

| | |
|---|---|
| SO | sulfur oxide |
| $SO_2$ | sulfur dioxide |
| SRES | Special Report on Emission Scenarios |
| SUV | sport utility vehicles |
| T&S&D | Fuel Transportation, Storage, and Distribution |
| TB | total benefits |
| TC | total cost |
| U.S.C. | United States Code |
| U.S.C.A. | United States Code Annotated |
| UCS | Union of Concerned Scientists |
| UMD | University of Maryland |
| USCCSP | United States Climate Change Science Program |
| USGS | United States Geological Survey |
| VCR | Variable Compression Ratio |
| VMT | vehicle-miles traveled |
| VOC | volatile organic compounds |
| Volpe Center | Volpe National Transportation Systems Center |
| WCI | Western Climate Initiative |
| WG1 | IPCC Work Group 1 |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |
| XBT | expendable bathy-thermographs |

# Glossary

To help readers more fully understand this Draft Environmental Impact Statement, we have provided the following list of definitions for technical and scientific terms, as well as plain English terms used differently in the context of this DEIS.

| Term | Definition |
|---|---|
| **25 Percent Above Optimized Alternative** | Alternative regulatory measure reflecting standards that exceed the optimized scenario by 25 percent of the interval between the optimized scenario and an alternative based on applying technologies until total costs equal total benefits. |
| **25 Percent Below Optimized Alternative** | Alternative regulatory measure reflecting standards that fall below the optimized scenario by the same absolute amount by which the 25 percent above optimized alternative exceeds the optimized scenario. |
| **50 Percent Above Optimized Alternative** | Alternative regulatory measure reflecting standards that exceed the optimized scenario by 50 percent of the interval between the optimized scenario and an alternative based on applying technologies until total costs equal total benefits. |
| **Adaptation** | Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. |
| **Afforestation** | Planting of new forests on lands that historically have not contained forests (for at least 50 years). |
| **Anthropgenic** | Resulting from or produced by human beings. |
| **Aquaculture** | Farming of plants and animals that live in water. |
| **Baseline Alternative** | See “No Action Alternative.” |
| **Benthic** | Habitat occurring at the bottom of a body of water. |
| **Biosphere** | The part of the Earth system comprising all ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus. |
| **Carbon sink** | Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere. |
| **Coral bleeching** | The paling in color which results if a coral loses its symbiotic, energy providing, organisms. |
| **Criteria pollutants** | Carbon monoxide (CO), airborne lead (Pb), nitrogen dioxide ($NO_2$), ozone ($O_3$), sulfur dioxide ($SO_2$), and fine particulate matter (PM). |

| Term | Definition |
|---|---|
| **Ecosystem** | A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth. |
| **El Nińo-Southern Oscillation** | The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basinwide warming of the tropical Pacific east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño-Southern Oscillation, or ENSO. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. |
| **Emission rates** | Grams per vehicle-mile of travel. |
| **Endemic** | Restricted to a region. |
| **Entire energy content** | Energy from petroleum and ethanol fuel additives. |
| **EPCA factors for setting “maximum feasible” CAFE standards** | Technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the nation to conserve energy. |
| **Eutrophication** | Enrichment of a water body with plant nutrients. |
| **Evapotranspiration** | The combined process of water evaporation from the Earth’s surface and transpiration from vegetation. |
| **GREET model** | Model developed by Argonne National Laboratory that provides estimates of the energy and carbon contents of fuels as well as energy use in various phases of fuel supply. |
| **Hydrology** | The science dealing with the occurrence, circulation, distribution, and properties of the earth's water. |
| **Hydrosphere** | The component of the climate system comprising liquid surface and subterranean water, such as oceans, seas, rivers, fresh water lakes, underground water, etc. |
| **Lake stratification** | Seasonal changes in the temperature profile of a lake system. |
| **Lifetime fuel consumption** | Total volume of fuel used by a vehicle over its lifetime. |
| **Maximum lifetime of vehicles** | The age after which less than 2 percent of the vehicles originally produced during a model year remain in service. |
| **MOBILE6.2** | EPA's motor vehicle emission factor model. |

| Term | Definition |
|---|---|
| **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. |
| **No Action Alternative** | Alternative regulatory measure in which CAFE standards are maintained at the MY 2010 levels of 27.5 mpg and 23.5 mpg for passenger cars and light trucks, respectively. |
| **Nonattainment area** | Regions where concentrations of criteria pollutants exceed federal standards. Nonattainment areas are required to develop and implement plans to comply with the NAAQS within specified time periods. |
| **Ocean acidification** | A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide. |
| **Optimized Scenario Alternative** | Alternative regulatory measure reflecting the optimized scenario. |
| **Optimized standards/scenario** | Standards set at levels such that the cost of the last technology application (using the Volpe model) equaled the benefits of the improvement in fuel economy resulting from that application. |
| **Overexploitation of species** | Exploitation of species to the point of diminishing returns. |
| **Pathways of fuel supply** | United States imports of refined gasoline and other transportation fuels; domestic refining of fuel using imported petroleum as a feedstock; and domestic fuel refining from crude petroleum produced within the united States. |
| **Permafrost** | Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years. |
| **Phenology** | The study of natural phenomena in biological systems that recur periodically (e.g., development stages, migration) and their relation to climate and seasonal changes. |
| **Rebound effect** | Improved fuel economy reduces the fuel cost of driving and leads to additional use of a light trucks and thus increased emissions of criteria pollutants by light trucks. |
| **Reformed CAFE program** | Consists of two basic elements: (1) a function that sets fuel economy targets for different values of vehicle footprint; and (2) a Reformed CAFE standard for each manufacturer, which is equal to the production-weighted harmonic average of the fuel economy targets corresponding to the footprint values of each light truck model it produces. |
| **Saltwater intrusion** | Displacement of fresh surface water or groundwater by the advance of saltwater due to its greater density. This usually occurs in coastal and estuarine areas due to reducing land-based influence (e.g., either from reduced runoff and associated groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (e.g., relative sea-level rise). |
| **Silviculture** | The management of forest resources. |

| Term | Definition |
|---|---|
| **Survival rate** | The proportion of vehicles originally produced during a model year that are expected to remain in service at the age they will have reached during each subsequent year. |
| **Total Costs Equal Total Benefits Alternative** | Alternative reflecting standards based on applying technologies until total costs equal total benefits (zero net benefits). |
| **Technologies** | Engine technologies, transmission characteristics, and vehicle design features that influence fuel economy. |
| **Technology Exhaustion Alternative** | Alternative in which NHTSA applied all feasible technologies without regard to cost by determining the stringency at which a reformed CAFE standard would require every manufacturer to apply every technology estimated to be potentially available for it MY 2011-1015 fleet. |
| **Tipping point** | A situation where the climate system reaches a point at which is there is a strong and amplifying positive feedback from only a moderate additional change in a driver, such as $CO_2$ or temperature increase. |
| **Total vehicle miles** | Total number of miles each vehicle will be driven over its lifetime. |
| **Track width** | The lateral distance between the centerlines of the base tires at ground, including the camber angle. |
| **Transpiration** | Water loss from plant leaves. |
| **Turbidity** | A decrease in the clarity of water due to the presence of suspended sediment. |
| **Vehicle footprint** | The product of track width times wheelbase divided by 144. |
| **Vehicle miles traveled** | Total number of miles driven. |
| **Volpe model** | CAFE Compliance and Effects Model developed by the U.S. Department of Transportation’s Volpe Center, that, for any given year, applies technologies to the manufacturer's fleet until the manufacturer achieves compliance with the standard under consideration. |
| **Wheelbase** | The longitudinal distance between front and rear wheel centerlines. |

# Chapter 1 Purpose and Need for the Proposed Action

## 1.1 INTRODUCTION

The Energy Policy and Conservation Act of 1975[1] (EPCA) established a program to regulate automobile fuel economy and provided for the establishment of average fuel economy standards for passenger cars and separate standards for light trucks. As part of that Act, the Corporate Average Fuel Economy (CAFE) program was established to reduce national energy consumption by increasing the fuel economy of passenger cars and light trucks. EPCA directs the Secretary of Transportation to set and implement fuel economy standards for passenger cars and light trucks sold in the United States. The National Highway Transportation Safety Administration (NHTSA) is delegated responsibility for implementing the EPCA fuel economy requirements assigned to the Secretary of Transportation.[2]

In December 2007, the Energy Independence and Security Act of 2007 (EISA)[3] amended EPCA's CAFE program requirements, granting the U.S. Department of Transportation (DOT) additional rulemaking authority and assigning the DOT new rulemaking responsibilities.[4] Pursuant to EISA, NHTSA recently proposed CAFE standards for model year (MY) 2011 through 2015 passenger cars and light trucks in its Notice of Proposed Rulemaking (NPRM).[5]

Under the National Environmental Policy Act[6] (NEPA), an environmental impact analysis must be performed if a federal agency implements a proposed action, provides funding for an action, or issues a permit for that action. Specifically, NEPA directs that "to the fullest extent possible," federal agencies proposing "major federal actions significantly affecting the quality of the human environment" must prepare "a detailed statement" on the environmental impacts of the proposed action (including alternatives to the proposed action). NHTSA submits this Draft Environmental Impact Statement (DEIS) to inform its evaluation of the potential environmental impacts of adopting CAFE standards for MY 2011-2015.

## 1.2 NEPA PROCESS

To inform its development of the new CAFE standards required under EPCA, as amended by EISA, NHTSA prepared this DEIS to disclose and analyze the potential environmental impacts of the proposed standards and reasonable alternative standards in the context of NHTSA's CAFE program and pursuant to NEPA implementing regulations issued by the Council on Environmental Quality (CEQ),

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[1] The Energy Policy and Conservation Act of 1975 was enacted for the purpose of serving the nation's energy demands and promoting conservation methods when feasibly obtainable. EPCA is codified at 49 U.S.C. 32901 et seq.

[2] 49 C.F.R. §§ 1.50, 501.2(a)(8). In addition, the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each automobile manufacturer that sells vehicles in the United States.

[3] EISA amends and builds on the Energy Policy and Conservation Act by setting out a comprehensive energy strategy for the 21st century by addressing renewable fuels and CAFE standards. EISA is Public Law 110-140, 121 Stat. 1492 (December 19, 2007).

[4] Accordingly, the Secretary of Transportation, DOT and NHTSA are used interchangeably in this section of the DEIS.

[5] Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 Federal Register (FR) 24352, May 2, 2008. At the same time, NHTSA requested updated product plan information from the automobile manufacturers. See Request for Product Plan Information, Passenger Car Average Fuel Economy Standards—Model Years 2008-2020 and Light Truck Average Fuel Economy Standards—Model Years 2008-2020, 73 FR 21490, May 2, 2008.

[6] 42 United States Code (U.S.C). § 4332(2)(C).

U.S. DOT Order 5610.1C, and NHTSA regulations.[7] This DEIS compares the potential environmental impacts of the NHTSA's proposed standards and reasonable alternatives, as well as a "no action" alternative. It also analyzes direct, indirect, and cumulative impacts and discusses impacts "in proportion to their significance."

## 1.3 PURPOSE AND NEED STATEMENT

NEPA analyses require that a proposed action's alternatives be developed based upon the action's purpose and need. The purpose and need statement should clearly and succinctly explain why the action is needed and the action's intended purpose. The purpose and need is considered the cornerstone of NEPA environmental documentation.

As recently amended, EPCA sets forth extensive requirements concerning the rulemaking to establish the MY 2011-2015 CAFE standards. These requirements form the purpose of and need for the proposed standards (action). These requirements are also the basis for establishing a range of alternatives to be considered in this NEPA analysis. Specifically, EPCA requires the Secretary of Transportation to establish average fuel economy standards for each MY at least 18 months before the beginning of that model year and to set them at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year." 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."[8] As explained in the NPRM:

- "Technological feasibility" means whether a particular method of improving fuel economy can be available for commercial application in the MY for which a standard is being established.

- "Economic practicability" means 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 a significant job losses or unreasonable elimination of consumer choice.

- "The effect of other motor vehicle standards of the Government on fuel economy" means "the unavoidable adverse effects on fuel economy of compliance with emission, safety, noise, or damageability standards."

- "The need of the United States to conserve energy" means "the consumer cost, national balance of payments, environmental, and foreign policy implications of our need for large quantities of petroleum, especially imported petroleum."

NHTSA construes the statutory factors as including environmental and safety considerations.[9] The potential environmental impacts of the proposed action and its alternatives, as identified in this DEIS and in NHTSA's other NEPA documents, will also be considered.

With respect to the standards for MY 2011-2020, EPCA further directs the Secretary, after consultation with the Secretary of Energy (DOE) and the Administrator of the Environmental Protection

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[7] NEPA is codified at 42 U.S.C. §§ 4321-4347. CEQ's NEPA implementing regulations are codified at 40 C.F.R. Pts. 1500-1508, and NHTSA's NEPA implementing regulations are codified at 49 C.F.R. Part 520.

[8] 49 U.S.C. §§ 32902(a), 32902(f).

[9] See, e.g., Competitive Enterprise Inst. v. NHTSA, 956 F.2d 321, 322 (D.C. Cir. 1992) (citing Competitive Enterprise Inst. v. NHTSA, 901 F.2d 107, 120 n.11 (D.C. Cir. 1990)), and 73 FR 24,352, 24,364, May 2, 2008.

Agency (EPA), to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each MY beginning with MY 2011, "to achieve a combined fuel economy average for model year 2020 of at least 35 miles per gallon for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year."[10] In doing so, the Secretary of Transportation is to adopt "annual fuel economy standard increases."[11] The standards for passenger cars and light trucks must be "based on one or more vehicle attributes related to fuel economy." In any single rulemaking, standards may be established for not more than five model years.[12] EPCA also mandates a minimum standard for domestically manufactured passenger cars.[13]

### 1.3.1 Notice of Intent and Scoping

In March 2008, NHTSA issued a Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for the MY 2011-2015 CAFE standards. The NOI described the statutory requirements for the proposed standards, provided initial information about the NEPA process, and initiated scoping[14] by requesting public input on the scope of the environmental analysis to be conducted.[15] Two important purposes of scoping are identifying the significant environmental issues that merit in-depth analysis in the EIS, and identifying and eliminating from detailed analysis the environmental issues that are not significant and therefore require only a brief discussion in the EIS.[16] Scoping should, "deemphasize insignificant issues, narrowing the scope of the environmental impact statement process accordingly."[17]

Consistent with NEPA and its implementing regulations, on April 10th and 11th, 2008, NHTSA mailed the NOI directly to:

- 78 contacts at Federal agencies having jurisdiction by law or special expertise with respect to the environmental impacts involved or authorized to develop and enforce environmental standards, including other modes within DOT;

- the Governors of every State and United States territory to share with the appropriate agencies and offices within their administrations, and with the local jurisdictions within their States;

- 23 organizations representing state and local governments;

- 14 Native American tribal organizations and academic centers that had issued reports on climate change and tribal communities; and

- 92 contacts at other stakeholder organizations that NHTSA reasonably expected to be interested in the NEPA analysis for the MY 2011-2015 CAFE standards, including auto industry organizations, environmental organizations, and other organizations that had expressed interest in prior CAFE rules.

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[10] 49 U.S.C.A. §§ 32902(b)(1), 32902(b)(2)(A).

[11] 49 U.S.C.A. § 32902(b)(2)(C).

[12] 49 U.S.C.A. §§ 32902(b)(3)(A), 32902(b)(3)(B).

[13] 49 U.S.C.A. § 32902(b)(4).

[14] Scoping, as defined under NEPA, is an early and open process for determining the scope of issues to be addressed in an EIS and for identifying the significant issues related to a proposed action. 40 C.F.R. § 1501.7.

[15] See Notice of Intent to Prepare an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 FR 16615, March 28, 2008.

[16] 40 C.F.R. §§ 1500.4(g), 1501.7(a).

[17] 40 C.F.R. § 1500.4(g).

NHTSA used its letters transmitting the NOI to develop a mailing list for future notices about the NEPA process for the CAFE standards. For instance, NHTSA asked each Governor to, "share [its] letter and the enclosed [NOI] with the appropriate environmental agencies and other offices within your administration and with interested local jurisdictions or local government organizations within your State." NHTSA further requested that each Governor ask its representative to provide contact information for the State's lead office on the CAFE EIS by returning a mailing list form to NHTSA or by sending NHTSA an e-mail containing the information requested on the form. NHTSA asked Federal agency contacts to share the NOI with other interested parties within their organizations. NHTSA asked contacts at other stakeholder organizations to let NHTSA know whether they wished to remain on the agency's NEPA mailing list for the CAFE EIS by returning a mailing list form or sending NHTSA an e-mail containing the information requested on the form. NHTSA indicated that organizations that did not return the form would be removed from the NEPA mailing list.

#### 1.3.1.1 Supplemental Notice of Public Scoping

In April 2008, NHTSA issued a supplemental notice of public scoping providing additional information about:

- participating in the scoping process;
- the proposed standards; and
- the alternatives NHTSA expected to consider in its NEPA analysis.[18]

NHTSA outlined its plans for its NEPA analysis for the MY 2011-2015 CAFE standards, explaining that it would:

> …consider the direct, indirect and cumulative environmental impacts of the proposed standards and those of reasonable alternatives. Among other potential impacts, NHTSA will consider direct and indirect impacts related to fuel and energy use, emissions, including Carbon Dioxide ($CO_2$) and their effects on temperature and climate change, air quality, natural resources, and the human environment. NHTSA also will consider the cumulative impacts of the proposed standards for MY 2011-2015 automobiles together with estimated impacts of NHTSA's implementation of the CAFE program through MY 2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by EPCA, as amended by EISA…[19]

NHTSA also acknowledged that it, "anticipate[d] considerable uncertainty in estimating and comparing the potential environmental impacts of the proposed standards and the alternatives relating to climate change in particular."[20]

In preparing the supplemental scoping notice, NHTSA consulted with CEQ and EPA. In that notice, NHTSA again invited all stakeholders to submit written comments on the appropriate scope of NHTSA's NEPA analysis for the proposed CAFE standards for MY 2011-2015 passenger cars and light trucks. To help identify and narrow the issues for analysis in the EIS, NHTSA specifically requested

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[18] Supplemental Notice of Public Scoping for an Environmental Impact Statement for New Corporate Average Fuel Economy Standards, 73 FR 22913, April 28, 2008.

[19] *Id.* at 22916.

[20] *Id.* at 22916.

comments, peer-reviewed scientific studies, and other information addressing the potential impacts of the proposed standards and reasonable alternatives relating to climate change.[21]

Following its publication in the Federal Register on April 28, 2008, NHTSA sent copies of the supplemental scoping notice directly to:

- 46 Governors from whom NHTSA had not received a lead State NEPA contact in response to the agency's initial letters;
- 24 State and local government NEPA contacts that had responded to the agency's initial letters;
- 11 Administrators or other officials at other DOT agencies and offices;
- 62 NEPA contacts at other Federal agencies; and
- 42 other stakeholders that asked to remain or be included on NHTSA's NEPA mailing list.

During the first week of May 2008, NHTSA mailed the supplemental scoping notice to the Governors and to stakeholders that had indicated a preference for receiving NHTSA's NEPA communications by United States mail. NHTSA e-mailed the supplemental scoping notice to all other stakeholders on May 6 and 7, 2008.

During the first week of May, NHTSA also mailed copies of the NOI and the supplemental scoping notice to more than 580 federally recognized Indian tribes, inviting them to submit written comments on the scope of NHTSA's NEPA analysis for the proposed CAFE standards. In letters transmitting the two notices, NHTSA asked contacts at each tribe to let NHTSA know whether they wished to remain on the agency's NEPA mailing list for the CAFE EIS by returning a mailing list form or sending NHTSA an e-mail containing the information requested on the form. NHTSA indicated that tribes that did not return the form would be removed from the NEPA mailing list.

NHTSA's letters transmitting the NOI also explained the agency's plans for communicating primarily by e-mail throughout the EIS process unless stakeholders indicated a preference for communications by United States mail. Representative copies of NHTSA's letters transmitting the NOI and the supplemental scoping notice to the stakeholders described above are available in the docket for this EIS, Docket No. NHTSA-2008-0060, at http://www.regulations.gov.

In June 2008, NHTSA contacted various Federal agencies and state agencies and held meetings in person or by telephone to discuss the projects effects. These agencies included Office of Protected Resources, National Oceanic and Atmospheric Administration (NOAA); Endangered Species Program, U.S. Fish and Wildlife Service; Cultural Resources, National Park Service; Advisory Council on Historic Preservation; Forest Health Monitoring Program and Forest Legacy Program, U.S. Forest Service; Division of Emergency and Environmental Health Services, Centers for Disease Control and Prevention (CDC); NEPA Compliance and Health Effects, Benefits, and Toxics Center, EPA; NEPA Oversight, CEQ; Historical and Cultural Programs, Maryland Historical Trust. Comments received from these agencies were incorporated into this DEIS.

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[21] *Id.* at 22917.

### 1.3.2 Summary of Scoping Comments and NHTSA's Responses

NHTSA received 1,748 comment letters in response to its two scoping notices (as of June 17, 2008). All but 11 of these letters were a form letter similar in content and sent by individuals. The non-form letters were provided by federal and state agencies, automobile trade associations, environmental advocacy groups, and two individuals.

Several comments addressed the issues on which NHTSA specifically sought comment in its supplemental scoping notice and helped the agency identify and narrow the environmental issues for analysis in this DEIS. Other comments questioned NHTSA's decision to prepare an EIS instead of an environmental assessment (EA). Still other comments raised issues that are more properly addressed outside the NEPA process in other rulemaking documents. For instance, some comments raised economic and social issues, and courts have generally held that such issues are appropriate for consideration under NEPA only if they directly interrelate to the effects on the physical environment.[22] Other comments made suggestions about the process to follow or the factors to be considered in setting CAFE standards – issues that are germane to the NPRM and other supporting documents.

This section first responds to those comments that spoke to the scope of NHTSA's NEPA analysis for the proposed MY 2011-2015 CAFE standards. It then responds to other comments or directs the commenter to the appropriate rulemaking documents that respond to the issues raised.

#### 1.3.2.1 Federal Agencies

Federal agencies that commented included the EPA (Docket No. NHTSA-2008-0060-0016) and the Department of Health and Human Services, CDC (Docket No. NHTSA-2008-0060-0010 and NHTSA-2008-0060-0140). After receiving scoping comments from the EPA and the CDC, NHTSA conducted a telephone conference with CDC on June 12, 2008, and NHTSA met with EPA officials at EPA's Washington, DC Headquarters on June 17, 2008, to discuss each agency's respective scoping comments. NHTSA also consulted with NOAA, Fish and Wildlife Service, National Park Service, and the Forest Service.

EPA indicated that some of the factors that affect air quality, such as meteorology and atmospheric processes, will not be taken into account when evaluating environmental impacts and that this limitation should be acknowledged. NHTSA agrees with EPA's suggestion, and this limitation is acknowledged in Chapters 3 and 4.

In addition to the regulatory scenarios that NHTSA developed using the Volpe model, EPA suggested that NHTSA evaluate reasonable alternative scenarios by using other combinations of inputs, including fuel prices, manufacturer compliance costs, economic discount rates, the projected benefits of greenhouse gas (GHG) emission reductions (including assumptions about the social cost of carbon (SCC) emissions), and the likely manufacturer and consumer response to the footprint curve embedded in the proposed rule. The NHTSA benefit-cost analysis did include several sensitivity analyses to examine the impact of different model input assumptions, such as the values of economic and environmental externalities and the price of gasoline. NHTSA presents the results of the sensitivity analyses in the Preliminary Regulatory Impact Analysis[23] (PRIA), and discusses them in Chapter 3 of this DEIS.

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[22] See, e.g., Ashley Creek Phosphate Co. v. Norton, 420 F.3d 934, 944 (9th Cir. 2005); Hammond v. Norton, 370 F. Supp.2d 226, 243 (D.D.C. 2005).

[23] The PRIA is available at http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/CAFE_2008_PRIA.pdf (last visited June 15, 2008).

EPA also stated that NHTSA should consider the impacts of each alternative on air toxics emissions. NHTSA conducted these suggested analyses; see Chapters 3 and 4.

EPA additionally recommended that the projected impacts of the EPCA program components that provide alternative means for manufacturers to demonstrate compliance with CAFE standards be analyzed in the EIS, because EPA believes that these components of the program can be expected to lower compliance costs and reduce projected fuel savings. As explained in Chapters 3 and 4, although NHTSA expects that manufacturers' use of CAFE-related flexibilities will lead to higher fuel consumption and emissions than presented in this analysis, NHTSA does not currently have a reasonable basis to develop specific quantitative estimates of such effects. The agency will reevaluate the potential to do so after reviewing the updated product plans it has requested of vehicle manufacturers, and related comments in response to the NPRM.

The Department of Health and Human Services, CDC suggested that NHTSA relate projected changes in fleet emissions, fuel consumption, and fleet design to human health outcomes. It indicated that the levels of automobile emissions such as ozone forming emissions, NOx, and hydrocarbons, are affected by the CAFE standards and in turn directly affect human health. Consequently, the CDC requested that potential health effects should be analyzed for all of the alternatives, including an economic analysis of the associated health costs. It also suggested that transportation-related emissions contribute to climate change with resulting environmental impacts that directly affect human health worldwide, so evaluating the health impacts of climate change should also be done.

NHTSA's analysis of alternative CAFE standards incorporates the economic value of reduced damages to human health that would result from the reductions in emissions of criteria air pollutants and GHGs estimated to result from each alternative. These reductions in damages to human health are valued using estimates of damage costs per unit of emissions of each pollutant that specifically reflect the chemical composition and geographic distribution of emissions generated by motor vehicle use and by production and distribution of transportation fuels. These estimates were developed by EPA for use in its analysis of benefits from regulations that would reduce emissions from motor vehicle use and from the production and distribution of transportation fuels. Human health is further discussed in Chapters 3 and 4.

The CDC raised safety concerns suggesting that crash-related injury be considered, including effects on other transportation system users, because it believes that changing CAFE standards would affect fleet design and have the potential to increase or decrease crash-related injury. It added that decreasing vehicle fleet disparities in size and weight can decrease crash-related injury to those driving lighter-weight vehicles. In addition, two commenters requested consideration of lightweight vehicle materials as a fuel-saving technology. As discussed in the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of lightweight materials on heavier vehicles for which doing so would be unlikely to compromise highway safety. Further, NHTSA expects that changing CAFE standards to be based on vehicle footprint would discourage manufacturers from reducing vehicle size. Therefore, although it does not have a reliable basis to estimate changes in crash frequency or severity, the agency expects that attribute-based standards would tend to improve rather than degrade highway safety.

Finally, the CDC recommended that NHTSA's NEPA analyses of potential health impacts of the proposed CAFE standards and alternatives should be done in collaboration with public health officials. NHTSA discussed the CDC scoping comments with CDC officials by telephone on June 12, 2008. NHTSA appreciates the suggestion and the effort CDC took to submit scoping comments. After a thorough discussion, NHTSA believes it reached a high degree of understanding and assured CDC that health impacts would be included in various ways in the DEIS. NHTSA feels confident that the consultants retained to assist in the analysis and development of the DEIS, along with its own staff, have the requisite knowledge and skills to effectively incorporate health issues into the document.

#### 1.3.2.2 States

A number of comments representing the interests of States were received, including comments from the New York State Department of Transportation (Docket No. NHTSA-2008-0060-0012), Washington State Department of Transportation (Docket No. NHTSA-2008-0060-0177), and the Minnesota Pollution Control Agency (Docket No. NHTSA-2008-0060-0011). A single, combined comment letter was also received from the Attorneys General of the State of California, Connecticut, New Jersey, New Mexico, Oregon, and Rhode Island, the Commonwealth of Pennsylvania Department of Environmental Protection, and the New York City Corporation Counsel (Docket No. NHTSA-2008-0060-0007.1).

Both State DOTs suggested that NHTSA consider the serious impacts of climate change and the consequent need for accelerated national fuel economy standards to be implemented both sooner than the year 2020 and to cover a greater number of vehicle types. They encouraged NHTSA to work with states and vehicle manufacturers to meet the common goals of economic stability and reduced transportation-related GHG emissions in an expedited way, including promoting the production of fuel efficient vehicles and vehicles capable of using alternative fuels and advanced biofuels and thereby advance the development of hybrid-electric, battery electric, cleaner diesel, and fuel cell technologies. NHTSA appreciates the New York and Washington State DOTs' interest in NHTSA's development of new CAFE standards. As in other CAFE rulemakings, NHTSA will give careful consideration to comments by States, vehicle manufacturers, and other stakeholders. The agency also notes that it engages regularly with other countries on matters related to vehicle research and regulation.

In response to the first comment regarding accelerated CAFE standards, as proposed in the NPRM and this DEIS, NHTSA is considering the environmental impacts of several alternatives covering a range of stringency for MY 2011-2015. The CAFE level required under the proposed standards identified in the NPRM increases at an average annual rate of 4.5 percent—a rate fast enough to, if extended through 2020, exceed the 35 mpg requirement established in the EISA. The NPRM and the DEIS also include more stringent CAFE standards than those that would be established by the proposed standards. The proposed standards result in the maximum difference between benefits and costs, or net benefits. Each of the other alternatives that would establish higher CAFE standards would result in larger fuel savings and emission reductions than those resulting from the proposed standards. But they would also result in lower net benefits than the proposed standards due to higher costs to society and may, therefore, fail to meet one or more of the statutory criteria applicable under EPCA.

The New York State DOT asked how Alternative 7, Technology Exhaustion, compares to the other alternatives under study. Alternative comparisons can be found in Section 2.4.

The Minnesota Pollution Control Agency suggested that the EIS should discuss the incremental change in emissions for each alternative over the projected lifetime of the MY vehicles affected, the respective changes in atmospheric concentrations of GHGs in terms of $CO_2$ equivalents, and the direct and indirect impacts of these changes in concentrations. The comment further included the recommendation that changes in concentrations be incorporated into the range of emission scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC), including other reasonably foreseeable United States emissions changes. This analysis is presented in Chapters 3 and 4 of this DEIS.

The Minnesota Pollution Control Agency also recommended the use of the published marginal cost estimates found in the economics literature for the next emitted ton of $CO_2$ in order to provide a basis for assessing the cumulative environmental impacts of releases as monetized damages that may contribute to a larger global problem. Detailed estimates of economic benefits and costs of establishing alternative CAFE standards are presented in the PRIA.[24] As that document explains, consistent with its treatment of pollutants such as nitrogen oxides, NHTSA's analysis applies an estimate representing damage costs, not marginal avoidance costs. As Chapter VIII of that document describes, these estimates utilize the value recommended in a survey of nearly 100 published estimates of the Social Cost of Carbon as a basis for assessing the monetized benefits of the reductions in $CO_2$ emissions projected to result from alternative CAFE standards.

The joint letter from the Attorneys General of California and several other states suggested that the EIS must do more than simply present raw data on tons of GHGs emitted from the relevant sources. The joint letter stated that the EIS must also educate the public about the scientific consensus on climate change and explain how the contribution made by the emissions from the standard coupled with emissions from other foreseeable sources would affect global warming (i.e. cumulative emissions should be modeled to determine a potential change in temperature, and this change should be compared to climate scenarios outlined by the IPCC).

This EIS educates the public about the scientific consensus on climate change and explains how the incremental contribution made by the emissions from the standards coupled with emissions from other foreseeable sources would affect global warming. Please see Chapter 3, Section 4, and Chapter 4, Section 4.

In another comment, the Attorneys General suggested that for each alternative, NHTSA should report not only the emissions that would result if each manufacturer meets the standard, but the emissions that would result if a series of other reasonably foreseeable events occur. NHTSA should report a range of emissions based on how the standard may operate in the real world. A similar comment was made by EPA and NHTSA's response is included above under the EPA comments.

The Attorneys General also referenced what they state to be significant new studies and research on the health-related effects, both direct and indirect, of global warming, and requested that NHTSA take these into account. These reviews and studies were reviewed and incorporated as appropriate in Chapters 3 and 4.

The Attorneys General letter also requested that NHTSA describe and discuss the potential "tipping points" associated with global warming "that could create unstoppable, large-scale, disastrous impacts for the planet." The term "tipping point" refers to a situation where the climate system reaches a point at which is there is a strong and amplifying positive feedback from only a moderate additional change in driver, such as $CO_2$ or temperature increase. These tipping points could potentially result in abrupt climate change defined in Alley et al. (2002) (cited in Meehl, et al., 2007) to "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."

While climate models do take positive (and negative, i.e., dampening) feedback mechanisms into account, the magnitude of their effect and threshold at which a tipping point is reached may not be well understood in some cases. In fact, MacCracken at al. (2008) note that existing climate models may not include some critical feedback loops, and Hansen et al. (2007a) state that the predominance of positive feedbacks in the climate system have the potential to cause large rapid fluctuations in climate change effects. Therefore, it is important to discuss these mechanisms, and the possibility of reaching points

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[24] The PRIA is available at http://www.nhtsa.gov.

which may bring about abrupt climate change. The existence of these mechanisms and other evidence has led some climate scientists including Hansen et al., (2007b) to conclude that a $CO_2$ level exceeding about 450 parts per million (ppm) is "dangerous."[25] Overall, however, the IPCC concludes that these abrupt changes are unlikely to occur this century…" (Meehl et al., 2007, p. 818). Whether these tipping points exist and the levels at which they occur are still a matter of scientific investigation.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 C.F.R. § 1502.22(b)). In this case, the DEIS acknowledges that information on tipping points or abrupt climate change is incomplete, and the state of the science does not allow for a characterization of how the CAFE alternatives influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change.

### 1.3.2.3 Automobile Trade Associations

Automobile trade associations that commented on the proposal included the National Automobile Dealers Association (NADA) (Docket No. NHTSA-2008-0060-0013) and the Alliance of Automobile Manufacturers (AAM) (Docket No. NHTSA-2008-0060-DRAFT-0033.1[1]). They noted that NHTSA is not responsible for GHG emissions, because vehicle usage is a voluntary choice, and that the scope of NHTSA's environmental analysis should be restricted to impacts that can clearly be attributed to the proposed standards, with other factors including fuel prices, manufacturer competition, and consumer preferences held constant. EPA's comment on the same topic argued that fuel price was an important input into the setting of the standards which could have an effect on the environmental benefits estimated.

As indicated in the response to EPA, NHTSA agrees that fuel price can have an impact on the environmental benefits and thus should be considered. Reformed CAFE, and the process used to set the standards insure that consumer preferences are maintained. The first step in setting standards involves collecting confidential manufacturer's product plan data. Vehicle manufacturers operate in a competitive environment. As profit maximizing firms, they make product plans to reflect their forecast of what consumers want to buy. In the standard setting process, NHTSA adds technologies at the individual vehicle-specific level to improve fleet-wide fuel economy. The number and attributes of the vehicles, including their performance, is not altered to preserve consumer preferences predicted by vehicle manufacturers. Reformed CAFE allows manufacturers to compete by producing a mix of vehicles they think consumers want to buy. No longer do manufacturers have to average out large vehicles with small ones to meet CAFE standards.

NADA also asked that all assumptions regarding the impacts on the rate of vehicle fleet turnover should be provided, and that NHTSA should forecast the introduction of vehicles meeting the standards into the fleet.

NHTSA's approach to analyzing the rate of vehicle fleet turnover is set forth in the NPRM. *See* 73 Fed. Reg. 24352, 24406-24407 (May 2, 2008).

Additionally, NADA requested that any unique environmental impacts associated with the manufacturing and maintenance of vehicles, including alternative fueled vehicles, impacted by the proposed action should be considered by NHTSA. Please see Section 3.5 for an explanation of these issues.

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[25] Defined as more than 1 degree C above level in 2000.

The AAM stated that it disputes NHTSA's choice of the No Action Alternative as the alternative of maintaining CAFE standards at MY 2010 levels, because it believes that the baseline for comparison of the alternatives under NEPA should be set based on the scope of legal authority NHTSA has under EISA. The AAM recommended that NHTSA redefine the No Action Alternative to be consistent with the minimum CAFE standard increases needed to achieve a combined fuel economy level of 35 miles per gallon by MY 2020. The AAM stated that such redefinition of the No Action Alternative would change NHTSA's calculation of the magnitude of the environmental impacts of the rulemaking, and may also change the agency's assessment of the significance of those effects. Accordingly, the AAM stated that it may be more appropriate for NHTSA to prepare a less elaborate EA, rather than a more-searching EIS.[26]

NEPA requires that NHTSA examine a "no action" alternative which reflects the state of the environment if the action were not taken. Even though NHTSA is required under EISA to set new fuel economy standards, the EIS must analyze a scenario where NHTSA does not take this action, which serves as a comparative baseline against which to compare the other alternatives (see Other Issues below concerning NHTSA's decision to prepare an EIS).

Another issue raised by the AAM was the extent of NHTSA's analysis of global effects associated with $CO_2$ emissions. The AAM stated that it agrees with NHTSA's statement in the May 2008 NPRM that "the appropriate value to be placed on changes [in] climate damages caused by carbon emissions should be ones that reflects the change in damages to the United States alone."[27] The AAM interpreted this statement in the NPRM as a proposal by NHTSA "to limit analysis undertaken in connection with the rulemaking to effects within the United States' own borders."[28] The AAM stated that this conclusion should carry over to the NEPA analysis, and that it believes NHTSA should scale back the estimated harms in any studies of the global effects associated with carbon emissions.

NHTSA agrees in part regarding the estimates employed for the social cost of carbon, as discussed in the NPRM. NHTSA disagrees, however, with the AAM's categorization of NHTSA's statement in the NPRM as being a proposal to limit the agency's environmental impact analysis under NEPA. Potential environmental impacts are global in this instance and the analysis must look beyond the borders of the United States. The section of the NPRM preamble quoted by the AAM discussed valuation of the social cost of carbon as an input into the Volpe model. NHTSA has an obligation under NEPA to "recognize the worldwide and long-range character of environmental problems."[29]

NHTSA has considered the AAM's comment on this issue of global effects of the agency's action. In the NPRM, NHTSA additionally requested "comment on its tentative conclusions for the value of the SCC emissions, the use of a domestic versus global value for the economic benefit of reducing $CO_2$ emissions, the rate at which the value of the SCC grows over time, the desirability of and procedures for incorporating benefits from reducing emissions of GHGs other than $CO_2$, and any other aspects of developing a reliable SCC value for purposes of establishing CAFE standards." *Id.* at 24414-24415.

Furthermore, an appropriate discussion of global climate change does not make sense if NHTSA limits analysis to the effects within the United States, since this environmental problem is inherently global in nature. Climate science focuses on the effects of carbon emissions in the global atmosphere

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[26] *Id.* at 18-22.

[27] *See* 73 FR 24352, 24414.

[28] Alliance Comments, *supra* at 29.

[29] 42 U.S.C. § 4332(f). *See also* CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), at 3, *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html (last visited June 16, 2008) (stating that "agencies must include analysis of reasonably foreseeable transboundary effects of proposed actions in their [NEPA] analysis of proposed actions in the United States").

because the atmospheric concentration of GHGs is basically uniform across the globe.[30] That is, carbon emissions from one nation disperse into the global atmosphere and have impacts in other nations, and conversely, benefits from emissions reductions in one nation are felt in all nations for the same reason. That being said, the agency considers the AAM's comment as a suggestion to focus on environmental impacts within the United States, and NHTSA agrees that this type of national rulemaking warrants specific discussion of regional United States impacts and how the United States is specifically affected by global climate change. NHTSA has accordingly devoted a substantial section of the DEIS to such discussion.

The AAM argued in its comments that "the principal cumulative effects on which NHTSA's NEPA analysis should focus are those associated with the additive effects over the last decade or more of CAFE standards on the light-truck side, combined with those for this proposed rulemaking, which increases CAFE standards for both passenger car and trucks." The AAM was primarily disputing the Ninth Circuit's decision in *Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 550 (9th Cir. 2007), in which the Court concluded that "by allowing particular fuel economy levels . . . NHTSA's regulations are the proximate cause of [tailpipe GHG] emissions."

In response to the AAM's comment, NHTSA notes that the CEQ regulations state that "cumulative impacts" are defined as the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR § 1508.7).

In this DEIS, the agency is addressing the cumulative impacts (through 2100) of the proposed MY 2011-2015 standards, NHTSA's implementation of the CAFE program through MY 2010, and "assumed" CAFE standards for MY 2016-2020 as required by EISA. NHTSA has reviewed the available research and literature, and is estimating the cumulative impacts on energy, air quality, and climate change. NHTSA's analysis is considering both physical effects and resource impacts due to the cumulative impacts on climate change. Physical effects include changes in temperature, precipitation, and sea level rise. Resource impacts include cumulative weather-based impacts on freshwater and terrestrial ecosystems and on human health and land-use patterns, as well as non-weather impacts. The agency's cumulative impacts analysis accounts for uncertainty and is consistent with the CEQ regulations.

To this end, while this NEPA analysis considers some of the issues suggested by the AAM, including an analysis of the cumulative emissions impacts resulting from the CAFE program since its inception (see Chapter 3) and an analysis of the proposed standards' and cumulative air quality impacts (in terms of criteria pollutant emissions, for example) on human health and the environment, NHTSA believes that the cumulative impacts analysis suggested by the AAM comments may be too narrow for the agency's purposes.

#### 1.3.2.4 Environmental Advocacy Groups

The Environmental Defense Fund (Docket No. NHTSA-2008-0060-0015) commented on the scope of NHTSA's NEPA analysis in conjunction with the Northern Health Impact Resource Group, Physicians for Social Responsibility, American Public Health Association, and the Johnson County Health Department. The commenters suggested a framework and methodology for analyzing the

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[30] *See* IPCC Technical Paper II, *An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report*, 13, 16-17, 25 (February 1997), *available at* http://www.ipcc.ch/ipccreports/technical-papers.htm.

potential health impacts of climate change related to the proposed CAFE standards and suggested that NHTSA request technical assistance from agencies with special expertise in this area. They suggested that the health benefits of the reduction of the emissions of pollutants regulated under the Clean Air Act, including criteria pollutants, and generated at every stage of the fuel cycle (i.e. fuel production, refining, transport, storage, and combustion in vehicle engines) be quantified using traditional risk assessment. The writers asserted that proper quantification of the economic benefits of reducing these adverse health impacts may justify adoption of more stringent fuel economy standards.

The commenters also suggested that the agency should consider the policy alternatives under consideration as conforming to (as one example) no action, moderate action, and stringent action pathways. These pathways may be comparable to the different emissions scenarios employed by the IPCC, and they are also consistent with NHTSA's proposed categorization of alternative policy options. Assessment of health impacts may then be conducted for the degree of reductions in national or global GHG emissions associated with the relative stringency of each pathway, to provide decision makers with some useful insight into the health consequences of the various degrees of stringency associated with specific CAFE alternatives. Estimates of changes in incidence or prevalence of climate-sensitive health outcomes could be performed at 5 year intervals into the future, and inflation-adjusted costs associated with those health outcomes could also be calculated as a means of valuing the incremental contribution of the alternatives.

NHTSA has in fact listed the alternatives in order of increasing stringency, as indicated by the mpg estimates associated with each one. NHTSA has presented a full range of alternatives from No Action through a full consideration and exhaustion of the technological approaches NHTSA believes are currently available to increase CAFE (with no regard for cost) consistent with the commenters' approach. Further, the analysis included in the DEIS employs three IPCC scenarios to estimate the changes in $CO_2$ concentrations and temperature that are due to the alternatives. These scenarios (A2, A1B, and B1) represent a high, moderate and low estimate of what future emissions levels might be. There is a great deal of uncertainty associated with estimating emissions levels in the year 2100, and the IPCC treats these scenarios (along with the other four scenarios) as equally probable. Given this uncertainty in the emission scenarios and in the analysis generally, it is not productive to estimate final impacts in human health or in other environmental areas since the range of error would obscure any reported differences in the alternatives. For these reasons, final human health and environmental outcomes resulting from the CAFE alternatives are qualitatively assessed, and NHTSA's analysis includes a sense of the direction of the impacts and the relative magnitude by alternative, which will inform NHTSA's decisions on the proposed standards.[31] Attempts to quantify impacts, including estimating health outcomes, would provide an unrealistic sense of precision that would not, in NHTSA's opinion, provide useful information for the decisionmaker.

In the DEIS, NHTSA has analyzed both the criteria pollutants and mobile source air toxics (MSATs) by estimating the emissions levels of each generated under the CAFE alternatives. Upstream emissions[32] are included to the extent possible. (Upstream emissions of acrolein are not available.). Transportation conformity[33] does not apply as the action is not being taken by Federal Highway

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[31] *See* 42 U.S.C. § 4332(2)(B) (directing agencies to "insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations"); *see also* 40 C.F.R. § 1502.22.

[32] Emissions associated with extraction, refining, storage, and distribution of the fuel.

[33] The Transportation Conformity Rules (40 CFR 51 Subpart T), which apply to transportation plans, programs, and projects funded under title 23 United States Code (U.S.C.) or the Federal Transit Act. Highway and transit infrastructure projects funded by FHWA or the Federal Transit Administration (FTA) usually are subject to transportation conformity.

Administration (FHWA) or the Federal Transit Administration. General conformity[34] provides an explicit exception for rulemaking activities. Consequently, there is no requirement to analyze concentrations for the criteria pollutants. See the discussion of conformity in Chapter 3 for more information.

NHTSA's approach regarding MSATs follows that of the FHWA guidance on MSAT analysis issued in February 2006 and the approach generally followed by the Federal Aviation Administration. FHWA cited that uncertainties associated with the exposure and health risk assessments, in addition to the fact that uncertainties are inherent in the emissions modeling process, raised concerns about the utility of studying MSATs beyond an emissions burden analysis. In addition, the NHTSA analysis demonstrates an overall reduction at the national level of both MSATs and criteria air pollutants which should reduce health risk, making any further level of analysis of marginal benefit.

Health costs are already included in the modeling process by which NHTSA analyzes alternatives for the CAFE standard. Using a process that maximizes net benefits, NHTSA assesses the societal costs and benefits associated with each of the alternatives. Included in the societal costs are damages to health.

Finally, NHTSA has received scoping comments from CDC and EPA and has consulted with each agency. NHTSA has also retained a nationally recognized consulting firm to assist with the analysis. It is NHTSA's belief that the agency has or has retained the requisite expertise and knowledge to address the health and environmental impacts as required under NEPA.

### 1.3.2.5 Individuals

Comments from individuals included approximately 1,737 letters that were similar in form and content. These letters recommended that NHTSA base the new standards on what the commenters considered more realistic gas prices and encourage the domestic automobile manufacturers to speed up the production of more fuel efficient automobiles.

NHTSA's analysis of alternative CAFE standards relies on fuel price forecasts reported in the U.S. Energy Information Administration's (EIA's) Annual Energy Outlook, an official United States federal government forecast that is widely relied upon by federal agencies in their analysis of proposed regulations. The alternative CAFE standards analyzed in the NPRM and the PRIA were developed and evaluated using fuel price forecasts from EIA's Annual Energy Outlook 2008 Revised Early Release, and NHTSA will consider any subsequent revisions in the final edition of Annual Energy Outlook 2008 in preparing the Final Rule and Final Regulatory Impact Analysis (RIA). Extensive tests of the effect of higher fuel prices on the stringency of the optimized CAFE standards, as well as upon the resulting fuel savings, reductions in $CO_2$ emissions, and total economic benefits are reported in Tables IX-5a and IX5b of the PRIA. In terms of the second comment, as previously indicated, the standards NHTSA proposed increase at a rate that, if sustained through 2020, would exceed the 35 mpg minimum average requirement specified by EISA.

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[34] The General Conformity Rules (40 CFR 51 Subpart W), which apply to all other Federal actions not covered under transportation conformity. The General Conformity Rules established emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of a project. If the net emission increases due to the project are less than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the emission increases exceed any of these thresholds, then a conformity determination is required. The conformity determination may entail air quality modeling studies, consultation with EPA and State air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

Comments from private individuals included a letter from Susan and Yuli Chew (The Chews) (Docket No. NHTSA-2008-0060-0014). They suggested that the fuel price assumptions used by NHTSA are out of date. This comment is similar to the comments of other individuals and is addressed above.

The Chews suggested that the assumptions of the buyer's payback calculation are flawed. From NHTSA's perspective, this comment appears to stem from or refer to the 4.7 and 4.2 year payback periods for the proposed car and light truck CAFE standards reported in PRIA Table IX-10, p. IX-14. These payback periods are calculated from the increases in fuel economy, annual fuel savings, and value per gallon of fuel saved at forecast retail fuel prices for the proposed standards. They are thus empirical estimates of the actual time required for buyers of new vehicles to recoup the higher purchase prices of those vehicles in the form of fuel cost savings, rather than assumptions about buyers' time horizons for valuing fuel savings.

They also questioned the "carry-forward" and "carry-back" credits. While NHTSA cannot precisely estimate the potential environmental impacts of discounting credits, NHTSA believes its analysis of how the various compliance flexibilities might affect the potential environmental impacts of the proposed standards spans the likely range of impacts that would be associated with discounting credits. The requirements covering the use of credits for alternatively fueled vehicles are explained in the EPCA. NHTSA does not have discretion to discount credits in future years. The point, however, will become moot as these credits are being phased out under the EISA, as noted by the commenter. They will no longer be allowed at all for the MY 2020 vehicles.

The Chews suggested that the effect of ethanol is not properly discussed in terms of air quality and natural and human resources and that the benefit of alternative fuel vehicles has been magnified, as only small portions of vehicles in the Midwest states have any E85 infrastructures in place.

In setting CAFE standards, NHTSA sets the fuel economy targets manufacturers are required to meet, but does not specify the technologies required to meet those targets. Companies are provided credits under Alternative Motor Fuels Act, but Congress is phasing out those credits. Even if the manufacturers employ the production of E85 vehicles (vehicles that can run on 85 percent ethanol) in their strategies to meet the new targets, the existence of these vehicles does not necessarily change the production of ethanol, since consumers would have to choose to fill their vehicles with E85 fuel, and also have it available at their filling stations.

NHTSA believes that the extent to which ethanol will actually be utilized as a transportation fuel will primarily be determined by its availability at retail fueling stations and its retail price relative to that of gasoline. Because the availability of ethanol and its price relative to that of gasoline are unlikely to be affected significantly by the stringency of CAFE standards, the use of ethanol is similarly unlikely to differ significantly among the alternative CAFE standards considered for MYs 2011-15. Thus while the volume of ethanol that is produced, distributed, and consumed could significantly affect total emissions from the production and use of transportation fuels, this effect is not likely to differ significantly among alternative CAFE standards. As a consequence, the extent of ethanol use is unlikely to affect the changes in total emissions from production and use of transportation fuels resulting from alternative CAFE standards, or the environmental impacts associated with those changes in emissions.

The Chews also stated that the benefits are almost twice as much as the costs for MY 2011-2015, so the target should be adjusted to be more aggressive than planned. Regarding these benefits, NHTSA's NPRM reflects the best information available to NHTSA when the analysis was performed, and the proposed standards reflect those benefits. NHTSA has requested comment on its estimate of benefits and costs, and on its analytical methods. After reviewing these comments, which are due on July 1, 2008, NHTSA will revisit its analysis in preparing the final rule.

The Chews suggested that the phasing out of the fuel economy incentives by dual-fueled vehicles (e.g. E85) is welcomed and overdue. Dual fuel vehicles are designed to run on gasoline or an alternative fuel. By law, vehicle manufacturers of these vehicles can lower their CAFE requirements by a certain amount within the limits specified in statute. In order to assess the environmental impacts of in-use operation of dual fuel vehicles, data detailing the operation of the vehicle using the alternative fuel would be necessary. Unfortunately such data depend on each individual's use of the dual-fueled vehicle and are not available.

#### 1.3.2.6 Other Comments

There were several comments submitted that go beyond the scoping process under NEPA or speak to regulatory issues with the NPRM or the PRIA. A brief explanation is provided below.

The AAM (Docket No. NHTSA-2008-0060-DRAFT-0033.1[1]) submitted comments suggesting that an EIS is not warranted, and that an EA would be adequate.

NHTSA's rationale for preparing an EIS is explained in its NOI to prepare an EIS.[35]

The AAM also stated its belief that because NHTSA's setting of CAFE standards under EPCA involves the consideration of environmental factors, the "functional equivalence doctrine" applies to NHTSA's mandate for setting CAFE standards.[36] The AAM maintains that the functional equivalence doctrine is applied by courts to eliminate the need for an agency to perform NEPA analysis where the agency's Congressional mandate already involves specific procedures for considering the environment that offer the functional equivalent of an EIS.[37] According to the AAM, courts have ruled that EPA regulation under the Clean Air Act is the functional equivalent of NEPA analysis, making separate application of NEPA by EPA unnecessary.

In those instances where courts have found an agency exempt from NEPA requirements via the functional equivalence doctrine, the doctrine has been narrowly drawn. For example, the D.C. Circuit has repeatedly described the functional equivalence doctrine as a narrow exemption that is applicable "when the agency's organic legislation mandates procedures for considering the environment that are 'functional equivalents' of the NEPA process."[38] Other circuit courts have adopted even more narrow interpretations of the functional equivalence doctrine, construing it to mean that one process requires the same steps as another.[39] Although NHTSA considers environmental impacts when setting CAFE standards, EPCA does not require explicit consideration of environmental impacts; rather, the analysis is one that the agency has conducted in the context of evaluating the nation's need to conserve energy.[40] EPCA does not require a

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[35] 73 Fed. Reg. 16615, 16616 (Mar. 28, 2008).

[36] Comments of the Alliance of Automobile Manufacturers, Document ID No. NHTSA-2008-0600-0176, 12-15 (June 2, 2008) (hereinafter "Alliance Comments").

[37] *Id.* at 5-6.

[38] *American Trucking Assns. v. EPA*, 175 F.3d 1027, 1042 (D.C. Cir. 1999) (quoting *Izaak Walton League of America v. Marsh*, 655 F.2d 346, 367 n.51 (D.C. Cir. 1981)); *Amoco Oil Co.*, 501 F.2d at 749 (quoting *Int'l Harvester Co. v. Ruckelshaus*, 478 F.2d, 615, 650 n.130 (D.C. Cir. 1973)); *Portland Cement Assn.*, 486 F.2d at 384-387 (describing the functional equivalence doctrine as a narrow exemption); *Environmental Defense Fund v. EPA*, 489 F.2d 1247, 1256 (D.C. Cir. 1973).

[39] *Douglas County v. Babbitt*, 48 F.3d 1495, 1504 n.10 (9th Cir. 1995); *see also State of Wyoming v. Hathaway*, 525 F.2d 66, 73-74 (10th Cir. 1976) (affirming the trial court's finding of no functional equivalence).

[40] *See Center for Biological Diversity v. NHTSA*, 508 F.3d 508, 547 (9th Cir. 2007) (describing as complementary EPCA's goal of energy conservation and NEPA's goal of helping public officials make decisions that are based on an understanding of environmental consequences); *Massachusetts v. EPA*, 127 S. Ct. 1438, 1462 (2007) (categorizing EPCA's requirement to set CAFE standards as "DOT's mandate to promote energy efficiency" and

***[Continued on bottom of next page]***

level of environmental analysis commensurate with the requirements of NEPA. Moreover courts have long held that NEPA applies except in limited circumstances.[41] Consequently, NHTSA declines to adopt the AAM's suggestion, and the agency has prepared a DEIS to consider the environmental impacts of the proposed standards in the context of NHTSA's CAFE program. The DEIS will aid the agency in completing a robust analysis of the environmental impacts of the rulemaking for MY 2011-2015 CAFE standards.

The AAM also suggested that NHTSA consider an alternative tied to the "least capable manufacturer" approach that was applied prior to the advent of Reformed CAFE. NHTSA does not adopt this approach for the following reasons. NHTSA's earlier "Unreformed CAFE" standards specified a "one size fits all" (uniform) level of CAFE that applied to each manufacturer and that was set with particular regard to the lowest projected level of CAFE among the manufacturers that have a significant share of the market. The manufacturer with the lowest projected CAFE level is typically known as the "least capable" manufacturer. However, NHTSA's 2006 CAFE standards for light trucks adopted a different "Reformed CAFE" approach. 71 Fed. Reg. 17566 (Apr. 6, 2006). EISA recently codified that approach, requiring that all CAFE standards be based on one or more vehicle attributes. 49 U.S.C. § 32902(b)(3)(A); see 73 Fed. Reg. 24352, 24354-24355 (May 2, 2008) (discussing NHTSA's proposal to base CAFE standards on the attribute of vehicle size, as defined by vehicle footprint).

As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to the capabilities of a single manufacturer in order to ensure that the standards are technologically feasible and economically practicable for all manufacturers with a significant share of the market. This is true both fleet wide and within any individual category of vehicles." See 70 Fed. Reg. 51414, 51432 (Aug. 30, 2005). Specifically:

> There is no need under Reformed CAFE to set the standards with particular regard to the capabilities of the "least capable" manufacturer. Indeed, it would often be difficult to identify which manufacturer should be deemed the "least capable" manufacturer under Reformed CAFE. The "least capable" manufacturer approach was simply a way of implementing the guidance in the conference report [part of EPCA's legislative history][42] in the specific context of Unreformed CAFE….
>
> …The very structure of Reformed CAFE standards makes it unnecessary to continue to use that particular approach in order to be responsive to guidance in the conference report. Instead of specifying a common level of CAFE, a Reformed CAFE standard specifies a variable level of CAFE that varies based on the production mix of each manufacturer. By basing the level required for an individual manufacturer on that manufacturer's own mix, a Reformed CAFE standard in effect recognizes and accommodates differences in production mix between full- and part-line manufacturers,

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distinguishing this mandate as "wholly independent" of the Clean Air Act's command that the EPA protect the public's health and welfare); *see also Center for Auto Safety v. NHTSA*, 793 F.2d 1322, 1324-1325 n.12 (D.C. Cir. 1986) (listing the four statutory factors NHTSA is to consider when determining "maximum feasible" fuel economy, and noting approvingly that NHTSA interpreted the "need of the Nation to conserve energy" factor as requiring consideration of, among other issues, the "environmental … implications of our need for large quantities of petroleum").

[41] *See Pacific Legal Foundation v. Andrus*, 657 F.2d 829, 833 (6th Cir. 1981); *Calvert Cliffs' Coordinating Committee, Inc. v. U.S. Atomic Energy Commission*, 449 F.2d 1109, 1114-1115 (D.C. Cir. 1971).

[42] *See* 70 Fed. Reg. 51414, 51425-51426 (Aug. 30, 2005) (discussing the conference report).

> and between manufacturers that concentrate on small vehicles and those that concentrate on large ones.
>
> There is an additional reason for ceasing to use the "least capable" manufacturer approach. There would be relatively limited added fuel savings under Reformed CAFE if we continued to use the "least capable" manufacturer approach even though there ceased to be a need to use it…." (70 Fed. Reg. at 51433).

In addition, the AAM's suggested approach would not result in the increases in fuel economy mandated by EISA – namely, 35 mpg by MY 2020.

In light of the fact that Congress recently codified the Reformed CAFE approach for both passenger cars and light trucks, and for all of the reasons stated above, NHTSA does not consider in detail an alternative tied to the historic "least capable manufacturer" approach as the commenter suggested.

Other comments, set out below, suggested that NHTSA's NEPA analysis consider certain economic or social issues that are beyond the scope of NEPA.

The AAM suggested that appropriate cumulative effects should include "The economic disbenefits and counterproductive/unintended consequences of CAFE standard increases," specifically including, "at a minimum, … the cumulative effects in this regard stemming from employment losses and associated health effects, for both this current proposed rule and the 2006 light truck rule. The same is true as to cumulative safety disbenefits and cumulative environmental disbenefits in terms of increased criteria pollutant emissions traceable to the fleet turnover and rebound effects."

The AAM also suggested that NHTSA consider what is characterized as additional categories of "environmental" effects in the DEIS, including the quality of life of unemployed automotive industry workers and fleet turnover.

The CDC suggested that "health and well-being"-related impacts of decreasing dependency on motor vehicle fuel, such as mental health benefits, reduced stress, and increased economic stability be evaluated in the DEIS. NHTSA discussed this comment with CDC during a June 12, 2008 telephone call. In particular, NHTSA and CDC discussed the potential for human health impacts in two areas – namely, the potential for social instability resulting from energy concerns and for changes in family expenditures related to energy. Further, in the discussion with CDC, the difficulty in addressing such issues was acknowledged. NHTSA agreed to examine the source provided by CDC concerning health issues related to petroleum scarcity (see Chapter 3).

Courts have generally held that economic and social issues need only be considered if they directly interrelate to the effects on the physical environment.[43] As these issues raised by the AAM and the CDC do not relate to the effects on the physical environment, they are not addressed in this document.

The Attorneys General also suggested the additional alternative of down-weighting for all vehicles, not just vehicles greater than 5,000 pounds, and stated that there is strong evidence that down-weighting of vehicles does not make them less safe. As discussed above, the down-weighting alternative and related concerns were also raised by other commenters. Chapter 2 explains the agency's rationale in choosing alternatives, and contains an explanation of why NHTSA believes that the safety risks with down-weighting preclude its selection as a reasonable alternative.

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[43] *See*, e.g., *Ashley Creek Phosphate Co. v. Norton*, 420 F.3d 934, 944 (9th Cir. 2005); *Hammond v. Norton*, 370 F. Supp.2d 226, 243 (D.D.C. 2005).

The Attorneys General also requested that NHTSA expand its analytical reliance on reduced vehicle weight as a means of improving fuel economy.  As mentioned above and discussed in the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of lightweight materials on heavier vehicles for which doing so would be unlikely to compromise highway safety.

Other comments refer to issues that NHTSA expects to address in the final rule.  These include comments from States concerning new technologies, comments from the AAM concerning the proper construction of the term, "ratably", and comments from individuals.

### 1.3.3 Next Steps in the NEPA Process and CAFE Rulemaking

After publishing and circulating (for public review and comment) this DEIS, NHTSA will:

- provide a 45-day public comment period where interested parties can submit written comments on this document (Summer 2008); and
- hold a public hearing in Washington, D.C. where interested parties can present oral testimony in early August 2008.

The Final Environmental Impact Statement (FEIS) is expected to be released later this year.  The FEIS will address comments received on the DEIS and identify the Preferred Alternative.  No sooner than 30 days after the availability of the FEIS is announced in the Federal Register by EPA and prior to, or in conjunction with, the release of a final CAFE rulemaking, NHTSA will execute a Record of Decision (ROD).  The ROD will state and explain NHTSA's decision.

# Chapter 2 The Proposed Action and Alternatives

## 2.1 INTRODUCTION

The National Environmental Policy Act[1] (NEPA) requires an agency to compare the environmental impacts of its proposed action and alternatives. An agency must rigorously explore and objectively evaluate all reasonable alternatives, including a No Action Alternative. For any alternative 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]

In developing the proposed Corporate Average Fuel Economy (CAFE) standards and possible alternatives, the National Highway Traffic Safety Administration (NHTSA) considered the four Energy Policy and Conservation Act (EPCA) factors that guide the agency's determination of "maximum feasible" standards:

- technological feasibility,
- economic practicability,
- the effect of other standards of the Government on fuel economy, and
- the need of the nation to conserve energy.[4]

In addition, NHTSA is also considering relevant safety and environmental factors. For instance, NHTSA has placed monetary values on energy security and environmental externalities, including the benefits of reductions in carbon dioxide ($CO_2$) emissions. The NEPA analysis presented in this DEIS and in NHTSA's Final EIS is informing the agency's action setting final CAFE standards. During the standard-setting process, NHTSA has consulted with the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) regarding a variety of matters as required by EPCA.

## 2.2 BENEFIT-COST ANALYSIS

In order to balance the EPCA factors relevant to standard-setting, NHTSA used a benefit-cost analysis to evaluate alternative CAFE standards (Appendix C). A benefit-cost analysis weighs the expected benefits against the expected costs of specific alternatives, relative to a "no action" baseline, in order to choose the best option. Costs of any specific CAFE alternative include the aggregate costs to increase the utilization of fuel-saving technologies, where such costs are expressed on a retail price equivalent (RPE) basis. The benefits of any specific alternative include fuel savings over the operational life of new vehicles with increased fuel economy, and the social benefits of reducing petroleum consumption and environmental externalities. The benefit-cost analysis reflects an assessment of what fuel saving technologies would be available, how effective they are, and how quickly they could be introduced in the marketplace. NHTSA used a computer model that, for any given model year (MY), applies technologies to the fleets of each automobile manufacturer, until each manufacturer either achieves compliance with the CAFE standard under consideration or exhausts available technologies. The model assumes that manufacturers apply the most cost-effective technologies first, yielding the greatest net benefits. As more stringent fuel economy standards are evaluated, the model recognizes that

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[1] 42 United States Code (U.S.C.) § 4332(2)(C). NEPA is codified at 42 U.S.C. §§ 4321 *et seq.*

[2] 40 Code of Federal Regulations (CFR) §§ 1502.14(a), (d).

[3] 40 CFR § 1502.13. *Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense 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).

manufacturers must apply less cost-effective technologies. The model then compares the present value (discounted at 7 percent) of costs and benefits for any specific CAFE standard.

NHTSA performed several sensitivity analyses to examine the impact of different model input assumptions, such as the value of externalities and the price of gasoline. The results of the sensitivity analyses indicate that minor variations in externality rates had almost no impact on the level of miles per gallon (mpg) standards that would maximize net benefits, but that significant increases in the forecast price of gasoline produced significant increases in the estimated optimal stringency. NHTSA presents the results of the sensitivity analyses in the Preliminary Regulatory Impact Analysis[5] (PRIA), and discusses them in Chapter 3 of this DEIS. As explained below (Section 2.2), the range of possible CAFE standards and associated costs and benefits are also effectively bounded by the continuum of alternatives examined. At one end of this range is the No Action Alternative and at the other end is the Technology Exhaustion Alternative, which would require every manufacturer to apply every feasible fuel saving technology to their MY 2011-2015 fleet.

As noted previously, NHTSA consulted with EPA and DOE in connection with NHTSA's development of the proposed standards and alternatives. The analysis of costs and benefits reflects NHTSA and EPA technical staff's current assessment of a broad range of technologies which can be applied to passenger cars and light trucks. EPA published the results of this collaboration in a report [6]and submitted it to the National Academy of Sciences (NAS). A copy of the report and other studies used in the technology update will be placed in NHTSA's docket.

The technologies considered by the model are briefly described below, under the five broad categories of engine, transmission, vehicle, accessory, and hybrid technologies.

**Types of engine technologies that were considered under the benefit-cost analysis include the following:**

- *Low-Friction Lubricants* reduce fuel consumption, and more advanced engine and transmission oils are now available with improved performance and better lubrication.

- *Reduction of Engine Friction Losses* can also be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, piston surface treatments, and other improvements in the design of engine components and subsystems that improve engine operation and fuel economy, and reduce friction and emissions.

- *Multi-Valve Overhead Camshaft Engines*, with more than two valves per cylinder, reduce fuel consumption through increased airflow at high engine speeds.

- *Cylinder Deactivation* shuts down some cylinders during light load operation. Active cylinders combust at almost double the load required if all cylinders were operating, with pumping losses significantly reduced as long as the engine is operated in this mode.

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[5] The PRIA is available at http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/CAFE_2008_PRIA.pdf (last visited June 15, 2008).

[6] EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Lightduty Vehicle Carbon Dioxide Emissions. EPA420-R-08-008, March, 2008

- *Variable Valve Timing* alters the timing of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control residual gases.

- *Variable Valve Lift and Timing* partially optimize both timing and lift, based on engine operating conditions, to achieve further reductions in pumping losses and increases in thermal efficiency.

- *Discrete Variable Valve Lift* reduces fuel consumption by switching between cam profiles that consist of a low and a high-lift lobe.

- *Continuous Variable Valve Lift* enables intake valve throttling, which allows the use of more complex sensors and electronic controls to enable further optimization of valve lift.

- *Camless Valve Actuation* relies on electromechanical actuators instead of camshafts to open and close the cylinder valves, coupled with sensors and microprocessor controls, to optimize valve timing and lift over all conditions.

- *Stoichiometric Gasoline Direct Injection Technology* injects fuel at high pressure into the combustion chamber to improve cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency.

- *Gasoline Engine Turbocharging* increases the available airflow and specific power level, allowing a reduced engine size while maintaining performance. This reduces pumping losses at lighter loads in comparison to a larger engine, while reducing net friction losses.

- *Diesel Engines* have several characteristics that give superior fuel efficiency, including reduced pumping losses due to lack of (or greatly reduced) throttling, and a combustion cycle that operates at a higher compression ratio, with a leaner air/fuel mixture than an equivalent-displacement gasoline engine.

- *Lean Nitrogen Oxides (NOx) Trap Catalyst After-Treatment* stores NOx when the engine is running in its normal (lean) state, and then switches to a rich operating mode that produces excess hydrocarbons that act as a reducing agent to convert the stored NOx to nitrogen ($N_2$) and water.

- *Selective Catalytic Reduction (SCR) NOx After-Treatment* uses a reductant (typically, ammonia) that combines with NOx in the SCR catalyst to form $N_2$ and water.

**Types of transmission technologies that were considered under the benefit-cost analysis include the following:**

- *Five-, Six-, Seven- and Eight-Speed Automatic Transmissions* influence the width of gear ratio spacing and transmission ratio optimization available under different operating conditions, and thereby offer greater engine optimization and higher fuel economy.

- *Aggressive Shift Logic* in an automatic transmission can maximize fuel efficiency by upshifting earlier and inhibiting downshifts under some conditions.

- *Early Torque Converter Lockup* reduces fuel consumption by locking up the torque converter (a fluid coupling located between the engine and transmission) to reduce slippage during light acceleration and cruising.

- *Automated Shift Manual Transmissions* (AMTs) are similar to conventional transmissions but shifting and launch functions are controlled by the vehicle. A dual-clutch AMT uses separate clutches for even-numbered and odd-numbered gears, so the next expected gear is pre-selected, which allows for faster and smoother shifting.

- *Continuously Variable Transmissions* (CVTs) do not use gears to provide ratios for operation. Unlike manual and automatic transmissions with fixed transmission ratios, CVTs can provide fully variable transmission ratios with an infinite number of gears, enabling finer optimization of the transmission ratio under different operating conditions.

- *Manual 6-, 7-, and 8-speed Transmissions*, like automatic transmissions, increase the number of available ratios in a manual transmission to improve fuel economy by allowing the driver to select a ratio that optimizes engine operation at a given speed.

**Types of vehicle technologies that were considered under the benefit-cost analysis include the following:**

- *Rolling Resistance Reduction* is achieved through tire characteristics that reduce frictional losses associated with the energy dissipated in the deformation of the tires under load.

- *Low Drag Brakes* reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake shoes are pulled away from the rotating drum.

- *Front or Secondary Axle Disconnect for Four-Wheel Drive Systems* provide shift-on-the-fly capabilities in many part-time four-wheel drive systems. For example, in two-wheel drive mode, front axle disconnect disengages the front axle from the front driveline so the front wheels do not turn the front driveline at road speed, saving wear and tear.

- *Aerodynamic Drag Reduction* is achieved by changing vehicle shape or frontal area, including skirts, air dams, underbody covers, and more aerodynamic side view mirrors.

- *Weight Reduction* encompasses a variety of techniques that include lighter-weight materials, higher strength materials, component redesign, and size matching of components.

**Types of accessory technologies that were considered under the benefit-cost analysis include the following:**

- *Electric Power Steering* (EPS) is advantageous over hydraulic steering in that it only draws power when the wheels are being turned, which is only a small percentage of a vehicle's operating time.

- *Engine Accessory Improvement* reduces accessory loads (from alternator, coolant, and oil pumps) by improving the efficiency or outright electrification of these accessories.

- *Forty-Two Volt (42V) Electrical Systems*, under consideration to meet increases in on-board electrical demands, may increase the power density of electrical components to the point that new and more efficient systems, such as electric power steering, may be feasible. A 42V system can also accommodate an integrated starter generator.

**Types of hybrid technologies that were considered under the benefit-cost analysis include the following:**

- *A hybrid vehicle* combines two or more sources of propulsion, where one uses a consumable fuel (like gasoline) and one is rechargeable (during operation, or by another energy source). Hybrids reduce fuel consumption by: (1) optimizing internal combustion engine operation (downsizing, or other control techniques); (2) recapturing lost braking energy and storing it for later use; and/or (3) turning off the engine when it is not needed (when vehicle is coasting or stopped).

- *Integrated Starter-Generator with Idle-Off* (ISG) systems offer basic idle-stop capability, and the least power assist and regeneration capability, with smaller electric motors and less battery capacity than other high efficiency vehicle (HEV) designs because of their lower power demand.

- *Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD)* utilizes a thin axial electric motor, connected to the transmission, which acts as both a motor for helping to launch the vehicle and a generator for recovering energy while slowing down.

- *2-Mode Hybrids* use an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors that control the ratio of engine speed to vehicle speed, while clutches allow the motors to be bypassed, which improves both the transmission's torque capacity for heavy-duty applications and fuel economy at highway speeds.

- *Power Split Hybrids* use a power split device that replaces the vehicle's transmission with a single planetary gear and a motor/generator. This motor/generator uses its engine torque to either charge the battery or supply additional power to the drive motor. A second, more powerful motor/generator is connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits the engine's torque between the first motor/generator and the drive motor.

- *Variable Compression Ratio* (VCR) improves fuel economy by the use of higher compression ratios at lower loads and lower compression ratios under higher loads.

- *Lean-Burn Gasoline Direct Injection Technology* dramatically improves an engine's thermodynamic efficiency by operating at a lean air-fuel mixture (excess air). Fuel system improvements, changes in combustion chamber design and repositioning of the injectors have allowed for better air/fuel mixing and combustion efficiency.

- *Homogeneous Charge Compression Ignition* (HCCI), also referred to as controlled auto ignition (CAI), is an alternate engine operating mode that does not rely on a spark event to initiate combustion, based on principles more closely aligned with a diesel combustion cycle, in which the compressed charge exceeds a temperature and pressure necessary for spontaneous ignition. The resulting burn is much shorter in duration with higher thermal efficiency.

- *Plug-In Hybrid Electric Vehicles* (PHEVs) could add a means to charge the battery pack from an outside source of electricity (usually the electric grid), have a larger battery pack with more energy storage and a greater capability to be discharged, and have a control system that allows the battery pack to be significantly depleted during normal operation.

## 2.3 ALTERNATIVES

Because CAFE standards are numerical performance standards, an infinite number of alternatives could hypothetically be defined (along a continuum from the least to the most stringent levels of CAFE). The specific alternatives NHTSA has examined, described below, were selected to encompass a reasonable range of stringencies to consider for purposes of evaluating the potential environmental impacts of the proposed CAFE standards and alternatives under NEPA. The alternatives also illustrate key alternatives with important cost, benefit, and net benefit (benefit minus cost) characteristics. At one end of this range is the No Action Alternative, which assumes that NHTSA would issue a rule directing manufacturers to proceed with current product plans and apply technology as needed to achieve only the MY 2010 mpg standard. Costs and benefits of other alternatives are calculated relative to the baseline of the No Action Alternative. The No Action Alternative, by definition, would yield no incremental costs or benefits (and it would not satisfy the EPCA requirement to achieve a combined average fuel economy of at least 35 mpg for MY 2020). At the other end of the range of possible alternatives is the Technology Exhaustion Alternative. This alternative would require every manufacturer to apply every available fuel saving technology, without consideration of the accompanying costs. By definition, this alternative would exceed nearly all manufacturers' capabilities (because manufacturers would not "run out" of technologies at the same stringency level), and produces a CAFE standard that requires the use of technologies that entail costs that exceed benefits.

NHTSA has examined five alternatives that fall between the extremes of the No Action Alternative and the Technology Exhaustion Alternative mpg standards. The preferred alternative establishes optimized mpg standards that yield the greatest net benefits of any feasible alternative. As mpg standards are increased beyond this optimized level, manufacturers are increasingly forced to apply technologies that entail higher incremental costs than benefits, thereby reducing total net benefits. Another specific alternative examined is the total costs (TC) equal total benefits (TB) level (Total Costs Equal Total Benefits Alternative), at which manufacturers are forced to apply technologies until total costs equal total benefits, yielding zero net benefits. The Total Costs Equal Total Benefits Alternative sets the second most stringent set of mpg standards examined, after the Technology Exhaustion Alternative (which yields negative net benefits). The other three alternatives illustrate how costs, benefits, and net benefits vary across other possible CAFE standards between the No Action and the Total Costs Equal Total Benefits Alternatives. As shown in Table 2.3-1, the 50 Percent Above Optimized Alternative would impose a 2015 mpg standard half-way between the Optimized and Total Costs Equal Total Benefits Alternatives. The 25 Percent Above Optimized Alternative would impose a 2015 mpg standard halfway between the Optimized and 50 Percent Above Optimized Alternatives, and the 25 Percent Below Optimized Alternative would impose a 2015 standard that falls below the Optimized Alternative by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds the Optimized scenario.

**TABLE 2.3-1**

**MY 2015 Required MPG by Alternative**

| | No Action | 25% Below Optimized | Optimized (Preferred) | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| Passenger Cars | 27.5 | 33.9 | 35.7 | 37.5 | 39.5 | 43.3 | 52.6 |
| Light Trucks | 23.5 | 27.5 | 28.6 | 29.8 | 30.9 | 33.1 | 34.7 |

The No Action Alternative and the action alternatives discussed in the Notice of Proposed Rulemaking (NPRM)[7] are described in more detail below.

NHTSA believes that these alternatives represent a reasonable range of alternatives to consider for purposes of evaluating the potential environmental impacts of proposed CAFE standards under NEPA, because these alternatives represent a full spectrum of potential impacts ranging from the current (i.e., MY 2010) standards to standards based on the maximum technology expected to be available over the period necessary to meet the statutory goals of EPCA, as amended by EISA. Given EPCA's mandate that NHTSA consider specific factors in setting CAFE standards and NEPA's instruction that agencies give effect to NEPA's policies "to the fullest extent possible," NHTSA recognizes that a very large number of alternative CAFE levels are potentially conceivable and that the alternatives described above essentially represent several of many points on a continuum of alternatives. Along the continuum, each alternative represents a different way in which NHTSA conceivably could weigh EPCA's statutory requirements and account for NEPA's policies.[8] While all of the alternatives discussed in detail here are important to NHTSA's NEPA analysis, NHTSA's provisional analysis suggests that some of these alternatives may not satisfy one or more of the four EPCA factors that NHTSA must apply in setting "maximum feasible" CAFE standards (i.e., technological feasibility, economic practicability, the effect of other motor vehicle standards of the government on fuel economy, and the need of the nation to conserve energy).

### 2.3.1 Alternative 1: No Action

This is the alternative of maintaining CAFE standards at the MY 2010 levels of 27.5 mpg and 23.5 mpg for passenger cars and light trucks, respectively.[9] NEPA requires agencies to consider a No Action Alternative in their NEPA analyses,[10] although the recent amendments to EPCA direct NHTSA to set new CAFE standards and do not permit the agency to take no action on fuel economy. In the NPRM, NHTSA refers to the No Action Alternative as the no increase or baseline alternative.

### 2.3.2 Alternative 2: 25 Percent Below Optimized

This alternative reflects standards that fall below the optimized scenario by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds the optimized scenario. As indicated in the Preliminary Regulatory Impact Analysis[11] (PRIA), this alternative mirrors the absolute difference in mpg derived from the 25 Percent Above Optimized Alternative in going the same mpg amount below the Optimized Alternative.

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[7] Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 FR 24352, May 2, 2008. At the same time, NHTSA requested updated product plan information from the automobile manufacturers. *See* Request for Product Plan Information, Passenger Car Average Fuel Economy Standards—Model Years 2008-2020 and Light Truck Average Fuel Economy Standards—Model Years 2008-2020, 73 FR 21490, May 2, 2008.

[8] Council on Environmental Quality (CEQ) guidance instructs that "[w]hen there are potentially a very large number of alternatives, only a reasonable number of examples, covering the full spectrum of alternatives, must be analyzed and compared in the EIS." CEQ, Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026, 18027, March 23, 1981 (emphasis original).

[9] See 40 CFR §§ 1502.2(e), 1502.14(d). To pursue this alternative, NHTSA would need to issue a rule providing that the MY 2010 standards would remain in effect for future model years.

[10] *See* 40 CFR 1502.14(b).

[11] The PRIA is available at http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/CAFE_2008_PRIA.pdf (last visited June 15, 2008).

For passenger cars, the average required fuel economy in mpg for the industry would range from 29.6 mpg in MY 2011 to 33.9 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 24.9 mpg in MY 2011 to 27.5 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 27.1 mpg in MY 2011 to 30.2 mpg in MY 2015, if each manufacturer exactly met its obligations under these standards. The annual average increase in mpg during the period from MY 2011-2015 would be approximately 3.6 percent.

### 2.3.3 Alternative 3: Optimized

This alternative is NHTSA's Preferred Alternative and reflects the optimized scenario, in which the proposed standards are based on applying technologies until net benefits (discounted at 7 percent) are maximized. As EPCA requires, NHTSA's recent NPRM proposed attribute-based (vehicle size) fuel economy standards for passenger cars and light trucks is consistent with the Reformed CAFE approach NHTSA used to establish standards for MY 2008-2010 light trucks.[12] The NPRM proposed separate standards for MY 2011-2015 passenger cars and separate standards for MY 2011-2015 light trucks.[13] Under the proposed standards, each vehicle manufacturer's required level of CAFE would be based on target levels of average fuel economy set for vehicles of different sizes and on the distribution of that manufacturer's vehicles among those sizes. Size would be defined by vehicle footprint.[14] The level of the performance target for each footprint would reflect the technological and economic capabilities of the industry. The target for each footprint would be the same for all manufacturers, regardless of differences in their overall fleet mix. Compliance would be determined by comparing a manufacturer's harmonically averaged fleet fuel economy levels in a model year with an average required fuel economy level calculated using the manufacturer's actual production levels and the targets for each footprint of the vehicles that it produces.

For passenger cars, the average required fuel economy in mpg for the industry would range from 31.2 mpg in MY 2011 to 35.7 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 25.0 mpg in MY 2011 to 28.6 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 27.8 mpg in MY 2011 to 31.6 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards proposed in the NPRM.[15]

Under the proposed standards, the annual average required mpg increase during the period from MY 2011-2015 would be approximately 4.5 percent, although the increases would vary between model years.[16] Pursuant to the 2007 Energy Independence and Security Act (EISA) mandate,[17] domestically

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[12] See Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 FR 17,566, 17,587-17,625, April 6, 2006 (describing that approach).

[13] The proposed standards include light truck standards for one model year (MY 2011) that was previously covered by a 2006 final rule, Average Fuel Economy Standards for Light Trucks, Model Years 2008-2011, 71 FR 17,566, April 6, 2006.

[14] A vehicle's footprint is generally defined as "the product of track width [the lateral distance between the centerlines of the base tires at ground, including the camber angle]… times wheelbase [the longitudinal distance between front and rear wheel centerlines] … divided by 144…." 49 CFR § 523.2.

[15] NHTSA notes that it cannot at this point determine the precise level of CAFE that each manufacturer would be required to meet for each model year under the proposed standards, because the level for each manufacturer would depend on that manufacturer's final production figures and fleet mix for a particular model year. That information will not be available until the end of each model year.

[16] With the proposed standards, the combined industry-wide average fuel economy would have to increase by an average of 2.1 percent per year from MY 2016 -MY 2020 in order to reach EISA's goal of at least 35 mpg by MY 2020.

manufactured passenger car fleets also must meet an alternative minimum standard for each model year. The alternative minimum standard would range from 28.7 mpg in MY 2011 to 32.9 mpg in MY 2015 under NHTSA's proposal.

### 2.3.4 Alternative 4: 25 Percent Above Optimized

This alternative reflects standards that take the mpg levels to the Optimized Alternative level plus 25 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative mpg levels.

For passenger cars, the average fuel required economy in mpg for the industry would range from 32.8 mpg in MY 2011 to 37.5 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 25.1 mpg in MY 2011 to 29.8 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 28.5 mpg in MY 2011 to 33.0 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards. The annual average mpg increase during the period from MY 2011-2015 would be approximately 5.4 percent.

### 2.3.5 Alternative 5: 50 Percent Above Optimized

This alternative reflects standards that take the mpg levels to the Optimized Alternative level plus 50 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative mpg levels.

For passenger cars, the average required fuel economy in mpg for the industry would range from 34.3 mpg in MY 2011 to 39.5 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 25.3 mpg in MY 2011 to 30.9 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 29.2 mpg in MY 2011 to 34.5 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards. The annual average mpg increase during the period from MY 2011-2015 would be approximately 6.4 percent.

### 2.3.6 Alternative 6: Total Costs Equal Total Benefits

This alternative reflects standards based on applying technologies until total costs equal total benefits (zero net benefits). This is known as the Total Costs Equal Total Benefits Alternative.

For passenger cars, the average required fuel economy in mpg for the industry would range from 37.5 mpg in MY 2011 to 43.3 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 25.6 mpg in MY 2011 to 33.1 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 27.8 mpg in MY 2011 to 37.3 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards. The annual average mpg increase during the period from MY 2011-2015 would be approximately 8.0 percent.

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[17] EISA is Public Law 110-140, 121 Stat. 1492 (December 19, 2007). EPCA is codified at 49 U.S.C. §§ 32901 et seq.

### 2.3.7 Alternative 7: Technology Exhaustion

For this alternative, NHTSA applied all technologies NHTSA considered to be available without regard to cost by determining the stringency at which a reformed CAFE standard would require every manufacturer to apply every technology estimated to be potentially available for its MY 2011-2015 fleet. Accordingly, the penetration rates for particular technologies would vary on an individual manufacturer basis. NHTSA has presented this alternative in order to explore how the stringency of standards would vary based solely on the potential availability of technologies at the individual manufacturer level and disregarding the cost impacts.

For passenger cars, the average required fuel economy in mpg for the industry would range from 38.6 mpg in MY 2011 to 52.6 mpg in MY 2015. For light trucks, the average required fuel economy for the industry would range from 25.9 mpg in MY 2011 to 34.7 mpg in MY 2015. The combined industry-wide average fuel economy for all passenger cars and light trucks would range from 31.1 mpg in MY 2011 to 41.4 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards. The annual average mpg increase during the period from MY 2011-2015 would be approximately 10.3 percent.

## 2.4 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

As a result of the scoping process, several suggestions were made to NHTSA regarding alternatives that should be included in this DEIS and examined in detail. NHTSA considered these alternatives and discusses them below along with the reasons why we believe these referenced alternatives do not warrant further analysis in this DEIS.

- **Downweighting Vehicles.** NHTSA was requested by commentators to consider as an alternative in the DEIS the potential for increased fuel economy by replacing heavy materials in passenger cars with lighter materials; a practice known as downweighting. As discussed in Chapter 1 and the NPRM, NHTSA's analysis does include the potential to improve fuel economy through greater utilization of lightweight materials on heavier vehicles for which doing so would be unlikely to compromise highway safety. Furthermore, this request relates to specific technology choices (which CAFE standards do not require) rather than regulatory alternatives. Consequently, this comment does not warrant an additional alternative analysis within the DEIS.

- **Least Capable Manufacturer Approach.** NHTSA's earlier Unreformed CAFE standards specified a "one size fits all" (uniform) level of CAFE that applied to each manufacturer and that was set with particular regard to the lowest projected level of CAFE among the manufacturers that have a significant share of the market. The major manufacturer with the lowest projected CAFE level is typically known as the "least capable" manufacturer. However, NHTSA's 2006 CAFE standards for light trucks adopted a different Reformed CAFE approach (71 *Federal Register* [FR] 17566, April 6, 2006). EISA recently codified that approach, requiring that all CAFE standards be based on one or more vehicle attributes (49 United States Code [U.S.C.] § 32902(b)(3)(A); 73 FR 24352, 24354-24355, May 2, 2008) (discussing NHTSA's proposal to base CAFE standards on the attribute of vehicle size, as defined by vehicle footprint).

  As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to the capabilities of a single manufacturer in order to ensure that the standards are technologically feasible and economically practicable for all manufacturers with a significant share of the market. This is true both fleet-wide and within any individual category of vehicles" (70 FR 51414, 51432, Aug. 30, 2005). Specifically:

> There is no need under Reformed CAFE to set the standards with particular regard to the capabilities of the "least capable" manufacturer. Indeed, it would often be difficult to identify which manufacturer should be deemed the "least capable" manufacturer under Reformed CAFE. The "least capable" manufacturer approach was simply a way of implementing the guidance in the conference report (part of EPCA's legislative history)[18] in the specific context of Unreformed CAFE….
>
> …The very structure of Reformed CAFE standards makes it unnecessary to continue to use that particular approach in order to be responsive to guidance in the conference report. Instead of specifying a common level of CAFE, a Reformed CAFE standard specifies a variable level of CAFE that changes based on the production mix of each manufacturer. By basing the level required for an individual manufacturer on that manufacturer's own mix, a Reformed CAFE standard in effect recognizes and accommodates differences in production mix between full- and part-line manufacturers, and between manufacturers that concentrate on small vehicles and those that concentrate on large ones.
>
> There is an additional reason for ceasing to use the "least capable" manufacturer approach. There would be relatively limited added fuel savings under Reformed CAFE if we continued to use the "least capable" manufacturer approach even though there ceased to be a need to use it…." (70 FR 51433).

In addition, the commenter's suggested approach would not result in the increases in fuel economy mandated by EISA – namely, 35 mpg by MY 2020. In light of the fact that Congress recently codified the Reformed CAFE approach for both passenger cars and light trucks, and for all of the reasons stated above, NHTSA declines to consider in detail an alternative tied to the historic "least capable manufacturer" approach as the commenter suggested.

- **More Aggressive or Accelerated Standards.** There were several scoping comments that requested NHTSA to set more aggressive standards along with a completion timeline earlier than 2020. This approach is not a new alternative based on the range of alternatives considered by NHTSA and as explained above in our discussion of the alternative analyses that we conducted.

  As proposed in the NPRM and this DEIS, NHTSA is considering the environmental impacts of several alternatives covering a range of stringency for model years 2011-2015. The preferred alternative identified in the NPRM increases at an average annual rate of 4.5 percent – a rate fast enough to, if extended through 2020, exceed the 35 mpg requirement established in EISA. The NPRM and this DEIS also include consideration of more stringent CAFE standards than those that would be established by the preferred alternative. The preferred results in the maximum difference between benefits and costs, or net benefits. Each of the other alternatives that would establish higher CAFE standards would result in larger fuel savings and emission reductions than those resulting from the preferred alternative. However, they would also result in lower net benefits than the preferred alternative due to

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[18] *See* 70 FR 51414, 51425-51426, Aug. 30, 2005 (discussing the conference report).

higher costs to society. As such, NHTSA is already considering accelerated fuel economy standards.

- **Different Economic Inputs to the Volpe Model.** Scoping comments suggested that NHTSA consider alternative scenarios developed by using other combinations of inputs into the Volpe model, such as varying assumptions about fuel prices, economic discount rates, and the projected benefits of greenhouse gas (GHG) emissions reductions (including assumptions about the "social cost" of carbon emissions), among other inputs. Again, NHTSA recognizes that hypothetically, there are an infinite number of alternative CAFE standards along a continuum, given the nature of fuel economy standards and EPCA's instruction that NHTSA weigh several factors in determining "maximum feasible" standards. NHTSA believes that its alternatives analysis captures a reasonable range for purposes of NEPA.

  As noted above, NHTSA presents the results of the sensitivity analyses in the PRIA for "high" and "low" values for several inputs to the Volpe model, including the "social cost" of carbon and fuel prices. To further inform its consideration of the potential environmental impacts of the proposed standards, NHTSA has also examined how the "high" and "low" values for these inputs affect carbon emission estimates. This analysis is presented in Chapter 3 of this DEIS.

As indicated in the PRIA, NHTSA examined a second optimized scenario that involved discounting benefits at 3 percent. As discussed in the NPRM, NHTSA believes that its use of a 7 percent discount rate is consistent with related Office of Management and Budget guidance and the fact that CAFE-related costs come at the expense of consumption (rather than investment), and is appropriate for purposes of estimating stringencies at which net benefits would be maximized. In the NPRM, NHTSA seeks comment on whether it should set standards based on discount rate assumptions of 3 percent, instead of 7 percent. The agency will revisit this issue in light of all related comments. Although the agency is not presenting results for an alternative developed using a 3 percent discount rate, the effects of such an alternative would, it is clear, fall between the Optimized (at 7 percent) and Technology Exhaustion alternatives.

## 2.5 COMPARISON OF ALTERNATIVES

The Council of Environmental Quality (CEQ) NEPA regulations (40 CFR Part 1500.2(e)) direct Federal agencies to use the NEPA process to identify and assess the reasonable alternatives to proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment. Analyses of alternatives are the heart of an EIS. CEQ regulations (40 CFR 1502.14) state:

> Based on the information and analysis presented in the sections on the Affected Environment (Sec. 1502.15) and the Environmental Consequences (Sec. 1502.16), it [an EIS] should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public.

Tables 2.5-1 through 2.5-11 and Figures 2.5-1 through 2.5-6 summarize the direct, indirect, and cumulative effects of the CAFE alternatives on energy, air quality, and climate. No quantifiable, alternative-specific effects were identified for the other resources discussed in Chapters 3 and 4. Please refer to the text in Chapters 3 and 4 for qualitative discussions of the potential direct and indirect effects of the alternatives on these other resources. Similarly, although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring, but only result in small reductions in the anticipated increases in $CO_2$ concentrations, temperature, precipitation, and sea level. As discussed below, NHTSA's presumption is that these reductions in climate effects will be reflected in reduced impacts on affected resources. The resources addressed in Chapter 4 of the DEIS include freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, and human heath. However, the magnitudes of the changes in these climate effects that the alternatives produce – a few parts per million (ppm) of $CO_2$, a hundredth of a degree celsius (C) difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2 millimeters (mm) of sea level – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions may be important – very small percentages of huge numbers can still yield significant results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change. Thus, there are no differences to report in this comparison of the alternatives.

## 2.5.1 Direct and Indirect Effects

### 2.5.1.1 Energy

Table 2.5-1 shows the impact on fuel consumption for passenger cars and light trucks from 2020 through 2050, a period in which an increasing volume of the fleet will be model year (MY) 2011-2015 passenger cars. The table shows total fuel consumption (both gasoline and diesel) under No Action Alternative and the six other alternative scenarios. Fuel consumption under the No Action Alternative is 256.9 billion gallons in 2060. Consumption falls to 228.5 billion gallons under the Optimized Alternative and would fall to 208.1 billion gallons under the Technology Exhaustion Alternative.

**TABLE 2.5-1**

**Comparison of Direct and Indirect Energy Consequences for Action Alternatives to the CAFE Standard for MY 2011 to MY 2015 and No Action Alternative**

| Years | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Passenger Cars and Light Trucks Fuel Consumption (billions of gallons) by Calendar Year** | | | | | | | |
| 2020 | 148.0 | 140.7 | 138.3 | 135.9 | 134.3 | 132.8 | 131.3 |
| 2030 | 176.8 | 163.0 | 158.5 | 153.9 | 150.9 | 148.2 | 145.3 |
| 2040 | 213.9 | 196.1 | 190.3 | 184.5 | 180.6 | 177.3 | 173.5 |
| 2050 | 256.9 | 235.5 | 228.5 | 221.5 | 216.7 | 212.5 | 208.1 |
| 2060 | 307.8 | 282.3 | 273.9 | 265.4 | 259.5 | 254.4 | 249.2 |

### 2.5.1.2 Air Quality

Table 2.5-2 summarizes the total national criteria and air toxic pollutant emissions in 2035 for the seven Alternatives, presented in left-to-right order of increasing fuel economy requirements. The No Action Alternative has the highest emissions of all the alternatives for all air pollutants except acrolein, which increases with the action alternatives because upstream emissions data were not available (emissions for acrolein reflect only increases due to the rebound effect). Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of the implementation of the CAFE standards under the Alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. Under the No Action alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect that would not need mitigation. Federal Highway Administration has funds dedicated to the reduction of air pollutants in nonattainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in nonattainment areas that would be observed under the proposed standard. Further, EPA has authority to continue to improve vehicle emissions standards.

### 2.5.1.3 Climate: GHG emissions

Table 2.5-3 shows total emissions and emission reductions from new passenger cars and light trucks from 2010-2100 for each of the seven alternatives. Compared to the No Action Alternative, projections of emission reductions over the 2010 to 2100 timeframe due to other MY 2011-2015 CAFE standard alternatives ranged from 18,333 to 35,378 million metric tons of carbon dioxide ($MMTCO_2$).[19] Over this period, this range of alternatives would reduce global $CO_2$ emissions by about 0.4 to 0.7 percent (based on global emissions of 4,850,000 $MMTCO_2$).

### 2.5.1.4 Climate: $CO_2$ Concentration and Global Mean Surface Temperature

Table 2.5-4 shows estimated $CO_2$ concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 for the No Action Alternative and the six action alternative CAFE levels. There is a fairly narrow band of estimated $CO_2$ concentrations as of 2100, from 705.4 ppm for Technology Exhaustion to 708.6 ppm for the No Action Alternative. As $CO_2$ concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish.

### 2.5.1.5 Climate: Global Mean Rainfall and Global Mean Surface Temperature

The CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, and thus reduce increases in precipitation slightly, as shown in Table 2.5-5. As shown in the table and figures, there is a fairly narrow band of estimated precipitation increase reductions as of 2090, from 4.30 percent to 4.32 percent, and there is very little difference between the alternatives.

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[19] The values here are summed from 2010 through 2100, and are thus considerably higher than the value of 520 $MMTCO_2$ that is cited in the NPRM for the "Optimized" alternative. The latter value is the reduction in $CO_2$ emissions by only model year 2011-15 cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the NPRM baseline of extending the CAFE standards for model year 2010 to apply to 2011-15.

## TABLE 2.5-2

## Comparison of Direct and Indirect Air Quality Consequences in Year 2035 for Action Alternatives to the CAFE Standard for MY 2011 to MY 2015 and No Action Alternative

| | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Carbon Monoxide (CO) | 26,446,292 | 26,158,046 | 26,044,977 | 24,159,436 | 23,111,813 | 22,362,860 | 21,927,726 |
| Nitrogen Oxides (NOx) | 2,720,799 | 2,590,414 | 2,547,317 | 2,340,656 | 2,222,744 | 2,136,859 | 2,080,801 |
| Particulate Matter (PM) | 583,318 | 568,326 | 564,238 | 524,529 | 500,769 | 483,889 | 473,062 |
| Sulfur Oxides (SOx) | 603,991 | 543,259 | 523,947 | 467,569 | 434,523 | 410,207 | 392,441 |
| Volatile Organic Compounds (VOC) | 2,477,999 | 2,399,287 | 2,372,905 | 2,203,377 | 2,105,993 | 2,034,852 | 1,990,799 |
| **Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Acetaldehyde | 14,354 | 14,198 | 14,137 | 13,360 | 12,931 | 12,622 | 12,447 |
| Acrolein | 663 | 676 | 677 | 677 | 685 | 690 | 696 |
| Benzene | 76,355 | 74,969 | 74,430 | 69,017 | 66,025 | 63,857 | 62,591 |
| 1,3-Butadiene | 8,062 | 7,991 | 7,949 | 7,463 | 7,216 | 7,038 | 6,941 |
| Diesel particulate Matter (DPM) | 265,474 | 238,004 | 229,040 | 205,151 | 191,609 | 181,604 | 174,200 |
| Formaldehyde | 19,851 | 19,486 | 19,356 | 18,628 | 18,241 | 17,963 | 17,798 |

**TABLE 2.5-3**

**Global Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard, from 2010-2100 (MMTCO$_2$)**

| Alternative | Emissions | Emission Reductions Compared to No-Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 229,558 | 18,333 |
| Optimized | 223,795 | 24,096 |
| 25 Percent Above Optimized | 221,003 | 26,887 |
| 50 Percent Above Optimized | 218,548 | 29,342 |
| Total Costs Equal Total Benefits | 215,714 | 32,176 |
| Technology Exhaustion | 212,512 | 35,378 |

**TABLE 2.5-4**

**MY 2011-2015 CAFE Alternatives Impact on CO$_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC**

| | CO$_2$ Concentration (ppm) | | | Global Mean Surface Temperature Increase ($^{o}$C) | | |
|---|---|---|---|---|---|---|
| | **2030** | **2060** | **2100** | **2030** | **2060** | **2100** |
| **Totals by Alternative** | | | | | | |
| No Action (A1B – AIM[20]) | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.3 | 574.4 | 706.9 | 0.788 | 1.835 | 2.757 |
| Optimized | 458.2 | 574.2 | 706.4 | 0.788 | 1.834 | 2.755 |
| 25 Percent Above Optimized | 458.2 | 574.1 | 706.1 | 0.788 | 1.833 | 2.754 |
| 50 Percent Above Optimized | 458.2 | 574.0 | 705.9 | 0.788 | 1.832 | 2.753 |
| Total Costs Equal Total Benefits | 458.1 | 573.9 | 705.6 | 0.788 | 1.832 | 2.752 |
| Technology Exhaustion | 458.1 | 573.7 | 705.4 | 0.788 | 1.831 | 2.751 |
| **Reduction from No Action** | | | | | | |
| 25 Percent Below Optimized | 0.1 | 0.8 | 1.7 | 0.001 | 0.002 | 0.006 |
| Optimized | 0.2 | 1.0 | 2.2 | 0.001 | 0.003 | 0.008 |
| 25 Percent Above Optimized | 0.2 | 1.1 | 2.5 | 0.001 | 0.004 | 0.009 |
| 50 Percent Above Optimized | 0.2 | 1.2 | 2.7 | 0.001 | 0.005 | 0.010 |
| Total Costs Equal Total Benefits | 0.3 | 1.3 | 3.0 | 0.001 | 0.005 | 0.011 |
| Technology Exhaustion | 0.3 | 1.5 | 3.2 | 0.001 | 0.006 | 0.012 |

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[20] The AIB-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B storyline.

**TABLE 2.5-5**

**MY 2011-2015 CAFE Alternatives: Impact on Reductions in Global Mean Precipitation based on A1B SRES Scenario (percent change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2020 | 2055 | 2090 |
|---|---|---|---|
| **Global mean rainfall change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature Above Average 1980-1999 Levels ($^{o}$C) for the A1B Scenario by 2100, Mid-level Results** | | | |
| No Action | 0.69 | 1.750 | 2.650 |
| 25 Percent Below Optimized | 0.690 | 1.747 | 2.645 |
| Optimized | 0.690 | 1.747 | 2.643 |
| 25 Percent Above Optimized | 0.690 | 1.746 | 2.642 |
| 50 Percent Above Optimized | 0.690 | 1.746 | 2.641 |
| Total Costs Equal Total Benefits | 0.690 | 1.745 | 2.640 |
| Technology Exhaustion | 0.690 | 1.745 | 2.639 |
| **Reduction in Global Temperature ($^{o}$C) for the A1B Scenario, Mid-level Results** | | | |
| 25 Percent Below Optimized | 0.000 | 0.003 | 0.005 |
| Optimized | 0.000 | 0.003 | 0.007 |
| 25 Percent Above Optimized | 0.000 | 0.004 | 0.008 |
| 50 Percent Above Optimized | 0.000 | 0.004 | 0.009 |
| Total Costs Equal Total Benefits | 0.000 | 0.005 | 0.010 |
| Technology Exhaustion | 0.000 | 0.005 | 0.011 |
| **Mid level Global Mean Precipitation Change (%)** | | | |
| No Action | 1.00 | 2.64 | 4.32 |
| 25 Percent Below Optimized | 1.00 | 2.64 | 4.31 |
| Optimized | 1.00 | 2.64 | 4.31 |
| 25 Percent Above Optimized | 1.00 | 2.64 | 4.31 |
| 50 Percent Above Optimized | 1.00 | 2.64 | 4.30 |
| Total Costs Equal Total Benefits | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion | 1.00 | 2.63 | 4.30 |
| **Reduction in Global Mean Precipitation (%)** | | | |
| 25 Percent Below Optimized | 0.00 | 0.00 | 0.01 |
| Optimized | 0.00 | 0.00 | 0.01 |
| 25 Percent Above Optimized | 0.00 | 0.01 | 0.01 |
| 50 Percent Above Optimized | 0.00 | 0.01 | 0.0 |
| Total Costs Equal Total Benefits | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion | 0.00 | 0.01 | 0.02 |

### 2.5.1.6 Climate: Impact on Sea Level Rise

Table 2.5-6 shows that the impact on sea level rise from the scenarios is at the threshold of the MAGICC model's reporting abilities: the alternatives reduce sea level rise by 0.1 cm. Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above), and the lower the sea level.

**TABLE 2.5-6**

**MY 2011-2015 CAFE Alternatives: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level (cm) |
|---|---|
| No Action | 37.9 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.8 |
| Total Costs Equal Total Benefits | 37.8 |
| Total Exhaustion | 37.8 |
| **Reduction in Sea Level Rise (% compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.1 |
| Total Exhaustion | 0.1 |

## 2.5.2 Cumulative Effects

### 2.5.2.1 Energy

The seven alternatives examined for CAFE standards will result in different future levels of fuel use, total energy, and petroleum consumption, which will in turn have an impact on emissions of greenhouse gas (GHG) and criteria air pollutants. Figure 2.5-1 shows the estimated lifetime fuel consumption of passenger cars and light trucks under the various CAFE standards. Figure 2.5-2 shows the savings in lifetime fuel consumption for passenger cars and light trucks depending on the CAFE alternative examined.

**Figure 2.5-1 Lifetime Fuel Consumption of Passenger Cars and Light Trucks under Alternative CAFE Standards**

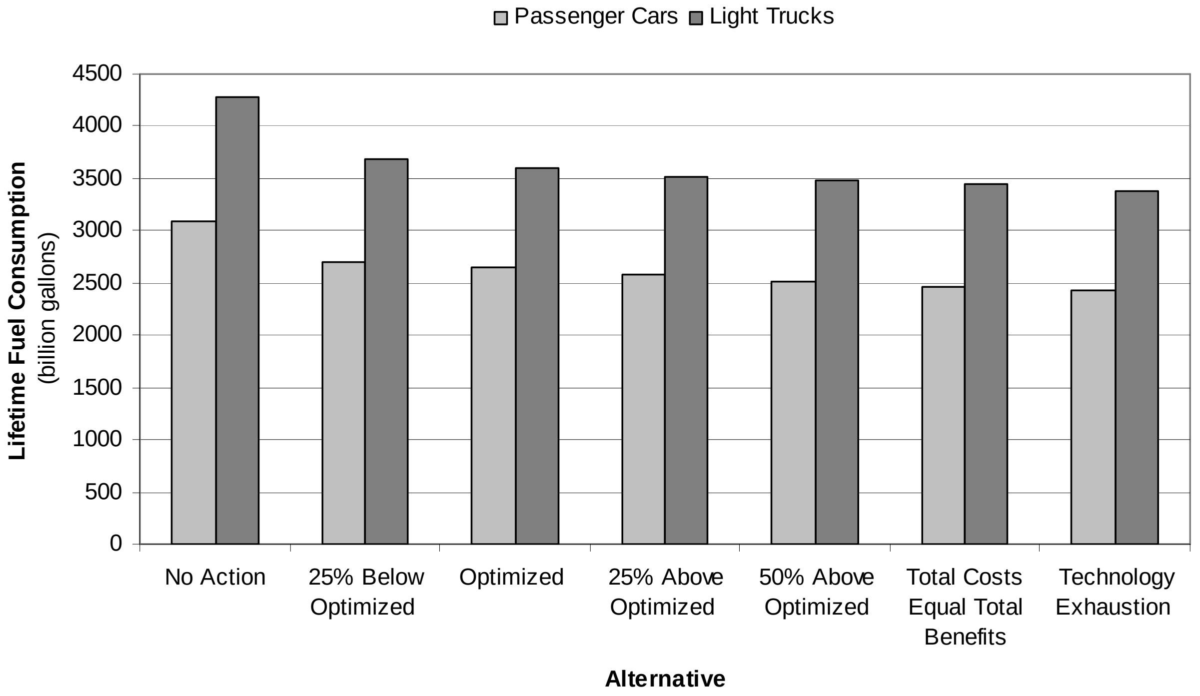
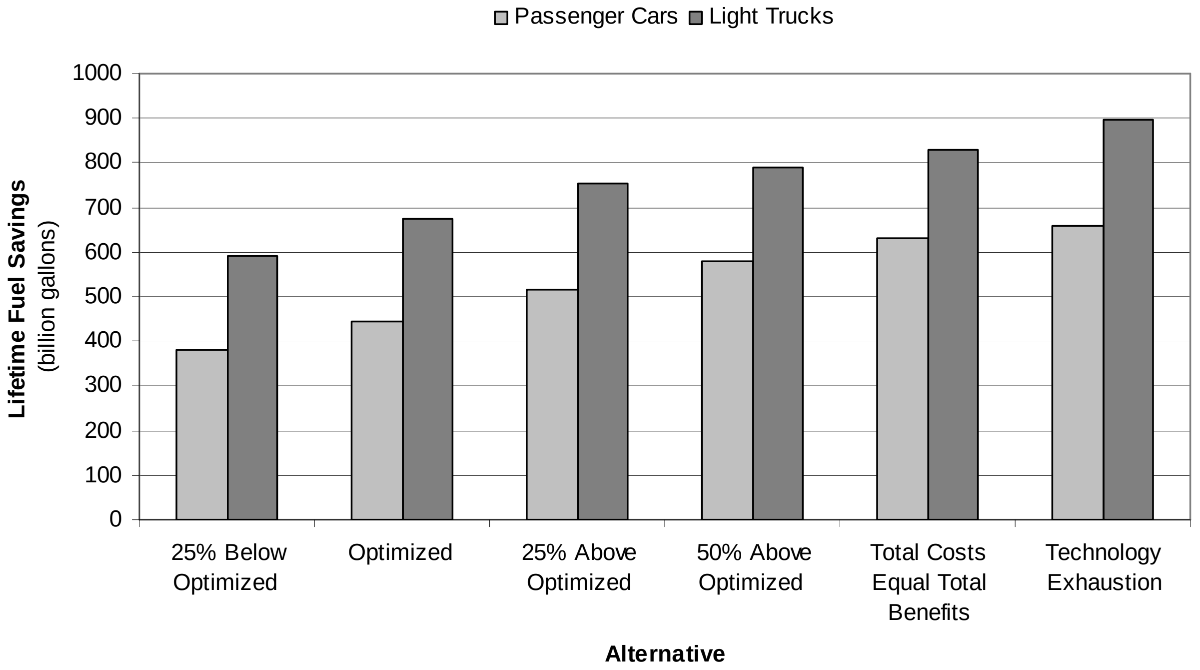


**Figure 2.5-2 Savings in Lifetime Fuel Consumption by Passenger Cars and Light Trucks under Alternative CAFE Standards**



### 2.5.2.2 Air Quality

Table 2.5-7 summarizes the cumulative national toxic and criteria pollutants, showing the No Action Alternative has the highest emissions of all the alternatives for all pollutants except acrolein, which increases with the action alternatives because upstream emissions data were not available (emissions for acrolein reflect only increases due to the rebound effect). Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas as a result of implementation of the CAFE standards under the Alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. Under the No Action alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect that would not need mitigation. Federal Highway Administration has funds dedicated to the reduction of air pollutants in non-attainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in nonattainment areas that would be observed under the proposed standard. Further, EPA has authority to continue to improve vehicle emissions standards.

### 2.5.2.3 Climate: Cumulative GHG Emissions

Total emission reductions from 2010-2100 new passenger cars and light trucks from for each of the seven alternatives are shown below in Table 2.5-8. Projections of emission reductions over the 2010 to 2100 timeframe due to the MY 2011-2020 CAFE standard ranged from 38,294 to 53,365 $MMTCO_2$. Compared against global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the IPCC A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global $CO_2$ emissions by about 0.8 to 1.1 percent.

### 2.5.2.4 Climate: $CO_2$ Concentration and Global Mean Surface Temperature

The mid-range results of MAGICC model simulations for the No Action Alternative and the six alternative CAFE levels, in terms of CO2 concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table 2.5-9 and Figures 2.5-3 to 2.5-6. As Figures 2.5-3 and 2.5-4 show, the impact on the growth in CO2 concentrations and temperature is just a fraction of the total growth in CO2 concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both CO2 concentrations and temperature in the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures 2.5-5 to 2.5-6.

As shown in the table and figures, there is a fairly narrow band of estimated CO2 concentrations as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. As CO2 concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global surface air temperature increases are also shown below in Table 2.5-9. For all alternatives, the temperature increase is about 0.8°C as of 2030, 1.8°C as of 2060, and 2.8°C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.012°C to 0.018°C. These estimates include considerable uncertainty due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid-point of 3.0 degrees C which directly relates to the uncertainty in the estimated global mean surface temperature.

## TABLE 2.5-7

### Comparison of Cumulative Air Quality Consequences for Six Action Alternatives to the CAFE Standard for MY 2011 to MY 2020 and No Action Alternative

| | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **Criteria Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Carbon Monoxide (CO) | 26,446,292 | 26,392,554 | 25,928,187 | 22,327,626 | 20,563,462 | 19,584,601 | 18,665,921 |
| Nitrogen Oxides (NOx) | 2,720,799 | 2,508,200 | 2,437,802 | 2,093,950 | 1,921,291 | 1,822,258 | 1,730,923 |
| Particulate Matter (PM) | 583,318 | 565,632 | 554,564 | 481,268 | 441,564 | 419,680 | 398,490 |
| Sulfur Oxides (SOx) | 603,991 | 493,989 | 469,439 | 385,825 | 342,328 | 316,867 | 292,926 |
| Volatile Organic Compounds (VOC) | 2,477,999 | 2,362,124 | 2,311,540 | 2,022,160 | 1,874,970 | 1,790,100 | 1,713,463 |
| **Toxic Air Pollutant Emissions (tons/year) for Passenger Cars and Light Trucks (Calendar Year 2035)** | | | | | | | |
| Acetaldehyde | 14,354 | 14,252 | 14,063 | 12,646 | 11,959 | 11,573 | 11,225 |
| Acrolein | 663 | 687 | 688 | 687 | 702 | 712 | 722 |
| Benzene | 76,355 | 74,938 | 73,498 | 63,637 | 58,866 | 56,161 | 53,696 |
| 1,3-Butadiene | 8,062 | 8,034 | 7,911 | 7,008 | 6,619 | 6,400 | 6,204 |
| Diesel particulate Matter (DPM) | 265,474 | 214,961 | 204,045 | 169,501 | 152,605 | 142,653 | 133,315 |
| Formaldehyde | 19,851 | 19,312 | 19,098 | 17,904 | 17,363 | 17,060 | 16,796 |

**TABLE 2.5-8**

**$CO_2$ Emissions and Emission Reductions (Compared to the No Action Alternative) Due to the MY 2011-2015 CAFÉ standard and potential MY 2016-2020 CAFE Standards, from 2010-2100 ($MMTCO_2$)**

| Alternative | Emissions | Emission Reductions Compared to No Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 209,596 | 38,294 |
| Optimized | 204,487 | 43,403 |
| 25 Percent Above Optimized | 202,075 | 45,815 |
| 50 Percent Above Optimized | 199,933 | 47,958 |
| Total Costs Equal Total Benefits | 197,434 | 50,456 |
| Technology Exhaustion | 194,525 | 53,365 |

**TABLE 2.5-9**

**MY 2011-2015 CAFE Standard and Potential MY 2016-2020 CAFE Alternatives Impact on $CO_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC**

| | $CO_2$ Concentration (ppm) | | | Global Mean Surface Temperature Increase ($^oC$) | | |
|---|---|---|---|---|---|---|
| | 2030 | 2060 | 2100 | 2030 | 2060 | 2100 |
| **Totals by Alternative** | | | | | | |
| No Action (A1B – AIM) a/ | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.2 | 573.7 | 705.1 | 0.788 | 1.832 | 2.751 |
| Optimized | 458.1 | 573.4 | 704.6 | 0.788 | 1.831 | 2.749 |
| 25 Percent Above Optimized | 458.1 | 573.3 | 704.4 | 0.788 | 1.83 | 2.748 |
| 50 Percent Above Optimized | 458.1 | 573.3 | 704.2 | 0.787 | 1.829 | 2.747 |
| Total Costs Equal Total Benefits | 458.0 | 573.2 | 703.9 | 0.787 | 1.829 | 2.746 |
| Technology Exhaustion | 458.0 | 573.0 | 703.7 | 0.787 | 1.828 | 2.745 |
| **Reduction from No Action Alternative** | | | | | | |
| 25 Percent Below Optimized | 0.2 | 1.5 | 3.5 | 0.001 | 0.005 | 0.012 |
| Optimized | 0.3 | 1.8 | 4 | 0.001 | 0.006 | 0.014 |
| 25 Percent Above Optimized | 0.3 | 1.9 | 4.2 | 0.001 | 0.007 | 0.015 |
| 50 Percent Above Optimized | 0.3 | 1.9 | 4.4 | 0.002 | 0.008 | 0.016 |
| Total Costs Equal Total Benefits | 0.4 | 2.0 | 4.7 | 0.002 | 0.008 | 0.017 |
| Technology Exhaustion | 0.4 | 2.2 | 4.9 | 0.002 | 0.009 | 0.018 |

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a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

Figure 2.5-3 CO2 Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020

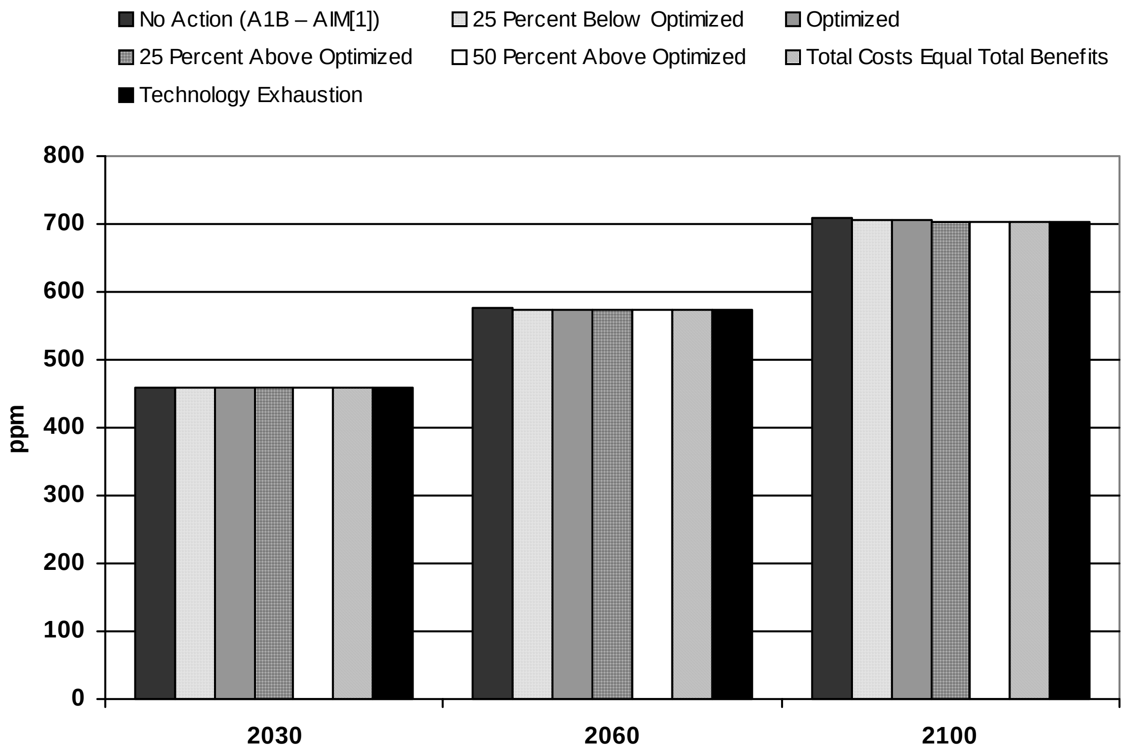


Figure 2.5-4 Increase in Global Mean Surface Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020

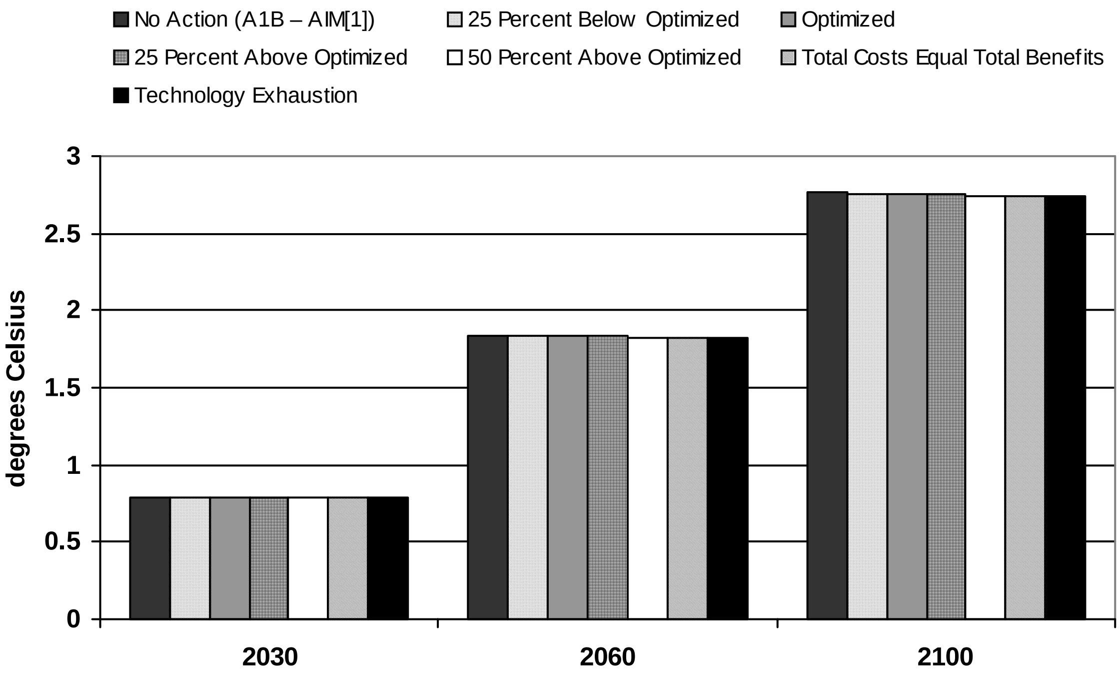


**Figure 2.5-5 Reduction in the Growth of $CO_2$ Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020**

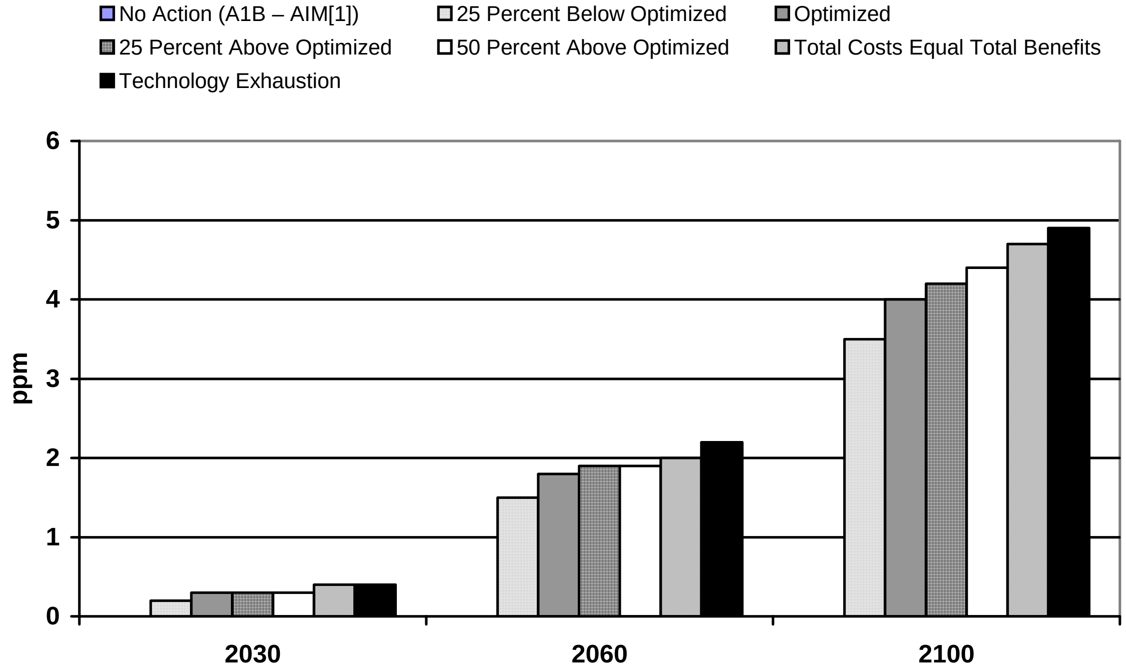
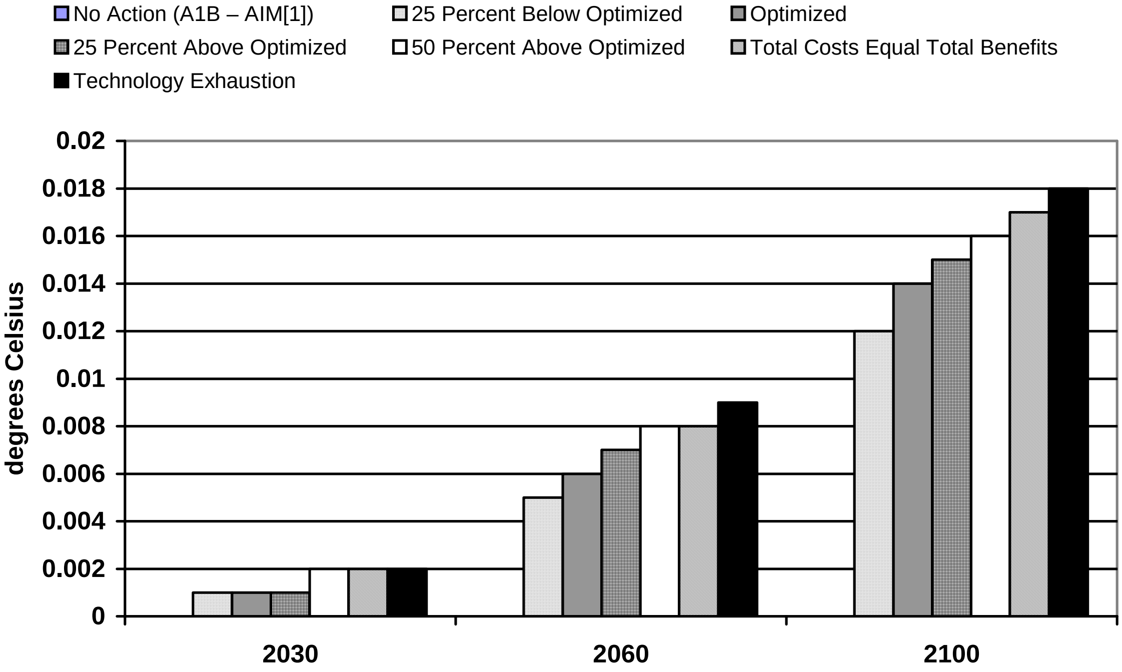


**Figure 2.5-6 Reduction in the Growth of Global Mean Temperature for the A1B Scenario MY 2011-2015 Standard and Potential MY 2016-2020**



To supplement the modeled estimates (generated by applying MAGICC) in Table S-11, a scaling approach was used to (1) validate that the modeled estimates are consistent with recent IPCC AR4 estimates and (2) characterize the sensitivity of the CO2 and temperature estimates to different assumptions about (a) global emissions from sources other than United States passenger cars and light trucks and (b) climate sensitivity (i.e., the equilibrium warming associated with a doubling of atmospheric CO2 concentrations compared to pre-industrial levels). The scaling analysis showed that the results for CO2 concentration and temperature are in good agreement with recent estimates from IPCC AR4. The analysis also indicates that the estimates for CO2 concentrations and global mean surface temperature vary considerably, depending on which global emissions scenario is used as a reference case. Furthermore, temperature increases are sensitive to climate sensitivity. Regardless of the choice of reference case or climate sensitivity, the differences among CAFE alternatives are small: CO2 concentrations as of 2100 are within 4 ppm across alternatives, and temperatures are within 0.03°C across alternatives (consistent with the MAGICC modeling results). The scaling results illustrate the uncertainty in CO2 concentrations and temperatures related to reference case global emissions and climate sensitivity.

### 2.5.2.5 Climate: Global Mean Rainfall and Global Mean Surface Temperature

The CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, thus they also reduce predicted increases in precipitation slightly, as shown in Table 2.5-10. As shown in the table and figures, there is a fairly narrow band of estimated precipitation increase reductions as of 2100, from 4.29 percent to 4.32 percent, and there is very little difference between the alternatives.

**TABLE 2.5-10**

**MY 2011-2020 CAFE Alternatives: Impact on Reductions in Global Mean Rainfall based on A1B SRES Scenario (% change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2011–2030/2020 | 2046–2065/2055 | 2080–2099/2090 |
|---|---|---|---|
| **Global mean rainfall change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature above average 1980-1999 levels (°C) for the A1B scenario by 2100, mid-level results** | | | |
| No Action | 0.69 | 1.75 | 2.65 |
| 25 Percent Below Optimized | 0.690 | 1.745 | 2.639 |
| Optimized | 0.690 | 1.744 | 2.638 |
| 25 Percent Above Optimized | 0.690 | 1.744 | 2.636 |
| 50 Percent Above Optimized | 0.690 | 1.743 | 2.636 |
| Total Costs Equal Total Benefits | 0.690 | 1.743 | 2.635 |
| Technology Exhaustion | 0.690 | 1.742 | 2.634 |
| **Reduction in Global Temperature (°C) for the A1B scenario, mid-level results** | | | |
| 25 Percent Below Optimized | 0.000 | 0.005 | 0.011 |
| Optimized | 0.000 | 0.006 | 0.012 |
| 25 Percent Above Optimized | 0.000 | 0.006 | 0.014 |
| 50 Percent Above Optimized | 0.000 | 0.007 | 0.014 |
| Total Costs Equal Total Benefits | 0.000 | 0.007 | 0.015 |
| Technology Exhaustion | 0.000 | 0.008 | 0.016 |

**TABLE 2.5-10 (cont'd)**

**MY 2011- 2015 Standard and Potential 2016-2020 CAFE Standard: Impact on Reductions in Global Mean Rainfall based on A1B SRES Scenario (% change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2011–2030/2020 | 2046–2065/2055 | 2080–2099/2090 |
|---|---|---|---|
| **Mid Level Global Mean Rain Fall Change by 2100 (%)** | | | |
| 25 Percent Below Optimized | 1.00 | 2.64 | 4.32 |
| Optimized | 1.00 | 2.63 | 4.30 |
| 25 Percent Above Optimized | 1.00 | 2.63 | 4.30 |
| 50 Percent Above Optimized | 1.00 | 2.63 | 4.30 |
| Total Costs Equal Total Benefits | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion | 1.00 | 2.63 | 4.30 |
| 25 Percent Below Optimized | 1.00 | 2.63 | 4.29 |
| **Reduction in Global Mean RainFall (%)** | | | |
| 25 Percent Below Optimized | 0.00 | 0.01 | 0.02 |
| Optimized | 0.00 | 0.01 | 0.02 |
| 25 Percent Above Optimized | 0.00 | 0.01 | 0.02 |
| 50 Percent Above Optimized | 0.00 | 0.01 | 0.02 |
| Total Costs Equal Total Benefits | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion | 0.00 | 0.01 | 0.03 |

### 2.5.2.6 Climate: Impact on Sea Level Rise

The impact on sea level rise from the alternatives is near the threshold of the MAGICC model's reporting capabilities: the alternatives reduce sea level rise by 0.1 to 0.2 cm (Table 2.5-11). Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above); and the lower the temperature, the lower the sea level. Thus, the more stringent alternatives are likely to result in slightly less sea level rise.

**TABLE 2.5-11**

**MY 2011- 2015 Standard and Potential 2016-2020 CAFE Standard: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level (cm) |
|---|---|
| Baseline | 37.9 |
| No Action | 37.8 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.7 |
| Total Costs Equal Total Benefits | 37.7 |

**TABLE 2.5-11 (cont'd)**

**MY 2011- 2015 Standard and Potential 2016-2020 CAFE Standard: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level (cm) |
|---|---|
| **Reduction in Sea Level Rise for the CAFE alternatives (% compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.2 |
| Technology Exhaustion | 0.2 |

# Chapter 3 Affected Environment and Consequences

## 3.1 INTRODUCTION

The regulations for implementing the National Environmental Policy Act (NEPA) suggest a standard format for an environmental impact statement that includes a section on affected environment and a section on environmental consequences. In this Draft Environmental Impact Statement (DEIS), the National Highway Traffic Safety Administration (NHTSA) combined these sections under the heading for each resource area – energy, air quality, climate, and various other potentially impacted resource areas listed in Section 3.5. This structure allows the reader to learn about the existing conditions of the resource followed by an analysis of the effect on the resource. Each section has subheadings identifying the discussion of affected environment and consequences, respectively, for the reader.

| Typical NEPA Topics | DEIS Subsections |
|---|---|
| Water | 3.4 Climate; 3.5.1 Water Resources |
| Ecosystems | 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources |
| Publicly Owned Parklands, Recreational Areas, Wildlife, and Waterfowl Refuges, and Historic Sites, 4(f) related issues. | 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources |
| Properties and Sites of Historic and Cultural Significance | 3.4 Climate; 3.5.3 Land Use and Development; 3.5.6 Land Uses Protected under Section 4(f); 3.5.7 Historic and Cultural Resources |
| Considerations Relating to Pedestrians and Bicyclists | 3.4 Climate; 3.5.3 Land Use and Development |
| Social Impacts | 3.2 Energy; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.9 Environmental Justice |
| Noise | 3.4 Climate; 3.5.3 Land Use and Development; 3.5.8 Noise |
| Air | 3.2 Energy; 3.3 Air Quality; 3.4 Climate |
| Energy Supply and Natural Resource Development | 3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development |
| Floodplain Management Evaluation | 3.4 Climate; 3.5.1 Water Resources |
| Wetlands or Coastal Zones | 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources |
| Construction Impacts | 3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development |
| Land Use and Urban Growth | 3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.1 Water Resources; 3.5.2 Biological Resources; 3.5.3 Land Use and Development |
| Human Environment involving Community Disruption and Relocation | 3.2 Energy; 3.3 Air Quality; 3.4 Climate; 3.5.3 Land Use and Development; 3.5.4 Safety and Other Human Health Impacts; 3.5.5 Hazardous Materials and Regulated Wastes; 3.5.9 Environmental Justice; |

### 3.1.1 Direct and Indirect Effects

The Council on Environmental Quality (CEQ) regulations state that an EIS "shall succinctly describe" the environment to be affected by the alternatives under consideration and to provide data and analyses "commensurate with the importance of the impact[s]" (40 Code of Federal Regulations [CFR] § 1502.15 and § 1502.16). Chapter 3 provides the analysis to determine and compare the significance of the direct and indirect effects of the proposed action and alternatives. Under NEPA, direct effects "are caused by the action and occur at the same time and place" (40 CFR §1508.8). CEQ regulations define indirect effects as those that "are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include … effects on air and water and other natural systems, including ecosystems" (40 CFR §1508.8). Sections 3.2, 3.3, and 3.4 provide a quantitative analysis for the direct and indirect effects of the proposed action on energy, air, and climate, respectively. Impacts to other resource areas typically found in an environmental impact statement, and the areas required by DOT order 5610 such as biological resources, water resources, noise, land use, environmental justice, etc., are described qualitatively in Section 3.5 because sufficient data was not available in the literature for a quantitative analysis, and because many of these effects are not localized. In this DEIS such qualitative analysis is sufficient for NEPA purposes.[1]

### 3.1.2 Areas not Affected

DOT's NEPA Procedures[2] describe various areas that should be considered in an EIS. Many of these areas are covered in the sections and subsections below. NHTSA has considered the proposed action and alternatives impact to all of the areas outlined by the Procedures and have determined the following are not directly or indirectly affected by this action: human environment including disruption and relocation; considerations relating to pedestrians and bicyclists; floodplain management; and construction impacts. Some of these areas are affected by the cumulative effect of this action with other foreseeable actions. Section 4.1 provides a reference of where to find the cumulative effects discussion of these and other topics.

### 3.1.3 Approach to Science Uncertainty and Incomplete Information

#### 3.1.3.1 CEQ Regulations

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

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[1] Department of Transportation Order Number 5610.1C, dated September 18, 1979 and entitled, Procedures For Considering Environmental Impacts.

[2] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited June 20, 2008) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

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

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

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

4) The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.

40 CFR § 1502.22(b). Relying on these provisions is appropriate where an agency is performing a NEPA analysis that involves potential environmental impacts due to carbon dioxide ($CO_2$) emissions. *See*, *e.g.*, *Mayo Found v. Surface Transp. Bd.*, 472 F.3d 545, 555 (8th Cir. 2006). The CEQ regulations also authorize agencies to incorporate material into a NEPA document by reference in order to "cut down on bulk without impeding agency and public review of the action." 40 CFR § 1502.21.

Throughout this DEIS, NHTSA uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas where NHTSA is unable to estimate precisely the potential environmental impacts of the proposed standards or reasonable alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of $CO_2$ and other greenhouse gases (GHG) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. NHTSA often relies on the IPCC's 2007 Fourth Assessment Report as a recent "summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment." *See* 40 CFR § 1502.22(b)(3).

#### 3.1.3.2 Uncertainty with the IPCC Framework

The IPCC Reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This is briefly explained in the IPCC 4th Assessment Synthesis Report[3] and the IPCC 4th Assessment Report Summary for Policy Makers.[4] A more detailed discussion of the IPCC's treatment of uncertainty can be found in the IPCC's Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties.[5]

The DEIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and 4, when discussing qualitative environmental impacts on certain resources. The reader should refer to the documents referenced above to gain a full understanding of the meaning of those uncertainty terms, as they may be separate from the meaning of language describing uncertainty in the DEIS as required by the CEQ regulations discussed above.

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[3] IPCC, 2007: Synthesis Report, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf .

[4] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf .

[5] IPCC, Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-uncertaintyguidancenote.pdf .

### 3.1.4 Common Methodologies

The CAFE Compliance and Effects Modeling System (referred to herein as the Volpe model) is a peer-reviewed modeling system developed by the Department of Transportation's Volpe National Transportation Systems Center (Volpe Center). The Volpe model serves two fundamental purposes: (1) identifying technologies each manufacturer could apply in order to comply with a specified set of CAFE standards, and (2) calculating the costs and effects of manufacturers' application of technologies—including changes in fuel use and therefore $CO_2$ emissions. The Volpe model provided data that was used for the analysis of energy, air, and climate impacts.

The Volpe model begins with an initial state of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the proposed rule. The vehicle market is defined on a model-by-model, engine-by-engine, and transmission-by-transmission basis, such that each defined vehicle model refers to a separately defined engine and a separately-defined transmission.

For the model years covered by the current proposal, the light vehicle (passenger car and light truck) market forecast included more than 3,000 vehicle models, more than 400 specific engines, and nearly 400 specific transmissions. This level of detail in the representation of the vehicle market is vital to an accurate analysis of manufacturer-specific costs and the analysis of reformed CAFE standards, and is much greater than the level of detail used by many other models and analyses relevant to light vehicle fuel economy.[6]

The Volpe model also uses several additional categories of data and estimates provided in various external input files for all vehicle categories (small, mid-size, and large sport utility vehicles [SUVs]; small and large pickups; minivans; sub-compact, compact, midsize, and large cars) including:

- Fuel-saving technology characteristics:
    i. commercialization year;
    ii. effectiveness and cost;
    iii. "learning effect" cost coefficients;
    iv. "technology path" inclusion/exclusion;
    v. "phase in caps" on penetration rates; and
    vi. "synergy" options.
- Vehicular emission rates, carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), particulate matter (PM), and sulfur dioxide ($SO_2$) for vehicular travel (i.e., vehicle-miles traveled or VMT).
- Economic and other data and estimates:
    i. vehicle survival (i.e., percent of vehicles of a given vintage that remain in service);
    ii. mileage accumulation (i.e., annual travel by vehicles of a given vintage);

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[6] Because CAFE standards apply to the average performance of each manufacturer's fleet of cars and light trucks, the impact of potential standards on individual manufacturers cannot be credibly estimated without analysis of manufacturers' planned fleets. Furthermore, because required CAFE levels under an attribute-based CAFE standard depend on manufacturers' fleet composition, the stringency of an attribute-based standard cannot be predicted without performing analysis at this level of detail.

    iii. price/fuel taxation rates for seven fuels (e.g., gasoline, diesel);
    iv. pump prices (i.e., including taxes) for vehicle fuel savings/retail price;
    v. rebound effect coefficient (i.e., the elasticity of VMT with respect to per-mile cost of fuel);
    vi. discount rate; "payback period" (i.e., the number of years purchasers consider when taking into account fuel savings);
    vii. fuel economy "gap" (e.g., laboratory versus actual);
    viii. per-vehicle value of travel time (in dollars per hour);
    ix. the economic costs (in dollars per gallon) of petroleum consumption;
    x. various external costs (all in dollars per mile) associated with changes in vehicle use;
    xi. damage costs (all on a dollar per ton basis) for each of the above-mentioned criteria pollutants; and
    xii. noncompliance civil penalties rate.

- Properties of different fuels:
    i. upstream $CO_2$ and criteria pollutant emission rates (i.e., United States emissions resulting from the production and distribution of each fuel);
    ii. density (pounds/gallon); energy density (British thermal unit [BTU]/gallon);
    iii. carbon content;
    iv. shares of fuel savings leading to reduced domestic refining; and
    v. relative shares of different gasoline blends.
- Sensitivity analysis coefficients; high and low fuel price forecasts.
- CAFE scenarios:
    i. baseline (i.e., business-as-usual) scenario; and
    ii. alternative scenarios defining coverage, structure, and stringency of CAFE standards.

With all of the above input data and estimates, the modeling system develops an estimate of a set of technologies each manufacturer could apply in response to each specified CAFE scenario.

The modeling system begins with the "initial state" (i.e., business as usual) of each manufacturer's future vehicles, and accumulates the estimated costs of progressive additions of fuel-saving technologies. Within a set of specified constraints, the system adds technologies following a cost-minimizing approach. At each step, the system evaluates the effective cost of applying available technologies to individual vehicle models, engines, or transmissions, and selects the application of technology that produces the lowest effective cost. The effective cost estimated to be considered by the manufacturer is calculated by adding the total incurred technology costs (in retail price equivalent or RPE), subtracting the reduction in civil penalties owed for noncompliance with the CAFE standard, subtracting the estimated value of the reduction in fuel costs, and dividing the result by the number of affected vehicles.

In representing manufacturer decision-making in response to a given CAFE standard, the modeling system accounts for the fact that historically some manufacturers have been unwilling to pay penalties and some have been willing to do so. Thus, the system applies technologies until any of the following conditions are met: the manufacturer no longer owes civil penalties for failing to meet the applicable standard, the manufacturer has exhausted technologies expected to be available in that model year, or the manufacturer is estimated to be willing to pay civil penalties, and doing so is estimated to be less expensive than continuing to add technologies.

The system then progresses to the next model year (if included in the vehicle market and scenario input files), "carrying over" technologies where vehicle models are projected to be succeeded by other vehicle models. The Volpe model does not attempt to account for CAFE credits or intentional over-compliance (i.e., achieving an average fuel economy higher than that required by law); or the "pull ahead" application of technologies.[7]

The Volpe model completes this compliance simulation for all manufacturers and all model years, and produces various outputs from the effects of changes in fuel economy. The outputs include:

- Total cost of all applied technologies.
- Year-by-year mileage accumulation—including rebound effect.
- Year-by-year fuel consumption.
- $CO_2$ and criteria pollutants—domestic full fuel-cycle emissions[8], monetary damages.
- Total discounted/undiscounted national societal costs of year-to-year fuel consumption.
- Additional travel—consumer surplus.[9]
- Economic externalities—congestion, accidents, noise.
- Value of time saved.
- Total discounted/undiscounted societal benefits—including net social benefits, and benefit-cost ratio.[10]

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[7] Manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards that they know will be steadily increasing over time. For example, if a manufacturer plans to redesign many vehicles in MY 2011 and not in MY 2013, but the standard for MY 2013 is considerably higher than that for MY 2011, the manufacturer might find it less expensive during MY 2011 through MY 2013 (taken together) to apply more technology in MY 2011 than is necessary for compliance with the MY 2011 standard.

[8] Domestic full fuel-cycle emissions include the emissions associate with production, transportation, and refining operations, as well as the carbon dioxide emissions from fuel combustion.

[9] Consumer surplus measures the net benefits that drivers receive from additional travel, and refers to the amount by which the benefits from additional travel exceed its costs (for fuel and other operating expenses).

## 3.2 ENERGY

Over the past decade and a half energy intensity in the United States (energy use per dollar of gross domestic product) has declined at about 2 percent per year.[11] Despite the growth in population and the economy, energy intensity has fallen due to a combination of increased efficiency and a structural shift in the economy to less energy intensive industries. Nevertheless, transportation fuel consumption has grown steadily and is the major component of the use of petroleum.

### 3.2.1 Affected Environment

Table 3.2-1 shows United States and global energy consumption by sector from the Energy Information Administration (EIA) which collects and provides the official energy statistics for the United States and whose data are the primary source for analysis and modeling of energy systems by government and private entities. Actual consumption data show a steady increase in the United States in most of the sectors, particularly the transportation sector. By 2004 transportation was the second highest after industrial use and comprised 27.8 and 17.3 percent of the United States and global (less United States) energy use respectively.

Projections by the EIA show a steady increase in both the United States and global transportation energy consumption.[12] Despite efforts to increase the use of non-fossil fuels in transportation, fuel use remains largely petroleum based. In 2007, United States consumption of finished motor gasoline and on-road diesel constituted 66 percent of all finished petroleum products consumed in the United States. If other transportation fuels (aviation fuels, marine and locomotive diesel, and bunkers) are added in, transportation fuels constitute approximately 79 percent of the finished petroleum products used.

Most United States gasoline and diesel is produced domestically.[13] In 2007, 4 percent of finished motor gasoline and 6 percent of on-road diesel was imported. However, increasing volumes of crude oil are imported for processing in United States refineries as indigenous production is declining steadily. By 2006, petroleum imports equaled 60 percent of total liquids supplied and by 2007 crude oil imports had surpassed 10,000 barrels per day[14].

A fall in the demand for transportation fuels most likely will affect the import of crude oil more than motor gasoline. Over the last decade there has been a shift in product imports with volumes of finished gasoline stabilizing and slightly declining. However, volumes of motor gasoline blending components have been rapidly increasing so that by 2007 the imports of blending components were twice that of finished gasoline.

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[10] Energy Information Administration, *Annual Energy Outlook*, 2008, Revised Reference Case.

[11] Energy Information Administration, *Annual Energy Outlook*, 2008, Revised Reference Case.

[12] The Energy Information Administration (EIA) provides the official energy statistics from the United States government and collects information on all aspects of energy production, transport, and use in the United States and Globally. This information is provided in annual reports with regular monthly, and in some cases more frequent, updates and except for some areas where private entities provide statistics in the only source of data on United States energy or provides the basis for other sources such as the International Energy Agency. The data provided by the EIA is used by government agencies, independent analysts, and other governments for analysis and modeling.

[13] Based on EIA petroleum supply and disposition data, http://tonto.eia.doe.gov/dnav/pet/pet_sum_snd_d_nus_mbblpd_a_cur.htm.

[14] Based on EIA petroleum supply and disposition data, http://tonto.eia.doe.gov/dnav/pet/pet_sum_snd_d_nus_mbblpd_a_cur.htm.

**TABLE 3.2-1**

**Energy Consumption By Sector**

| Sector (Quadrillion Btu) | Actual a/ | | | | Forecasted b/ | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2004 | 2010 | 2015 | 2020 | 2025 | 2030 |
| **United States** | | | | | | | | | |
| Residential | 17.0 | 18.6 | 20.5 | 21.2 | 22.2 | 22.6 | 23.4 | 24.2 | 25.0 |
| Commercial | 13.3 | 14.7 | 17.2 | 17.7 | 18.7 | 20.3 | 22.0 | 23.5 | 25.0 |
| Industrial | 31.9 | 34.0 | 34.8 | 33.6 | 33.3 | 33.9 | 34.3 | 34.9 | 35.0 |
| Transportation | 22.4 | 23.8 | 26.6 | 27.9 | 29.0 | 30.4 | 31.2 | 31.9 | 33.0 |
| Total | 84.7 | 91.2 | 99.0 | 100.4 | 103.3 | 107.3 | 110.8 | 114.5 | 118.0 |
| Transportation (%) | 26.5 | 26.2 | 26.8 | 27.8 | 28.1 | 28.4 | 28.2 | 27.9 | 28.0 |
| **World** | | | | | | | | | |
| Residential | - - | - - | - - | 47.7 | 53.9 | 59.0 | 62.7 | 65.8 | 69.0 |
| Commercial | - - | - - | - - | 24.5 | 28.3 | 31.7 | 34.6 | 37.5 | 40.7 |
| Industrial | - - | - - | - - | 163.6 | 183.1 | 201.4 | 220.5 | 238.1 | 257.1 |
| Transportation | - - | - - | - - | 87.7 | 97.5 | 106.3 | 115.4 | 125.3 | 136.5 |
| Total | 347.4 | 365.0 | 398.1 | 446.7 | 511.1 | 559.4 | 607.0 | 653.7 | 701.6 |
| Transportation (%) | - - | - - | - - | 19.6 | 19.1 | 19.0 | 19.0 | 19.2 | 19.5 |
| **International (World less United States)** | | | | | | | | | |
| Residential | - - | - - | - - | 26.5 | 31.7 | 36.4 | 39.3 | 41.6 | 44.0 |
| Commercial | - - | - - | - - | 6.8 | 9.6 | 11.4 | 12.6 | 14.0 | 15.7 |
| Industrial | - - | - - | - - | 130.0 | 149.8 | 167.5 | 186.2 | 203.2 | 222.1 |
| Transportation | - - | - - | - - | 59.8 | 68.5 | 75.9 | 84.2 | 93.4 | 103.5 |
| Total | 262.8 | 273.9 | 299.2 | 346.3 | 407.8 | 452.1 | 496.2 | 539.2 | 583.6 |
| Transportation (%) | - - | - - | - - | 17.3 | 16.8 | 16.8 | 17.0 | 17.3 | 17.7 |

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a/ **Actual United States data**: Annual Energy Review (AER) 2006, http://www.eia.doe.gov/aer/pdf/pages/sec2_4.pdf
**Actual World data**: International Energy Review (IER) 2005, http://www.eia.doe.gov/pub/international/iealf/tablee1.xls

b/ **Forecasted United States data**: Annual Energy Outlook (AEO) 2008, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls
**Forecasted World data**: International Energy Outlook (IEO) 2007, http://www.eia.doe.gov/oiaf/ieo/excel/ieonuctab_1.xls

According to EIA net imports, in part due to the changes in CAFE standards and biofuels, will fall to 51 percent in 2022 and then rise again to 54 percent in 2030. The impact on the industry and the environment in which it works will be felt largely by overseas producers. The actual impact on overseas producers and whether or not there is a decline in production, and a concomitant decline in emissions, will depend on the demand patterns in the developing nations.

The projections used in this DEIS do not include any large-scale, national efforts to reduce energy consumption or dramatically reduce fossil fuel use as a result of national security or climate change issues. NHTSA notes this only to remind readers that the DEIS projections are based on past trends and, in light of the current national focus on energy and climate change concerns, do not project future regulations or initiatives that may arise but are not, at this time, foreseeable. Any large-scale initiative such as this would obviously change the assumptions used in this analysis.

### 3.2.2 Methodology

The Volpe model, as described in Section 3.1.4, begins with an initial state of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the proposed rule. It uses several categories of data and estimates for all vehicle categories to develop an estimate of a set of technologies each manufacturer could apply in response to the standard. The Volpe model produces various outputs one of which is year by year fuel consumption which was used in the analysis below. Fuel consumption was estimated to 2060, at which point nearly all of the operating fleet of passenger cars and light trucks are made up of model year (MY) 2011-2016 or newer, thus achieving the maximum fuel savings under this rule.

### 3.2.3 Consequences

Table 3.2-2 shows the impact on fuel consumption for passenger cars from 2020 through 2060, a period in which an increasing volume of the fleet will be MY 2011-2015 cars which shows the increasing impact of the CAFE alternatives over time. The table shows total fuel consumption for passenger cars, both gasoline and diesel, under No Action Alternative and the six alternative CAFE standards. By 2060, when the entire fleet is likely to be composed of MY 2011 or later, cars fuel consumption reaches 131.5 billion gallons under the No Action Alternative. Consumption falls under all the alternatives from 127.7 billion gallons under the Optimized Alternative to 114.8 billion gallons in the Technology Exhaustion Alternative. As a comparison in 2007 the United States consumed 9.3 million barrels per day. Consumption under the Technology Exhaustion Alternative amounts to 5.9 million barrels per day.

**TABLE 3.2-2**

**Passenger Cars (billion gallons)**

| | Alternative CAFE Standards for Model Years 2011-2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| **Calendar Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Cost Equal Total Benefit** | **Technology Exhaustion** |
| **Fuel Consumption** | | | | | | | |
| 2020 | 62.1 | 59.7 | 58.6 | 57.4 | 56.4 | 55.5 | 55.1 |
| 2030 | 72.1 | 67.2 | 65.3 | 63.2 | 61.3 | 59.7 | 58.9 |
| 2040 | 88.9 | 82.5 | 80.1 | 77.5 | 75.0 | 73.1 | 72.0 |
| 2050 | 112.2 | 104.1 | 101.1 | 97.8 | 94.7 | 92.2 | 90.9 |
| 2060 | 141.7 | 131.5 | 127.7 | 123.5 | 119.6 | 116.5 | 114.8 |
| **Fuel Savings from No Action** | | | | | | | |
| 2020 | -- | 2.4 | 3.6 | 4.7 | 5.7 | 6.7 | 7.0 |
| 2030 | -- | 5.0 | 6.9 | 8.9 | 10.8 | 12.4 | 13.2 |
| 2040 | -- | 6.4 | 8.8 | 11.4 | 13.8 | 15.8 | 16.9 |
| 2050 | -- | 8.1 | 11.1 | 14.4 | 17.5 | 20.0 | 21.3 |
| 2060 a/ | -- | 10.2 | 14.0 | 18.2 | 22.1 | 25.2 | 26.9 |

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a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

Table 3.2-3 shows similar results for the light trucks/SUVs for the same time period and with the same alternative scenarios. As with the previous table fuel consumption is combined diesel and gasoline. Fuel consumption under the No Action Alternative is 144.7 billion gallons in 2050. Consumption falls under the alternative CAFE standards to 127.4 under the Optimized Alternative to 117.2 billion gallons under the Technology Exhaustion Alternative for a savings of 27.5 billion gallons.

**TABLE 3.2-3**

**Light Trucks (billion gallons)**

| | Alternative CAFE Standards for Model Years 2011-2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| **Calendar Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Cost Equal Total Benefit** | **Technology Exhaustion** |
| **Fuel Consumption** | | | | | | | |
| 2020 | 85.9 | 81.0 | 79.7 | 78.5 | 77.9 | 77.3 | 76.2 |
| 2030 | 104.7 | 95.8 | 93.2 | 90.7 | 89.6 | 88.5 | 86.4 |
| 2040 | 125.0 | 113.6 | 110.2 | 107.0 | 105.6 | 104.2 | 101.5 |
| 2050 | 144.7 | 131.4 | 127.4 | 123.7 | 122.0 | 120.3 | 117.2 |
| 2060 | 166.1 | 150.8 | 146.2 | 141.1 | 139.9 | 138.0 | 134.4 |
| **Fuel Savings from No Action** | | | | | | | |
| 2020 | -- | 5.0 | 6.2 | 7.4 | 8.0 | 8.6 | 9.8 |
| 2030 | -- | 8.9 | 11.6 | 14.0 | 15.2 | 16.2 | 18.4 |
| 2040 | -- | 11.4 | 14.7 | 17.9 | 19.4 | 20.8 | 23.5 |
| 2050 | -- | 13.3 | 17.3 | 21.1 | 22.8 | 24.4 | 27.5 |
| 2060 a/ | -- | 15.3 | 19.9 | 24.2 | 26.2 | 28.0 | 31.7 |

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a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.

# 3.3 AIR QUALITY

## 3.3.1 Affected Environment

### 3.3.1.1 Relevant Pollutants and Standards

The proposed standards and the alternatives would affect air pollution, which has potential effects on public health and welfare, and in turn, air quality. The primary Federal legislation that addresses air quality is the Clean Air Act (CAA). Under the authority of the CAA and amendments, the U.S. Environmental Protection Agency (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. The air quality analysis assesses the impacts of the alternatives with respect to criteria pollutants and Hazardous Air Pollutants (HAPs, also known as toxic air pollutants or air toxics) as defined under Section 112(b) of the CAA.

The criteria pollutants are CO, nitrogen dioxide ($NO_2$) which is one of several NOx, ozone, $SO_2$, suspended PM of 10 microns diameter or less (PM10) and 2.5 microns diameter or less (PM2.5), and lead. Ozone is not emitted directly from vehicles but is evaluated based on emissions of the ozone precursor pollutants NOx and VOC.

The United States transportation sector is a major source of emissions of certain criteria pollutants or their chemical precursors. Total emissions from on-road mobile sources (cars and trucks) have declined dramatically since 1970 as a result of pollution controls on vehicles and regulation of the chemical content of fuels, despite continuing increases in the amount of vehicle travel. From 1970 to 2006, the most recent year for which data are available, emissions from on-road mobile sources declined 67 percent for CO, 48 percent for NOx, 62 percent for PM10, 31 percent for $SO_2$, and 77 percent for VOC. Emissions of PM2.5 from onroad mobile sources declined 62 percent from 1990, the earliest year of available data, to 2006 (EPA, 2006).[15]

On-road mobile sources (EPA, 2006) are responsible for 54 percent of the total United States emissions of CO, 5 percent of PM2.5, and 1 percent of PM10. Almost all of the PM in vehicle exhaust is PM2.5, thus this analysis focuses on PM2.5 rather than PM10. On-road mobile sources also contribute 22 percent of total nationwide emissions of VOC and 36 percent of NOx which are chemical precursors of ozone. On-road mobile sources contribute only 1 percent of $SO_2$, but $SO_2$ and other sulfur oxides are important because they contribute to the formation of PM2.5 in the atmosphere. With the elimination of lead in gasoline, lead is no longer emitted in more than negligible quantities from motor vehicles, and is no longer a pollutant of significance for transportation projects. Lead is not evaluated further in this analysis.

Table 3.3-1 shows the primary and secondary air quality standards established by the NAAQS for each criteria pollutant. Primary standards are set at levels that are intended to protect against adverse effects on human health, while 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. The NAAQS for some pollutants include standards for both short-term and long-term average levels. Short-term standards,

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[15] U.S. Environmental Protection Agency. *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data*. http://www.epa.gov/ttn/chief/trends/trends06/nationaltier1upto2006basedon2002finalv2.1.xls, accessed 6/22/08.)

which typically specify higher levels of a pollutant, are intended to protect against acute health effects from short-term exposure to high levels, while long-term standards are established to protect against chronic health effects resulting from long-term exposure to lower levels of a pollutant.

**TABLE 3.3-1**

**National Ambient Air Quality Standards**

| Pollutant | Primary Standards | | Secondary Standards | |
|---|---|---|---|---|
| | **Level a/** | **Averaging Time** | **Level a/** | **Averaging Time** |
| Carbon Monoxide | 9 ppm<br>(10 mg/m3) | 8-hour b/ | None | |
| | 35 ppm<br>(40 mg/m3) | 1 hour b/ | | |
| Lead | 1.5 µg/m3 | Quarterly Average | Same as Primary | |
| Nitrogen Dioxide | 0.053 ppm<br>(100 µg/m3) | Annual (Arithmetic Mean) | Same as Primary | |
| Particulate Matter (PM10) | 150 µg/m3 | 24-hour c/ | Same as Primary | |
| Particulate Matter (PM2.5) | 15.0 µg/m3 | Annual d/ (Arithmetic Mean) | Same as Primary | |
| | 35 µg/m3 | 24-hour e/ | Same as Primary | |
| Ozone | 0.075 ppm<br>(2008 std.) | 8-hour f/ | Same as Primary | |
| | 0.08 ppm<br>(1997 std.) | 8-hour g/ h/ | Same as Primary | |
| | 0.12 ppm | 1-hour i/ j/ (Applies only in limited areas) | Same as Primary | |
| Sulfur Dioxide | 0.03 ppm | Annual (Arithmetic Mean) | 0.5 ppm<br>(1300 µg/m3) | 3-hour b/ |
| | 0.14 ppm | 24-hour b/ | | |

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

b/ Not to be exceeded more than once per year.

c/ Not to be exceeded more than once per year on average over 3 years.

d/ To attain this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m3.

e/ To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 µg/m3 (effective December 17, 2006).

f/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. (effective May 27, 2008)

g/ To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.

h/ The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.

i/ The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than 1.

j/ As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

Source: 40 CFR 50, as presented in EPA, 2008a.

Under the CAA, EPA is required to review the NAAQS every five years and to change the levels of the standards if warranted by new scientific information. The NAAQS formerly included an annual standard, but EPA revoked the annual PM10 standard in 2005 based on an absence of evidence of health effects associated with annual PM10 levels. In September 2006, EPA tightened the 24-hour PM2.5 standard from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$. In March 2008, EPA tightened the eight-hour ozone standard from 0.08 parts per million (ppm) to 0.075 ppm. EPA currently is considering further changes to the PM2.5 standards.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the atmosphere to the levels established by the NAAQS. Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts of air (ppm) or in micrograms of a pollutant per cubic meter ($\mu g/m^3$) of air present in repeated air samples taken at designated monitoring locations. These ambient concentrations of each criteria pollutant are compared to the permissible levels specified by the NAAQS in order to assess whether the region's air quality is potentially unhealthful.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by the NAAQS, the region is designated by EPA as an attainment area for that pollutant, while regions where concentrations of criteria pollutants exceed Federal standards are called nonattainment areas (NAAs). Former NAAs that have attained the NAAQS are designated as maintenance areas. Each NAA is required to develop and implement a State Implementation Plan (SIP), which documents how the region will reach attainment levels within time periods specified in the CAA. In maintenance areas, the SIP documents how the State intends to maintain compliance with the NAAQS. When EPA changes an NAAQS, States must revise their SIPs to address how they will attain the new standard.

The relevant air toxics for this analysis are referred to by EPA and Federal Highway Administration (FHWA) as the priority Mobile Source Air Toxics (MSAT). The priority MSATs are acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde (EPA, 2008).[16] DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the PM2.5 particle size class.

The major GHGs, consisting of $CO_2$, methane ($CH_4$), and nitrous oxides ($N_2O$), are evaluated in Section 3.4 and are not included in this air quality analysis except that $N_2O$, as one of the oxides of nitrogen, is included in the evaluation of NOx.

### 3.3.1.2 Health Effects of Criteria Pollutants

The health effects of the six Federal criteria pollutants are briefly summarized below. (This section is adapted from EPA, 2008b.)

- Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly into the air but is formed through complex chemical reactions between precursor emissions of VOCs and NOx in the presence of the ultraviolet component of sunlight. Ground-level ozone causes health problems because it and irritates the mucous membranes, damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants.

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[16] U.S. Environmental Protection Agency. *Control of Hazardous Air Pollutants From Mobile Sources*, final rule (the 2007 "MSAT rules"). 40 CFR Parts 59, 80, 85, and 86. Promulgated in the Federal Register at 72 FR 37: 8428-8476. February 26, 2007

Exposure to ozone for several hours at relatively low concentrations has been found to significantly reduce lung function and induce respiratory inflammation in normal, healthy people during exercise.

- PM includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air, as well as particles formed in the atmosphere by condensation or the transformation of emitted gases such as $SO_2$ and VOCs. Heavy-duty diesel vehicles (large trucks and buses) are a major source of PM emissions. In general, the smaller the PM, the deeper it can penetrate into the respiratory system, and the more damage it can cause. Depending on the size and composition, PM can damage lung tissue, aggravate existing respiratory and cardiovascular diseases, alter the body's defense systems against foreign materials, damage lung tissue, and cause cancer and premature death.

- CO is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. Motor vehicles are the largest source of CO emissions nationally. When CO enters the bloodstream, it acts as an asphyxiant by reducing the delivery of oxygen to the body's organs and tissues. It can impair the brain's ability to function properly. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease.

- Lead is a toxic heavy metal used in industry such as in battery manufacturing, and formerly in widespread use as an additive in paints. Lead exposure can occur through multiple pathways, including inhalation of air and ingestion of lead in food, water, soil, or dust. Excessive lead exposure can cause seizures, mental retardation, behavioral disorders, severe and permanent brain damage, and death. Even low doses of lead can lead to central nervous system damage. Because of the prohibition of lead as an additive in liquid fuels, transportation sources are no longer a major source of lead pollution.

- $SO_2$, one of various oxides of sulfur (SO), is a gas formed from combustion of fuels containing sulfur. Most $SO_2$ emissions are produced by stationary sources such as power plants. $SO_2$ is also formed when gasoline is extracted from crude oil in petroleum refineries, and in other industrial processes. High concentrations of $SO_2$ cause severe respiratory distress (difficulty breathing), irritate the upper respiratory tract, and may aggravate existing respiratory and cardiovascular disease. $SO_2$ also is a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues.

- $NO_2$ is a reddish-brown, highly reactive gas, one of the NOx formed by high temperature combustion (as in vehicle engines) of nitrogen and oxygen. Most NOx that is created in the combustion reaction consists of nitric oxide (NO), and the NO oxidizes to $NO_2$ in the atmosphere. $NO_2$ can irritate the lungs and mucous membranes, cause bronchitis and pneumonia, and lower resistance to respiratory infections. Nitrogen oxides are an important precursor both to ozone and acid rain and may affect both terrestrial and aquatic ecosystems.

#### 3.3.1.3 Health Effects of Mobile Source Air Toxics

The health effects of the priority MSATs are briefly summarized below (adapted from Claggett and Houk, 2006.)

- Acetaldehyde is a probable human carcinogen based on increased incidence of nasal tumors in rats and throat tumors in hamsters after inhalation exposure. Acetaldehyde is also a potent respiratory irritant.
- Acrolein, an aldehyde, is a respiratory irritant. Its potential carcinogenic effects are uncertain.
- Benzene, an aromatic hydrocarbon, is a known human carcinogen (causing leukemia) by all routes of exposure. Benzene also affects the immune system.
- 1,3-Butadiene, a hydrocarbon, is characterized as carcinogenic to humans by inhalation. It also damages the reproductive system.
- Diesel particulate matter is a component, along with diesel exhaust organic gases, of diesel exhaust. The particles are very fine with most particles smaller than 1 micron, and their small size allows inhaled DPM to reach the lung. Particles typically have a carbon core coated by condensed organic compounds, which include mutagens and carcinogens. Diesel exhaust is likely to be carcinogenic to humans by inhalation from environmental exposure.
- Formaldehyde is a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys. Formaldehyde also is a respiratory and eye irritant.

#### 3.3.1.4 Clean Air Act and Conformity Regulations

##### 3.3.1.4.1 Vehicle Emissions Standards

Under the CAA, EPA has established emissions standards for vehicles. EPA has tightened the emission standards over time as more effective emission control technologies have become available. These reductions in the levels of the standards are responsible for the declines in total emissions from motor vehicles as discussed above. The emission standards that will apply to MY 2011-2015 passenger car and light trucks were established by EPA's Tier 2 Vehicle & Gasoline Sulfur Program which went into effect in 2004[17] (EPA, 1999). Under the Tier 2 standards, emissions from passenger car and light trucks will continue to decline. In 2004, the Nation's refiners and importers of gasoline began to manufacture gasoline with sulfur levels capped at 300 parts per million (ppm), approximately a 15 percent reduction from the previous industry average of 347 ppm. By 2006, refiners met a 30-ppm average sulfur level with a cap of 80 ppm. These fuels enable post-2006 MY vehicles to use emissions controls that reduce tailpipe emissions of NOx by 77 percent for passenger cars and by as much as 95 percent for pickup trucks, vans, and SUVs compared to 2003 levels. Figure 3.3-1 shows that cleaner vehicles and fuels will result in continued reductions in emissions from passenger car and light trucks despite increases in travel.

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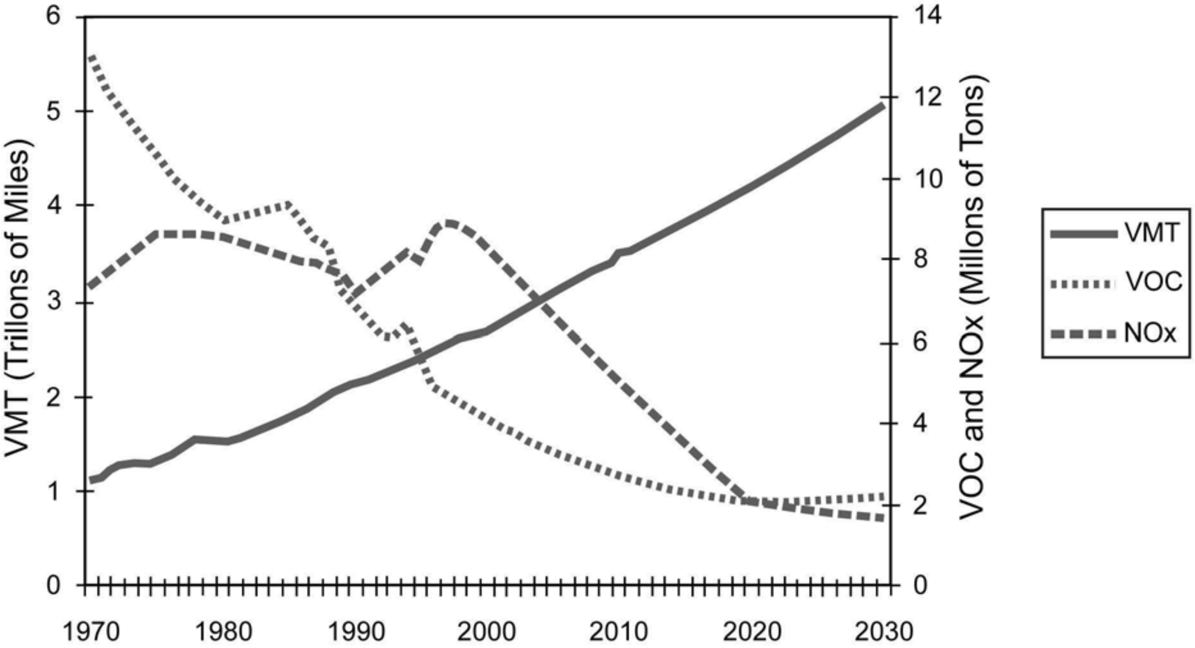
[17] U.S. Environmental Protection Agency. *Cleaner Vehicles and Cleaner Gasoline Tier 2/Gasoline Sulfur Rule*. December 22, 1999. http:www.epa.gov/otaq/regs/ld-hwy/tier-2/index.htm. Accessed June 22, 2008.

**Figure 3.3-1 Vehicle Miles Traveled (VMT) vs. Vehicle Emissions**



From 1970 to 1999, aggregate emissions traditionally associated with vehicles significantly decreased (with the exception of NOx) even as vehicle miles traveled have increased by approximately 149 percent. NOx emissions increased between 1970 and 1999 by 16 percent, due mainly to emissions from light-duty trucks and heavy-duty vehicles. However, as future trends show, vehicle travel is having a smaller and smaller impact on emissions as a result of stricter engine and fuel standards, even with additional growth in VMT.[18]

EPA is addressing air toxics through its MSAT rules (EPA, 2008). 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 car and light trucks when they are operated at cold temperatures. The cold temperature standard will be phased in from 2010 to 2015. The MSAT rules also adopt nationally the California evaporative emissions standards. EPA projects that these controls will substantially reduce emissions of benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein.

#### 3.3.1.4.2 Conformity Regulations

Section 176(c) of the CAA prohibits Federal agencies from taking actions in nonattainment or maintenance areas that do not “conform” to the State Implementation Plan (SIP). The purpose of this conformity requirement is to ensure that Federal activities do not interfere with meeting the emissions targets in the SIPs, do not cause or contribute to new violations of the NAAQS, and do not impede the ability to attain or maintain the NAAQS. The EPA has issued two sets of regulations to implement CAA Section 176(c):

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[18] Source: Statement of Senator Bob Smith, Environment & Public Works Committee Hearing on Transportation & Air Quality, July 30, 2002. In FHWA, *Vehicle Miles Traveled (VMT) and Vehicle Emissions*, http://www.fhwa.dot.gov/environment/vmtems.htm. Accessed June 22, 2008.

- The Transportation Conformity Rules (40 CFR 51 Subpart T), which apply to transportation plans, programs, and projects funded under title 23 United States Code (U.S.C.) or the Federal Transit Act. Highway and transit infrastructure projects funded by FHWA or the Federal Transit Administration (FTA) usually are subject to transportation conformity.

- The General Conformity Rules (40 CFR 51 Subpart W) apply to all other Federal actions not covered under transportation conformity. The General Conformity Rules established emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of a project. If the net emission increases due to the project are less than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the emission increases exceed any of these thresholds, then a conformity determination is required. The conformity determination may entail air quality modeling studies, consultation with EPA and State air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The CAFE standards and associated program activities are not funded under title 23 U.S.C. or the Federal Transit Act. Further, CAFE standards are established by NHTSA and are not an action undertaken by FHWA or FTA. Accordingly, the proposed CAFE standards and associated rulemakings are not subject to transportation conformity.

The General Conformity Rules contain several exemptions applicable to "Federal actions," which the conformity regulations define as: "any activity engaged in by a department, agency, or instrumentality of the Federal Government, or any activity that a department, agency or instrumentality of the Federal Government supports in any way, provides financial assistance for, licenses, permits, or approves, other than activities [subject to transportation conformity]." 40 CFR 51.852. "Rulemaking and policy development and issuance" are exempted at 40 CFR 51.853(c)(2)(iii). Since NHTSA's proposed CAFE standards involve a rulemaking process, NHTSA believes that its action is exempt from general conformity. Also, emissions for which a Federal agency does not have a "continuing program responsibility" are not considered "indirect emissions" subject to general conformity under 40 CFR 51.852. "Emissions that a Federal agency has a continuing program responsibility for means emissions that are specifically caused by an agency carrying out its authorities, and does not include emissions that occur due to subsequent activities, unless such activities are required by the Federal agency." 40 CFR 51.852. Emissions that occur as a result of the CAFE standards are not caused by NHTSA carrying out its statutory authorities and clearly occur due to subsequent activities, including vehicle manufacturers' production of passenger car and light truck fleets and consumer purchases and driving behavior. Thus, changes in any emissions that result from NHTSA's new CAFE standards are not those for which the agency has a "continuing program responsibility" and NHTSA believes that a general conformity determination is not required. NHTSA is evaluating the potential impacts of air emissions for the purposes of NEPA.

## 3.3.2 Consequences

### 3.3.2.1 Methodology

#### 3.3.2.1.1 Overview

The air quality impacts of the action alternatives were analyzed by calculating the emissions from passenger car and light trucks that would occur under each alternative, and assessing the changes in emissions relative to the No Action Alternative. The analysis assumes that assessing emissions is a valid approach to assessing air quality impacts because emissions, concentrations, and health effects are connected. Lower emissions should result in lower ambient concentrations of pollutants on an overall average basis, which should lead to decreased health effects of those pollutants.

The No Action Alternative consists of the existing CAFE standards with no changes into the future. The basic method used to estimate emissions entails multiplying activity levels of passenger cars and light trucks expressed as VMT, by emission factors in grams of pollutant emitted per VMT. National emission estimates were provided by the Volpe model. The Volpe model entails the EPA's MOBILE6.2 emission factor model (EPA, 2004b).[19] MOBILE6.2 is EPA's required model for calculating emission factors for onroad vehicles In calculating emission factors MOBILE6.2 accounts for EPA's emission control requirements for passenger cars and light trucks, including exhaust (tailpipe) emissions, evaporative emissions, and the Tier 2 Vehicle & Gasoline Sulfur Program.

The tightened CAFE standards would create an incentive to drive more because they would decrease the vehicle's fuel cost per mile. The total amount of passenger car and light truck VMT would increase slightly due to this "rebound effect." Emissions from passenger cars and light trucks would increase proportionately to the rebound effect. Although the tightened CAFE standards would decrease the total amount of fuel consumed despite the rebound effect, the decrease in fuel usage cannot be linked directly to any decrease in emissions. The EPA emission standards and the NHTSA CAFE standards are separate sets of requirements and do not depend on each other. Vehicle manufacturers must meet both the EPA emission standards and the CAFE standards simultaneously, but neither EPA nor NHTSA dictates the design and technology choices that manufacturers must make in order to comply. For example, a manufacturer could use a technique that increases fuel economy but also increases emissions, as long as the manufacturer's production still meets both the EPA emission standards and the CAFE standards. For this reason, the air quality methodology does not assume any emissions benefits solely due to fuel economy improvements.

The proposed standards also would lead to reductions in "upstream" emissions which are those emissions associated with extraction, refining, storage, and distribution of the fuel. Upstream emissions would decrease with the proposed CAFE standards because the total amount of fuel used by passenger cars and light trucks would decrease. At the national scale the reduction in upstream emissions would offset the rebound effect, resulting in a slight net decrease in emissions from passenger cars and light trucks.

While the rebound effect is assumed to affect all areas equally as a percentage of regional VMT, upstream emissions vary by region because fuel refining and storage facilities are not uniformly distributed across the country. An individual region may experience either a net increase or a net decrease in emissions due to the proposed CAFE standards. To assess regional differences in the effects of the proposed alternatives, net emissions changes were calculated for individual NAAs. NAAs were used because these are the regions in which are quality problems have been greatest. All NAAs assessed were nonattainment for ozone or PM2.5 because these are the pollutants for which emissions from passenger cars and light trucks are of greatest concern. NHTSA did not quantify PM10 emissions separately from PM2.5. The road dust component of PM10 emissions from passenger car and light trucks would increase in proportion to the rebound effect, but because almost all PM from vehicle exhaust consists of PM2.5, the proposed alternatives would have almost no effect on exhaust PM10. There are no longer any NAAs for annual PM10 because EPA revoked the annual PM10 standard.

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[19] U.S. Environmental Protection Agency. Approved final version of MOBILE6.2 computer program released by memorandum *Policy Guidance on the Use of MOBILE6.2 and the December 2003 AP-42 Method for Re-Entrained Road Dust for SIP Development and Transportation Conformity*. Margo Tsirigotis Oge, Director, Office of Transportation and Air Quality, and Steve Page, Director, Office of Air Quality Planning and Standards. February 24, 2004. Software and documents available at http://www.epa.gov/otaq/m6.htm.

#### 3.3.2.1.2 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 the NAAQS is 1 year. (The ozone and PM2.5 NAAQS use annual averages over a 3-year period to account for meteorological variations). The air quality analysis considers the emissions that would occur over annual periods, consistent with the NAAQS. Calendar years were selected that are meaningful for the timing of likely effects of the proposed alternatives.

Passenger car and light trucks last for many years, so the change in emissions due to any change in the CAFE standards will also continue for many years. The influence of vehicles of a particular model year declines with age as vehicles are driven less or scrapped. The Volpe model defines vehicle lifetime as the point at which two percent of the vehicles originally produced in a model year survive. Under this definition cars can survive in the fleet to 26 years of age and light trucks survive to 37. Any individual vehicle may not necessarily survive to these ages. The survival of vehicles and the amount they are driven can be forecast with reasonable accuracy for a decade or two, while the influences of fuel prices and general economic conditions are less certain. In order to evaluate air quality impacts, specific years must be selected for which emissions will be estimated and effects calculated. The air quality analysis was conducted in two ways that affect the choice of analysis years: for the NEPA Environmental Consequences of the alternatives, we assumed that the CAFE standards for MY 2011-2015 would remain in force indefinitely at the 2015 level. Potential CAFE standards for MY 2016-2020 were not included because they are not within the scope of this rulemaking action. However, under NEPA the assessment of Cumulative Impacts must include potential future actions that are “reasonably foreseeable”. In the cumulative impacts analysis (Chapter 4) we included potential CAFE standards for MY 2016-2020 because they are considered a reasonably foreseeable action. With the potential MY 2016-2020 standards, model years after 2020 would continue to meet the MY 2020 standards.

The analysis years that were used in this DEIS and the rationales for each are listed below.

- 2015 – Required attainment date for most PM2.5 nonattainment areas; first year of complete implementation of the proposed MY 2011-2015 CAFE standards; year of highest overall emissions from passenger cars and light trucks following complete implementation.

- 2020 – Latest required attainment date for 8-hour ozone nonattainment areas (2020 is latest full year, as last attainment date is June 2021 for South Coast Air Basin, CA); by this point a large proportion of passenger car and light truck VMT would be driven by vehicles that meet the MY 2011-2015 standards; first year of complete implementation of potential MY 2016-2020 CAFE standards ( Section 4.3);

- 2025 – By this point a large proportion of passenger car and light truck VMT would be driven by vehicles that meet the potential MY 2016-2020 standards;

- 2035 – By 2035, almost all passenger cars and light trucks in operation would meet at least the MY 2011-2015 standards and the impact of the standards would start to come only from VMT growth rather than further tightening of the standards. The impacts of the CAFE and EPA standards on a year-by-year basis by 2035 will change little from model year turnover, and most changes in emissions from year to year will come from the rebound effect. Year 2035 represents a reasonable limit to the ability to forecast important variables such as survival rates and mileage accrual rates of vehicles in the fleet, future EPA emissions standards, emission control technologies and the emission rates from vehicles. NHTSA believes the year 2035 is a practical maximum for impacts of criteria and toxic air pollutants to be considered reasonably foreseeable rather than speculative.

- 2100 – Used for climate change effects but not criteria and toxic air pollutants; NHTSA believes that given the current state-of-the-science the year 2100 is a practical maximum for impacts of climate change to be considered reasonably foreseeable rather than speculative.

#### 3.3.2.1.3 Treatment of Incomplete or Unavailable Information

As noted above, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information. *See* 40 CFR § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the DEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis.

#### 3.3.2.1.4 Allocation of Exhaust Emissions to Nonattainment Areas

National emission estimates were provided by the Volpe model. The national emissions were allocated to the county level using VMT data and projected population for each county. Passenger car and light truck VMT was determined for all counties in the United States with data from the National County Database (NCD) included in the National Mobile Inventory Model or NMIM (EPA, 2006).[20] NMIM contains MOBILE6.2 and other models, and all parameters necessary to estimate on- and off-road mobile emissions in the United States. NMIM is used by EPA in its rulemakings and is the best available tool for this purpose. The passenger car and light truck VMT data was queried from the NCD for all counties as the sum over all roadway types in each county, for all passenger car and light truck types included in MOBILE6.2. Over time some counties will grow faster than others, and VMT growth rates will vary as well. NTHSA accounted for differing growth rates by adjusting each county's fraction of national VMT according to United States Census population trends projected for the period 2007-2012 (the latest projection year available). Emissions for each county were calculated as national emissions times the population-adjusted fraction of national VMT that occurred in the county. From the county-level emissions, the emissions for each nonattainment area were derived by summing the emissions for the counties in each NAA.

The geographical definitions of ozone and PM2.5 NAAs came from the current EPA Greenbook list (EPA, 2008). For those NAAs that include portions of counties, we calculated the proportion of county population that falls within the NAA boundary as a proxy for the proportion of county VMT that occurs within the NAA boundary. Partial county boundaries were taken from geographic information system files based on 2006 NAA definitions. In some cases partial counties within NAAs as currently defined were not included in the 2006 NAAs. In those cases we did not add any part of the missing counties' VMT to our NAA totals, on the basis that partial counties added to NAAs between 2006 and 2008 likely represent relatively small additions to total NAA VMT. Several urban areas are in

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[20] U.S. Environmental Protection Agency. National Mobile Inventory Model, version 20060310. National County Database, version 20060201. http://www.epa.gov/otaq/nmim.htm. Accessed June 22, 2008.

nonattainment for both ozone and PM2.5. Where boundary areas differ between the two pollutants we use the ozoned NAA boundary, which is larger in all cases.

Table 3.3-2 lists the current nonattainment and maintenance areas.

**TABLE 3.3-2**

**Nonattainment Areas for Ozone and PM2.5**

| | **Classification a/** | | **General Conformity Threshold b/** | |
|---|---|---|---|---|
| **Nonattainment/Maintenance Area** | **$O_3$** | **PM2.5** | **$O_3$** | **PM2.5** |
| Albany-Schenectady-Troy, NY | Subpart 1 | - | 100 | - |
| Allegan Co., MI | Subpart 1 | - | 100 | - |
| Amador and Calavaras Cos. (Central Mountain Counties), CA | Subpart 1 | - | 100 | - |
| Atlanta, GA | Moderate | Nonattainment | 100 | 100 |
| Baltimore, MD | Moderate | Nonattainment | 100 | 100 |
| Baton Rouge, LA | Moderate | - | 100 | - |
| Beaumont/Port Arthur, TX | Moderate | - | 100 | - |
| Birmingham, AL | - | Nonattainment | - | 100 |
| Boston-Lawrence-Worcester (E. MA), MA | Moderate | - | 100 | - |
| Boston-Manchester-Portsmouth, MA-SE. NH | Moderate | - | 100 | - |
| Buffalo-Niagara Falls, NY | Subpart 1 | - | 100 | - |
| Canton-Massillon, OH | - | Nonattainment | - | 100 |
| Charleston, WV | - | Nonattainment | - | 100 |
| Charlotte-Gastonia-Rock Hill, NC-SC | Moderate | - | 100 | - |
| Chattanooga, AL-TN-GA | - | Nonattainment | - | 100 |
| Chicago-Gary-Lake Co., IL-IN | Moderate | Nonattainment | 100 | 100 |
| Chico, CA | Subpart 1 | - | 100 | - |
| Cincinnati-Hamilton, OH-KY-IN | Subpart 1 | Nonattainment | 100 | 100 |
| Clearfield and Indiana Cos., PA | Subpart 1 | - | 100 | - |
| Cleveland-Akron-Lorain, OH | Moderate | Nonattainment | 100 | 100 |
| Columbus, OH | Subpart 1 | Nonattainment | 100 | 100 |
| Dallas-Fort Worth, TX | Moderate | - | 100 | - |
| Dayton-Springfield, OH | - | Nonattainment | - | 100 |
| Denver-Boulder-Greeley-Ft. Collins, CO | Subpart 1 | - | 100 | - |
| Detroit-Ann Arbor, MI | Marginal | Nonattainment | 100 | 100 |
| Door Co., WI | Subpart 1 | - | 100 | - |
| Essex Co., NY (Whiteface Mountain) | Subpart 1 | - | 100 | - |
| Evansville, IN | - | Nonattainment | - | 100 |
| Greater Connecticut, CT | Moderate | - | 100 | - |
| Greene Co., PA | Subpart 1 | - | 100 | - |
| Greensboro-Winston Salem-High Point, NC | - | Nonattainment | - | 100 |
| Harrisburg-Lebanon-Carlisle, PA | - | Nonattainment | - | 100 |

**TABLE 3.3-2 (cont'd)**

**Nonattainment Areas for Ozone and PM2.5**

| Nonattainment/Maintenance Area | Classification a/ | | General Conformity Threshold b/ | |
|---|---|---|---|---|
| | $O_3$ | PM2.5 | $O_3$ | PM2.5 |
| Haywood and Swain Cos. (Great Smoky Mountains National Park), NC | Subpart 1 | - | 100 | - |
| Hickory, NC | - | Nonattainment | - | 100 |
| Houston-Galveston-Brazoria, TX | Moderate | - | 100 | - |
| Huntington-Ashland, WV-KY-OH | - | Nonattainment | - | 100 |
| Imperial Co., CA | Moderate | - | 100 | - |
| Indianapolis, IN | - | Nonattainment | - | 100 |
| Jamestown, NY | Subpart 1 | - | 100 | - |
| Jefferson Co., NY | Moderate | - | 100 | - |
| Johnstown, PA | - | Nonattainment | - | 100 |
| Kern Co. (Eastern Kern), CA | Subpart 1 | - | 100 | - |
| Knoxville, TN | Subpart 1 | Nonattainment | 100 | 100 |
| Lancaster, PA | - | Nonattainment | - | 100 |
| Las Vegas, NV | Subpart 1 | - | 100 | - |
| Libby, MT | - | Nonattainment | - | 100 |
| Liberty-Clairton, PA | - | Nonattainment | - | 100 |
| Los Angeles South Coast Air Basin, CA | Severe 17 | Nonattainment | 25 | 100 |
| Los Angeles-San Bernardino Cos. (W. Mojave Desert), CA | Moderate | - | 100 | - |
| Louisville, KY-IN | - | Nonattainment | - | 100 |
| Macon, GA | - | Nonattainment | - | 100 |
| Manitowoc Co., WI | Subpart 1 | - | 100 | - |
| Mariposa and Tuolumne Cos. (Southern Mountain Counties), CA | Subpart 1 | - | 100 | - |
| Martinsburg, WV-Hagerstown, MD | - | Nonattainment | - | 100 |
| Memphis, TN-AR | Moderate | - | 100 | - |
| Milwaukee-Racine, WI | Moderate | - | 100 | - |
| Nevada (Western Part), CA | Subpart 1 | - | 100 | - |
| New York-N. New Jersey-Long Island, NY-NJ-CT | Moderate | Nonattainment | 100 | 100 |
| Parkersburg-Marietta, WV-OH | - | Nonattainment | - | 100 |
| Philadelphia-Wilmington, Atlantic City, PA-DE-MD-NJ | Moderate | Nonattainment | 100 | 100 |
| Phoenix-Mesa, AZ | Subpart 1 | - | 100 | - |
| Pittsburgh-Beaver Valley, PA | Subpart 1 | Nonattainment | 100 | 100 |
| Poughkeepsie, NY | Moderate | Nonattainment | 100 | 100 |
| Providence (All RI), RI | Moderate | - | 100 | - |
| Reading, PA | - | Nonattainment | - | 100 |
| Riverside Co., CA (Coachella Valley) | Serious | - | 50 | - |
| Rochester, NY | Subpart 1 | - | 100 | - |
| Rome, GA | - | Nonattainment | - | 100 |

**TABLE 3.3-2 (cont'd)**

**Nonattainment Areas for Ozone and PM2.5**

| Nonattainment/Maintenance Area | Classification a/ O$_3$ | Classification a/ PM2.5 | General Conformity Threshold b/ O$_3$ | General Conformity Threshold b/ PM2.5 |
|---|---|---|---|---|
| Sacramento Metro, CA | Serious | - | 50 | - |
| San Diego, CA | Subpart 1 | - | 100 | - |
| San Francisco Bay Area, CA | Marginal | - | 100 | - |
| San Joaquin Valley, CA | Serious | Nonattainment | 50 | 100 |
| Sheboygan, WI | Moderate | - | 100 | - |
| Springfield (Western MA), MA | Moderate | - | 100 | - |
| St. Louis, MO-IL | Moderate | Nonattainment | 100 | 100 |
| Steubenville-Weirton, OH-WV | - | Nonattainment | - | 100 |
| Sutter County (Sutter Buttes), CA | Subpart 1 | - | 100 | - |
| Ventura Co., CA | Moderate | - | 100 | - |
| Washington, DC-MD-VA | Moderate | Nonattainment | 100 | 100 |
| Washington County (Hagerstown), MD | - | Nonattainment | - | 100 |
| Wheeling, WV-OH | - | Nonattainment | - | 100 |
| York, PA | - | Nonattainment | - | 100 |

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a/ Pollutants for which the area is designated nonattainment or maintenance as of 2008, and severity classification.
b/ Tons per year of: VOC or NOx in ozone NAAs; primary PM2.5 in PM2.5 NAAs.

Source: EPA, 2008.

#### 3.3.2.1.5 Allocation of Upstream Emissions to Nonattainment Areas

Upstream emissions from light-duty 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
- Fuel Transportation, Storage, and Distribution (T&S&D)

Feedstock recovery refers to the extraction or production of fuel feedstocks. In the case of petroleum, this is the stage of crude oil extraction. During the next stage, feedstock transportation, crude oil is shipped to refineries. Fuel refining refers to the processing of crude oil into gasoline and diesel. T&S&D refers to the movement of gasoline and diesel from refineries to bulk terminals, storage at bulk terminals, and transportation of fuel from bulk terminals to retail outlets. Emissions of pollutants at each stage are associated with expenditure of energy and spillage and evaporation of fuel products.

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model (Argonne, 2002) estimates upstream emissions associated with various vehicle fuel pathways for light duty vehicles in the United States. GREET includes various assumptions about the production and transportation of feedstocks and fuels. The model assumes that more than half of the crude oil supplied to United States refineries arrives by ocean tanker from foreign countries and Alaska. More than a third of crude oil is produced domestically. Once in the lower 48 states, almost all (92 percent) of crude oil is transported to refineries by pipeline.

The model assumes that nearly all (96 percent) of gasoline and diesel consumed in the United States comes from United States refineries. Around three quarters of that fuel is transported from refineries to bulk terminals by pipeline, an average distance of 400 miles. Smaller shares are transported by ocean tanker, barge, and rail. Fuel is transported from bulk terminals to retail outlets by truck, an average distance of thirty miles.

The GREET and Volpe modeling provided changes in upstream emissions of NOx, PM, VOC, SOx, and CO and four air toxics (acetaldehyde, benzene, butadiene, and formaldehyde) associated with the proposed action and alternatives. The Volpe model shows that nationwide upstream emissions would be reduced by all of the alternatives examined. Increasing the fuel economy of light duty vehicles will cause less fuel to be consumed, which will in turn reduce upstream emissions of criteria pollutants associated with feedstock and fuel production, processing, and transportation.

In order to analyze the impact of the alternatives on individual nonattainment areas, we allocated emission reductions to geographic areas according to the following methodology:

- Feedstock Recovery –assumed that little to no extraction of crude oil occurs in NAAs. NAAs tend to be major urban areas, whereas most oil extraction occurs in rural areas or offshore. There is no readily available data to determine the precise location of all domestic oil wells. NHTSA therefore ignored emission reductions from feedstock recovery in NAAs.

- Feedstock Transportation –assumed that little to no crude oil is transported through NAAs. Most refineries are located outside of, or on the outskirts of, urban areas. Crude oil is typically transported hundreds of miles from extraction points and ports to reach refineries. Most transportation is by ocean tanker and pipeline. Probably only a very small proportion of criteria pollutants emitted in the transport of crude oil occur in NAAs. NHTSA therefore ignored emission reductions from feedstock transportation in NAAs.

- Fuel Refining – Fuel refining is the largest source of upstream emissions of criteria pollutants. Depending on the specific fuel and pollutant, fuel refining accounts for between one third and three quarters of all upstream emissions (based on outputs of the Volpe model). NHTSA compiled a list of all crude oil refineries in the United States along with their locations and refining capacity, and then calculated each NAA's share of total nationwide refining capacity. It is assumed that fuel refining will decrease uniformly across all refineries nationwide as a result of the proposed alternatives. For the NAAs examined, we estimated the change in emissions from fuel refining as a share of the total national emissions, proportional to the area's share of national refining capacity.

- Fuel T&S&D – Based on the assumptions of the GREET model, we assume that most T&S&D emissions occur near the point of fuel sale and use. The pipelines which carry fuel from refineries to bulk hubs are a relatively low emissions mode. The trucks which carry the fuel to retail outlets are likely to be the largest source of emissions in this category. If the average distance that a truck hauls the fuel is 30 miles, then the truck is likely to emit most criteria pollutants within the same airshed as that in which the fuel will be purchased and used. NHTSA used county-level light-duty VMT data from EPA's NMIM to estimate the proportion of national fuel demand in each nonattainment area, and population forecasts by county to account for likely shifts in demand in future years, as discussed above. Finally, we apportioned the national T&S&D emissions to NAAs based on their total share of national fuel demand.

Since we ignore emissions changes from the first two upstream stages, our assumptions produce conservative estimates of emission reductions in NAAs.

For acetaldehyde, benzene, butadiene, and formaldehyde, the GREET modeling provided proportions of total upstream emissions by only two categories: feedstock recovery and transportation, and fuel refining and T&S&D. No split between emissions from fuel refining and emissions from T&S&D was provided. NHTSA assumed that all upstream emissions of these pollutants from fuel refining and T&S&D occur during fuel refining. This assumption results in over-assignment of emissions of these pollutants to NAAs that have refineries and under-assignment of emissions to those that have none.

The GREET model also provided no information on upstream emissions of acrolein or DPM and so upstream emissions reductions for acrolein or DPM were not applied. As a result the emissions of acrolein and DPM given in the DEIS are conservative (high) because they account only for the increase due to the rebound effect.

### 3.3.2.2 Results of the Emissions Analysis

The CAA has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and EPA projects that they will continue to decline. This trend will continue regardless of the alternative that is chosen for future CAFE standards. The analysis by alternative in this section shows that the alternative CAFE standards will lead to further reductions in emissions from passenger cars and light trucks. The amount of the reductions would vary by alternative CAFE standard. The more restrictive alternatives would result in greater emission reductions compared to the No Action Alternative. Under all of the action alternatives there are no emissions increases that would exceed any of the general conformity thresholds.

### 3.3.2.3 Alternative 1: No Action

#### 3.3.2.3.1 Criteria Pollutants

With the No Action Alternative, the Corporate Average Fuel Economy (CAFE) standards would remain at the MY 2010 level in future years. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT. The EPA vehicle emission standards regulate all criteria pollutants except $SO_2$ which is regulated through fuel sulfur content. The No Action Alternative (Alternative 1) would not result in any increase or decrease in criteria pollutant emissions in nonattainment and maintenance areas throughout the United States

Table 3.3-3 summarizes the total national emissions from passenger cars and light trucks for the No Action Alternative for each of the criteria pollutants and analysis years. The other alternatives (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy requirements. Table 3.3-2 and Figure 3.3-2 show that the No Action Alternative has the highest emissions of all the alternatives for all criteria pollutants.

## TABLE 3.3-3

## Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)

| Pollutant and Year | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | Alt. 5 | Alt. 6 | Alt. 7 |
|---|---|---|---|---|---|---|---|
| | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Costs Equal Total Benefits** | **Technology Exhaustion** |
| Carbon Monoxide (CO) | | | | | | | |
| 2015 | 24,914,653 | 24,904,320 | 24,898,268 | 24,802,581 | 24,719,280 | 24,638,863 | 24,621,307 |
| 2020 | 23,046,827 | 22,983,807 | 22,949,337 | 22,458,913 | 22,135,977 | 21,868,008 | 21,767,568 |
| 2025 | 23,127,970 | 22,978,383 | 22,915,856 | 21,885,707 | 21,258,486 | 20,778,423 | 20,546,999 |
| 2035 | 26,446,292 | 26,158,046 | 26,044,977 | 24,159,436 | 23,111,813 | 22,362,860 | 21,927,726 |
| Nitrogen Oxides (NOx) | | | | | | | |
| 2015 | 2,902,481 | 2,881,806 | 2,874,890 | 2,856,240 | 2,841,395 | 2,826,796 | 2,821,773 |
| 2020 | 2,521,207 | 2,466,715 | 2,448,284 | 2,384,003 | 2,341,872 | 2,306,772 | 2,289,227 |
| 2025 | 2,438,747 | 2,352,173 | 2,323,433 | 2,204,293 | 2,130,760 | 2,073,720 | 2,041,003 |
| 2035 | 2,720,799 | 2,590,414 | 2,547,317 | 2,340,656 | 2,222,744 | 2,136,859 | 2,080,801 |
| Particulate Matter 2.5 (PM2.5) | | | | | | | |
| 2015 | 418,882 | 416,703 | 415,881 | 409,853 | 404,907 | 400,345 | 398,997 |
| 2020 | 445,866 | 439,438 | 437,454 | 420,066 | 408,671 | 399,749 | 395,320 |
| 2025 | 483,176 | 472,988 | 470,102 | 442,963 | 426,020 | 413,491 | 406,241 |
| 2035 | 583,318 | 568,326 | 564,238 | 524,529 | 500,769 | 483,889 | 473,062 |
| Sulfur Oxides ($SO_x$) | | | | | | | |
| 2015 | 449,551 | 438,815 | 435,224 | 426,238 | 419,304 | 412,532 | 409,972 |
| 2020 | 469,521 | 441,973 | 432,933 | 407,908 | 392,013 | 378,992 | 371,426 |
| 2025 | 503,641 | 461,512 | 447,923 | 409,137 | 385,537 | 367,388 | 355,347 |
| 2035 | 603,991 | 543,259 | 523,947 | 467,569 | 434,523 | 410,207 | 392,441 |
| Volatile Organic Compounds (VOC) | | | | | | | |
| 2015 | 2,583,711 | 2,572,126 | 2,568,198 | 2,554,827 | 2,544,009 | 2,533,536 | 2,530,153 |
| 2020 | 2,277,973 | 2,246,761 | 2,236,175 | 2,189,265 | 2,158,343 | 2,132,803 | 2,120,573 |
| 2025 | 2,231,152 | 2,180,731 | 2,164,066 | 2,074,990 | 2,019,501 | 1,976,563 | 1,953,121 |
| 2035 | 2,477,999 | 2,399,287 | 2,372,905 | 2,203,377 | 2,105,993 | 2,034,852 | 1,990,799 |

**Figure 3.3-2 Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)**

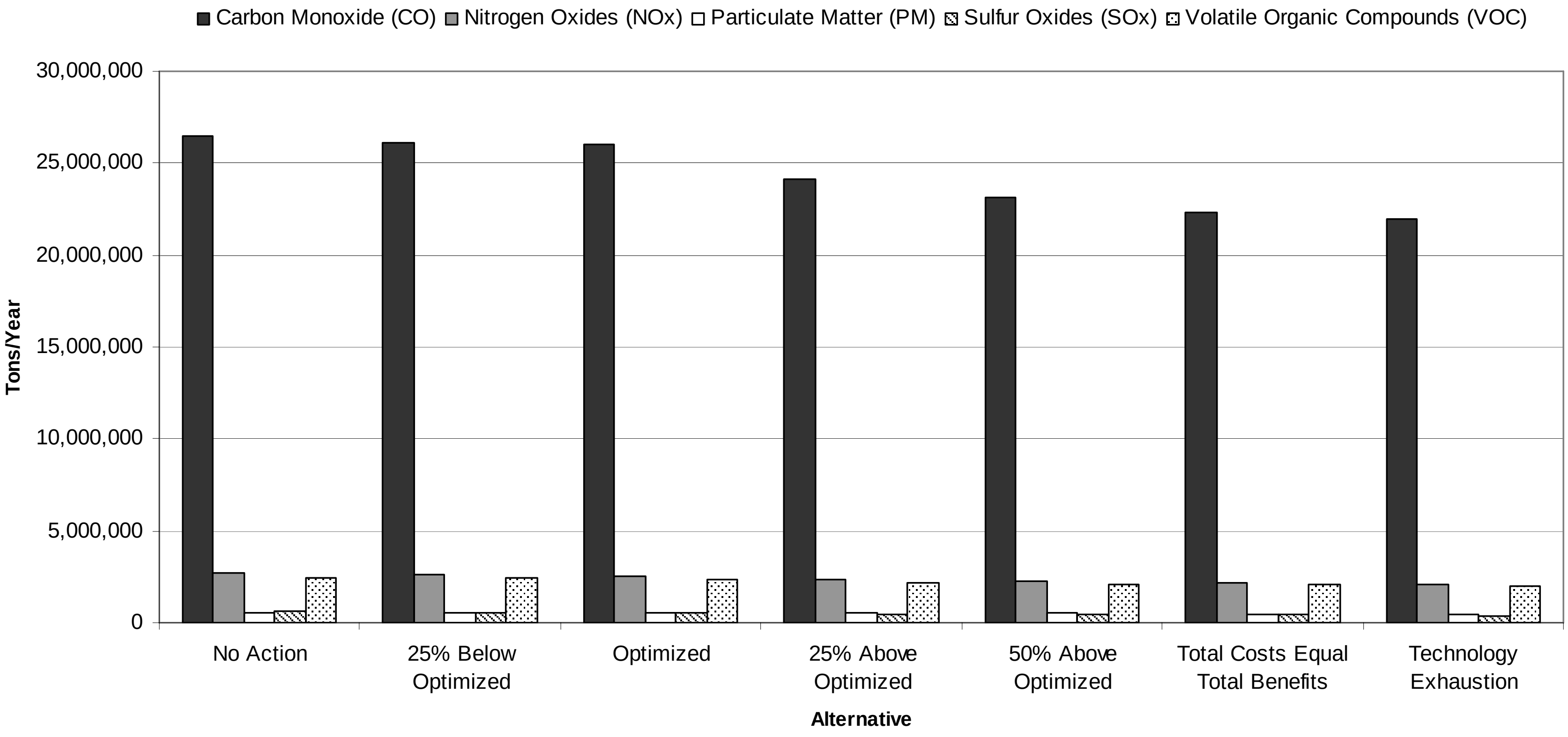

Table 3.3-4 presents the net change in nationwide emissions from passenger cars and light trucks for the No Action Alternative for each of the criteria pollutants and analysis years. The other alternatives (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy requirements. In Table 3.3-4 the nationwide emissions reductions become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives.

**TABLE 3.3-4**

**Nationwide Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards, Compared to the No Action Alternative (tons/year)**

| Pollutant and Year | Alt. 1<br>No Action | Alt. 2<br>25% Below Optimized | Alt. 3<br>Optimized | Alt. 4<br>25% Above Optimized | Alt. 5<br>50% Above Optimized | Alt. 6<br>Total Costs Equal Total Benefits | Alt. 7<br>Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide (CO) | | | | | | | |
| 2015 | 0 a/ | -10,333 b/ | -16,385 | -112,072 | -195,373 | -275,790 | -293,346 |
| 2020 | 0 | -63,021 | -97,490 | -587,914 | -910,851 | -1,178,819 | -1,279,260 |
| 2025 | 0 | -149,587 | -212,115 | -1,242,263 | -1,869,484 | -2,349,548 | -2,580,971 |
| 2035 | 0 | -288,246 | -401,315 | -2,286,856 | -3,334,479 | -4,083,432 | -4,518,566 |
| Nitrogen Oxides (NOx) | | | | | | | |
| 2015 | 0 | -20,675 | -27,591 | -46,241 | -61,086 | -75,685 | -80,707 |
| 2020 | 0 | -54,492 | -72,923 | -137,205 | -179,335 | -214,435 | -231,981 |
| 2025 | 0 | -86,574 | -115,314 | -234,454 | -307,986 | -365,027 | -397,743 |
| 2035 | 0 | -130,384 | -173,482 | -380,143 | -498,055 | -583,940 | -639,998 |
| Particulate Matter (PM2.5) | | | | | | | |
| 2015 | 0 | -2,179 | -3,001 | -9,029 | -13,975 | -18,537 | -19,885 |
| 2020 | 0 | -6,429 | -8,412 | -25,800 | -37,196 | -46,117 | -50,547 |
| 2025 | 0 | -10,188 | -13,074 | -40,213 | -57,156 | -69,685 | -76,934 |
| 2035 | 0 | -14,991 | -19,079 | -58,789 | -82,549 | -99,429 | -110,256 |
| Sulfur Oxides ($SO_x$) | | | | | | | |
| 2015 | 0 | -10,736 | -14,327 | -23,313 | -30,247 | -37,019 | -39,580 |
| 2020 | 0 | -27,549 | -36,588 | -61,613 | -77,508 | -90,529 | -98,095 |
| 2025 | 0 | -42,129 | -55,718 | -94,504 | -118,104 | -136,253 | -148,294 |
| 2035 | 0 | -60,732 | -80,044 | -136,422 | -169,468 | -193,784 | -211,550 |
| Volatile Organic Compounds (VOC) | | | | | | | |
| 2015 | 0 | -11,585 | -15,513 | -28,884 | -39,702 | -50,175 | -53,558 |
| 2020 | 0 | -31,212 | -41,798 | -88,708 | -119,631 | -145,171 | -157,400 |
| 2025 | 0 | -50,421 | -67,085 | -156,162 | -211,651 | -254,589 | -278,031 |
| 2035 | 0 | -78,712 | -105,094 | -274,622 | -372,006 | -443,147 | -487,200 |

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a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

### 3.3.2.3.2 Air Toxics

With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. As with the criteria pollutants, current trends in the levels of air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT. The EPA regulates air toxics from motor vehicles through vehicle emission standards and fuel quality standards, as discussed in Section 3.3.1. The No Action Alternative (Alternative 1) would not result in any other increase or decrease in toxic air pollutant emissions in nonattainment and maintenance areas throughout the United States

Table 3.3-5 summarizes the total national emissions of air toxics from passenger cars and light trucks with the No Action Alternative for each of the pollutants and analysis years. As with the criteria pollutants, the No Action Alternative has the highest emissions of all the alternatives for all toxic air pollutants except acrolein. Table 3.3-3 shows increases for acrolein with the action alternatives because data on upstream emissions reductions were not available. The emissions for acrolein in Table 3.3-3 reflect only the increases due to the rebound effect. Because the upstream emissions reductions result from the decline in the amount of fuel processed, it is reasonable that upstream acrolein emissions should decrease as the other pollutants' upstream emissions do. Thus, the acrolein emissions given in Table 3.3.3 are an upper bound estimate.

**TABLE 3.3-5**

**Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)**

| | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | Alt. 5 | Alt. 6 | Alt. 7 |
|---|---|---|---|---|---|---|---|
| Pollutant and Year | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
| Acetaldehyde | | | | | | | |
| 2015 | 15,753 | 15,742 | 15,738 | 15,722 | 15,705 | 15,688 | 15,685 |
| 2020 | 13,781 | 13,741 | 13,726 | 13,589 | 13,488 | 13,402 | 13,373 |
| 2025 | 13,168 | 13,086 | 13,056 | 12,698 | 12,471 | 12,293 | 12,212 |
| 2035 | 14,354 | 14,198 | 14,137 | 13,360 | 12,931 | 12,622 | 12,447 |
| Acrolein a/ | | | | | | | |
| 2015 | 744 | 746 | 746 | 750 | 753 | 756 | 757 |
| 2020 | 643 | 648 | 650 | 658 | 664 | 669 | 672 |
| 2025 | 611 | 619 | 621 | 629 | 636 | 642 | 646 |
| 2035 | 663 | 676 | 677 | 677 | 685 | 690 | 696 |
| Benzene | | | | | | | |
| 2015 | 82,225 | 82,080 | 82,028 | 81,754 | 81,523 | 81,297 | 81,236 |
| 2020 | 72,284 | 71,844 | 71,667 | 70,392 | 69,550 | 68,844 | 68,559 |
| 2025 | 69,648 | 68,845 | 68,540 | 65,808 | 64,138 | 62,842 | 62,204 |
| 2035 | 76,355 | 74,969 | 74,430 | 69,017 | 66,025 | 63,857 | 62,591 |
| 1,3-Butadiene | | | | | | | |
| 2015 | 8,913 | 8,909 | 8,908 | 8,897 | 8,887 | 8,877 | 8,875 |
| 2020 | 7,819 | 7,805 | 7,795 | 7,709 | 7,655 | 7,607 | 7,592 |
| 2025 | 7,449 | 7,415 | 7,395 | 7,174 | 7,048 | 6,948 | 6,905 |
| 2035 | 8,062 | 7,991 | 7,949 | 7,463 | 7,216 | 7,038 | 6,941 |
| Diesel Particulate Matter (DPM) | | | | | | | |
| 2015 | 197,948 | 193,038 | 191,399 | 187,606 | 184,734 | 181,907 | 180,788 |
| 2020 | 206,542 | 194,039 | 189,868 | 179,277 | 172,741 | 167,354 | 164,157 |
| 2025 | 221,435 | 202,359 | 196,065 | 179,645 | 169,968 | 162,489 | 157,450 |
| 2035 | 265,474 | 238,004 | 229,040 | 205,151 | 191,609 | 181,604 | 174,200 |

**TABLE 3.3-5 (cont'd)**

**Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)**

| | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | Alt. 5 | Alt. 6 | Alt. 7 |
|---|---|---|---|---|---|---|---|
| **Pollutant and Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Costs Equal Total Benefits** | **Technology Exhaustion** |
| Formaldehyde | | | | | | | |
| 2015 | 21,385 | 21,328 | 21,311 | 21,297 | 21,281 | 21,264 | 21,259 |
| 2020 | 18,721 | 18,575 | 18,529 | 18,407 | 18,314 | 18,233 | 18,200 |
| 2025 | 18,021 | 17,785 | 17,708 | 17,379 | 17,172 | 17,011 | 16,929 |
| 2035 | 19,851 | 19,486 | 19,356 | 18,628 | 18,241 | 17,963 | 17,798 |

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a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the increases due to the rebound effect.

Table 3.3-5 and Figure 3.3-3 present the net change in nationwide emissions from passenger cars and light trucks for the No Action Alternative for each of the air toxic pollutants and analysis years. The other alternatives (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy requirements. In Table 3.3-5 the nationwide emissions reductions become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives, except for acrolein.

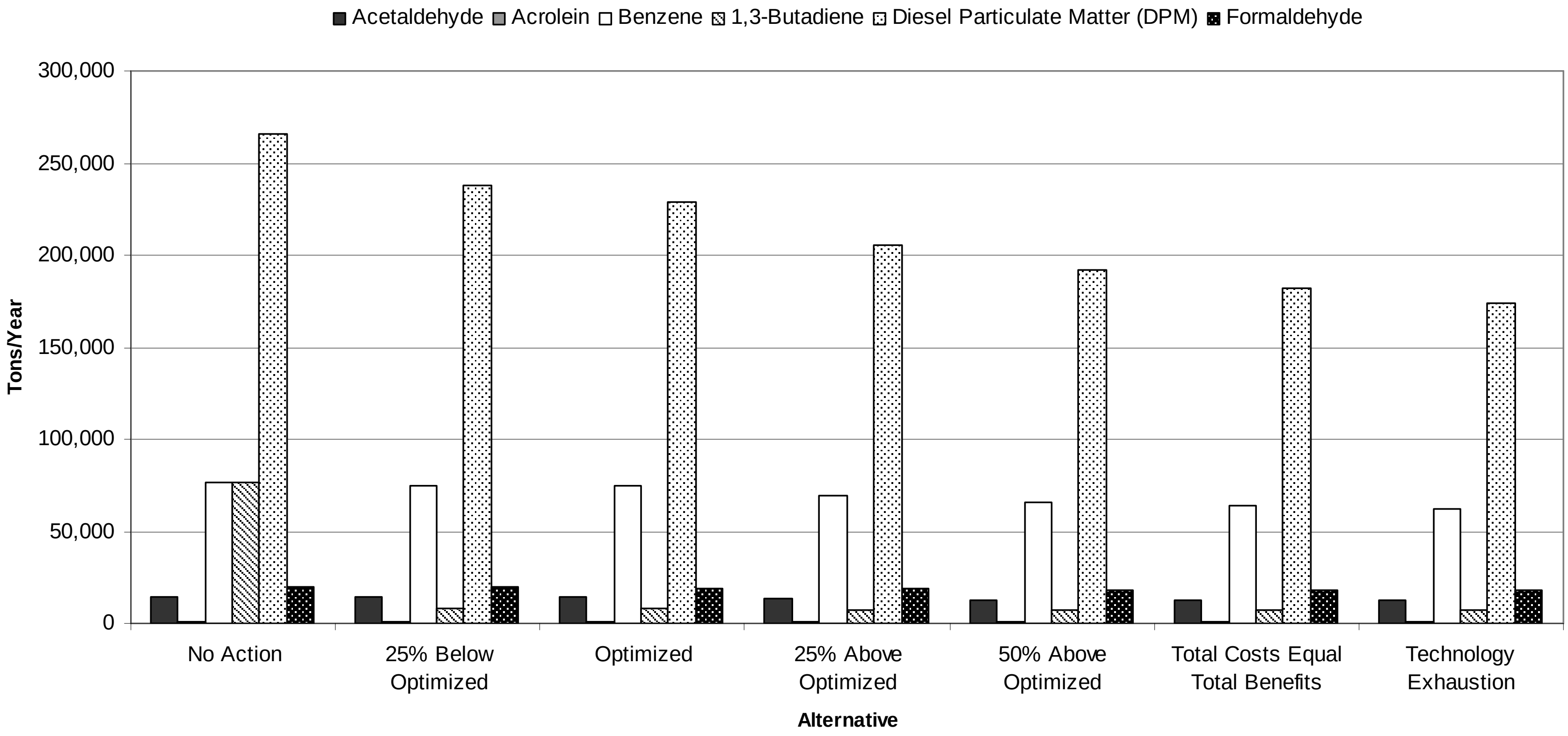
Table 3.3-5 shows increases for acrolein with the action alternatives because data on upstream emissions reductions were not available, as noted above. Thus, the acrolein emissions given in Table 3.3-5 are an upper bound estimate.

### 3.3.2.4 Alternative 2: 25 Percent Below Optimized

#### 3.3.2.4.1 Criteria Pollutants

With the 25 Percent Below Optimized Alternative (Alternative 2), the CAFE standards would require increased fuel economy compared to the No Action Alternative. The 25 Percent Below Optimized Alternative would increase fuel economy less than would Alternatives 3 through 7. There would be reductions in nationwide emissions of criteria pollutants with the 25 Percent Below Optimized Alternative compared to the No Action Alternative in 2020 by 63,021 tons CO, 54,492 tons NOx, 6,429 tons PM, 27,549 tons $SO_x$, 31,212 tons VOC, and 13,138 tons for 6 air toxics. These reductions amount to an average emission reduction of between 0.8 percent to 22.8 percent depending on the pollutant between 2015 and 2035. The 25 Percent Below Optimized Alternative would reduce emissions less than would Alternatives 3 through 7 by between 0.3 percent for Alternative 3 and 18.5 percent for Alternative 7, on average, depending on the pollutant (Table 3.3-6). All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA. The criteria air pollutant results by NAA are summarized in Table 3.3-7.

**Figure 3.3-3 Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)**



## TABLE 3.3-6

## Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards, Compared to the No Action Alternative (tons/year)

| | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | Alt. 5 | Alt. 6 | Alt. 7 |
|---|---|---|---|---|---|---|---|
| **Pollutant and Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Costs Equal Total Benefits** | **Technology Exhaustion** |
| Acetaldehyde | | | | | | | |
| 2015 | 0 a/ | -12 b/ | -15 | -31 | -48 | -66 | -68 |
| 2020 | 0 | -39 | -54 | -192 | -293 | -379 | -408 |
| 2025 | 0 | -82 | -112 | -470 | -698 | -875 | -956 |
| 2035 | 0 | -156 | -217 | -995 | -1,424 | -1,732 | -1,907 |
| Acrolein c/ | | | | | | | |
| 2015 | 0 | 2 | 3 | 7 | 10 | 13 | 14 |
| 2020 | 0 | 6 | 7 | 15 | 22 | 27 | 29 |
| 2025 | 0 | 9 | 10 | 18 | 26 | 32 | 36 |
| 2035 | 0 | 13 | 14 | 14 | 22 | 27 | 33 |
| Benzene | | | | | | | |
| 2015 | 0 | -144 | -196 | -471 | -702 | -927 | -988 |
| 2020 | 0 | -441 | -618 | -1,892 | -2,734 | -3,440 | -3,726 |
| 2025 | 0 | -803 | -1,109 | -3,840 | -5,510 | -6,807 | -7,444 |
| 2035 | 0 | -1,386 | -1,925 | -7,338 | -10,330 | -12,498 | -13,764 |
| 1,3-Butadiene | | | | | | | |
| 2015 | 0 | -4 | -6 | -17 | -26 | -36 | -38 |
| 2020 | 0 | -15 | -24 | -110 | -165 | -212 | -228 |
| 2025 | 0 | -34 | -54 | -274 | -401 | -500 | -544 |
| 2035 | 0 | -71 | -113 | -600 | -846 | -1,025 | -1,122 |
| Diesel Particulate Matter (DPM) | | | | | | | |
| 2015 | 0 | -4,910 | -6,549 | -10,342 | -13,213 | -16,041 | -17,160 |
| 2020 | 0 | -12,503 | -16,674 | -27,265 | -33,801 | -39,188 | -42,385 |
| 2025 | 0 | -19,076 | -25,370 | -41,790 | -51,467 | -58,946 | -63,985 |
| 2035 | 0 | -27,470 | -36,434 | -60,323 | -73,865 | -83,869 | -91,274 |
| Formaldehyde | | | | | | | |
| 2015 | 0 | -58 | -74 | -89 | -104 | -122 | -126 |
| 2020 | 0 | -146 | -191 | -314 | -407 | -488 | -521 |
| 2025 | 0 | -236 | -312 | -642 | -848 | -1,010 | -1,092 |
| 2035 | 0 | -365 | -494 | -1,223 | -1,609 | -1,887 | -2,052 |

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a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the increases due to the rebound effect.

**TABLE 3.3-7**

**Changes in Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards Maximum Changes by Nonattainment Area**

| Pollutant | Increase/ Decrease | Change (tons/year) | Year | Alt. No. | Nonattainment Area |
|---|---|---|---|---|---|
| **Criteria Pollutants** | | | | | |
| CO | | | | | |
| | Maximum Increase | No CO increases. | | | |
| | Maximum Decrease | 204,806.6 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| NOx | | | | | |
| | Maximum Increase | No NOx increases. | | | |
| | Maximum Decrease | 24,473.6 | 2035 | 7 | Houston-Galveston-Brazoria, TX |
| PM2.5 | | | | | |
| | Maximum Increase | No PM2.5 increases. | | | |
| | Maximum Decrease | 5,424.7 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| SOx | | | | | |
| | Maximum Increase | No $SO_x$ increases. | | | |
| | Maximum Decrease | 16,538.9 | 2035 | 7 | Houston-Galveston-Brazoria, TX |
| VOC | | | | | |
| | Maximum Increase | No VOC increases. | | | |
| | Maximum Decrease | 24,770.7 | 2035 | 7 | Houston-Galveston-Brazoria, TX |

#### 3.3.2.4.2 Air Toxics

As with the criteria pollutants, there would be reductions in nationwide emissions of toxic air pollutants with the 25 Percent Below Optimized Alternative compared to the No Action Alternative. The 25 Percent Below Optimized Alternative would reduce air toxics emissions less than would Alternatives 3 through 7 by between 0.2 percent for Alternative 3 and 11.8 percent for Alternative 7, on average, depending on the pollutant. At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, the reductions in upstream emissions are not uniformly distributed to individual NAAs. For example, an NAA that contains petroleum refining facilities, such as Houston-Galveston-Brazoria, TX, would experience more reductions in upstream emissions than an area that has none. This occurs because the reduction in upstream emissions in such areas more than offsets the increase within the NAA due to the rebound effect

With the 25 Percent Below Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1, and emission increases would be distributed throughout each NAA.

### 3.3.2.5 Alternative 3: Optimized

#### 3.3.2.5.1 Criteria Pollutants

With the Optimized Alternative, the CAFE standards would increase fuel economy more than would the No Action Alternative and the 25 Percent Below Optimized Alternative but less than would

Alternatives 4 through 7. There would be greater reductions in nationwide emissions of criteria pollutants with the Optimized Alternative than with the 25 Percent Below Optimized Alternative: by 34,469 tons CO, 18,431 tons NOx, 1,983 tons PM, 9,039 tons $So_x$, and 10,586 tons VOC for 2020. The Optimized Alternative would reduce emissions less than would Alternatives 4 through 7 by between 1.0 percent for Alternative 4 and 17.1 percent for Alternative 7 depending on pollutant and year. All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 3.3.2.5.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the Optimized Alternative compared to the 25 Percent Below Optimized Alternative and the No Action Alternative. The Optimized Alternative would reduce air toxics emissions less than would Alternatives 4 through 7 (Table 3.3-8). At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the 25 Percent Below Optimized Alternative, the reductions in upstream emissions are not uniformly distributed to individual NAAs. With the Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1, and emission increases would be distributed throughout each NAA.

**TABLE 3.3-8**

**Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards Maximum Changes by Nonattainment Area**

| Pollutant | Increase/Decrease | Change (tons/year) | Year | Alt. No. | Nonattainment Area |
|---|---|---|---|---|---|
| **Hazardous Air Pollutants** | | | | | |
| Acetaldehyde | Maximum Increase | 0.3 | 2020 | 3 | Atlanta, GA |
| | Maximum Decrease | 91.2 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| Acrolein | Maximum Increase | 1.6 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| | Maximum Decrease | No Acrolein decreases. (Upstream emissions decreases are not included for acrolein.) | | | |
| Benzene | Maximum Increase | No Benzene increases. | | | |
| | Maximum Decrease | 670.9 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| 1,3-Butadiene | Maximum Increase | 0.1 | 2015 | 3 | Dallas-Fort Worth, TX |
| | Maximum Decrease | 54.2 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |

**TABLE 3.3-8 (cont'd)**

**Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards Maximum Changes by Nonattainment Area**

| Pollutant | Increase/Decrease | Change (tons/year) | Year | Alt. No. | Nonattainment Area |
|---|---|---|---|---|---|
| Diesel Particulate Matter | Maximum Increase | No Diesel Particulate Matter increases. | | | |
| | Maximum Decrease | 3,580.4 | 2035 | 7 | Los Angeles South Coast Air Basin, CA |
| Formaldehyde | Maximum Increase | 5.4 | 2020 | 7 | Dallas-Fort Worth, TX |
| | Maximum Decrease | 171.6 | 2035 | 7 | Houston-Galveston-Brazoria, TX |

### 3.3.2.6 Alternative 4: 25 Percent Above Optimized

#### 3.3.2.6.1 Criteria Pollutants

With the 25 Percent Above Optimized Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 3 but less than would Alternatives 5 through 7. There would be greater reductions in nationwide emissions of criteria pollutants with the 25 Percent Above Optimized Alternative than with Alternatives 1 through 3: 1.3 percent to 8.9 percent greater reductions compared to Alternative 2 depending on pollutant and year. There would be lesser reductions than with Alternatives 5 (as low as 0.8 percent) through 7 (as high as 9.6 percent), depending on pollutant and year. All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years compared to Alternative 1, No Action. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 3.3.2.6.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the 25 Percent Above Optimized Alternative compared to Alternatives 1 through 3: between 0.3 percent to 6.1 percent depending on year, pollutant, and Alternative. The 25 Percent Above Optimized Alternative would reduce air toxics emissions less than would Alternatives 5 through 7: between 0.2 percent and 5.7 percent depending on year, pollutant, and alternative. At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the Optimized Alternative, the reductions in upstream emissions are not uniformly distributed to individual NAAs.

With the 25 Percent Above Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small as shown in Appendix B-1. Potential air quality impacts from these increases would be minor because the VMT and emission increases would be distributed throughout each NAA.

### 3.3.2.7 Alternative 5: 50 Percent Above Optimized

#### 3.3.2.7.1 Criteria Pollutants

With the 50 Percent Above Optimized Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 4 but less than would Alternatives 6 and 7. There would be greater reductions in nationwide emissions of criteria pollutants with the 50 Percent Above Optimized Alternative than with Alternatives 1 through 4: from 0.8 percent for Alternative 4 to 13.3 percent for Alternative 2 on average, depending on year and pollutant. There would be lesser reductions than with Alternatives 6 and 7: from 0.8 percent to 5.2 percent depending on year, pollutant, and alternative. All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 3.3.2.7.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the 50 Percent Above Optimized Alternative compared to Alternatives 1 through 4: between 0.3 percent for Alternative 4 and 8.8 percent for Alternative 2 on average, depending on year and pollutant. The 50 Percent Above Optimized Alternative would reduce air toxics emissions less than would Alternatives 6 and 7: between 0.3 percent and 3.1 percent on average, depending on year, pollutant, and alternative. At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the 25 Percent Above Optimized Alternative, the reductions in upstream emissions are not uniformly distributed to individual NAAs. With the 50 Percent Above Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small as shown in Appendix B-1, and emission increases would be distributed throughout each NAA.

### 3.3.2.8 Alternative 6: Total Costs Equal Total Benefits

#### 3.3.2.8.1 Criteria Pollutants

With the Total Costs Equal Total Benefits Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 5 but less than would Alternative 7. There would be greater reductions in nationwide emissions of criteria pollutants with the Total Costs Equal Total Benefits Alternative than with Alternatives 1 through 5: between 0.8 percent for Alternative 5 and 16.5 percent for Alternative 2 on average, depending on pollutant and year. There would be lesser reductions than with Alternative 7: between 0.3 percent for 2015 and 2.1 percent for 2035. All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 3.3.2.8.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the Total Costs Equal Total Benefits Alternative compared to Alternatives 1 through 5:

from 0.3 percent for Alternative 5 to 10.7 percent for Alternative 2 on average depending on year and pollutant. The Total Costs Equal Total Benefits Alternative would reduce air toxics emissions less than would Alternative 7: from 0.1 percent for 2015 to 1.1 percent for 2035. At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the 50 Percent Above Optimized Alternative, the reductions in upstream emissions are not uniformly distributed to individual NAAs. With the Total Costs Equal Total Benefits Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1, and emission increases would be distributed throughout each NAA.

### 3.3.2.9 Alternative 7: Technology Exhaustion

#### 3.3.2.9.1 Criteria Pollutants

With the Technology Exhaustion Alternative, the CAFE standards would increase fuel economy the most of all the alternatives. There would be greater reductions in nationwide emissions of criteria pollutants with the Technology Exhaustion Alternative than with any other alternative: between 0.3 percent for Alternative 6 and 18.5 percent for Alternative 2 on average depending on year and pollutant. All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 3.3.2.9.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the Technology Exhaustion Alternative than with any other alternatives: between 0.1 percent for Alternative 6 and 11.8 percent for Alternative 2 on average depending on year and pollutant. At the nationwide level emissions of toxic air pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect. However, as with the Total Costs Equal Total Benefits Alternative, the reductions in upstream emissions are not uniformly distributed to individual NAAs. With the Technology Exhaustion Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1, and emission increases would be distributed throughout each NAA.

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## 3.4 CLIMATE

This section describes the environment affected by the CAFE standards. As there is little precedent for addressing climate change within the structure of an EIS, several reasonable judgments were called for when deciding where to draw the line between the direct and indirect effects of the alternatives (Chapter 3) and the cumulative impacts associated with the alternatives (Chapter 4).

NHTSA determined that the scope of climate change issues covered in Chapter 3 would be more tailored than those in Chapter 4 in two respects: (1) the discussion of impacts in Chapter 3 would focus on those associated with greenhouse gases only due to the MY 2010-2015 CAFE standards (which affect cars and light trucks built from 2010-2015, and are then assumed to remain in place at the MY 2015 levels from 2015 through 2100), and (2) the discussion of consequences would focus on emissions and effects on the climate system, e.g., atmospheric $CO_2$ concentrations, temperature, sea level, and precipitation. Chapter 4 is broader in that it (1) covers foreseeable effects of the MY 2010-2015 standards, which include a set of more stringent CAFE standards for MY 2016-2020 (the MY 2020 levels would affect cars and light trucks built from 2020-2100) and (2) extends the discussion of consequences to include not only the effects on the climate system, but also the impacts of climate on key resources (e.g., freshwater resources, terrestrial ecosystems, coastal ecosystems). Thus, the reader is encouraged to explore the Cumulative Impacts discussion in Chapter 4 to fully understand NHTSA's approach to climate change in this DEIS.

The remainder of this section is divided into four subsections: 3.4.1, which provides an introduction to key topics in greenhouse gases and climate change; 3.4.2, which outlines the methodology used to evaluate climate effects; 3.4.3, a description of the affected environment; and 3.4.4, consequences.

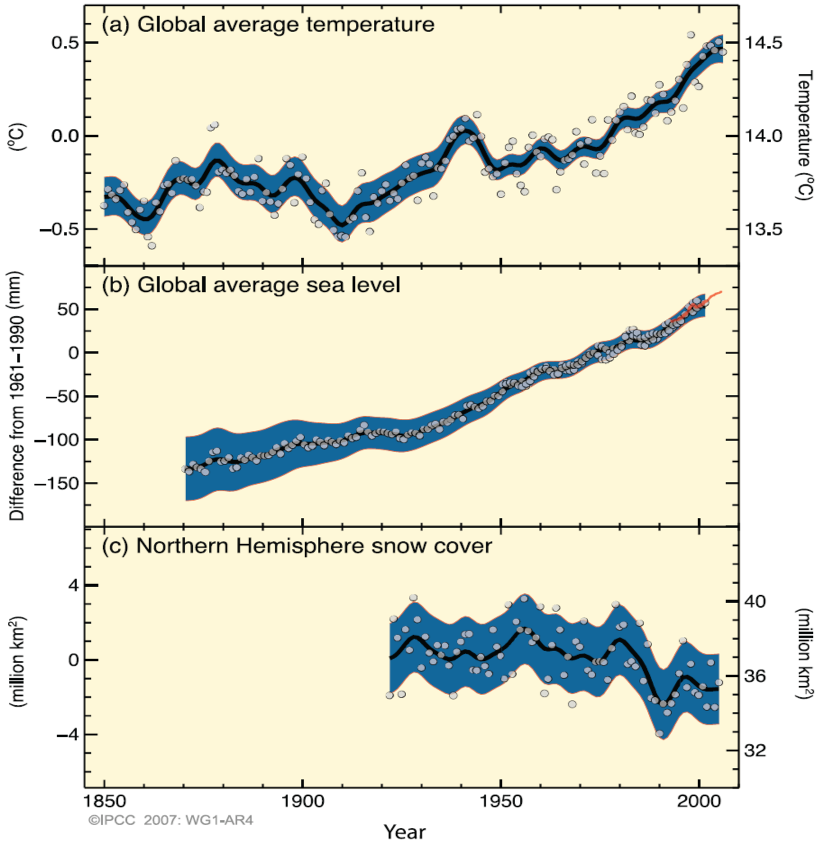
### 3.4.1 Introduction - Greenhouse Gases and Climate Change

There have been a series of intensive and extensive analyses conducted by the Intergovernmental Panel on Climate Change (IPCC), the scientific body tasked by the United Nations to evaluate the risk of human-induced climate change), the United States Climate Change Science Program (USCCSP), and many other government, non-government organization (NGO), and industry-sponsored programs. Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and United States climate change: the IPCC Fourth Assessment Report (AR4, *Climate Change 2007*), and reports by the USCCSP that include the *Scientific Assessment of the Effects of Global Change on the United States* and Synthesis and Assessment Products. These sources and the studies they review are frequently quoted throughout this DEIS. Since new evidence is continuously emerging on the subject of climate change impacts, the discussions on climate impacts in this DEIS also draw on more recent studies, where possible.

#### 3.4.1.1 What is Climate Change?

Global climate change refers to long-term fluctuations in global surface temperatures, precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) (0.74° C) (IPCC, 2007); sea levels have risen 6.7 inches (0.17 meters) (IPCC, 2007); and Arctic Sea ice has shrunk by 2.7 percent per decade with larger decreases in summer of 7.4 percent as well as decreases in mountain glaciers and snow cover (IPCC, 2007) (Figure 3.4-1).

**Figure 3.4-1 Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover (source: IPCC, 2007)**



### 3.4.1.2 What Causes Climate Change?

The earth absorbs heat energy from the sun, and returns some of this heat to space as terrestrial infrared radiation. GHGs trap heat in the troposphere (i.e., the atmosphere close to the Earth's surface), reradiate it back to Earth, and thereby cause warming. This process—known as the "greenhouse effect"—is responsible for maintaining surface temperatures that are warm enough to sustain life (Figure 3.4-2). Human activities, particularly fossil fuel combustion, contribute to the presence of GHGs in the atmosphere. There are increasing concerns that the buildup of greenhouse gases in the atmosphere is upsetting the Earth's energy balance.

Most scientists now agree that this climate change is largely a result of GHG emissions from human activities. The IPCC recently asserted that, "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" (IPCC, 2007, p. 10).[21]

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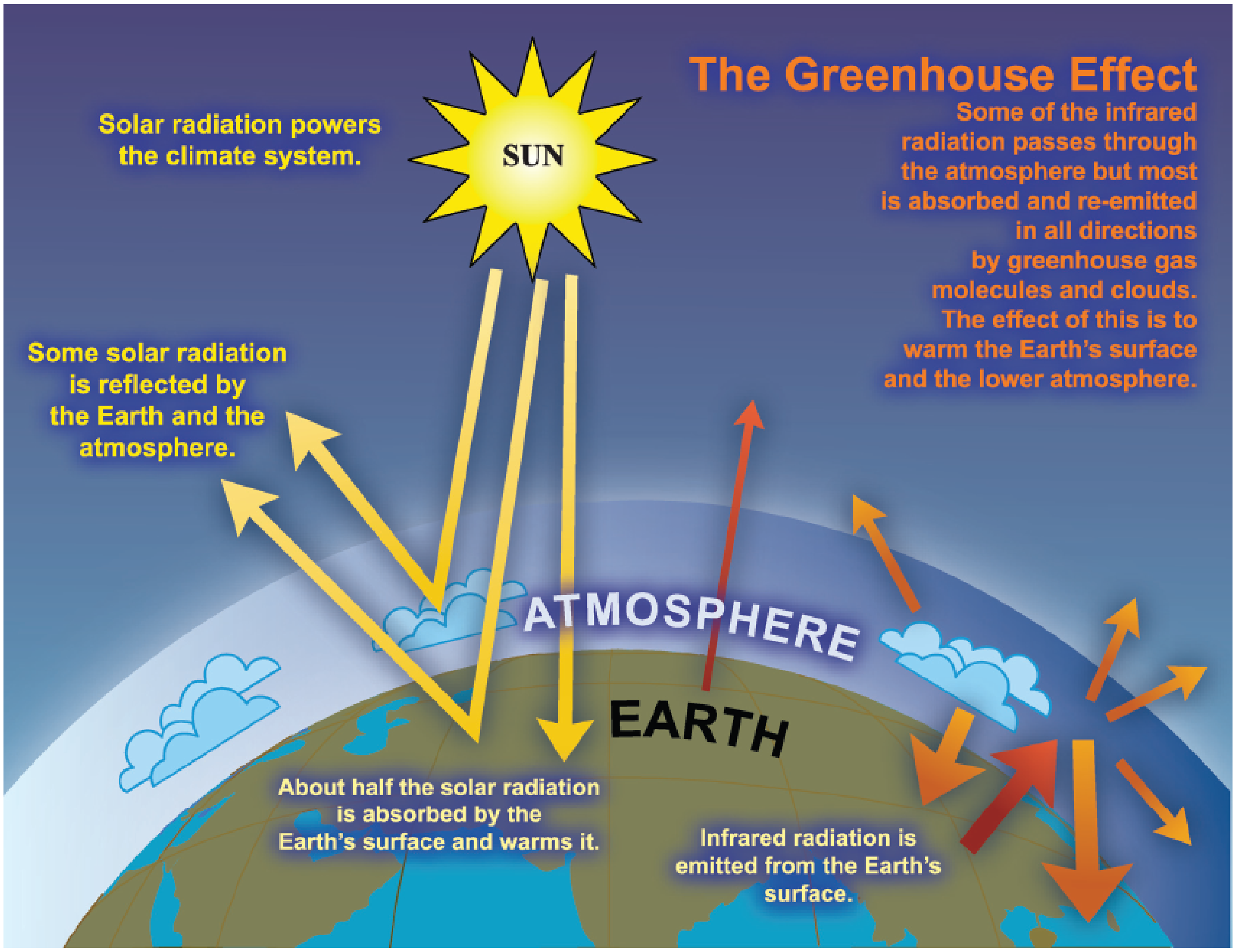
[21] The IPCC uses standard terms to "define the likelihood of an outcome or result where this can be estimated probabilistically". The term "very likely," cited in italics above and elsewhere in this section, corresponds to a >90 percent probability of an occurrence or outcome, whereas the term "likely" corresponds to a >66 percent probability. These two terms are used in this section; a more expansive set of IPCC terminology regarding likelihood is used and defined in Section IV.E.

**Figure 3.4-2 The Greenhouse Effect (source: Le Treut et al., 2007)**



Most GHGs are naturally occurring, including $CO_2$, $CH_4$, $N_2O$, water vapor, and ozone. Human activities such as the combustion of fossil fuel, the production of agricultural commodities, and the harvesting of trees can contribute to increased concentrations of these gases in the atmosphere. In addition, a number of very potent anthropogenic GHGs, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$), are created and emitted through industrial processes.

### 3.4.1.3 What are the Anthropogenic Sources of Greenhouse Gases?

Human activities that emit GHGs to the atmosphere include the combustion of fossil fuels, industrial processes, solvent use, land-use change and forestry, agriculture production, and waste management. Atmospheric concentrations of $CO_2$, $CH_4$, and $N_2O$—the most important anthropogenic GHGs—have increased approximately 35, 150, and 18 percent, respectively, since the beginning of the Industrial Revolution in the mid 1700s (IPCC, 2007). The rise in GHGs in the past century is widely attributed to the combustion of fossil fuels (i.e., coal, petroleum, and gas) used to produce electricity, heat buildings, and run motor vehicles and planes, among other uses.

Contributions to the build-up of GHG in the atmosphere vary greatly from country to country, and depend heavily on the level of industrial and economic activity. Emissions from the United States accounted for approximately 15-20 percent of global GHG emissions in the year 2000 (CAIT, 2008).[22] With about one-third of United States emissions due to the combustion of petroleum fuels in the transportation sector (EPA, 2008), $CO_2$ emissions from the United States transportation sector alone represent nearly 4 percent of all global GHG emissions (CAIT, 2008).

#### 3.4.1.4 Evidence of Climate Change

Observations and studies across the globe are reporting evidence that the earth is currently undergoing climatic change much quicker than would be expected from natural variations. Global temperatures are increasing, with 11 of the hottest 12 years on record occurring over the past 12 years (IPCC, 2007). Sea levels have risen, caused by thermal expansion of the ocean and melting snow and ice. More frequent weather extremes such as droughts, floods, severe storms, and heat waves have also been observed (IPCC, 2007).

#### 3.4.1.5 Future Climactic Trends and Expected Impacts

As the world population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions are expected to grow substantially over the next century. Based on the current trajectory, the IPCC predicts that $CO_2$ concentrations could rise to more than three times the pre-industrial level by the year 2100 (Meehl et al., 2007).

Among other trends forecasted, the average global surface temperature is *likely* to rise 2.0° to 11.5° F (1.1 to 6.4° C) over the next century, accompanied by a *likely* sea level rise of approximately 0.6 to 1.9 feet (0.18 to 0.59 m) (IPCC, 2007). In addition to rising temperatures and sea levels, climate change is expected to have many environmental, human health, and economic consequences.

For a more in-depth analysis on the future impacts of climate change on various sectors, please see the Cumulative Impacts discussion in Chapter 4.

### 3.4.2 Affected Environment

This subsection describes the affected environment in terms of current and anticipated trends in GHG emissions and climate. Both emissions and climate involve very complex processes with considerable variability, which complicates the measurement and detection of change. Recent advances in the state of the science, however, are contributing to an increasing body of evidence that anthropogenic GHG emissions are affecting climate in detectable ways.

This subsection opens with a discussion of emissions and then turns to climate. Both of these discussions start with a description of United States conditions, followed by a description of the global environment. As global conditions are a macrocosm of United States conditions, many of the themes in the United States discussions reappear in the global discussions.[23]

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[22] CAIT is a database of emissions and other metrics maintained by the World Resources Institute. It includes data from EIA's *International Energy Annual*, RIVM/TNO's *EDGAR 3.2*, EPA's *Global Anthropogenic Non-$CO_2$ Greenhouse Gas Emissions: 1990 – 2020*, Houghton's "*Emissions (and Sinks) of Carbon from Land-Use Change*, and IEA's *$CO_2$ Emissions from Fuel Combustion*. The UNITED STATES contributes about 20 percent of gross GHG emissions, but only 15 percent of net emissions, which take into account carbon sinks from forestry and agriculture.

[23] For NEPA purposes, it is appropriate for this agency to consider global environmental impacts. Under NEPA a federal agency is required to "recognize the worldwide and long-range character of environmental problems." 42

***[Continued on bottom of next page]***

### 3.4.2.1 Greenhouse Gas Emissions (Historic and Current)

#### 3.4.2.1.1 United States Emissions

GHG emissions for the United States in 2006 were estimated at 7,054 million metric tons of carbon dioxide ($MMTCO_2$) equivalent[24] (EPA, 2008), and, as noted earlier, comprise about 15-20 percent of total global emissions[25] (CAIT, 2008). Annual United States emissions, which have increased 15 percent since 1990 and typically increase each year, are heavily influenced by "general economic conditions, energy prices, weather, and the availability of non-fossil alternatives" (EPA, 2008).

Carbon dioxide is by far the primary GHG emissions emitted in the United States, representing nearly 85 percent of all United States GHG emissions in 2006 (EPA, 2008). The other gases include $CH_4$, $N_2O$, and a variety of fluorinated gases, including, HFCs, PFCs, and $SF_6$. The fluorinated gases are collectively referred to as high global warming potential (GWP) gases. Methane accounted for 8 percent of the remaining GHGs on a GWP-weighted basis, followed by $N_2O$ (5 percent), and the high-GWP gases (2 percent) (EPA, 2008, ES4-6).

GHGs are emitted from a wide variety of sectors, including energy, industrial processes, waste, agriculture, and forestry. The majority of United States emissions are from the energy sector, largely due to $CO_2$ emissions from the combustion of fossil fuels, which alone account for 80 percent of total United States emissions (EPA, 2008). These emissions are due to fuels consumed in the electric power (41 percent of fossil fuel emissions), transportation (33 percent), industry (15 percent), residential (6 percent), and commercial (4 percent) sectors (EPA, 2008). However, when the United States $CO_2$ emissions are apportioned by end use, transportation becomes the single leading source of United States emissions from fossil fuels, at approximately one-third of total $CO_2$ emissions from fossil fuels (EPA, 2008).

Cars and light duty trucks, which include sport utility vehicles, pickup trucks, and minivans, accounted for over half of United States transportation emissions, and emissions from these vehicles have increased by 21 percent since 1990 (EPA, 2008). This growth was driven by two factors, an increase in travel demand and a relatively stagnant average fuel economy. Population growth and expansion, economic growth, and low fuel prices led to more miles traveled, while the rising popularity of SUVs and other light trucks resulted a slight decline in average combined fuel economy of new cars and light trucks (EPA, 2008).

#### 3.4.2.1.2 Global Emissions

Although humans have always contributed to some level of GHG emissions to the atmosphere through activities like farming and land clearing, significant 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, to power trains and cars, and to run factories and industrial operations. Today the burning of fossil fuels is still the predominant source of GHG emissions.

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U.S.C. § 4332(f). *See also* CEQ, *Council on Environmental Quality Guidance on NEPA Analyses for Transboundary Impacts* (July 1, 1997), at 3, *available at* http://ceq.hss.doe.gov/nepa/regs/transguide.html (last visited June 16, 2008) (stating that "agencies must include analysis of reasonably foreseeable transboundary effects of proposed actions in their [NEPA] analysis of proposed actions in the United States").

[24] Each GHG has a different level of radiative forcing, i.e., the ability to trap heat. To compare their relative contributions, gases are converted to carbon dioxide equivalent using their unique global warming potential (GWP).

[25] The UNITED STATES contributes about 20 percent of gross GHG emissions, but only 15 percent of net emissions, which take into account carbon sinks from forestry and agriculture.

In 2000, global GHG emissions were estimated at 44,347 MMT$CO_2$ equivalent, a 6 percent increase since 1990[26] (CAIT, 2008). In general, global GHG emissions have increased regularly, though annual increases vary according to a variety of factors (e.g., weather, energy prices, and economic factors).

As in the United States, the primary GHGs emitted globally are $CO_2$, $CH_4$, $N_2O$, and the fluorinated gases HFCs, PFCs, and $SF_6$. In 2000, $CO_2$ emissions comprised 79 percent of global emissions on a GWP-weighted basis, followed by $CH_4$, (14 percent) and $N_2O$ (7 percent). Collectively, fluorinated gases represented 1 percent of global emissions (CAIT, 2008).

A wide variety of sectors contribute to global GHG emissions, including energy, industrial processes, waste, agriculture, land-use change and forestry, and international bunkers. The sector that contributes the majority of global GHG emissions is energy, accounting for 61 percent of global emissions in 2000. In this sector, the generation of electricity and heat accounts for 26 percent of total global emissions. The next highest contributors to emissions are land-use change and forestry (17 percent), agriculture (13 percent), and transportation (12 percent; this is included within the 61 percent of emissions in the energy sector) (CAIT, 2008).

Emissions from transportation are primarily due to the combustion of petroleum to power vehicles such as cars, trucks, trains, planes, and ships. In 2000, transportation represented 12 percent of total emissions and 15 percent of $CO_2$ emissions; transportation emissions increased 11 percent since 1990 (CAIT, 2008).

### 3.4.2.2 Climate Change Effects and Impacts (Historic and Current)

#### 3.4.2.2.1 United States Climate Change Effects

This subsection describes observed historical and current climate change effects and impacts for the United States. Much of the discussion that follows is drawn from the USCCSP's *Scientific Assessment of the Effects of Global Change on the United States* (USCCSP, 2008) and citations therein.

##### Observed Changes to the Climate

The last decade is the warmest in more than a century of direct observations, with average temperatures for the contiguous United States rising at a rate near 0.6 °F per decade in the past few decades; since 1950, the number of heat waves has increased, although those recorded in the 1930s remain the most severe. There were also less unusually cold days in the last few decades with less severe cold waves for the past 10-year period in the record (USCCSP, 2008).

Over the contiguous United States, total annual precipitation increased about 6 percent from 1901 to 2005, with the greatest increases in precipitation in the northern Midwest and the South; heavy precipitation also increased, primarily during the last three decades of the 20th century, and mainly over eastern regions. Most regions experienced decreases in drought severity/duration during the second half of the 20th century, though there was severe drought in the Southwest in 1999–2007, and the Southeast recently experienced severe drought as well (USCCSP, 2008).

Relative sea level is rising 0.8–1.2 inches per decade along most of the Atlantic and Gulf Coasts, and a few inches per decade along the Louisiana Coast (due to land subsidence); and it is falling (due to land uplift) a few inches per decade in parts of Alaska (USCCSP, 2008).

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[26] All GHG estimates cited in this section include land use change and forestry, where applicable.

### Observed Impacts from the Changing Climate

Streamflow decreased about 20 percent over the past century in the central Rocky Mountain region, while in the East it increased 25 percent in the last 60 years. Annual peak streamflow (dominated by snowmelt) in western mountains is presently occurring at least a week earlier than in the middle of the 20th century. Winter streamflow is increasing in seasonal snow-covered basins while the fraction of annual precipitation falling as rain (rather than snow) increased in the last half century (USCCSP, 2008). Spring and summer snow cover decreased in the West, and in mountainous regions of the western United States, April snow water equivalent has declined 15 to 30 percent since 1950, particularly at lower elevations and primarily due to warming (Field et al., 2007 as cited by USCCSP, 2008). However, total United States snow-cover area increased in the November to January season from 1915–2004 (USCCSP, 2008).

Annual average Arctic sea ice extent decreased 2.7 ± 0.6 percent per decade from 1978–2005. In 2007, sea ice extent was approximately 23 percent below the previous all-time minimum observed in 2005. Average sea ice thickness in the central Arctic *very likely* decreased up to approximately 3 feet from 1987–1997. These area and thickness reductions allow winds to generate stronger waves, which have increased shoreline erosion along the Alaskan coast. Alaska has also experienced permafrost thawing of up to 1.6 inches per year since 1992 (USCCSP, 2008).

Rivers and lakes are freezing over later (average rate (5.8 ± 1.6) days per century) with ice breakup taking place earlier (average rate (6.5 ± 1.2 days per century). Glacier mass loss is occurring in the Northwest; and is especially rapid in Alaska since the mid-1990s (USCCSP, 2008).

Sea level rise extends the zone of impact from storm surge and waves from tropical and other storms causing coastal erosion and other damage. It is *likely* that the annual numbers of tropical storms, hurricanes, and major hurricanes in the North Atlantic have increased over the past 100 years (USCCSP SAP 3.3 2008 as cited in USCCSP, 2008) with Atlantic sea surface temperatures increasing over the same period; however, these trends are complicated by multi-decadal variability and data quality issues. In addition, there is evidence of an increase in extreme wave height characteristics over the past couple of decades, associated with more frequent and more intense hurricanes (USCCSP, 2008).

## 3.4.2.2.2 Global Climate Change Effects

This subsection describes observed historical and current climate change effects and impacts at a global scale. As with the discussion of United States effects, much of the material that follows is drawn from the following studies including the citations therein: IPCC WGI's *Summary for Policymakers* (IPCC, 2007), and the USCCSP's *Scientific Assessment of the Effects of Global Change on the United States* (USCCSP, 2008).

In their latest 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, 2007, p. 5).

### Observed Changes to the Climate

Global temperatures have been increasing over the past century. The 100-year linear trend (1906–2005) is 0.13 ± 0.03 °F per decade, while the corresponding 50-year linear trend of 0.23 ± 0.05 °F per decade is nearly double (USCCSP, 2008). Average arctic temperatures increased at almost twice the global average rate in the past 100 years. Permafrost top layer temperatures have generally increased since the 1980s (about 5°F in the Arctic) while the maximum area covered by seasonal frozen ground has decreased since 1900 by about 7 percent in the Northern Hemisphere, with a decrease in spring of up to 15 percent (IPCC, 2007).

Extreme temperatures have been observed to change extensively over the last 50 years. Hot days, hot nights, and heat waves have become more frequent; cold days, cold nights, and frost have become less frequent (IPCC, 2007).

Average atmospheric water vapor content has increased since at least the 1980s over land, ocean, and in the upper troposphere, largely consistent with air temperature increases (IPCC, 2007). Heavy precipitation events have increased in frequency over most land areas as a result (IPCC, 2007).

Average temperatures of the oceans have increased since 1961 to depths of at least 10,000 feet—the ocean absorbing more than 80 percent of the heat added to the climate system. As seawater warms, it expands and sea levels rise. Mountain glaciers, ice caps, and snow cover have declined on average, contributing to further sea level rise. Losses from the Greenland and Antarctica ice sheets have *very likely* contributed to sea level rise over 1993–2003. Dynamical ice loss explains most of Antarctic net mass loss and about half of Greenland net mass loss; the other half occurred because melting has exceeded snowfall accumulation (IPCC, 2007).

Global average sea level rose at an average rate of 0.07 ± 0.02 inches per year over 1961–2003 with the rate increasing to about 0.12 ± 0.03 inches per year over 1993–2003. Total 20th-century rise is estimated at 0.56 ± 0.16 feet (IPCC, 2007). However, since the IPCC Fourth Assessment Report, a recent study improved the historical estimates of upper-ocean warming (300-meters and 700-meters) from 1950 to 2003 by correcting for expendable bathy-thermographs (XBT) instrument bias and found the improved estimates demonstrate clear agreement with the decadal variability of the climate models that included volcanic forcing (Domingues et. al., 2008). Further, this study estimated the globally averaged sea-level trend from 1961 to 2003 to be 0.063 ± 0.01 inch per year with a rise of 0.094 inch per year evident from 1993 to 2003 consistent with the estimated trend of 0.091 inch per year from tide gauges after taking into account thermal expansion in the upper-ocean and deep ocean, variations in the Antarctica and Greenland ice sheets, glaciers and ice caps, and terrestrial storage.

### Observed Impacts from the Changing Climate

The IPCC concludes that, "At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones" (IPCC, 2007, p. 7).

Long-term trends in global precipitation amounts have been observed since 1900. Precipitation has significantly 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 is limited for some regions (IPCC, 2007).

Droughts that are more intense and longer have been observed since the 1970s, particularly in the tropics and subtropics, and have been caused by higher temperatures and decreased precipitation. Changes in sea surface temperatures, wind patterns, and decreased snowpack and snow cover have also been linked to droughts (IPCC, 2007).

Long-term trends in tropical cyclone activity have been reported, but there is no clear trend in the number of tropical cyclones each year. There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. However, concerns over data quality and multi-decadal variability persist (IPCC, 2007). 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 as, "there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record" (WMO, 2006).

Other characteristics of the global climate have not changed. The diurnal temperature range has not changed from 1979–2004 since day- and night-time temperatures have risen at similar rates. Antarctic sea ice extent shows no significant average trends—despite inter-annual variability and localized changes—consistent with the lack of warming across the region from average atmospheric temperatures. There is also insufficient evidence to determine whether trends exist in large-scale phenomena such as the meridional overturning circulation (a mechanism for heat transport in the North Atlantic Ocean, where warm waters are carried north and cold waters are carried toward the equator) or in small-scale phenomena such as tornadoes, hail, lightning and dust storms (IPCC, 2007).

### 3.4.3 Methodology

The methodology employed to characterize the effects of the alternatives on climate has two key elements:

1. Analyzing the effects of the alternatives on GHG emissions, and
2. Analyzing how the GHG emissions affect the climate system (climate effects).

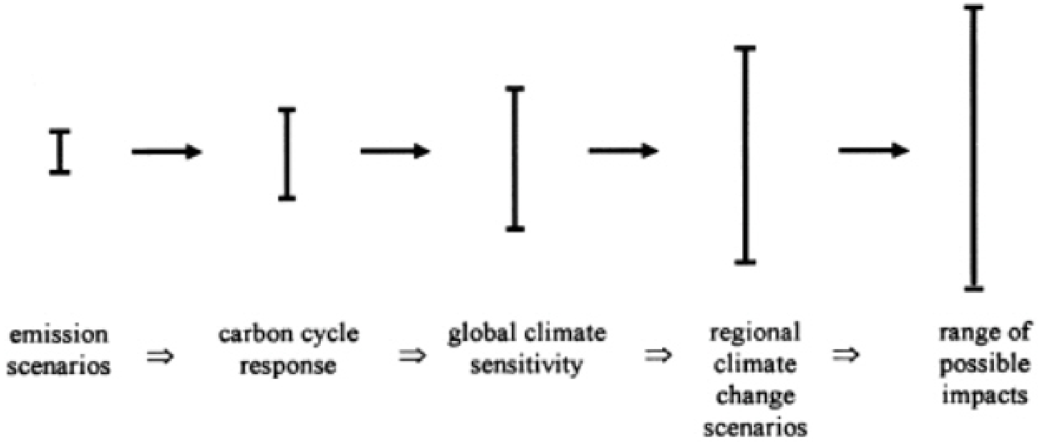
Each element is discussed below.

For both the effects on GHG emissions and the effects on the climate system, this DEIS expresses results – for each of the alternatives – in terms of the environmental attribute being characterized (emissions, $CO_2$ concentrations, temperature, precipitation, sea level). It also expresses the change in between the No Action Alternative and each of the action alternatives to illustrate the difference in environmental effects among the CAFE alternatives.

The methods used to characterize emissions and climate effects involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in both the transportation sector and other sectors that emit GHGs; changes in the future fuel supply that could affect emissions; the sensitivity of climate to increased GHG concentrations; the rate of change in the climate system in response to changing GHG concentrations; the potential existence of thresholds in the climate system (which cannot be predicted and simulated); regional differences in the magnitude and rate of climate changes; and many other factors.

Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change simulations (see Figure 3.4-3). As indicated in the figure, the emission estimates used in this DEIS have narrower bands of uncertainty than the global climate effects, which in turn have less uncertainty than the regional climate change effects. The effects on climate are in turn less uncertain than the impacts of climate changes on affected resources (e.g., terrestrial and coastal ecosystems, human health, and other sectors discussed in Section 4.5).

**Figure 3.4-3 From Moss and Schneider (2000, p. 39): "Cascade of uncertainties typical in impact assessments showing the "uncertainty explosion" as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses."**



Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (*See* 40 CFR § 1502.22(b)). The understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decisionmaking, the analysis described below involves many assumptions and uncertainties in the course of evaluating reasonably foreseeable significant adverse impacts on the human environment. The DEIS uses methods and data that represent the best available information on this topic, and which have been subject to peer review and scrutiny. In fact, the information cited throughout this section that is extracted from the IPCC and U.S. Climate Change Science Program has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The MAGICC model, and the scaling approaches, and the IPCC emission scenarios described below are generally accepted in the scientific community.

NHTSA is aware of the USCCSP's recent release for comment of a draft Synthesis and Assessment Product (SAP) 3.1 regarding the strengths and limitations of climate models.[27] The reader might find the discussions in this draft Synthesis and Assessment Product useful to grasp a better understanding of the methodological limitations regarding modeling the environmental impacts of the proposed action and the range of alternatives on climate change.

### 3.4.3.1 Methodology for Greenhouse Gas Emissions Modeling

GHG emissions were estimated using the Volpe model, described earlier in Section 3.B. The Volpe model assumes that major manufacturers will exhaust all available technology before paying noncompliance civil penalties. In the more stringent alternatives, the Volpe model predicts that increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to penalty payment. Setting standards this high may not be technologically feasible, nor may it serve the need of the nation to conserve fuel and/or reduce emissions.

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[27] U.S. Climate Change Science Program, Synthesis and Assessment Product 3.1 (Climate Models: An Assessment of Strengths and Limitations), Final (third) review draft (May 15, 2008)., *available at* http://www.climatescience.gov/Library/default.htm#sap.

Fuel savings from stricter CAFE standards also result in lower emissions of $CO_2$, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[28] There is a direct relationship between fuel economy and $CO_2$ emissions. Lower fuel consumption reduces carbon dioxide emissions directly, because the primary source of transportation-related $CO_2$ emissions is fuel combustion in internal combustion engines. NHTSA estimates reductions in carbon dioxide emissions resulting from fuel savings by assuming that the entire carbon content of gasoline, diesel, and other fuels is converted to $CO_2$ during the combustion process.[29] Reduced fuel consumption also reduces $CO_2$ emissions that result from the use of carbon-based energy sources during fuel production and distribution. NHTSA currently estimates the reductions in $CO_2$ emissions during each phase of fuel production and distribution using $CO_2$ emission rates obtained from the GREET model, using the previous assumptions about how fuel savings are reflected in reductions in each phase.[30] The total reduction in $CO_2$ emissions from the improvement in fuel economy under each alternative CAFE standard is the sum of the reductions in emissions from reduced fuel use and from lower fuel production and distribution.

### 3.4.3.2 Methodology for Estimating Climate Effects

This DEIS estimates and reports on four direct and indirect effects of climate change, driven by alternative scenarios of GHG emissions, including:

- Changes in $CO_2$ concentrations
- Changes in global mean surface temperature
- Changes in regional temperature and precipitation
- Changes in sea level

The change in $CO_2$ concentration is a direct effect of the changes in GHG emissions, and influences each of the other factors.

This DEIS uses two methods to estimate the key direct and indirect effects of the alternate CAFE standards.

1. Use a climate model, along with emission scenarios that correspond to each of the alternatives. For purposes of this DEIS, NHTSA chose to employ a simple climate model, MAGICC (Model for Assessment of Greenhouse gas-Induced Climate Change) version 4.1 (Wigley, 2003) to estimate changes in key direct and indirect effects. The application of

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[28] For purposes of this rulemaking, NHTSA estimated emissions of vehicular $CO_2$, $CH_4$, and $N_2O$ emissions, but did not estimate vehicular emissions of hydrofluorocarbons. Methane and nitrous oxide account for less than 3 percent of the tailpipe GHG emissions from passenger cars and light trucks, and $CO_2$ emissions accounted for the remaining 97 percent. Of the total (including non-tailpipe) GHG emissions from passenger cars and light trucks, tailpipe $CO_2$ represents about 93.1 percent, tailpipe methane and nitrous oxide represent about 2.4 percent, and hydrofluorocarbons (i.e., air conditioner leaks) represent about 4.5 percent. Calculated from U.S EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006*, EPA430-R-08-05, April 15, 2008. Available online at: http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf, Table 215. (Last accessed April 20, 2008.)

[29] This assumption results in a slight overestimate of carbon dioxide emissions, since a small fraction of the carbon content of gasoline is emitted in the forms of carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimate is likely to be extremely small. This approach is consistent with the recommendation of the Intergovernmental Panel on Climate Change for "Tier 1" national greenhouse gas emissions inventories. *Cf.* Intergovernmental Panel on Climate Change, *2006 Guidelines for National Greenhouse Gas Inventories*, Volume 2, Energy, p. 3.16.

[30] See Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 FR 24352, 24412-24413 (May 2, 2008).

MAGICC version 4.1 utilizes the emission estimates for $CO_2$, $CH_4$, and $N_2O$ from the Volpe model.

2. Examine the reported relationship (in the IPCC Fourth Assessment [IPCC, 2007] and more recent peer reviewed literature) between various scenarios of global emissions paths and the associated direct and indirect effects for each scenario. If one assumes that the relationships can be scaled through linear interpolation, these relationships can be used to infer the effect of the emissions associated with the regulatory alternatives on direct and indirect climate effects. The emission estimates used in these scaling analyses were based only on $CO_2$ emissions.[31]

The MAGICC, the scaling approach, and the emission scenarios used in the analysis are described in the three subsections below.

#### 3.4.3.2.1 MAGICC Version 4.1

The selection of MAGICC for this analysis was driven by a number of factors:

- MAGICC has been used in a number of peer reviewed literature to evaluate changes in global mean surface temperature and sea level rise, including the IPCC Fourth Assessment for WG1 (IPCC, 2007) where it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[32] to estimate the global mean surface temperature and the sea level rise for SRES scenarios that the AOGCMs did not run.
- MAGICC is publicly available and is already populated with the SRES scenarios.
- MAGICC was designed for the type of analysis performed in this DEIS.
- 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 such as the B1 (low), A1B (medium), and A2 (high) scenarios.

For the analysis using MAGICC, we have assumed that global emissions consistent with the No Action Alternative follow the trajectory provided by the SRES A1B (medium) scenario.

#### 3.4.3.2.2 Scaling Approach

The scaling approach is designed to use information on relative changes in emissions to estimate relative changes in $CO_2$ concentrations, global mean surface temperature, precipitation, and sea level rise based on interpolation between the results provided for the three SRES scenarios (B1-low, A1B-medium, and A2-high) provided by the IPCC WG1 (IPCC, 2007). [33] This approach uses the following steps to estimate these changes:

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[31] We based the scaling on the changes in $CO_2$ emissions because $CO_2$ comprises the vast majority of GHG emissions from passenger cars and light trucks and the change in emissions of other GHGs ($CH_4$ and $N_2O$) is much smaller compared to global emissions of these gases.

[32] For a discussion of AOGCMs, seeWG1, Chapter 8 in IPCC (2007).

[33] The use of three emission scenarios provides insight into the impact of alternative global emission scenarios on the effect of the CAFE alternatives.

1. NHTSA assumed that global emissions consistent with the No Action Alternative follow the trajectories provided by the three SRES scenarios, providing results illustrating the uncertainty due to factors influencing future global emissions of greenhouse gases.

2. $CO_2$ concentrations are estimated in 2100 for each of the three SRES scenarios and for each CAFE alternative based on the relative reduction in emissions for the CAFE alternative using the average share of emitted $CO_2$ that remains in the atmosphere for each of the SRES scenarios.

3. Determine the global mean surface temperature at equilibrium from $CO_2$ alone for each SRES scenario, each CAFE alternative, and different estimates of the climate sensitivity. See the following sections for definitions of the global mean temperature at equilibrium and the climate sensitivity.

4. The global mean surface temperature for some of the cases described above were determined by using low and high estimates of the ratio of global mean surface temperature to global mean surface temperature at equilibrium.

5. The increase in global mean surface temperature was used along with factors relating increase in global average precipitation to this increase in global mean surface temperature to estimate the increase in global averaged precipitation for each CAFE alternative for the A1B (medium) scenario.

6. In order to estimate the sea level rise for each CAFE alternative, NHTSA calculated the change in sea level rise as a function of change in emissions, using the SRES A1B (medium) and B1 (low) emissions scenario. As described in the body of the DEIS, a correction factor was applied to account for the "momentum" in the processes affecting temperature and sea level, also known as the "commitment" to climate change and sea level rise. The resulting scaling factor was used to estimate the change in sea level for each of the CAFE alternatives.

#### 3.4.3.2.3 Emission Scenarios

As described above, both the MAGICC and the scaling approach use long-term emission scenarios representing different assumptions about key drivers of GHG emissions. All three of the scenarios used are based on IPCC's effort to develop a set of long-term (1990-2100) emission scenarios to provide some standardization in climate change modeling. The most widely used scenarios are those from the Special Report on Emission Scenarios (SRES) (Nakicenovic et al., 2000).

Both the MAGICC and the scaling approach rely primarily the SRES scenario referred to as "A1B" to represent a "reference case" emission scenario, i.e., emissions for the No Action Alternative. NHTSA selected this scenario because it is regarded as a moderate emissions case and has been widely used in AOGCMs, including several AOGCM runs developed for the IPCC Work Group 1 (WG1) Fourth Assessment Report (IPCC, 2007).

Separately, each of the other alternatives was simulated by calculating the difference in annual GHG emissions with respect to the No Action Alternative, and subtracting this change from the A1B (medium) scenario to generate modified global-scale emission scenarios, which each show the effect of the various regulatory alternatives on the global emissions path. For example, the emissions from United States autos and light trucks in 2020 for the No Action Alternative are 1,617 $MMTCO_2$; the emissions in 2020 for the Optimized Alternative are 1,514 $MMTCO_2$. The difference is 103 $MMTCO_2$. Global emissions for the A1B (medium) scenario in 2020 are 46,339 $MMTCO_2$, and represent the No Action Alternative. Global emissions for the optimized scenario are 103 $MMTCO_2$ less, or 46,236 $MMTCO_2$.

The A1B (medium) scenario provides a global context for emissions of a full suite of greenhouse gases and ozone precursors. There are some inconsistencies between the overall assumptions used by IPCC in its SRES (Nakicenovic et al., 2000) to develop global emission scenario and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand. However, these inconsistencies affect the characterization of each of the CAFE alternatives in equal proportion, so the relative estimates provide a reasonable approximation of the differences in environmental impact among the alternatives.

Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, despite the inconsistencies between the IPCC assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the Volpe model on the United States transportation sector, the approach used is valid for this analysis; these inconsistencies affect all of the alternatives equally, and thus they do not hinder a comparison of the alternatives in terms of their relative effects on climate.

The approaches focus on the marginal climate effect of marginal changes in emissions. Thus, they generate a reasonable characterization of climate changes for a given set of emission reductions, regardless of the underlying details associated with those emission reductions. In the discussion that follows, projected climate change under the No Action Alternative is characterized, as well as the changes associated with each of the alternative CAFE standards.

The scaling approach also uses the B1 (low) and A2 (high) emission scenarios (Nakicenovic et al., 2000) as "reference" scenarios. This provides a basis for interpolating climate responses to varying levels of emissions. Some responses of the climate system are believed to be non-linear; by using a low- and high-emissions case, it is possible to estimate the incremental effects of the alternatives with respect to different reference cases.

#### 3.4.3.2.4 Tipping Points and Abrupt Climate Change

In a linear system, the response is proportional to the change in a driver. For climate, $CO_2$ and temperature are two key drivers. However, the climate system is complex; there are many positive and negative feedback mechanisms. Moreover, there may be thresholds in the response of the system. Below the thresholds, the response may be small or zero, and above the thresholds, the response could be much quicker than previously observed or expected. The term "tipping point" refers to a situation where the climate system reaches a point at which there is a strong and amplifying positive feedback from only a moderate addition change in driver, such as $CO_2$ or temperature increase. These tipping points can result in abrupt climate change—defined in Alley at al (2002) (cited in Meehl, et al. 2007, p. 775) to "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."

While climate models do take positive (and negative, i.e., dampening) feedback mechanisms into account, the magnitude of their effect and threshold at which a tipping point is reached may not be well understood in some cases. In fact, MacCracken at al. (2008) note that existing climate models may not include some critical feedback loops, and Hansen et al. (2007a) states that the predominance of positive feedbacks in the climate system have the potential to cause large rapid fluctuations in climate change effects. Therefore, it is important to discuss these mechanisms, and the possibility of reaching points which may bring about abrupt climate change. The existence of these mechanisms and other evidence has led some climate scientists including Hansen et al., (2007b) to conclude that a $CO_2$ level exceeding about 450 ppm is “dangerous.”[34]

A number of these positive feedback loops may occur with the melting of land ice cover, including glaciers and the Greenland and West Antarctic ice sheets. As land ice cover melts due to increasing temperatures, the ground underneath is exposed. This ground has a lower albedo (it reflects less infrared radiation back to the atmosphere) compared to the ice, and results in the absorption of more heat, further raising temperatures. In addition, increased surface temperatures cause more precipitation to falls as rain instead of snow, increasing surface melt water which may further increase ice flow (Meehl et al., 2007). The albedo affect is also relevant for sea ice melt, as darker open water absorbs the heat of the sun at a higher rate than the lighter sea ice does, with the warmer water leading to further melting.

Changes in ocean circulation patterns are also well documented as examples of potential abrupt climate change. The conveyor belt of circulation in the Atlantic Ocean, called the Meridional Overturning Circulation (MOC), brings warm upper waters into northern latitudes and returns cold deep waters southward to the Equator. There is concern that increasing ocean temperatures and reductions in salinity may cause this circulation to slow and possibly cease, as has happened in the past, triggering disastrous climate change. It is important to note that none of the AOGCMs show an abrupt change in circulation through 2100, though “some long-term model simulations suggest that a complete cessation can result for large forcings” (Stouffer and Manabe, 2003 as cited in Meehl et al., 2007, p. 775). However, the IPCC concludes that, “there is no direct model evidence that the MOC could collapse within a few decades”, and current simulations do not model out far enough to determine whether the cessation of this circulation would be irreversible (Meehl et al., 2007).

Another factor that may accelerate climate change at rates faster than those currently observed is the possible changing role of soil and vegetation as a carbon source, instead of a sink. Currently, soil and vegetation act as a sink, absorbing carbon in the atmosphere and translating this additional carbon to accelerated plant growth and soil carbon storage. However, around mid-century, increasing temperatures and precipitation cause increased rates of transpiration, resulting in soil and vegetation becoming a potential source of carbon emissions (Cox et al., 2000 as cited in Meehl et al., 2007). There is also the potential for warming to thaw frozen arctic soils (permafrost) with the wet soils emitting more methane; there is evidence that this is already taking place (Walter et al., 2007). Therefore, a widespread change in soils, from a sink to a source of carbon, could further exacerbate climate change.

Overall, IPCC concludes that these abrupt changes are unlikely to occur this century, but raises concerns that the likelihood of experiencing events such as this are increasing (Meehl et al., 2007, p. 818):

> “Abrupt climate changes, such as the collapse of the West Antarctic Ice Sheet, the rapid loss of the Greenland Ice Sheet or large-scale changes of ocean circulation systems, are not considered likely to occur in the 21st century, based on currently available model results. However, the occurrence of such changes becomes increasingly more likely as the perturbation of the climate system progresses.”

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ’s regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the DEIS acknowledges that information on tipping points or abrupt climate change is incomplete, but the state of the science does not allow for a characterization how the CAFE alternatives

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[34] Defined as more than 1ºC above the level in 2000.

influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change.

### 3.4.4 Consequences

This subsection describes the consequences of the MY 2011-2015 CAFE standards in terms of (1) GHG emissions and (2) climate effects.

#### 3.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger car and light truck CAFE standards, NHTSA uses the Volpe model (see Section 3.1.4 for a discussion of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total and petroleum energy use, which in turn affects the amount of $CO_2$ emissions. Reducing fuel use also lowers $CO_2$ emissions from the use of fossil carbon-based energy during crude oil extraction, transportation, and refining, as well in the transportation, storage, and distribution of refined fuel. Because $CO_2$ accounts for such a large fraction of total GHG emitted during fuel production and use – more than 95 percent, even after accounting for the higher global warming potentials of other GHGs – NHTSA's consideration of GHG impacts focuses on reductions in $CO_2$ emissions resulting from the savings in fuel use that accompany higher fuel economy.

GHG emissions were estimated for each alternative. In the discussion and table that follows, emission reductions represent the differences in total annual emissions by all cars or light trucks in use between their estimated future levels under the No Action Alternative, and with each alternative CAFE standard in effect. Emission reductions resulting from the CAFE standard for MY 2011-2015 cars and light trucks were estimated from 2010 to 2100. Reductions begin in the year 2010, the first year that MY 2011 vehicles are on the road. For each alternative, all vehicles after MY 2015 were assumed to meet the MY 2015 CAFE standard. Emissions were estimated for all alternatives through 2100, and these emissions were compared against the Notice of Proposed Rulemaking (NPRM) baseline (which assumes all vehicles post MY 2010 meet the MY 2010 standard) to estimate emission reductions. The Volpe model estimates emissions through the year 2060.[35] As a simplifying assumption, annual emission reductions from 2061-2100 were held constant at 2060 levels.

Total emissions and emission reductions resulting from implementation of the seven alternatives to new passenger cars and light trucks from 2010-2100 are shown below in Table 3.4-1 and Figure 3.4-4. Emissions for the period range from 213,000 $MMTCO_2$ for the technology exhaustion alternative to 248,000 $MMTCO_2$ for the No Action Alternative. Compared to the No Action Alternative, projections of emission reductions over the 2010 to 2100 timeframe due to the MY 2011-2015 CAFE standard ranged from 18,333 to 35,378 $MMTCO_2$.[36] Compared against global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the A1B-medium scenario), this rulemaking is expected to reduce global $CO_2$ emissions by about 0.4 to 0.7 percent.

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[35] See section 3.1.3 for a summary of the scope and parameters of the Volpe model.

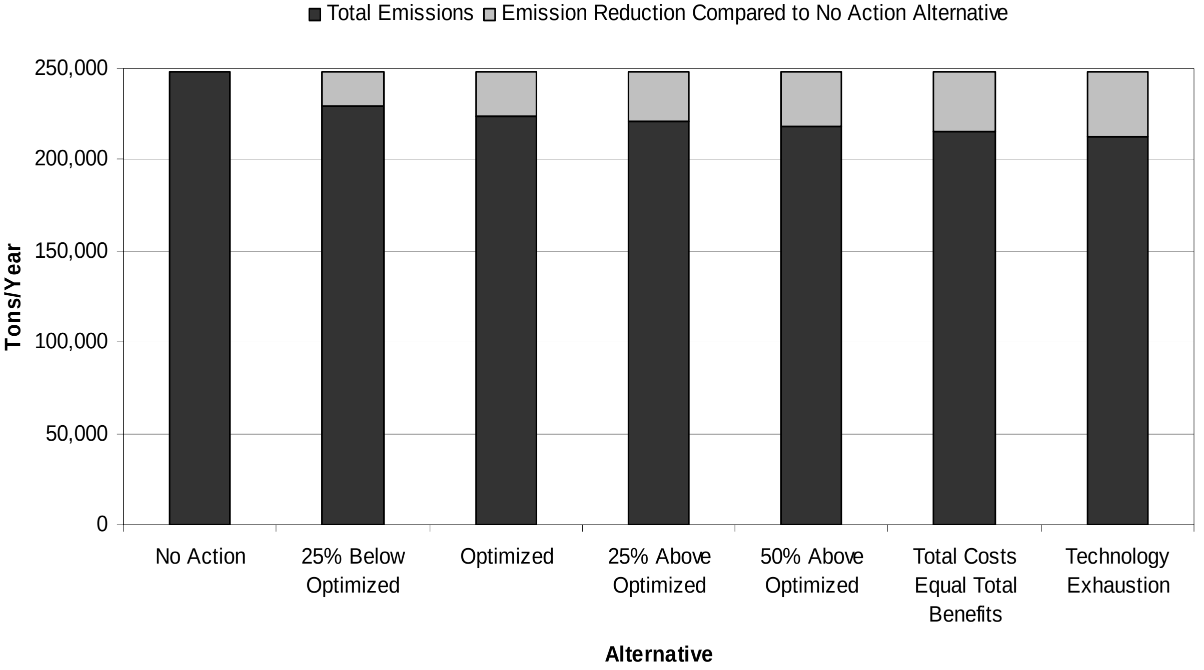
[36] The values here are summed from 2010 through 2100, and are thus considerably higher than the value of 520 $MMTCO_2$ that is cited in the NPRM for the "Optimized" alternative. The latter value is the reduction in $CO_2$ emissions by only model year 2011-15 cars and light trucks over their lifetimes resulting from the optimized CAFE standards, measured as a reduction from the NPRM baseline of extending the CAFE standards for model year 2010 to apply to 2011-15.

**TABLE 3.4-1**

**Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard, from 2010-2100 ($MMTCO_2$)**

| Alternative | Emissions | Emission Reductions Compared to No Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 229,558 | 18,333 |
| Optimized | 223,795 | 24,096 |
| 25 Percent Above Optimized | 221,003 | 26,887 |
| 50 Percent Above Optimized | 218,548 | 29,342 |
| Total Costs Equal Total Benefits | 215,714 | 32,176 |
| Technology Exhaustion | 212,512 | 35,378 |

**Figure 3.4-4 Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 CAFE Standard, from 2010-2100 (MMTCO2)**



To gain a sense of the relative impact of these reductions, it can be helpful to compare them against emission projections from the transportation sector, as well as expected or stated goals from existing programs designed to reduce $CO_2$ emissions.

As Table 3.4-2 shows, total $CO_2$ emissions accounted for by the U.S. car and light truck fleets are projected to increase significantly from their level in 2010 under the No Action alternative, which would extend passenger car and light truck CAFE standards for model year 2010 to apply to all future model years. The table also shows that each of the Action alternatives would reduce total car and light truck $CO_2$ emissions in future years from their projected levels under the No Action alternative. Progressively larger reductions in $CO_2$ emissions from their level under the No Action alternative are projected to occur during each future year as the Action Alternatives require successively higher fuel economy levels for model year 2011-2015 and later passenger cars and light trucks.

**TABLE 3.4-2**

**Nationwide Emissions of Greenhouse Gases from Passenger Cars and Light Trucks with Alternative CAFE Standards for Model Years 2011-15 (MMT per Year)**

| | **Alt. 1** | **Alt. 2** | **Alt. 3** | **Alt. 4** | **Alt. 5** | **Alt. 6** | **Alt. 7** |
|---|---|---|---|---|---|---|---|
| **GHG and Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Costs Equal Total Benefits** | **Technology Exhaustion** |
| Carbon Dioxide ($CO_2$) | | | | | | | |
| 2010 | 1,427 | 1,427 | 1,427 | 1,427 | 1,427 | 1,427 | 1,427 |
| 2020 | 1,617 | 1,539 | 1,514 | 1,499 | 1,488 | 1,475 | 1,461 |
| 2030 | 1,936 | 1,791 | 1,746 | 1,724 | 1,705 | 1,683 | 1,657 |
| 2040 | 2,342 | 2,157 | 2,100 | 2,074 | 2,050 | 2,022 | 1,989 |
| 2050 | 2,813 | 2,591 | 2,521 | 2,489 | 2,460 | 2,426 | 2,387 |
| 2060 | 3,369 | 3,105 | 3,021 | 2,981 | 2,945 | 2,904 | 2,858 |
| Methane ($CH_4$) | | | | | | | |
| 2010 | 1.68 | 1.68 | 1.68 | 1.68 | 1.68 | 1.68 | 1.68 |
| 2020 | 1.89 | 1.80 | 1.77 | 1.75 | 1.73 | 1.71 | 1.69 |
| 2030 | 2.26 | 2.09 | 2.03 | 1.99 | 1.95 | 1.92 | 1.89 |
| 2040 | 2.73 | 2.52 | 2.44 | 2.38 | 2.34 | 2.30 | 2.26 |
| 2050 | 3.28 | 3.02 | 2.93 | 2.86 | 2.81 | 2.76 | 2.71 |
| 2060 | 3.93 | 3.62 | 3.52 | 3.43 | 3.36 | 3.31 | 3.25 |
| Nitrous Oxide ($N_2O$) | | | | | | | |
| 2010 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 2020 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 2030 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 2040 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 |
| 2050 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 |
| 2060 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.06 |

However, Table 3.4-2 also shows that none of the action alternatives would reduce total $CO_2$ emissions accounted for by passenger cars and light trucks below the levels that are projected to occur in calendar year 2010. This results from the fact that forecast growth in the number of cars and light trucks in use throughout the United States, combined with assumed increases in their average use, is projected to result in sufficiently rapid growth in total car and light truck travel to more than offset the increases in fuel economy that would result even under the Technology Exhaustion Alternative. As a consequence, total fuel consumption by United States passenger cars and light trucks is projected to increase over the period shown in the table under each of the action alternatives. Because $CO_2$ emissions are a direct consequence of total fuel consumption, the same result is projected to occur for total $CO_2$ emissions from passenger cars and light trucks.

In their *Annual Energy Outlook 2007*, EIA projects United States transportation $CO_2$ emissions to increase from 2,037 $MMTCO_2$ in 2010 to 2,682 $MMTCO_2$ in 2030,[37] with total United States emissions from transportation over this period at 49,287 $MMTCO_2$. Over this same timeframe, the emissions reductions over the range of the proposed standards are projected to be 1,562 to 3,072 $MMTCO_2$, which would yield a 5 to 10 percent reduction from the transportation sector. The environmental impact from increasing fuel economy standards grows as new vehicles enter the fleet and older vehicles are retired. For example, in 2030, projected emission reductions are 190 $MMTCO_2$, a 7 percent decrease from projected United States transportation emissions of 2,682 $MMTCO_2$ in 2030. It is important to note that the EIA did not take into account the expected effects of this rulemaking into their forecast (EIA, 2007), thus allowing a comparison of the impact of this rulemaking to United States transportation emissions under the No Action Alternative.

As another measure of the relative environmental impact of this rulemaking, these emission reductions can be compared to existing programs designed to reduce GHG emissions in the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate Initiative (WCI) to develop regional strategies to address climate change. The WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent over the period from 2009-2020 (WCI, 2007). By comparison, this rulemaking is expected to reduce $CO_2$ emissions by 379 to 762 $MMTCO_2$ over the same time period. In the Northeast, nine Northeast and Mid-Atlantic states have formed the Regional Greenhouse Gas Initiative (RGGI) to reduce $CO_2$ emissions from power plants in that region. Emission reductions from 2006-2024 are estimated at 268 $MMTCO_2$ (RGGI, 2006).[38] By comparison, NHTSA forecasts that this rulemaking will reduce $CO_2$ emissions by 773 to 1,540 $MMTCO_2$ over this timeframe. It is, important to note, however, that these projections are only estimates, and the scope of these climate programs differs from this rulemaking in geography, sector, and purpose.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the comparison of emission reductions from the CAFE alternatives to emission reductions associated with other programs is intended to assist decisionmakers by providing relative benchmarks, rather than absolute metrics for selecting among alternatives.

In summary, the alternatives analyzed here deliver GHG emission reductions that are on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States.

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[37] AEO provides projections through 2030, not through 2100 (the relevant timeframe for climate modeling).

[38] 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.

### 3.4.4.2 Sensitivity Analysis

NTHSA previously conducted sensitivity analyses to examine how changes in key economic assumptions affect the CAFE standards under the Optimized Alternative. These analyses also examined the fuel savings, economic benefits, and environmental impacts resulting from the CAFE standards that would be established under the Optimized Alternative[39] The sensitivity analysis did not examine the effect of variations in economic assumptions on CAFE standards and their impacts under other action alternatives. However, three of the remaining five action alternatives would establish fuel economy standards that are based directly on those under the Optimized Alternative, while CAFE standards under the alternative equating total costs and total benefits would also vary in response to changes in CAFE standards under the Optimized Alternative. Thus it is reasonable to assume that fuel economy levels under each of those alternatives, as well as the resulting fuel savings and reductions in $CO_2$ emissions, will vary similarly to those under the Optimized Alternative in response to changes in economic assumptions.

The specific economic assumptions that were varied in conducting these sensitivity analyses include:

- The value of economic damages caused by $CO_2$ emissions (the "social cost of carbon");
- The discount rate applied to future benefits;
- The value of economic externalities caused by United States petroleum imports;
- The prices of gasoline and diesel fuel; and
- The magnitude of the fuel economy rebound effect.

The sensitivity analysis reported in the Preliminary Regulatory Impact Analysis (PRIA) found that variations in the value of $CO_2$, the value of oil import externalities, and the value of the rebound effect have only modest impacts on the level of optimized CAFE standards. However, higher fuel prices and a lower discount rate each raised the optimized CAFE standards to a greater degree: the MY 2015 passenger car and light truck standards rose by 6.7 mpg, and 0.8 mpg, while a lower discount rate raised the optimized passenger car and light truck standards for MY 2015 by 4.0 mpg and 0.4 mpg.. All other parameters used in the PRIA are held constant in this analysis. The analysis presented below summarizes how these changes in economic assumptions would affect the reductions in $CO_2$ emissions by cars and light trucks over the period 2010-2100 resulting from the increases in MY 2011-2015 CAFE standards under the optimized alternative, measured by comparison to $CO_2$ emissions resulting from the No Action Alternative (described in Chapter 2).

#### 3.4.4.2.1 Range of Input Values in Sensitivity Analysis

The sensitivity analysis examines a range of $CO_2$ values from \$0 per metric ton to \$14 per metric ton $CO_2$ (\$51.34 per metric ton carbon). The PRIA uses a reference value of \$7.50 per metric ton $CO_2$ (\$27.50 per metric ton carbon). Like the reference value, the alternative values for $CO_2$ are assumed to increase at 2.4 percent annually beginning in 2011.

The analysis examines a range of the value of economic externalities resulting from United States petroleum imports between \$0.120 per gallon of fuel and \$0.504 per gallon. The PRIA uses a reference value of \$0.295 per gallon of fuel for the value of these externalities.

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[39] PRIA Page IX-10

The sensitivity analysis examines the range of low to high price estimates for gasoline in the *AEO 2008 Early Release Forecast*[40]. For the "high-case" scenario the price of gasoline was $3.37 per gallon (average price for MY 2011-2030); while for the "low-case" scenario the price of gasoline was $2.04 per gallon (average price for MY 2011-2030.) The PRIA uses the reference price estimate for gasoline in the *AEO 2008 Early Release Forecast*.[41]

The analysis examines rebound effects of 10 percent and 20 percent, compared to the PRIA reference value for the rebound effect of 15 percent.

Finally, the sensitivity analysis examines the effect of a discount rate of 3 percent, rather than the 7 percent reference value for the discount rate used in the PRIA. The sensitivity analysis did not include the effect of discount rates higher than the 7 percent reference value.

#### 3.4.4.2.2 Sensitivity Analysis for $CO_2$ Reduction under Optimized Alternative

Table 3.4-3 shows that the range of estimated $CO_2$ reductions mirrors the findings from the PRIA sensitivity analysis about how changes in economic assumptions affect the levels of optimized fuel economy. As in the case of CAFE standards, Table 3.4-3 shows that variations in the value of $CO_2$, the value of petroleum import externalities, and the rebound effect have relatively little impact on $CO_2$ reductions, while higher fuel prices and a lower discount rate have a more substantial effect.

**TABLE 3.4-3**
**Sensitivity Analysis for 2010-2100 Emission Reductions (MMTCO$_2$)**
**MY 2011-2015 Optimized CAFE Standard (compared to the No Action Alternative)**

| | Range of 2010-2100 $CO_2$ Reductions (MMT) |
|---|---|
| The value of $CO_2$ | 23,664 - 23,721 |
| The discount rate | 34,137 |
| The value of externalities | 22,348 - 24,537 |
| The price of gasoline; and | 21,734 - 35,939 |
| The rebound effect | 22,939 - 25,143 |

NHTSA selected the various economic assumptions to be used in the Volpe model carefully, and described those values and the process for selecting each of them in detail in Section 7 of Chapter V of the NPRM, as well as in Chapter VIII of the PRIA. Please see those passages for detailed discussions of the rationale for selecting each value. With regard to each of these economic inputs, NHTSA notes that:

- **Social Cost of Carbon:** NHTSA reviewed published estimates of the "social cost of carbon emissions," and relies in part on a review of carbon costs done by Tol who reviewed and summarized 103 estimates of the SCC from 28 published studies. The Tol study is cited repeatedly as an authoritative survey in various IPCC reports.

- **Value of Externalities:** NHTSA relied on Oak Ridge National Laboratories (ORNL), a part of the DOE, for its value of externalities in the NPRM, as it had in analyzing benefits from the light truck CAFE standards for model years 2005 to 2007 and 2008 to 2011. In that effort, NHTSA relied on a 1997 study by ORNL to estimate the value of reduced economic

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[40] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2008 Early Release*, Reference Case Table 12, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_12.xls.

[41] PRIA Page VIII-20, Table VIII-3 -- Adjustment of Forecast Retail Gasoline Price to Reflect Social Value of Fuel Savings

externalities from petroleum consumption and imports.[42] More recently, ORNL updated its estimates of the value of these externalities, using the analytic framework developed in its original 1997, and used them in a study for EPA in its Renewable Fuel Standard Rule of 2007. The updated ORNL study was subjected to a detailed peer review by experts selected by EPA.

- **Fuel Price:** NHTSA relied on the most recent fuel price projections from the EIA's *Annual Energy Outlook* (AEO) for this analysis. Specifically, NHTSA used the AEO 2008 Early Release forecasts of inflation-adjusted (constant-dollar) retail gasoline and diesel fuel prices, which represent the EIA's most up-to-date estimate of the most likely course of future prices for petroleum products.[43] Federal government agencies generally use EIA's projections in their assessments of future energy-related policies.

- **Rebound Effect:** In order to arrive at a preliminary estimate of the rebound effect for use in assessing the fuel savings, emissions reductions, and other impacts of alternative standards, NHTSA reviewed 22 studies of the rebound effect conducted from 1983 through 2005. Then a detailed analysis of the 66 separate estimates of the long-run rebound effect was conducted and reported in these studies.

- **Discount Rate:** The White House Office of Management and Budget (OMB) provides detailed guidance for federal agencies in conducting Regulatory Impact Assessments.[44] This guidance directs federal agencies to provide estimates of net benefits from proposed regulations using a discount rate of 7 percent as a base case. When the costs of proposed regulations are likely to be reflected in higher consumer prices, however, a discount rate of 3 percent is more appropriate. Thus OMB guidance advises federal agencies to evaluate proposed regulations using both 3 percent and 7 percent discount rates.

#### 3.4.4.3 Effect of Credit Flexibility on Emissions

Consistent with the Energy Independence and Security Act (EISA), NHTSA's NPRM not only proposes new CAFE standards for passenger cars and light trucks, but also revises provisions regarding the creation and application of CAFE credits. In this context, CAFE credits refer to flexibilities allowed under the Energy Policy and Conservation Act (EPCA) provisions governing use of Alternative Motor Fuels Act (AMFA) credits, allowable banked credits, and transfers of credits between the car and truck fleets allowed under EISA. The additional flexibility to transfer credits between manufacturing companies is addressed separately below. Because EPCA prohibits NHTSA from considering these flexibilities when determining the stringency of CAFE standards, NHTSA did not attempt to do so when it developed proposed standards by using the Volpe Model to estimate the stringency at which net benefits to society would be maximized.

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[42] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997. *Available at* http://pzl1.ed.ornl.gov/ORNL6851.pdf (last accessed April 20, 2008).

[43] Energy Information Administration, *Annual Energy Outlook 2008, Early Release,* Reference Case Table 12. *Available at* http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_12.pdf (last accessed April 20, 2008). EIA says that it will release the complete version of AEO 2008 – including the High and Low Price and other side cases – at the end of April. The agency will use those figures for the final rule.

[44] White House Office of Management and Budget, Office of Information and Regulatory Affairs, Circular A-4, September 17, 2003. *Available at* http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf (last accessed June 23, 2008).

Under the EISA, AMFA credits are being phased out. The allowable credits are reduced so that by 2020 such credits will no longer be allowed under law.

However, responding to the Federal Register notice regarding the scope of analysis required by NEPA, EPA and the California Attorney General have indicated that, notwithstanding EPCA's constraints regarding the context for the establishment of CAFE standards, NHTSA should attempt to account for the creation and application of CAFE credits when evaluating the effects of proposed CAFE standards.

As we explained in the NPRM, NHTSA believes that manufacturers are likely to take advantage of these flexibility mechanisms, thereby reducing benefits and costs. With respect to AMFA credits, for example, the product plans of manufacturers identify the models and quantities of flex-fuel vehicles they intend to build. While individual product plans are protected as confidential commercial information, in the aggregate they reveal that manufacturers could make use of AMFA credits to assist in compliance with the standards. Manufacturers building dual fuel vehicles are entitled to a CAFE benefit of up to 1.2 mpg in 2011-2014 and 1.0 mpg in 2015 for each fleet. The agency tentatively estimates that the impact of the use of AMFA credits identified in these product plans could result in an average reduction of approximately 0.7 mpg in each year for model years 2011 through 2015, and a related increase in $CO_2$ emissions. The agency recognizes that these product plans were submitted in May 2007, and our AMFA credit estimate may change based on updated product plan projections. With respect to other than AMFA credits (e.g., CAFE credits earned through over-compliance, credits transferred between fleets, and credits acquired from other manufacturers), the agency does not have a sound basis to predict the extent to which manufacturers might use them, particularly since the credit transfer and credit trading programs have been only recently authorized.

#### 3.4.4.3.1 Difficulties in Quantifying Emissions Implications of Credits

Questions NHTSA might need to address in performing an analysis of potential credit use and the resulting emissions include the following:

- Would manufacturers that have never made use of CAFE flexibilities do so in the future?
- Would flexibility-induced increases in the sale of flexible fuel vehicles (FFVs) lead to increases in the use of alternative fuels?
- Having earned CAFE credits in a given model year, in what model year would a given manufacturer most likely apply those credits?
- Having earned CAFE credits in one fleet (*i.e.*, passenger or nonpassenger), to which fleet would a given manufacturer most likely apply those credits?

Such questions are similar to, though possibly less tractable than the behavioral and strategic questions that would be entailed in attempting to represent manufacturers' ability to "pull ahead" the implementation of some technologies, and in attempting to estimate CAFE-induced changes in market shares. As discussed on pp. 24393-24394 of the NPRM, data and approaches are lacking on how to analyze manufacturers' ability to develop and strategically time the application of new technologies. Significant concerns remain on how to develop a credible market share model for integration into the modeling system NHTSA has used to analyze the costs and effects of CAFE standards.

#### 3.4.4.3.2 Market Behavior

Some manufacturers make significant use of current flexibilities. Other manufacturers regularly exceed CAFE standards applicable to one or both fleets, and allow the corresponding excess CAFE credits to expire. Some manufacturers transfer earned CAFE credits to future (or past) model years, but do not produce FFVs and create corresponding CAFE credits. Finally, still other manufacturers regularly pay civil penalties for noncompliance, even when producing FFVs would significantly reduce the magnitude of those penalties.

Notwithstanding these uncertainties, NHTSA anticipates that manufacturers would make varied use of the flexibilities provided by EPCA, as amended by EISA. These flexibilities may result in somewhat lower benefits (i.e., $CO_2$ emission reduction) than estimated here, as manufacturers' actions would cause VMT levels, fuel consumption, and emissions to be higher than reported here. The agency expects that all of the seven alternatives reported here—including the No Action Alternative relative to which the effects of the other six are measured—would be affected. Insofar as the No Action Alternative would be affected, it is even less certain how the net effects of each of the other six would change.

NHTSA expects that use of flexibilities would tend to be greater under more stringent standards. As stringency increases, the potential for manufacturers to face greater cost increases, and for some, depending on its level of technological implementation, may rise significantly. The economic advantage of employing allowed flexibilities increases and may affect manufacturer behavior in this regard. A critical factor in addressing the fuel and emissions impacts of such flexibilities is that the likely extent of utilization cannot be assumed constant across the alternatives.

#### 3.4.4.3.3 Trading Between Companies

The allowable trading between manufacturers is categorically different from the case discussed above. The provisions in section104 of Title I of the EISA require that fuel savings, and thus, GHG emissions, be conserved in any trades effected between manufacturers. As such, there would not be an environmental impact of any such since any increases in fuel use or emissions would have to be offset by the manufacturer buying the credits.

### 3.4.4.4 Direct and Indirect Effects on Climate Change

The direct and indirect effects of the alternatives on climate change are described in the following section in terms of (1) atmospheric $CO_2$ concentrations, (2) temperature, (3) precipitation, and (4) sea level rise. Within each section, the MAGICC results are reported first, followed by the results of the scaling approach.

#### 3.4.4.4.1 Atmospheric Carbon Dioxide Concentrations

MAGICC Results

The MAGICC is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emission scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 3.4-4.[45] As the table indicates, the model runs developed for this analysis achieves relatively good agreement with IPCC WG1 estimates in terms of both $CO_2$ concentrations and surface temperature.

**TABLE 3.4-4**

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[45] The default climate sensitivity in MAGICC of 2.6 °C was used.

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

| Scenario | $CO_2$ Concentration (ppm) |  | Radiative Forcing ($W/m^2$) |  | Global Mean Increase in Surface Temperature (°C) |  |
|---|---|---|---|---|---|---|
|  | IPCC WG1 (2100) | MAGICC (2100) | IPCC WG1 (2080-2099) | MAGICC (2090) | IPCC WG1 (2080-2099) | MAGICC (2090) |
| B1 | 550 | 537 | N/A | 3.22 | 1.79 | 1.82 |
| A1B | 715 | 709 | N/A | 4.85 | 2.65 | 2.60 |
| A2 | 836 | 854 | N/A | 6.09 | 3.13 | 3.01 |

As discussed earlier in methodology, Section 3.4.2, the SRES A1B (medium) scenario was used to represent the No Action Alternative in the MAGICC runs. The results of MAGICC simulations for the No Action Alternative and the six alternative CAFE levels, in terms of $CO_2$ concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table 3.4-5 and Figures 3.4-4 to 3.4-7. As Figures 3.4-4 and 3.4-5 show, the impact on the growth in $CO_2$ concentrations and temperature is just a fraction of the total growth in $CO_2$ concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both $CO_2$ concentrations and temperature in the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures 3.3-6 and 3.4-7.

**TABLE 3.4-5**

**2011-2015 CAFE Alternatives Impact on $CO_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC**

| Totals by Alternative | $CO_2$ Concentration (ppm) |  |  | Global Mean Surface Temperature Increase (°C) |  |  |
|---|---|---|---|---|---|---|
|  | 2030 | 2060 | 2100 | 2030 | 2060 | 2100 |
| No Action (A1B – AIM a/) | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.3 | 574.4 | 706.9 | 0.788 | 1.835 | 2.757 |
| Optimized | 458.2 | 574.2 | 706.4 | 0.788 | 1.834 | 2.755 |
| 25 Percent Above Optimized | 458.2 | 574.1 | 706.1 | 0.788 | 1.833 | 2.754 |
| 50 Percent Above Optimized | 458.2 | 574.0 | 705.9 | 0.788 | 1.832 | 2.753 |
| Total Costs Equal Total Benefits | 458.1 | 573.9 | 705.6 | 0.788 | 1.832 | 2.752 |
| Technology Exhaustion | 458.1 | 573.7 | 705.4 | 0.788 | 1.831 | 2.751 |
| **Reduction from CAFE Alternatives** |  |  |  |  |  |  |
| 25 Percent Below Optimized | 0.1 | 0.8 | 1.7 | 0.001 | 0.002 | 0.006 |
| Optimized | 0.2 | 1.0 | 2.2 | 0.001 | 0.003 | 0.008 |
| 25 Percent Above Optimized | 0.2 | 1.1 | 2.5 | 0.001 | 0.004 | 0.009 |
| 50 Percent Above Optimized | 0.2 | 1.2 | 2.7 | 0.001 | 0.005 | 0.010 |
| Total Costs Equal Total Benefits | 0.3 | 1.3 | 3.0 | 0.001 | 0.005 | 0.011 |
| Technology Exhaustion | 0.3 | 1.5 | 3.2 | 0.001 | 0.006 | 0.012 |

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a/ The AIB-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

**Figure 3.4-4 CO2 Concentrations for the A1B Scenario and CAFE Alternatives**

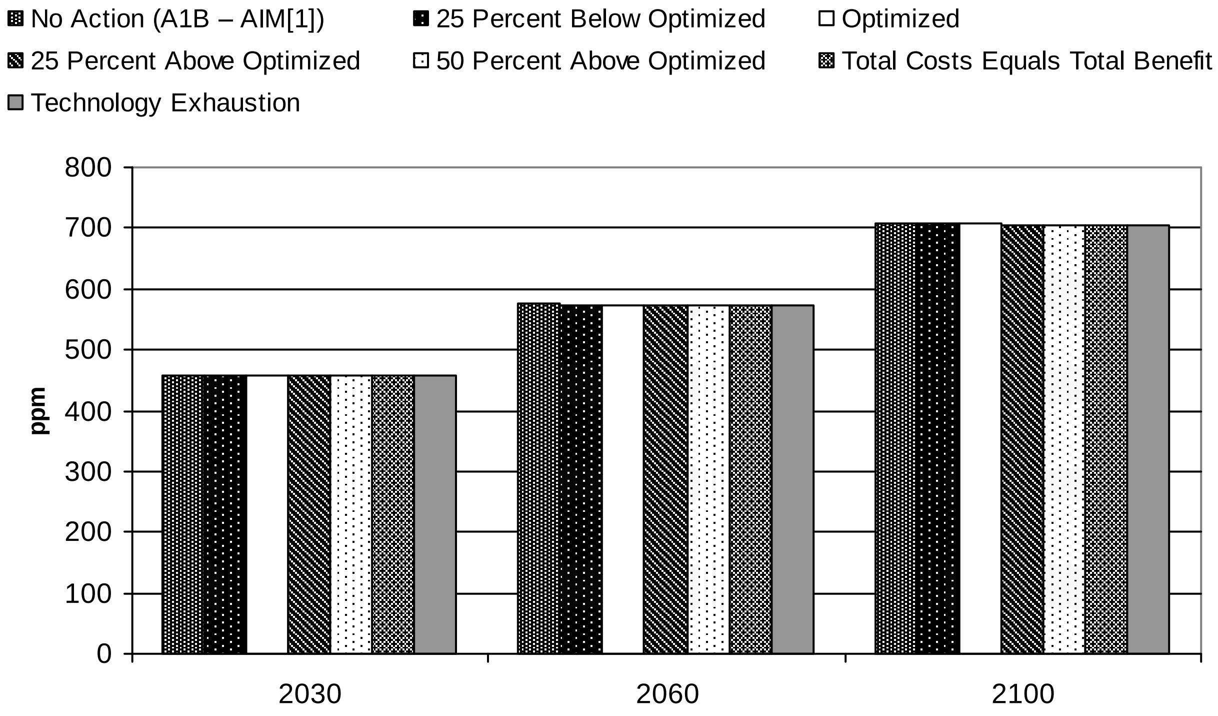


**Figure 3.4-5 Increase in Global Mean Surface Temperature for the A1B Scenario and CAFE Alternatives**

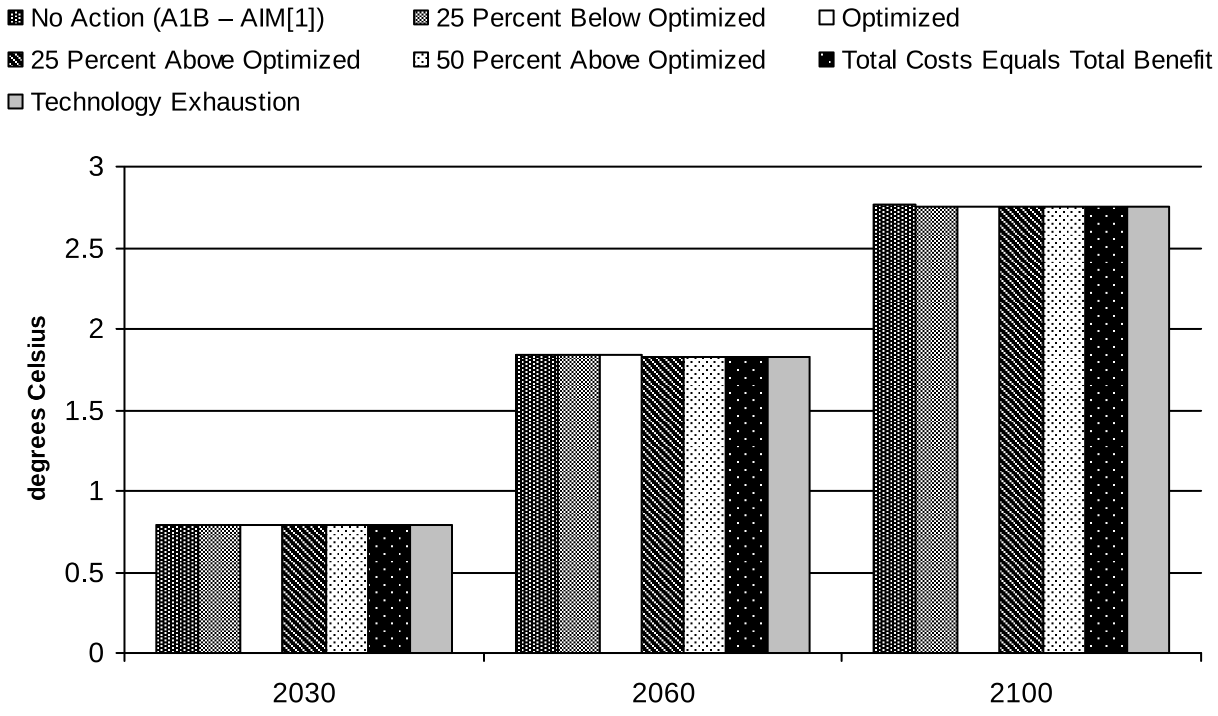


**Figure 3.4-6 Reduction in the Growth of $CO_2$ Concentrations for the A1B Scenario and CAFE Alternatives**

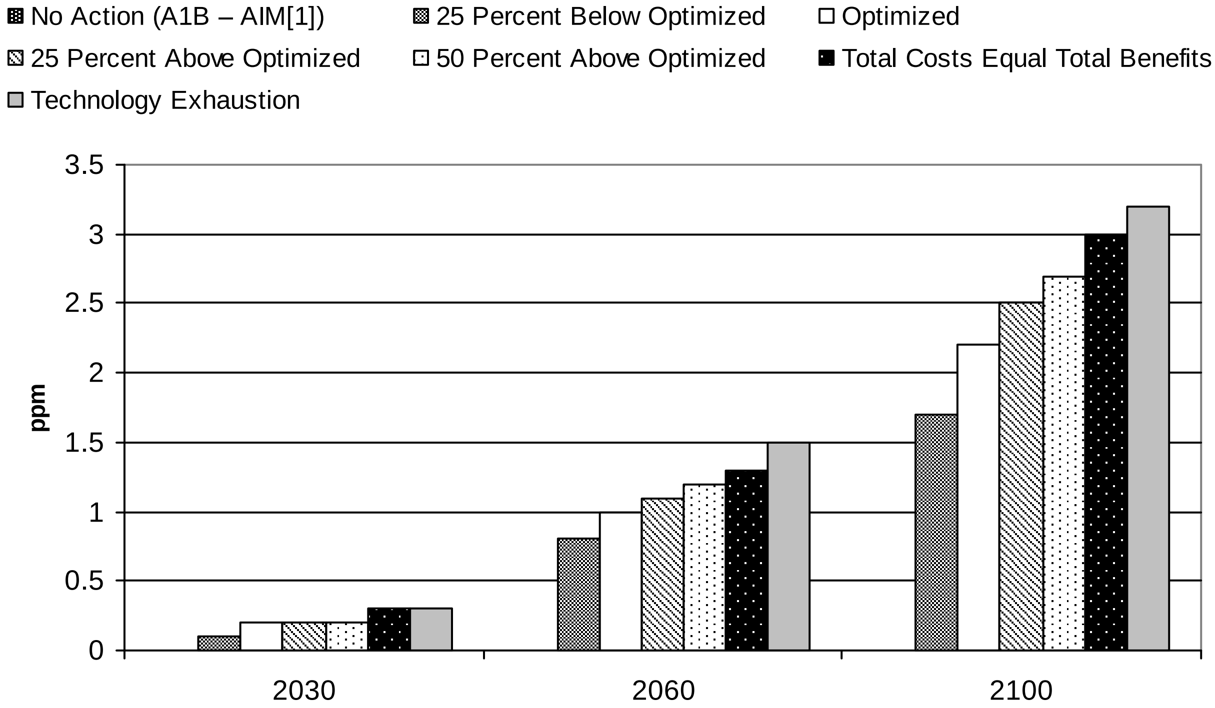
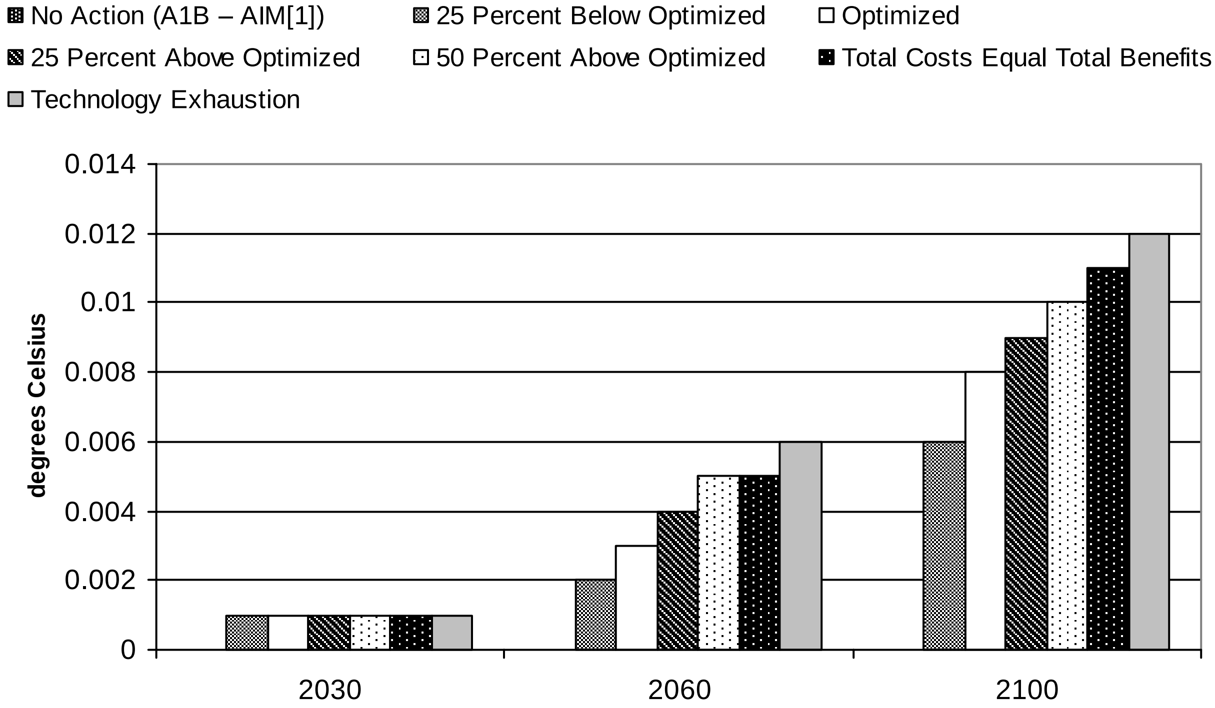


**Figure 3.4-7 Reduction in the Growth of Global Mean Temperature for the A1B Scenario and CAFE Alternatives**



As shown in the table and figures, there is a fairly narrow band of estimated $CO_2$ concentrations as of 2100, from 705 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. For earlier years, the range is tighter. As $CO_2$ concentrations are the key driver of all the other climate effects (which in turn act as drivers on the resource impacts discussed in Chapter 4), this narrow range implies that the differences among alternatives are difficult to distinguish.

### Scaling Results

The global emission scenarios developed by the IPCC in the SRES (Nakicenovic et al., 2000), showed ranges of cumulative emissions from 1990 to 2100 of $CO_2$ from 770 Gt[46] C to 2,450 Gt C (2,825 to 8,985 billion metric tons of $CO_2$). The three scenarios used in the IPCC WG1 Fourth Assessment Report (IPCC, 2007) have the following emissions of $CO_2$ from 2005 to 2100[47]:

- Low – B1: 3,145 gigatons (Gt) $CO_2$
- Mid – A1B: 5,020 Gt $CO_2$
- High – A2: 6,640 Gt $CO_2$

As indicated earlier in Table 3.4-4, for these emission scenarios, $CO_2$ concentrations increase from 379 ppm in 2005 to mid-range estimates in 2100 of 550 ppm for the B1 (low) scenario, 715 ppm for the A1B (medium) scenario, and 836 ppm for the A2 (high) scenario (IPCC, 2007). This implies that 42 percent, 52 percent, and 53 percent of the emitted $CO_2$ from 2005 to 2100 in the SRES B1 (low), A1B (medium), and A2 (high) scenarios, respectively, is still in the atmosphere in 2100.[48] These percentages can be used in a scaling approach. The amount of emitted $CO_2$ that remains in the atmosphere as of 2100 varies considerably depending upon when the $CO_2$ is emitted, which determines the length of time it is subject to land and ocean uptake.

By applying the scaling factors developed above, the emission reductions for the six alternatives yield $CO_2$ concentrations, as of 2100, as shown in Table 3.4-6. The results for scenario A1B (medium) in this table (713 to 715 ppm) agree relatively well with the MAGICC results in Table 3.4-5 above (705 to 709 ppm). These concentrations are considerably higher than current concentrations, which were approximately 379 ppm in 2005 (IPCC, 2007).

**TABLE 3.4-6**

**Emissions and Estimated $CO_2$ Concentrations in 2100 for the 2011-2015 CAFE Alternatives**

| Totals by Alternative | $CO_2$ Emissions 2005-2100 (Bt $CO_2$) | | | $CO_2$ Concentrations in 2100 (ppm) a/ | | |
|---|---|---|---|---|---|---|
| | B1 | A1B | A2 | B1 | A1B | A2 |
| No Action | 3,144 | 5,022 | 6,642 | 550 | 715 | 836 |
| 25 Percent Below Optimized | 3,126 | 5,004 | 6,624 | 549.0 | 713.8 | 834.8 |
| Optimized | 3,120 | 4,998 | 6,618 | 548.7 | 713.4 | 834.3 |
| 25 Percent Above Optimized | 3,117 | 4,995 | 6,615 | 548.5 | 713.2 | 834.1 |
| 50 Percent Above Optimized | 3,115 | 4,993 | 6,613 | 548.4 | 713.1 | 834.0 |
| Total Costs Equal Total Benefits | 3,112 | 4,990 | 6,610 | 548.3 | 712.9 | 833.8 |
| Technology Exhaustion | 3,109 | 4,987 | 6,607 | 548.1 | 712.7 | 833.6 |

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[46] Gt C is Gigaton or billion metric tons of carbon.

[47] Calculated by averaging cumulative emissions from 2000 to 2010 from the SRES scenario results (IPCC,2000a)

[48] 1 ppm of $CO_2$ equals 2.13 Gt C (CDAIC, 1990) = 7.81 Gt $CO_2$

**TABLE 3.4-6 (cont'd)**

**Emissions and Estimated $CO_2$ Concentrations in 2100 for the 2011-2015 CAFE Alternatives**

| Totals by Alternative | $CO_2$ Emissions 2005-2100 (Bt $CO_2$) | | | $CO_2$ Concentrations in 2100 (ppm) a/ | | |
|---|---|---|---|---|---|---|
| | B1 | A1B | A2 | B1 | A1B | A2 |
| **Reduction from CAFE Alternatives** | | | | | | |
| 25 Percent Below Optimized | 18 | 18 | 18 | 1.0 | 1.2 | 1.2 |
| Optimized | 24 | 24 | 24 | 1.3 | 1.6 | 1.7 |
| 25 Percent Above Optimized | 27 | 27 | 27 | 1.5 | 1.8 | 1.9 |
| 50 Percent Above Optimized | 29 | 29 | 29 | 1.6 | 1.9 | 2.0 |
| Total Costs Equal Total Benefits | 32 | 32 | 32 | 1.7 | 2.1 | 2.2 |
| Technology Exhaustion | 35 | 35 | 35 | 1.9 | 2.3 | 2.4 |

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a/ Emission reduction estimates based on share of emitted $CO_2$ still in atmosphere from IPCC, 2007.

#### 3.4.4.4.2 Temperature

MAGICC Results

The MAGICC simulations of mean global surface air temperature increases are shown above in Table 3.4-5. For all alternatives, the temperature increase is about 0.8°C as of 2030, 1.8°C as of 2060, and 2.8°C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.006°C to 0.012°C.

Scaling Results

The relationship between emissions and temperature is a dynamic one, given the feedback loops and transient phenomena involved in the climate system. The scaling approach used here is based on the relationship between emissions and the global mean surface temperature at equilibrium (GMSTE), i.e., the temperature increase if $CO_2$ concentrations were to equilibrate at levels reached as of 2100.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the methodology uses three different emission scenarios (B1-low, A1B-medium, and A2-high) to provide a range of values to address uncertainty in the factors that drive global GHG emissions.

According to IPCC (2007a), temperature change can be estimated using the following equation:

$$\Delta T = S \times \log(CO_2 / 280 \text{ ppm}) / \log(2)$$

Where:
T = Temperature (ºC)
S = Climate sensitivity
$CO_2$ = $CO_2$ concentration (ppm)

Using this equation, the impact of the emission reductions from the 2011-2015 CAFE alternatives for the range of climate sensitivities provided by the IPCC (IPCC, 2007) are estimated and shown in Table 3.4-7, below. These are shown for three different levels of "climate sensitivity," or the mean temperature increase resulting from a sustained doubling of atmospheric $CO_2$ concentrations over pre-industrial levels (IPCC, 2007). The calculations are also shown for three different emission scenarios: B1 (low), A1B (medium), and A2 (high). The range of GMSTE reductions (with respect to the No Action Alternative) due to the different CAFE alternatives is 0.005 °C to 0.023 °C depending upon the climate sensitivity and the CAFE alternative.

The IPCC estimates that for the A1B (medium) and B1 (low) scenarios, the average warming from the AOGCMs as of 2100 is 65 to 70 percent of the estimated eventual equilibrium warming in the 21st century. With this information, and the data in Table 3.4-6, one can construct a bounding analysis on the effects of the CAFE alternatives on average warming by 2100. The lower bound combines the lower ends of the ranges on (a) the proportion of warming as of 2100 compared to eventual warming (viz., 65 percent), (b) the lowest value for the reduction in temperature for an action alternative compared to the No Action Alternative from the table (viz., 0.005 $^{o}$C, the value for the 25 Percent Below Optimized Alternative, A2 (high) emission scenario, and climate sensitivity at 2.5 $^{o}$C). This yields an estimate of a lower bound temperature effect (compared to the No Action Alternative) of 65 percent * 0.005$^{o}$C = 0.003$^{o}$C. The upper bound, derived by the same approach but using high end values, is 70 percent * 0.023$^{o}$C = 0.016$^{o}$C for the Technology Exhaustion Alternative using a climate sensitivity of 4.5$^{o}$C.

The range of 0.003$^{o}$C to 0.016$^{o}$C from the scaling approach encompasses the range of MAGICC values (in Table 3.4-5) of 0.006$^{o}$C to 0.012$^{o}$C. Note that the scaling approach uses three different values for climate sensitivity, whereas MAGICC only uses one (2.6 $^{o}$C, the middle value used for the scaling analysis), and so the greater range with the scaling approach is to be expected. The use of the scaling approach illustrates that the alternatives' effectiveness in reducing temperature increases is somewhat broader than the range projected in the DEIS using the MAGICC, and that the results are sensitive to the value of climate sensitivity.

Table 3.4-8 summarizes the regional changes to warming and seasonal temperatures from the IPCC fourth assessment. It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives but it is expected that they would reduce the changes relative to the reduction in global mean surface temperature.

#### 3.4.4.4.3 Precipitation

MAGICC Results

According to the IPCC WG1 (IPCC, 2007), global mean precipitation is expected to increase under all the scenarios. Generally, precipitation increases occur in the tropical regions and high latitudes, with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in future precipitation for the three SRES scenarios.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the IPCC (2007) summary of precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in proportion to their effects on temperature.

## TABLE 3.4-7

## Reductions in Estimated $CO_2$ Concentrations for the 2011-2015 CAFE Alternatives and Estimated Impact on Global Mean Surface Temperature at Equilibrium by 2100 for Low (B1), Mid (A1B), and High (A2) Emission Scenarios

| | Concentration (ppm) | | | Global Mean Surface Temperature at Equilibrium from $CO_2$ Only ($^oC$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GMSTE: Climate Sensitivity=2.5 $^oC$ | | | GMSTE: Climate Sensitivity=3 $^oC$ | | | GMSTE: Climate Sensitivity =4.5 $^oC$ | | |
| | **B1** | **A1B** | **A2** | **B1** | **A1B** | **A2** | **B1** | **A1B** | **A2** | **B1** | **A1B** | **A2** |
| **Total Concentrations** | | | | | | | | | | | | |
| No Action | 550.0 | 715.0 | 836.0 | 2.435 | 3.381 | 3.945 | 2.922 | 4.058 | 4.734 | 4.383 | 6.086 | 7.101 |
| 25 Percent Below Optimized | 549.0 | 713.8 | 834.8 | 2.429 | 3.375 | 3.940 | 2.914 | 4.050 | 4.728 | 4.371 | 6.075 | 7.092 |
| Optimized | 548.7 | 713.4 | 834.3 | 2.426 | 3.373 | 3.938 | 2.912 | 4.048 | 4.726 | 4.368 | 6.072 | 7.089 |
| 25 Percent Above Optimized | 548.5 | 713.2 | 834.1 | 2.425 | 3.372 | 3.937 | 2.910 | 4.047 | 4.725 | 4.366 | 6.070 | 7.087 |
| 50 Percent Above Optimized | 548.4 | 713.1 | 834.0 | 2.425 | 3.371 | 3.937 | 2.910 | 4.046 | 4.724 | 4.364 | 6.069 | 7.086 |
| Total Costs Equal Total Benefits | 548.3 | 712.9 | 833.8 | 2.424 | 3.370 | 3.936 | 2.908 | 4.045 | 4.723 | 4.362 | 6.067 | 7.084 |
| Technology Exhaustion | 548.1 | 712.7 | 833.6 | 2.423 | 3.369 | 3.935 | 2.907 | 4.043 | 4.722 | 4.361 | 6.065 | 7.083 |
| **Reduction from CAFE Alternatives (with respect to No Action Alternative)** | | | | | | | | | | | | |
| 25 Percent Below Optimized | 1.0 | 1.2 | 1.2 | 0.006 | 0.006 | 0.005 | 0.008 | 0.007 | 0.006 | 0.012 | 0.011 | 0.010 |
| Optimized | 1.3 | 1.6 | 1.7 | 0.009 | 0.008 | 0.007 | 0.010 | 0.010 | 0.009 | 0.015 | 0.015 | 0.013 |
| 25 Percent Above Optimized | 1.5 | 1.8 | 1.9 | 0.010 | 0.009 | 0.008 | 0.012 | 0.011 | 0.010 | 0.017 | 0.016 | 0.014 |
| 50 Percent Above Optimized | 1.6 | 1.9 | 2.0 | 0.010 | 0.010 | 0.009 | 0.012 | 0.012 | 0.010 | 0.019 | 0.018 | 0.016 |
| Total Costs Equal Total Benefits | 1.7 | 2.1 | 2.2 | 0.011 | 0.011 | 0.010 | 0.014 | 0.013 | 0.011 | 0.021 | 0.019 | 0.017 |
| Technology Exhaustion | 1.9 | 2.3 | 2.4 | 0.013 | 0.012 | 0.010 | 0.015 | 0.014 | 0.012 | 0.023 | 0.021 | 0.019 |

## TABLE 3.4-8

## Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC fourth Assessment (IPCC, 2007, Ch 11)

| Land Area | Sub-region | Mean Warming | Maximum Summer Temperatures |
|---|---|---|---|
| Africa | Mediterranean area and northern Sahara | *Likely* larger than global mean throughout continent and in all seasons | |
| | Southern Africa and western margins | | |
| | East Africa | | |
| Mediterranean and Europe | Northern Europe | *Likely* to increase more than the global mean with largest warming in winter | Maximum summer temperatures *likely* to increase more than average. |
| | Southern and Central Europe | | |
| | Mediterranean area | | |
| Asia | Central Asia | *Likely* to be well above the global mean | |
| | Tibetan Plateau | *Likely* to be well above the global mean | |
| | Northern Asia | *Likely* to be well above the global mean | |
| | Eastern Asia | *Likely* to be above the global mean | *Very likely* that heat waves/hot spells in summer will be of longer duration, more intense, and more frequent.<br>*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.<br>Minimum winter temperatures are *likely* to increase more than the average. |
| | Southwest | | Warming is *likely* to be greatest in summer.<br>Maximum summer temperatures are *likely* to increase more than the average. |
| North America (cont'd) | Northeast USA | | |
| | Southern Canada | | |
| | Canada | | |
| | Northernmost part of Canada | | |
| Central and South America | Southern South America | *Likely* to be similar to the global mean warming | |
| | Central America | *Likely* to be larger than global mean warming | |
| | Southern Andes | | |
| | Tierra del Fuego | | |

**TABLE 3.4-8 (cont'd)**

**Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC fourth Assessment (IPCC, 2007, Ch 11)**

| Land Area | Sub-region | Mean Warming | Maximum Summer Temperatures |
|---|---|---|---|
| Central and South America (cont'd) | Southeastern South America | | |
| | Northern South America | | |
| Australia and New Zealand | Southern Australia | *Likely* comparable to the global mean but less than in the rest of Australia | Increased frequency of extreme high daily temperatures and a decrease in the frequency of cold extremes is *very likely*. |
| | Southwestern Australia | *Likely* comparable to the global mean | |
| | Rest of Australia | *Likely* comparable to the global mean | |
| | New Zealand, South Island | *Likely* less than the global mean | |
| | Rest of New Zealand | *Likely* comparable to the global mean | |
| Polar Regions | Artic | *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 | |

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (IPCC, 2007) is given as the scaled change in precipitation (as a percentage change from 1980-1999 averages) divided by the increase in global mean surface warming for the same period (per degree C) as shown in Table 3.4-9 below. The IPCC provides scaling factors in the year ranges of 2011-2030, 2046-2065, 2080-2099, and 2180-2199. The scaling factors for the A1B (medium) scenario were used in our analysis since MAGICC does not directly estimate changes in global mean rainfall.

**TABLE 3.4-9**

**Global Mean Precipitation Change (IPCC 2007a)**

| Global Mean Precipitation Change (scaled, % per degree C) | 2011–2030 | 2046–2065 | 2080–2099 | 2180–2199 |
|---|---|---|---|---|
| A2 | 1.38 | 1.33 | 1.45 | NA |
| A1B | 1.45 | 1.51 | 1.63 | 1.68 |
| B1 | 1.62 | 1.65 | 1.88 | 1.89 |

Applying these to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the CAFE alternatives reduce temperature increases slightly with respect to the No Action Alternative, they also reduce predicted increases in precipitation slightly, as shown in Table 3.4-10 (again based on the A1B (medium) scenario).

**TABLE 3.4-10**

**MY 2011-2015 CAFE Alternatives: Impact on Reductions in Global Mean Precipitation based on A1B SRES Scenario ( percent change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2020 | 2055 | 2090 |
|---|---|---|---|
| **Global Mean Precipitation Change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature above average 1980-1999 levels ($^{o}$K) for the A1B scenario and CAFE alternatives, mid-level results** | | | |
| No Action | 0.69 | 1.750 | 2.650 |
| 25 Percent Below Optimized | 0.690 | 1.747 | 2.645 |
| Optimized | 0.690 | 1.747 | 2.643 |
| 25 Percent Above Optimized | 0.690 | 1.746 | 2.642 |
| 50 Percent Above Optimized | 0.690 | 1.746 | 2.641 |
| Total Costs Equal Total Benefits | 0.690 | 1.745 | 2.640 |
| Technology Exhaustion | 0.690 | 1.745 | 2.639 |
| **Reduction in Global Temperature ($^{o}$K) for CAFE alternatives, mid-level results (compared to No Action Alternative)** | | | |
| 25 Percent Below Optimized | 0.000 | 0.003 | 0.005 |
| Optimized | 0.000 | 0.003 | 0.007 |
| 25 Percent Above Optimized | 0.000 | 0.004 | 0.008 |
| 50 Percent Above Optimized | 0.000 | 0.004 | 0.009 |
| Total Costs Equal Total Benefits | 0.000 | 0.005 | 0.010 |
| Technology Exhaustion | 0.000 | 0.005 | 0.011 |
| **Mid Level Global Mean Precipitation Change (%)** | | | |
| No Action | 1.00 | 2.64 | 4.32 |
| 25 Percent Below Optimized | 1.00 | 2.64 | 4.31 |
| Optimized | 1.00 | 2.64 | 4.31 |
| 25 Percent Above Optimized | 1.00 | 2.64 | 4.31 |
| 50 Percent Above Optimized | 1.00 | 2.64 | 4.30 |
| Total Costs Equal Total Benefits | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion | 1.00 | 2.63 | 4.30 |
| **Reduction in Global Mean Precipitation Change for CAFE alternatives (% compared to No Action Alternative)** | | | |
| 25 Percent Below Optimized | 0.00 | 0.00 | 0.01 |
| Optimized | 0.00 | 0.00 | 0.01 |
| 25 Percent Above Optimized | 0.00 | 0.01 | 0.01 |
| 50 Percent Above Optimized | 0.00 | 0.01 | 0.01 |
| Total Costs Equal Total Benefits | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion | 0.00 | 0.01 | 0.02 |

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation as described below (IPCC, 2007, pg 750):

> "Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation intensity

> is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas."

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This is due primarily to the availability of AOGCMS required to estimate these changes. These models are typically used to provide results between scenarios with very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios and very small changes in emission profiles would produce results that would be difficult to resolve between scenarios with small changes in emissions. In addition, the multiple AOGCMs produce results that are regionally consistent in some cases but for other areas inconsistent.

### Scaling Results

Given that the MAGICC approach is based on a scaling methodology (per Table 3.4-9 above), a separate scaling calculation was not employed to characterize precipitation.

Table 3.4-11 summarizes the regional changes to precipitation from the IPCC fourth assessment. It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives but it is expected that they would reduce the changes relative to the reduction in global mean surface temperature.

**TABLE 3.4-11**

**Summary of Regional Changes to Precipitation Extracted from the IPCC fourth Assessment (IPCC, 2007, Ch 11)**

| Land Area | Sub-region | Precipitation | Snow Season and Snow Depth |
|---|---|---|---|
| Africa | Mediterranean area and northern Sahara | *Very likely* to decrease. | |
| | Southern Africa and western margins | Winter rainfall *likely* to decrease in southern parts. | |
| | East Africa | *Likely* to be an increase in annual mean rainfall. | |
| Mediterranean and Europe | Northern Europe | *Very likely* to increase and extremes are *likely* to increase. | *Likely* to decrease |
| | Southern and Central Europe | | |
| | Mediterranean area | *Very likely* to decrease and precipitation days are *very likely* to decrease. | |
| Asia | Central Asia | Precipitation in summer is *likely* to decrease. | |
| | Tibetan Plateau | Precipitation in boreal winter is *very likely* to increase. | |
| | Northern Asia | Precipitation in boreal winter is *very likely* to increase.<br>Precipitation in summer is *likely* to increase. | |

1

**TABLE 3.4-11 (cont'd)**

**Summary of Regional Changes to Precipitation Extracted from the IPCC fourth Assessment (IPCC, 2007, Ch 11)**

| Land Area | Sub-region | Precipitation | Snow Season and Snow Depth |
|---|---|---|---|
| Asia (cont'd) | Eastern Asia | Precipitation in boreal winter is *likely* to increase.<br>Precipitation in summer is *likely* to increase.<br>*Very likely* to be an increase in the frequency of intense precipitation.<br>Extreme rainfall and winds associated with tropical cyclones are *likely* to increase. | |
| | South Asia | Precipitation in summer is *likely* to increase.<br>*Very likely* to be an increase in the frequency of intense precipitation.<br>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.<br>Precipitation in summer is *likely* to increase in most parts of southeast Asia.<br>Extreme rainfall and winds associated with tropical cyclones are *likely* to increase. | |
| North America | Northern regions/Northern North America | | Snow season length and snow depth are *very likely* to decrease |
| | Southwest | Annual mean precipitation is *likely* to decrease. | |
| | Northeast USA | Annual mean precipitation is *very likely* to increase. | |
| | Southern Canada | | |
| | Canada | Annual mean precipitation is *very likely* to increase. | |
| | Northernmost part of Canada | | Snow season length and snow depth are *likely* to increase |
| Central and South America | Southern South America | | |
| | Central America | Annual precipitation is *likely* to decrease. | |
| | Southern Andes | Annual precipitation is *likely* to decrease. | |
| | Tierra del Fuego | Winter precipitation is *likely* to increase. | |
| Central and South America (cont'd) | Southeastern South America | Summer precipitation is *likely* to increase. | |
| | Northern South America | Uncertain how rainfall will change. | |

**TABLE 3.4-11 (cont'd)**

**Summary of Regional Changes to Precipitation Extracted from the IPCC fourth Assessment (IPCC, 2007, Ch 11)**

| Land Area | Sub-region | Precipitation | Snow Season and Snow Depth |
|---|---|---|---|
| Australia and New Zealand | Southern Australia | Precipitation *likely* to decrease in winter and spring. | |
| | Southwestern Australia | Precipitation is *very likely* to decrease in winter. | |
| | Rest of Australia | | |
| | New Zealand, South Island | Precipitation is *likely* to increase in the west. | |
| | Rest of New Zealand | | |
| Polar Regions | Artic | Annual precipitation is *very likely* to increase. It is *very likely* that the relative precipitation increase will be largest in winter and smallest in summer. | |
| | Antarctic | Precipitation is *likely* to increase. | |
| Small Islands | | Mixed depending on the region. | |

#### 3.4.4.4.4 Sea Level Rise

IPCC identifies four primary components to sea level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland (IPCC, 2007). Ice sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise, using a non-linear temperature- and pressure-dependent expansion coefficient (Wigley, 2003). It also addresses the other three primary components through ice-melt models for small glaciers, and the Greenland and Antarctic ice sheets.

The state-of-the-science reflected as of the publication of the IPCC AR4 report (IPCC 2007) project sea level to rise of 18 to 59 centimeters (cm) by 2090 to 2099 (Parry, 2007 as cited by National Science and Technology Council, 2008). This projection does not include all changes in ice sheet flow or the potential for rapid acceleration in ice loss (Alley et al, 2005; Gregory and Huybrechts, 2006; Hansen, 2005 as cited by Pew, 2007). Several recent studies have found the IPCC's estimates of potential sea level rise may be underestimated regarding ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wignham, 2007; Csatho et al., 2008) and ice loss from mountain glaciers (Meier et al., 2007). Further, IPCC results for sea level projections may underestimate sea level rise that would be gained through changes in global precipitation (Wentz et al., 2007; Zhang et al., 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality coefficient of 3.4 millimeters (mm) per year per degree C of warming, and a projected sea-level rise of 0.5 to 1.4 meters (m) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007, p. 370) concludes that, "A rise over 1 meter by 2100 for strong warming scenarios cannot be ruled out."

Sea level rise is discussed in more detail in Section 4.5.5, Coastal Ecosystems.

##### MAGICC Results

MAGICC reports sea level rise in increments of 0.1 centimeter (i.e., 1 millimeter). The impact on sea level rise from the scenarios is at the threshold of the model's reporting: the alternatives reduce sea level rise by 0.1 centimeter (Table 3.4-12). Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above); and the lower the temperature, the lower the sea level. Thus, the more stringent alternatives are likely to result in slightly less sea level rise.

**TABLE 3.4-12**

**MY 2011-2015 CAFE Alternatives: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea level rise with respect to 1990 level, cm |
|---|---|
| **Total Sea Level Rise for the CAFE Alternatives** | |
| No Action | 37.9 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.8 |
| Total Costs Equal Total Benefits | 37.8 |
| Technology Exhaustion | 37.8 |
| **Reduction in Sea Level Rise for the CAFE Alternatives (compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.1 |
| Technology Exhaustion | 0.1 |

### Scaling Results

One of the areas of climate change research where there have been many recent developments is the science underlying the projection of sea level rise. As noted above, there are four key components of sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-the-science, so the scaling approach is an important supplement.

Table 3.4-13 presents estimates of sea level rise provided by the IPCC WG1, excluding the effect of scaled-up ice sheet discharge, where further accelerations have been observed but could not be quantified with confidence (IPCC, 2007). Note that "for each scenario the lower/upper bound for sea level rise is larger/smaller than the total of the lower/upper bounds of the contributions, since the uncertainties of the contributions are largely independent" (IPCC 2007a, p. 620). The midpoint value for the A1B (medium) scenario is 0.35 meter or 35 centimeters, in good agreement with the MAGICC estimate of 38 centimeters. The midpoints for the B1 (low) and A2 (high) scenarios are 28 centimeters and 37 centimeters, respectively.

**TABLE 3.4-13**

**IPCC Sea Level Rise Estimates for 21st Century Compared to 1990 (IPCC, 2007)**

| Scenario | Increase from Thermal Expansion (meters) | Increase from glaciers and ice caps, Greenland Ice Sheet; Antarctic Ice Sheet | Total Sea Level Rise (meters) |
|---|---|---|---|
| B1 (low) | 0.10 to 0.24 | 0.04 to 0.18 | 0.18 to 0.38 |
| A1B (medium) | 0.13 to 0.32 | 0.04 to 0.20 | 0.21 to 0.48 |
| A2 (high) | 0.14 to 0.35 | 0.04 to 0.20 | 0.23 to 0.51 |

The scaling approach to estimate the impact of changes in sea level rise involved the following steps:

1. Changes in global mean temperature due to the alternate CAFE standards were compared with the difference between the global mean temperature increase from B1 (low) to A1B (medium). These values were taken from Table 3.4-7.

2. The change in sea level between scenarios B1 (low) and A1B (medium) was calculated (the simple difference in centimeters).

3. The resulting temperature ratios were used to interpolate within the interval of sea level estimates for the B1 (low) and A1B (medium) scenarios, reported by IPCC.

This approach captures two effects which could overstate the impacts by just scaling the sea level rise by changes in global temperature. The first effect is the current "commitment" (i.e., the inertia in the climate system that would result in climate change even if concentrations did not increase in the future) to global warming, which will occur despite the emission reduction from the CAFE alternatives. The second is the current commitment to sea level rise similar to the current "commitment" to global warming. By examining the difference between the low (B1 [low]) scenario and the mid-level (A1B [medium]) scenario, these terms, which will be the same in both scenarios, are eliminated.

The commitment to increases in temperature, precipitation, and sea level rise is described in the IPCC WG1 fourth assessment report (IPCC, 2007) which indicates that if concentrations of GHGs were to stabilize at current levels then an additional warming of 0.5 degree C would occur along with an additional increase of global averaged precipitation of 1 to 2 percent, and sea level would rise due to thermal expansion by an additional 0.3 to 0.8 meters by 2300 relative to the 1980 to 1999 period.

Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the approach seeks to apply some of the results from state-of-the-art models to address the complex issues of climate system commitment and sea level rise commitment. NHTSA believes this approach provides a valid approximation, while recognizing that the recent developments in the science of sea level rise suggest that these estimates may be understated (as noted earlier).

The results are shown below in Table 3.4-14 for scenario A1B (medium). Across the CAFE alternatives, the mean change in the global mean surface temperature, as a ratio of the increase in warming between the B1 (low) to A1B (medium) scenarios, ranges from 0.5 percent to 1.1 percent. The resulting change in sea level rise (compared to the No Action Alternative) ranges, across the alternatives, from 0.04 centimeter to 0.07 centimeter. This compares well to the MAGICC results of about 0.1

centimeter.  Thus, despite the fact that MAGICC does not reflect some of the more recent developments in the state-of-the-science, the results are of the same magnitude.

**TABLE 3.4-14**

**The Estimated Impact on Sea Level Rise in 2100 From the 2011-2015 CAFE Alternatives for SRES Scenario A1B; Scaling Approach**

| | Reduction in Equilibrium Warming for the 3.0 °C Climate Sensitivity (°C) | Reduction in Global Mean Surface Temperature for the 3.0 °C Climate Sensitivity (°C) | Reduction in Global Mean Warming as Share of B1 - A1B Increase in Warming (%) | Mid Range of Sea Level Rise (cm) |
|---|---|---|---|---|
| No Action | NA | 2.65 | 0.00 | 28.00 |
| 25 Percent Below Optimized | NA | 2.645 | 0.50 | 27.96 |
| Optimized | NA | 2.643 | 0.80 | 27.95 |
| 25 Percent Above Optimized | NA | 2.643 | 0.90 | 27.94 |
| 50 Percent Above Optimized | NA | 2.642 | 0.90 | 27.94 |
| Total Costs Equal Total Benefits | NA | 2.641 | 1.00 | 27.93 |
| Technology Exhaustion | NA | 2.640 | 1.10 | 27.93 |
| **Reduction from the CAFE Alternatives** | | | | |
| 25 Percent Below Optimized | 0.007 | 0.005 | 0.5 | 0.04 |
| Optimized | 0.010 | 0.007 | 0.8 | 0.05 |
| 25 Percent Above Optimized | 0.011 | 0.007 | 0.9 | 0.06 |
| 50 Percent Above Optimized | 0.012 | 0.008 | 0.9 | 0.06 |
| Total Costs Equal Total Benefits | 0.013 | 0.009 | 1.0 | 0.07 |
| Technology Exhaustion | 0.014 | 0.009 | 1.1 | 0.07 |

In summary, the impacts of the MY 2011-2015 CAFE alternatives on global mean surface temperature, sea level rise, and precipitation are relatively small in the context of the expected changes associated with the emission trajectories in the SRES scenarios.  This is due primarily to the global and multi-sectoral nature of the climate problem.  Emissions of $CO_2$, the primary gas driving the climate effects, from the United States automobile and light truck fleet represented about 2.5 percent of total global emissions of all GHGs in the year 2000 (EPA, 2008; CAIT, 2008). While a significant source, this is a still small percentage of global emissions, and the relative contribution of $CO_2$ emissions from the United States light vehicle fleet is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions).  In the SRES A1B (medium) scenario (Nakicenovic et al., 2000), the share of liquid fuel use – mostly petroleum and biofuels – from Organization for Economic Cooperation and Development (OECD) countries declines from 60 percent in 2000 to 17 percent in 2100.

## 3.5 OTHER POTENTIALLY AFFECTED RESOURCE AREAS

This section describes the affected environment and environmental consequences of the alternatives on Water Resources (3.5.1), Biological Resources (3.5.2), Land Use and Development (3.5.3), Safety (3.5.4), Hazardous Materials and Regulated Wastes (3.5.5), Natural Areas Protected under Section 4(f) (3.5.6), Historic and Cultural Resources (3.5.7), Noise (3.5.8), and Environmental Justice (3.5.9). These sections discuss the current and projected future threats to these resources from non-global climate change impacts relevant to the alternatives, and provide primarily qualitative assessments of any potential consequences of the alternatives, either positive or negative, on these resources.

This section does not describe the affected environment in relation to, or address potential environmental consequences resulting from, global climate change. For a description of potential impacts of global climate change, see Chapter 4.

### 3.5.1 Water Resources

### 3.5.1.1 Affected Environment

Water resources include surface water and groundwater. Surface waters are waterbodies open to the atmosphere, such as rivers, streams, lakes, oceans, and wetlands; surface waters can contain either fresh or salt water. Groundwater is found in natural reservoirs or aquifers below the earth’s surface. Sources of groundwater include rainfall and surface water, which penetrate the ground and recharge the water table. The following section discusses the current and projected future threats to these resources from non-global climate change impacts relevant to the proposed action. The production and combustion of fossil fuels and the production of biofuels are the identified relevant sources of impact. Biological Resources, in Section 3.5.2, describes relevant aspects of surface water resources from a habitat perspective. For a discussion of the effects of global climate change on freshwater sand coastal systems, please see Sections 4.5.3 and 4.5.5.

Impacts to water resources during recent decades have come from a number of different sources. These impacts include increased water demand for human and agricultural use, pollution from point and non-point sources, and climatic changes. One of the major anthropogenic, or human-made, causes of water quality impacts has been the extraction, refining, and combustion of petroleum products, or oil.

#### 3.5.1.1.1 Oil Extraction and Refining

Oil refineries, which produce the gasoline and diesel used for transportation fuels and the motor vehicles that combust petroleum based fuels, are major sources of VOCs, $SO_2$, NOx, CO, and other air pollutants (EPA, 2008; EPA, 1997). In the atmosphere, $SO_2$ and NOx pollutants contribute to the formation of acid rain (the wet, dry, or fog deposition of $SO_2$ and NOx), which enters water bodies either directly or as runoff from terrestrial systems (see Section 3.3. for further information on air quality). Once in surface waters, these pollutants can cause acidification of the waterbody, changing the pH of the system and affecting the function of freshwater ecosystems (Van Dam, 1996; Baum, 2001; EPA, 2008). An EPA survey of sensitive freshwater lakes and streams, those with a low capacity to neutralize, or buffer against, decreases in pH, found that 75 percent of the lakes and 50 percent of the streams had experienced acidification as a result of acid rain (EPA, 2008). EPA has identified the areas of the United States most sensitive to acid rain as, “the Adirondacks and Catskill Mountains in New York State, the mid-Appalachian highlands along the east coast, the upper Midwest, and mountainous areas of the western United States (EPA, 2008).”

Water quality may also be affected by petroleum products released during the refining and distribution process. Oil spills can lead to contamination of surface and ground water, and can result in impacts to drinking water, marine, and freshwater ecosystems (Section 3.5.2). 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 nearshore (within 3 miles of shore), with 17.5 percent spilled from pipeline spills, often in inland areas (EPA, 2004). The environmental impacts on and recovery time for individual water bodies vary based on a number of factors (e.g., salinity, water movement, wind, temperature), with faster moving and warm water locations recovering more quickly (EPA, 2008b).

During oil extraction, the primary waste product is a highly saline liquid called "produced water" which may contain metals and other potentially toxic components (Section 3.5.5 Hazardous Materials for more on produced water). Produced water and other oil extraction wastes are most commonly disposed of via reinjection to the well, which increases pressure thus forcing out more oil. Potential impacts from these wastes generally occur if large amounts are spilled and enter surface waters, decommissioned wells are improperly sealed, or saline water from the wells intrudes into fresh surface water or ground water (Kharaka and Otton, 2005).

Water quality impacts also occur as a result of contamination by VOCs. A nationwide study of groundwater aquifers conducted by United States Geological Survey (USGS) found VOCs in 90 of 98 major aquifers sampled (Zogorski et al., 2006). The study concluded that, "[t]he widespread occurrence of VOCs indicates the ubiquitous nature of VOC sources and the vulnerability of many of the Nation's aquifers to low-level VOC contamination." Several of the most commonly identified VOCs were a gasoline additive (gasoline oxygenate methyl tertiary butyl ether [MTBE]) and a gasoline hydrocarbon (toluene). USGS notes, however, that only 1 to 2 percent of the well samples had concentrations of VOCs that were at levels of potential concern to human health; none of the VOCs found in potentially hazardous quantities were primarily used in the manufacture of fuels or as fuel additives (Zogorski et al., 2006). See Section 3.5.5 for a description of toxic chemicals released during fuel production and combustion.

#### 3.5.1.1.2 $CO_2$ Emissions

Oceanic concentrations of $CO_2$ from anthropogenic sources, primarily the combustion of fossil fuels, have increased since the industrial revolution and will likely continue to increase into the future. In addition to its role as a GHG, atmospheric $CO_2$ plays a key role in the biogeochemical cycle of carbon. Atmospheric $CO_2$ concentrations influence the chemistry of natural waters.

Atmospheric concentrations of $CO_2$ are in equilibrium with aqueous carbonic acid ($H_2CO_3$), which in turn influences the aqueous concentrations of bicarbonate ion ($HCO_3^-$) and carbonate ion ($CO_3^2$). The carbonate system is one of the key features of natural waters in that it affects pH, which controls the availability of some nutrients and toxic materials in freshwater and marine systems.

One of the large-scale non-climatic effects of an increase in $CO_2$ emissions is the potential for ocean acidification. The ocean exchanges huge quantities of $CO_2$ with the atmosphere, and when atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere into the oceans. This lowers the pH of the oceans, reducing the availability of calcium. According to Richardson and Poloczanska (2008), "declines in ocean pH may impact calcifying organisms, from corals in the tropics to pteropods (winged snails) in polar ecosystems, and will take tens of thousands of years to reequilibrate to preindustrial conditions. For more information on the non-climate effects of $CO_2$ on plant and animal communities, see Section 3.1.2 and Section 4.7.

#### 3.5.1.1.3 Biofuel Cultivation

The need to supply agricultural products for a growing population will continue to affect water resources; future irrigation needs are likely to include increased production of both food and biofuel crops (Simpson, 2008). Global demand for water is increasing as a result of population growth and economic development, and irrigation currently accounts for around 70 percent of global water withdrawals (Shiklomanov and Rodda, 2003 as cited in Kundzewicz et al., 2007). The EPA states that, "Demand for biofuels is also likely to have impacts on water including increasing land in agricultural production, resulting in increased risk of runoff of sediments, nutrients, and pesticides. Production of biofuels also uses significant amounts of water" (EPA, 2008, p. 21). Runoff from agricultural sources often contains nitrogen, phosphorus, and other fertilizers and chemicals that harm water quality and can lead to euthropication (the enrichment of a water body with plant-essential nutrients leading to a depletion of oxygen) (Vitousek et al., 1997). If biofuel production in the United States continues to be based on input-intensive crops like corn and soybeans, projected expansions to meet demand will likely result in significantly increased runoff of fertilizer and sediment (Simpson, 2008).

### 3.5.1.2 Environmental Consequences

As discussed in Section 3.3, Air Quality, each alternative except the No Action Alternative is expected to decrease the amount of VOCs, $SO_{2,}$ NOx, and other air pollutants in relation to the No Action Alternative levels. Reductions in these pollutant levels would be the result of lower petroleum fuel consumption by the cars and light trucks, as well as a potential for reduced extraction, transportation, and refining of crude oil. The agency expects that lower releases (air emissions) would decrease the formation of acid rain in the atmosphere as compared to baseline levels (Appendix B-1); these factors would have a beneficial impact on fresh water quality thorough decreased eutrophication and acidification.

The positive effects on acid rain formation would likely be relatively low because of the limited overall effect of the release of $SO_2$ and NOx (Section 3.3).

As discussed in Section 3.4, the impact of the CAFE alternatives on $CO_2$ is relatively small compared to global emissions of $CO_2$. The United States automobile and light truck fleet represent less than 4 percent of the global emissions of $CO_2$ from cars and light trucks and these percentage are projected to decline in the future, due primarily to rapid growth of emissions from developing countries.

Each alternative to the proposed action could potentially lead to an indirect increase in the production of biofuels, depending upon the mix of tools manufacturers use to meet the increased CAFE standards, economic demand, and technological capabilities. If biofuel production increased, additional agricultural runoff could occur. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed standards prescribe increased biofuel use, these potential impacts are not quantifiable.

## 3.5.2 Biological Resources

### 3.5.2.1 Affected Environment

Biological resources include vegetation, wildlife, and special status species (those classified as "Threatened" or "Endangered" under the Endangered Species Act). The U.S. Fish and Wildlife Service has jurisdiction over terrestrial and freshwater special status species and the National Marine Fisheries Service has jurisdiction over marine special status species. States and other Federal agencies, such as the Department of the Interior Bureau of Land Management, also have species of concern to which they have assigned additional protections. The following section discusses the current and projected future threats to these biological resources from non-global climate change impacts related to the proposed action. As discussed below, the production and combustion of fossil fuels and the cultivation and production of biofuels from agricultural crops are the identified relevant sources of impact on biological resources. For a discussion of the effects of global climate change on ecosystems, please see Section 4.5.

##### 3.5.2.1.1 Petroleum Extraction and Refining

Oil extraction activities have the potential to impact biological resources through habitat destruction and encroachment, raising concern about their affects on the preservation of animal and plant populations and their habitats. Oil exploration and extraction result in intrusions into onshore and offshore natural habitats, and may involve construction within natural habitats. "The general environmental effects of encroachment into natural habitats and the chronic effects of drilling and generating mud and discharge water on benthic (bottom-dwelling) populations, migratory bird populations, and marine mammals constitute serious environmental concerns for these ecosystems" (Epstein and Selber, 2002 as cited in O'Rourke and Connolly, 2003, p. 594).

Oil extraction and transportation can also result in oil and hazardous material spills. Oil contamination of aquatic and coastal habitats can directly smother small species and is dangerous to animals and fish if ingested or coated on their fur, skin, or scales. Oil refining and related activities result in chemical and thermal pollution of water, both of which can be harmful to animal and plant populations (Epstein and Selber, 2002). Offshore and onshore drilling and oil transport can lead to spills, vessel or pipeline breakage, and other accidents that release petroleum, toxic chemicals, and highly saline water into the environment and affect plant and animal communities.

Oil extraction, refining and transport activities, as well as the combustion of fuel during motor vehicle operation, result in air emissions that affect air quality and may result in acid rain production; these effects can create negative impacts on plants and animals. Once present in surface waters, air pollutants can cause acidification of waterbodies, changing the pH of the system and impacting the function of freshwater ecosystems (Section 3.5.1 water resources for a discussion of acid rain). The EPA states that,

> "plants and animals living within an ecosystem are highly interdependent… Because of the connections between the many fish, plants, and other organisms living in an aquatic ecosystem, changes in pH or aluminum levels affect biodiversity as well. Thus, as lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease (EPA, 2008)."

Acid rain has also been shown to affect forest ecosystems negatively, both directly and indirectly. These impacts include stunted tree growth and increased mortality, primarily as a result of the leaching of calcium and other soil nutrients (Driscoll, 2001; DeHayes, 1999; Baum, 2001). Declines in biodiversity of aquatic species and changes in terrestrial habitats likely have ripple effects on other wildlife dependent upon these resources.

The combustion of fossil fuels and certain agricultural practices have lead to a disruption in the nitrogen cycle, the process by which gaseous nitrogen from the atmosphere is used and recycled by biological organisms, with serious repercussions for biological resources. Nitrogen cycle disruption has occurred through the introduction of large amounts of anthropogenic nitrogen in the form of ammonium and nitrogen oxides to aquatic and terrestrial systems (Vitousek, 1994). Increased availability of nitrogen in these systems is a major cause of eutrophication in freshwater and marine waterbodies. Eutrophic systems usually contain communities dominated by phytoplankton and can result in the contamination of aquatic environments, fish and other aquatic animal kills, and harmful algal blooms. Acid rain enhances eutrophication of aquatic systems through the deposition of additional nitrogen (Lindberg, n.d.). Introduction of large quantities of nitrogen to certain terrestrial systems has also been predicted to lead to an increase in decomposing soil bacteria and subsequent increase in the release of $CO_2$ into the atmosphere as these bacteria consume organic matter (Black, 2008).

#### 3.5.2.1.2 $CO_2$ Emissions

Ocean acidification as a result of increasing concentrations of atmospheric $CO_2$, primarily from the combustion of fossil fuels, is expected to affect calciferous marine organisms. In conjunction with rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Hoegh-Guldberg et al. (2007, p. 1737) state that "Under conditions expected in the 21st century, global warming and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on reef systems. The result will be less diverse reef communities and carbonate reef structures that fail to be maintained."

In contrast to its potential adverse effect on the productivity of marine ecosystems, higher $CO_2$ concentrations in the atmosphere could increase the productivity of terrestrial systems, because plants use $CO_2$ as an input to photosynthesis. The IPCC Fourth Assessment Report states that "On physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising $CO_2$, called $CO_2$ fertilization (Denman et al., 2007, p. 526).

Under bench-scale and field-scale experimental conditions, a number of investigators have found that higher concentrations have a "fertilizer" effect on plant growth (e.g., Long et al., 2006; Schimel et al., 2000). IPCC reviewed and synthesized field and chamber studies, finding that:

> "There is a large range of responses, with woody plants consistently showing NPP [net primary productivity] increases of 23 to 25 percent (Norby et al., 2005), but much smaller increases for grain crops (Ainsworth and Long, 2005) … Overall, about two-thirds of the experiments show positive response to increased $CO_2$ (Ainsworth and Long, 2005; Luo et al., 2005). Since saturation of $CO_2$ stimulation due to nutrient or other limitations is common (Dukes et al., 2005; Koerner et al., 2005), it is not yet clear how strong the $CO_2$ fertilization effect actually is."

The $CO_2$ fertilization effect could potentially mitigate some of the increase in atmospheric $CO_2$ concentrations by resulting in more storage of carbon in vegetation.

Increased atmospheric $CO_2$ could potentially in conjunction with other environmental factors and changes in plant communities, alter growth, abundance, and respiration rates of some soil microbes (Lipson et al. 2005; Chung et al. 2007; Lesaulnier et al. 2008).

#### 3.5.2.1.3 Biofuel Production

Future demands for biofuel production are predicted to require increased commitments of land to agricultural production (EPA, 2008). Putting additional land into agricultural production or returning marginal agricultural land to production for the purpose of growing perennial grass or trees for use in cellulosic ethanol would decrease the area available as natural habitat. A decrease in habitat and potential habitat for plants and animal species would likely result in negative impacts to certain species. Increased agriculture production would also likely result in increased surface runoff of sediments and fertilizers. Additional fertilizer inputs to water could increase eutrophication and associated impacts. Sediment runoff can settle to the bottom of waterbodies and degrade essential habitat for some species of aquatic organism, bury food sources and areas used for spawning, and kill benthic organisms (EPA, 2000).

#### 3.5.2.1.4 Endangered Species

Off-shore drilling, on-shore oil and gas drilling, and roads created to access remote extraction sites through habitats used by threatened or endangered species, as designated under the Endangered Species Act, may also affect these plants and animals both directly, through loss of individual animals or habitat, and indirectly, through water quality degradation or cumulative impacts with other projects. Loss of potential habitat to the production of biofuels could also result in negative impacts to some species (e.g. diminished potential for habitat expansion, increased runoff related impacts, etc).

### 3.5.2.2 Environmental Consequences

The decrease in overall fuel consumption by cars and light trucks, anticipated under all of the alternatives except the No Action Alternative, could lead to reductions in oil exploration, extraction, transportation, and refining. The agency expects that a reduction in these activities would result in a decrease in impacts to on- and off-shore habitat and plant and animal species. This decrease could have a small overall benefit to plants and animals mainly through lower levels of direct ground disturbance and oil and hazardous material release.

Reductions in fuel consumption would lead to a decrease in the release of SOx and NOx. Reductions in acid rain could lower levels of eutrophication in surface waters caused by acid rain and potentially slow direct impacts to forests and soil leaching. The positive effects on eutrophic water bodies would likely be relatively low because of the limited overall effect of the release of $SO_2$ and NOx (Appendix B-1 and Chapter 3.3).

Reductions in fuel consumption would also lead to a decrease in the release of $CO_{2.}$ Lower levels of atmospheric $CO_2$ could slow projected effects to terrestrial plant growth ,calciferous marine organisms, and microorganisms. However, as discussed in Section 3.5.1.2, the reduction in $CO_2$ as a result of the proposed action and alternatives would be relatively small compared to current and projected global $CO_2$ releases (Chapter 2 and Section 3.3).

The alternatives to the proposed action could potentially lead to an increase in the production of biofuels, depending on the mix of tools manufacturers use to meet the proposed CAFE standards, economic demands from consumers and manufacturers, and technological developments. Depending on these factors, increased production of biofuels could result in the conversion of existing food-agricultural lands and non-agricultural areas to biofuel crop production. This change in land use would have implications for environmental issues associated with fertilizer runoff precipitated waterbody eutrophication, and sediment runoff effects to aquatic organism food and spawning habitat. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed standards prescribe increased biofuel use, these potential effects are not quantifiable.

## 3.5.3 Land Use and Development

### 3.5.3.1 Affected Environment

Land use and development refers to human activities that alter land (e.g., industrial and residential construction in urban and rural settings, clearing of natural habitat for agricultural or industrial use) and may affect the amount of carbon or biomass in existing forest or soil stocks in the affected areas. For the purposes of this analysis, the potential conversion of agricultural food or non-agricultural lands to biofuel crop production and changes to manufacturing plants that produce cars and light trucks are the identified relevant sources of impact.

#### 3.5.3.1.1 Agricultural Changes

Biofuel production is predicted to require increased devotion of land to agricultural production (EPA, 2008; Keeney and Hertel, 2008). Converting areas into cropland would decrease the overall land area kept in a natural state as well as the potential area available for other types of uses (such as commercial development or pastureland) (Keeney and Hertel, 2008). Uncertainty exists regarding how much additional land could be required to meet projected future biofuel needs in the United States as well as how an increase in biofuel production could affect other land uses (Keeney and Hertel, 2008).

#### 3.5.3.1.2 Manufacturing Changes

Recent shifts in consumer demand in the United States away from less fuel efficient vehicles have begun to change the types of vehicles produced and the manufacturing plants where they are made. Sharp decreases in demand for trucks and sport utility vehicles have recently resulted in plant closures and production shifts to plants where small cars and gas-electric hybrid vehicle are made (WWJ, 2008; Keenan and Mckenna, 2008; Bunkley, 2008).

### 3.5.3.2 Environmental Consequences

The alternatives could potentially lead to an increase in the production of biofuels, depending on the mix of tools manufacturers use to meet the proposed CAFE standards, economic demands from consumers and manufacturers, and technological developments. Depending on these factors, increased production of biofuels could result in the conversion of existing food-agricultural lands and natural areas to the production of these fuel crops. This change would have implications for environmental issues associated with land use and development. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed standards prescribe increased biofuel use, these potential impacts are not quantifiable.

Major changes to manufacturing facilities, such as those occurring with the apparent shift in consumer demand toward more fuel efficient vehicles, might have implications for environmental issues associated with land use and development. However, NHTSA's review of existing and available technologies and capabilities shows that the CAFE standards proposed under all of the alternatives can be met by existing and planned manufacturing facilities. Because of the availability of sufficient existing and planned capacity, and because none of the proposed alternatives prescribe particular technologies for meeting these standards, the various alternatives are not projected to force changes in product mixes that would result in plant changes.

## 3.5.4 Safety and Other Human Health Impacts

This section addresses the manner in which future improvements in fuel economy might affect human health and welfare through vehicle safety performance, particularly crashworthiness and the rate of traffic fatalities. It also addresses how the proposed standards might affect energy concerns which could have ramifications for family health and welfare.

### 3.5.4.1 Affected Environment

There are multiple factors that influence traffic fatality rates including driver demographics (age, gender, etc), driver behavior (e.g., driving under the influence, seat belt use, observance of speed limits and other traffic laws, miles driven), and vehicle characteristics such as size, weight, and various technologies designed to increase vehicle safety performance (e.g., air bags, anti-lock braking systems, structural reinforcement, impact crumple zones, etc.). Several studies have attempted to define the relationship between vehicle crashworthiness (specifically as it relates to traffic fatalities) and fuel economy standards, however different methodologies have yielded different conclusions. While much of the research identifies a link between vehicle downsizing and decreased crashworthiness, there are contrasting studies found.

The 2002 National Academy of Sciences (NAS)[49] report made explicit links between weight and vehicle safety. The NAS study conclusions were divided, with 11 of 13 committee members representing the majority view and 2 of 13 the minority view. The findings of the majority presented on page 77 states, "… the majority of the committee finds that the downsizing and weight reduction that occurred in the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993. The proportion of these casualties attributable to CAFE standards is uncertain." Two members provided a minority view which was summarized on page 123: "The relationship between vehicle weight and safety are complex and not measurable with any reasonable degree of certainty at present. The relationship of fuel economy to safety is even more tenuous. … it appears that in certain kinds of accidents, reducing weight will increase safety risk, while in others it may reduce it. Reducing the weights of light-duty vehicles will neither benefit nor harm all highway users, there will be winners and losers…."

The Kahane study[50] estimates the effect of 100-pound reductions in heavy light trucks and vans (LTVs), light LTVs, heavy passenger cars, and light passenger cars. It compares the fatality rates of LTVs and cars to quantify differences between vehicle types, given drivers of the same age/gender, etc. It found that annual fatalities increased with a reduction in weight in all groups of passenger vehicles except light trucks with a curb weight greater than 3,900 pounds. The net safety effect of removing 100 pounds from a light truck is close to zero for the group of all light trucks with a curb weight greater than 3,900 pounds.

Honda has cited several reports, which it asserted demonstrated that limited weight reductions would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study by Dynamic Research Inc. (DRI) found that reducing weight without reducing size slightly decreased fatalities, and that this was confirmed in a 2004 study by DRI[51] that assessed new data and methodology changes in the 2003 Kahane Study. DRI submitted an additional study, *Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs*, (Van Auken, R.M. and J. W. Zellner, May 20, 2005) (Docket No. 2003-16128-1456). This DRI study concluded that reductions in footprint are harmful to safety, whereas reductions in mass while holding footprint constant would benefit safety.

NHTSA's analyses of the relationships between fatality risk, mass, track width and wheelbase in 4-door 1991-1999 passenger cars (Docket No. 2003-16318-16) found a strong relationship between track width and the rollover fatality rate, but only a modest (although significant) relationship between track width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – e.g., by

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[49] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

[50] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph. D., NHTSA, October 2003, DOT HS 809-662.

[51] See Docket Nos. 2003-16318-2, 2003-16318-3, and 2003-16318-7.

holding footprint constant – weight reduction in the lighter cars is strongly, significantly associated with higher non-rollover fatality rates in the NHTSA analysis.

While further scientific examination continues, EISA included an important reform that requires the Transportation Department to issue "attribute-based standards," which eliminates or reduces the incentive to decrease the size (weight) of the vehicle to comply with the fuel economy standard since smaller footprint (size) vehicles have to achieve higher fuel economy targets. The attribute-based approach was originally recommended by the NAS to remove the apparent incentive to reduce size and/or the weight of vehicles as a means of meeting the standards.

NHTSA adopted an attribute based approach for light trucks in 2006. NHTSA continues to examine this important safety issue and has tentatively concluded in its current NPRM that use of the footprint-attribute will achieve greater fuel economy/emissions reductions without creating an incentive to downsize vehicles.

Another way that the proposed standards could affect human health and welfare is by increasing the amount of VMT. NHTSA tracks very closely the rate of traffic fatalities as a function of VMT even while recognizing that many other factors are critical in determining fatality risks. In February 2008, NHTSA reported that the fatality rate in 2006 was 1.41 per million miles of VMT, a decline from 2005 rates (Subramanian, 2008). These effects are not limited to vehicle occupants only (bicyclists and pedestrians may also have an increased risk as a result of increased VMT). However, as with vehicle occupant fatalities, many other factors are important in determining the overall risk associated with vehicle, pedestrian and bicycle fatalities.

Finally, there is scientific literature that posits the relationship between petroleum scarcity and human health. (Frumkin et al., 2007). Frumkin argues that increased oil prices could result in the increase of other fuels used for power generation and increase hospital costs for providing back-up power via diesel generator. Petroleum scarcity could also result in more expensive food (due to transport and agricultural costs) which may be intensified by several factors including climate change, market demand for biofuels (that will inflate some food prices), and agricultural land degradation. These effects may threaten the health of poor people and others with insecure access to food. Other effects of peak petroleum on health are more speculative, but concerns remain for issues such as: 1) higher petroleum prices triggering a persistent economic downturn, which could increase the ranks of the uninsured; 2) social disruptions that may create a substantial burden of anxiety, depression, and other psychological ailments; and 3) resource scarcity, including petroleum scarcity, that could trigger armed conflict, which poses multiple risks to public health. To the extent that the proposed CAFE standards affect petroleum supply or price, they may have an effect on human welfare.

#### 3.5.4.2 Consequences

Because of the attribute based approach recommended by NAS and adopted by NHTSA, the incentive to meet the proposed standards by making more smaller vehicles and fewer larger vehicles should be reduced or eliminated. Further, NHTSA chose fuel economy levels that could be achieved without reductions in weight for vehicles less than 5,000 pounds. Because the proposed action and alternatives do not mandate the method by which the CAFE standards are achieved, vehicle manufacturers could achieve increased fleet fuel economy by reducing vehicle weight. To the extent that manufacturers choose this approach, there may be some additional traffic fatalities, and more serious injuries resulting from vehicle accidents. The extent to which these effects may be experienced cannot be estimated without knowing the extent to which manufacturers choose to meet the proposed CAFE standards by making lighter vehicles of a similar footprint.

The PRIA for the CAFE Standards of MY 2011–2015 passenger cars and light trucks concluded that increases in fleet fuel economy is likely to lead to more miles being driven by the United States population (NHTSA, 2008). Known as the “rebound effect,” higher CAFE standards would lead to the perception of a lower cost of driving, which is typically the largest component of the cost of operating a vehicle. In response to the perception of lowered costs, consumers would increase the number of miles they drive. By one estimate, a 10 percent increase in fuel economy would ultimately result in a 2.4 percent increase in total miles traveled (Small and Dender, 2005). The recent and unprecedented decline in miles driven – a 4.3 percent drop in the total miles driven in March of 2008 as compared to March of 2007, a decrease of 11 billion miles (FHWA, 2008) – in response to recent surges in the price of gasoline, underscores the relationship between the cost of operating a passenger vehicle and driver behavior as it relates to miles driven. Because increased average fuel economy would lead to vehicles that cost less to operate, it can be expected that individuals would drive more miles, and traffic accidents and fatalities of vehicle occupants, bicyclists and pedestrians would increase on the whole, however, an estimate of increased fatalities based on miles driven is influenced, in part, by unpredictable market forces, and is uncertain to predict.

The proposed standards and the alternatives will reduce petroleum use. To the extent that petroleum scarcity will be reduced by higher fuel economy standards, any adverse health impacts as described by Frumkin will also be reduced.

### 3.5.5 Hazardous Materials and Regulated Wastes

#### 3.5.5.1 Affected Environment

Hazardous wastes are defined here as solid wastes, which also include certain liquid or gaseous materials, that because of their quantity and concentration, or their physical, chemical, or infectious characteristics may cause or contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or may pose a substantial hazard to human health or the environment when improperly treated, stored, used, transported, disposed of, or otherwise managed. Hazardous wastes are generally designated as such by individual states or the EPA, under the Resource Conservation and Recovery Act of 1976. Additional Federal and State legislation and regulations, such as The Federal Insecticide, Fungicide, and Rodenticide Act, determine handling and notification standards for other potentially toxic substances. For the purposes of this analysis, hazardous materials and wastes generated during the oil extraction and refining processes as well as by agricultural production are the identified relevant sources of impact.

##### 3.5.5.1.1 Wastes Produced during the Extraction Phase of Oil Production

The primary waste created during the extraction of oil is “produced water,” a highly saline water pumped from oil and gas wells during mining (The American Petroleum Institute, 2000; EPA, 2000a). In 1995, approximately 15 billion barrels of produced water were generated by the onshore oil and gas industry (The American Petroleum Institute, 2000). Produced waters are generally, “highly saline (total dissolved solids may exceed 350,000 milligrams per liter [mg/L] dissolved solids), may contain toxic metals, organic and inorganic components, and radium-226/228 and other naturally occurring radioactive materials (Kharaka and Otton, 2005, p. 2).” Drilling wastes, primarily mud and rock cuttings, account for 149 million barrels of extraction wastes and “associated wastes”, generally the most hazardous wastes produced during extraction (often containing benzenes, arsenic, and toxic metals), account for another 22 million barrels (The American Petroleum Institute, 2000; EPA, 2000).

Wastes produced during oil and gas extraction have been known to have serious environmental effects on soil, water, and ecosystems (Kharaka and Otton, 2005; O’Rourke and Connolly, 2003).

Onshore environmental effects result, “primarily from the improper disposal of large volumes of saline water produced with oil and gas, from accidental hydrocarbon and produced water releases, and from abandoned oil wells that were not correctly sealed” (Kharaka and Otton, 2005, p. 1). Offshore effects result from improperly treated produced water released into the waters surrounding the oil platform (EPA, 2000).

#### 3.5.5.1.2 Wastes Produced during the Refining Phase of Oil Production

Wastes produced during the petroleum refining process are primarily released to the air and water, accounting for 75 percent (air emissions) and 24 percent (wastewater discharges) of the total respectively (EPA, 1995). EPA defines a release as the, “on-site discharge of a toxic chemical to the environment…emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells” (EPA, 1995). EPA reports that nine of the ten most common toxic substances released by the petroleum refining industry are volatile chemicals, highly reactive substances prone to state changes or combustion, that include benzene, toluene, ethylbenzene, xylene, cyclohexane, 1,2,4-trimethylbenzene and ethylbenze (EPA, 1995). These substances occur within both crude oil and finished petroleum products. Other potentially dangerous substances commonly released during the refining process include ammonia, “gasoline additives (i.e., methanol, ethanol, and MTBE) and chemical feedstocks (propylene, ethylene, and napthalene)” (EPA, 1995). 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, 1995).

Wastes released during the oil refining process can cause environmental impacts to water quality, air quality, and human health. The volatile chemicals released during the refining process are know to react in the atmosphere and contribute to ground-level ozone and smog (EPA, 1995). Several of the produced volatile chemicals are also known or suspected carcinogens, and many others are known to cause respiratory problems and impair internal organ functions, particularly in the liver and kidneys (EPA, 1995). Ammonia is a form of nitrogen and can contribute to eutrophication in surface waters.

#### 3.5.5.1.3 Agricultural Materials

Agricultural production, especially of the type required to grow the corn and soy beans mostly commonly used to produce biofuels in the United States, also results in the release of potentially hazardous materials and wastes. Wastes from agricultural production can include pesticide (insecticides, rodenticides, fungicides, and herbicides) and fertilizer runoff and leaching, wastes used in the maintenance and operation of agricultural machinery (used oil, fuel spills, organic solvents, metal machining wastes, spent batteries), and other assorted process wastes (EPA, 2000).

Agricultural wastes in the form of runoff from agricultural fields can cause environmental impacts to water and human health. Fertilizers can run off into surface waters and cause eutrophication, while pesticides can directly affect beneficial insects and wildlife (EPA, 2000). A National Renewable Energy Lab report concludes that the negative environmental impacts on soil and water due to impacts of increased biofuel production are likely to occur disproportionately in the Midwest, where the majority of these crops are grown (Powers 2005). Human health can also be affected by improperly handled or applied pesticides, with potential effects ranging from minor respiratory or skin inflammation to death (EPA, 2000). Nitrogen fertilizer runoff to drinking water sources can lead to methemogloinemia, the potentially fatal binding of a form of nitrogen to hemoglobin in infants (Powers, 2005).

Ethanol, as a biofuel additive to gasoline, is suspected of enhancing the plume size after a gasoline-blended ethanol spill and may decrease degradation of the spilled hydrocarbon and related compounds, such as benzene (Powers et al., 2001; Deeb et al., 2002; Williams et al., 2003).

#### 3.5.5.1.4 Automobile Production and Assembly

Hazardous materials and toxic substances are produced by the motor vehicles and motor vehicle equipment industry, businesses engaged in the manufacture and assembly of cars, trucks, and busses. EPA reports that solvents (xylene, methyl ethyl ketone, acetone, etc.) are the most commonly released toxic substance it tracks for this industry (EPA, 1995a). These solvents are used to clean metal and in the vehicle finishing process during assembly and painting and to clean metal (EPA, 1995a). Additional industry wastes include metal paint and component part scrap.

#### 3.5.5.1.5 $CO_2$ Emissions

$CO_2$ is not currently classified as a hazardous material or regulated waste. For a discussion of the release of $CO_2$ relevant to the proposed action and its impacts on climate change, see Section 3.4. For discussions of the impacts of $CO_2$ on water resources, see Section 3.5.1. For discussions of the impacts of $CO_2$ on biological resources, see Section 3.5.2.

### 3.5.5.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the proposed action and alternatives may lead to a reduction in the amount of hazardous materials and wastes created by the oil extraction and refining industries. The agency expects corresponding decreases in the associated environmental and health impacts of these substances. However, these effects would likely be small if they occurred because of the limited overall effect of the proposed action on these areas.

All of the alternatives to the proposed action could potentially lead to an increase in the production of biofuels, depending on the mix of tools manufacturers use to meet the proposed CAFE standards, economic demands from consumers and manufacturers, and technological developments. If biofuel production increased, additional runoff of agricultural fertilizers and pesticides could occur. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed standards prescribe increased biofuel use, these potential impacts are not quantifiable.

## 3.5.6 Land Uses Protected under Section 4(f)

### 3.5.6.1 Affected Environment

Section 4(f) resources are publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites, which are given special consideration by the DOT. Originally included as part of the Department of Transportation Act of 1966, Section 4(f) stipulates that DOT agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless: "(1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use" *(*49 U.S.C. 303).

### 3.5.6.2 Environmental Consequences

"Section 4(f) only applies where land is permanently incorporated into a transportation facility and when the primary purpose of the activity on the 4(f) resource is for transportation" (FHWA, 2005). Therefore, these resources are not affected by the types of environmental issues under consideration as part of the proposed action or alternatives.

### 3.5.7 Historic and Cultural Resources

#### 3.5.7.1 Affected Environment

National Historic Preservation Act of 1966, Section 106 states that agencies of the Federal government must take into account the impacts of their action to historic properties; the regulations to meet this requirement can be found at 36 CFR Part 800. This process, known as the "Section 106 process" is intended to support historic preservation and mitigate impacts to significant historical or archeological properties through the coordination of Federal agencies, states, and other affected parties. Historic properties are generally identified through the National Register of Historic Places, which lists properties of significance to the United States or a particular locale because of their setting or location, contribution to or association with history, or unique craftsmanship or materials. National Register eligible properties must also be sites: "A. That are associated with events that have made a significant contribution to the broad patterns of our history; or B. That are associated with the lives of persons significant in our past; or C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or D. That have yielded, or may be likely to yield, information important in prehistory or history" (NPS, n.d.). Acid rain as a result of the processing of petroleum products and the combustion of petroleum-based fuels is the identified relevant source of impact to historic and cultural resources for this analysis.

Acid rain, the primary source of which is the combustion of fossil fuels, is one cause of degradation to exposed cultural resources and historic sites. EPA states that, "[a]cid rain and the dry deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). These effects significantly reduce the societal value of buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars" (EPA, n.d.).

#### 3.5.7.2 Environmental Consequences

The projected reduction in fuel production and combustion as a result of the proposed action and alternatives may lead to a minor reduction in the amount of acid rain causing pollutants in relation to current levels. A decrease in the production of acid rain-causing pollutants could result in a corresponding decrease in the amount of acid rain-caused damage to historic and other structures. However, the affects of any such effects are not quantifiable.

### 3.5.8 Noise

#### 3.5.8.1 Affected Environment

Excessive amounts of noise, which is measured in decibels, can present a disturbance and a hazard to human health at certain levels. Potential health hazards from noise range from annoyance (sleep disturbance, lack of concentration, and stress) to hearing loss at high levels (Delucchi and Hsu, 1998; Geary, 1998; Fleming et al., 2005). Motor vehicle noise also effects property value; a study of the impacts of roadway noise on property value estimated this cost to be roughly 3 billion dollars in 1991 dollars (Delucchi and Hsu, 1998). The noise from motor vehicles has been shown to be one of the primary causes of noise disturbance in homes (OECD, 1988 as cited in Delucchi and Hsu, 1998; Geary, 1998). Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property. Hybrid gas-electric vehicles have been shown to have lower noise emissions than standard internal combustion engines (Hogan and Gregory, 2006).

### 3.5.8.2 Environmental Consequences

As a result of the "Rebound-Effect," the increase in VMT as the cost per mile for fuel decreases, NHTSA predicts that increased vehicle use will occur under all of the proposed alternatives; higher overall VMTs would result in increases in vehicle road noise. However, determining if noise impacts will occur is not possible based on the available data. Noise levels are location specific, meaning factors such as the time of day at which increases in traffic occur, existing ambient noise levels, the presence or absence of noise abatement structures, and the location of school, residences, and other sensitive noise receptors all influence whether noise impacts will occur.

All of the alternatives to the proposed action could potentially lead to an increase in use of hybrid vehicles, depending on the mix of tools manufacturers use to meet the proposed CAFE standards, economic demands from consumers and manufacturers, and technological developments. An increased percentage of hybrid vehicles could result in reduced road noise, potentially offsetting some of the increase in road noise predicted to result from increased VMT. However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed standards prescribe increased production of hybrid vehicles, and the location specific quality of noise impacts, these potential impacts are not quantifiable.

## 3.5.9 Environmental Justice

### 3.5.9.1 Affected Environment

Federal agencies must identify and address disproportionably high and adverse impacts to minority and low-income populations in the United States (Executive Order 12898- Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations). DOT Order 5610.2 to Address Environmental Justice in Minority Populations and Low-Income Populations establishes the process the department uses to "incorporate environmental justice principles (as embodied in the Executive Order) into existing programs, policies, and activities." The production and use of fossil fuels and the production of biofuels are the identified relevant sources of impact to environmental populations for this analysis. For a discussion of the effects of changes in climate on environmental justice populations, please see Section 4.6.

Numerous studies have noted that a historic and ongoing relationship between the environmental impacts of petroleum extraction, processing, and use and environmental justice populations appears to exist (Pastor et al., 2001; O'Rourke and Connolly, 2003; Lynch et al., 2004; Hymel, 2007; Srinivasan, 2003).

Potential impacts of the oil exploration and extraction process on environmental justice communities include "human health and safety risks for neighboring communities and oil industry workers, and displacement of indigenous communities" (O'Rourke and Connolly 2003, p. 594). Subsistence use activities (collecting plants or animals to fulfill basic needs for food, clothing, or shelter) can also be affected by extraction and exploration through the direct loss of subsistence use areas or impacts to culturally/economically important plants and animals as a result of a spill or hazardous material release (O'Rourke and Connolly, 2003; Kharaka and Otton, 2005).

It has been shown that minority and low income populations often disproportionately reside near high risk polluting facilities, such as oil refineries (Pastor et al., 2001; Graham et al., 1999; O'Rourke and Connolly, 2003), and "mobile" source of air toxins and pollutants, such as highways (Morello-Frosch, 2002; Jerret et al., 2001; O'Neil et al., 2003). Populations near refineries may be disproportionately impacted by exposure to potentially dangerous petroleum and by-products of the refining process, such as benzene (Epstein and Selber, 2002). Exposure to the toxic chemicals associated with refineries, primarily by refinery workers, has been shown to be related to increases in certain diseases and types of cancer (Pukkala, 1998; Chan, 2005); the precise nature and severity of these health impacts are still under debate. Pollutants from transportation sources, such as $NO_2$ and CO from roadway traffic, are often unevenly distributed and tend to remain near their release locations (O'Neil et al., 2003). A correlation between this uneven distribution of some pollutants and minority and low income populations has been documented, demonstrating the potential for a disproportionate allocation of the health impacts of these air pollutants to environmental justice populations (Jerret et al., 2001; Morello-Frosch, 2002). Recent reviews by health and medical researchers indicate a general consensus that proximity to high-traffic roadways could result in health effects in the areas of cardiovascular health (Adar and Kaufman, 2007), and asthma and respiratory health (Heinrich and Wichmann, 2004; Salam et al., 2008). The exact nature of the relationship between these health impacts, traffic-related emissions, and the influence of confounding factors such as traffic noise are not known at this time (Samet, 2007).

The production of biofuels could, depending on the mix of agricultural crops or crop residues used in its production, affect food prices. The International Food Policy Research Institute states, "An aggressive biofuel scenario that assumes that current plans for expansion of the sector in Africa, Asia, Europe, and North and South America are actually realized could lead to significant price increases for some food crops by 2020—about 80 percent for oilseeds and about 40 percent for maize—unless new technologies are developed that increase efficiency and productivity in both crop production and biofuel processing" (von Braun and Pachauri, 2006, p. 11). Such an increase in food prices would disproportionately affect low income and minority populations, as these groups are less likely to be capable of absorbing the impacts of higher prices.

### 3.5.9.2 Environmental Consequences

The projected reduction in fuel production and consumption as a result of the action alternatives may lead to a minor reduction in the amount of direct land disturbance that occurs as a result of oil exploration and extraction, and the amount of air pollution produced by the oil refineries. Corresponding decreases in impacts on environmental justice populations could occur as a result of the alternatives to the proposed action, but the effects of any such decreases are not quantifiable and would likely be minor should they occur.

As stated in Section 3.3, the overall decrease in toxic air and criteria air pollutants predicted to occur as a result of the alternatives is not evenly distributed due to the increase in traffic in some areas from the "rebound effect"; some criteria and toxic air pollutants are predicted to increase in some air quality NAAs, potentially resulting in adverse impacts to environmental justice and other resident populations (see Appendix C for the increases in air pollutant levels by year and non-attainment area). These localized increases are a decline in the rate of reductions being achieved by implementation of the CAA. Environmental justice populations often occur in disproportionate numbers along travel corridors, therefore, it is possible that location-specific disproportionate impacts could occur in some of these non-attainment areas; however, it is not possible to determine the specific locations where these impacts might occur at this time. As discussed in Section 3.3, the incremental increase as a result of the proposed action is small and overall pollutant levels are decreasing.

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

# Chapter 4 Cumulative Impacts

## 4.1 INTRODUCTION

The Council on Environmental Quality (CEQ) identifies the impacts that must be addressed and considered by Federal agencies in satisfying the requirements of the National Environmental Policy Act (NEPA). This includes permanent, temporary, indirect, and cumulative impacts.

CEQ regulations implementing the procedural provisions of NEPA define cumulative effects as, "The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions." Cumulative effects should be evaluated along with the overall impacts analysis of each alternative. The range of alternatives considered should include the No Action Alternative as a baseline against which to evaluate cumulative effects. The range of actions to be considered includes not only the proposed action but all connected and similar actions that could contribute to cumulative effects. Related actions should be addressed in the same analysis. CEQ recommends that an agency's analysis accomplish the following:

- Focus on the effects and resources within the context of the proposed action.
- Present a concise list of issues that have relevance to the anticipated effects of the proposed action or eventual decision.
- Reach conclusions based on the best available data at the time of the analysis.
- Rely on information from other agencies and organizations on reasonably foreseeable projects or activities that are beyond the scope of the analyzing agency's purview.
- Relate to the geographic scope of the proposed project.
- Relate to the temporal period of the proposed project.

A cumulative effects analysis involves assumptions and uncertainties. Monitoring programs and/or research can be identified to improve the available information and, thus, the analyses in the future. The absence of an ideal database should not prevent the completion of a cumulative effects analysis.

This cumulative impacts section addresses areas of the quantitative analyses presented in Chapter 3, with particular attention to energy, air and climate. Chapter 4 describes the indirect cumulative effects of climate change on a global scale. This chapter is organized according to the conventions of the climate change literature rather than the conventions of an Environmental Impact Statement (EIS) format. To assist the reader, the chart below maps topics found in U.S. Department of Transportation (DOT) NEPA documents (DOT Order 5610.1C).

| Typical NEPA Topics | DEIS Subsections |
|---|---|
| Water | 4.4 Climate; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.3 Freshwater Resources |
| Ecosystems | 4.5.5 Coastal Systems and Low-lying Areas; 4.5.3 Freshwater Resources; 4.5.4 Terrestrial Ecosystems; 4.5.6 Food, Fiber, and Forest Products; 4.7 Non-climate Cumulative Impacts of $CO_2$ |
| Publicly Owned Parklands, Recreational Areas, Wildlife, and Waterfowl Refuges, and Historic Sites, 4(f) related issues. | 4.5.5 Coastal Systems and Low-lying Areas; 4.5.3. Freshwater Resources; 4.5.7 Industry, Settlements, and Society; 4.5.4 Terrestrial Ecosystems |
| Properties and Sites of Historic and Cultural Significance | 4.5.7 Industry, Settlements, and Society |
| Considerations Relating to Pedestrians and Bicyclists | 4.5.7 Industry, Settlements, and Society |
| Social Impacts | 4.5.7 Industry, Settlements, and Society; 4.6 Environmental Justice |
| Noise | 4.5.7 Industry, Settlements, and Society |
| Air | 4.3 Air Quality |
| Energy Supply and Natural Resource Development | 4.2 Energy; 4.5.4 Terrestrial Ecosystems; 4.5.6 Food, Fiber, and Forests; 4.5.7 Industry, Settlements, and Society; |
| Floodplain Management Evaluation | 4.5.5 Coastal Systems and Low-lying Areas; 4.5.3 Freshwater Resources |
| Wetlands or Coastal Zones | 4.5.5 Coastal Systems and Low-lying Areas; 4.5.3 Freshwater Resources |
| Construction Impacts | 4.3 Air Quality; Climate; 4.5.7 Industry, Settlements, and Society; 4.5.8 Human Health |
| Land Use and Urban Growth | 4.3 Climate; 4.5.6 Food, Fiber, and Forests; 4.5.7 Industry, Settlements, and Society |
| Human Environment involving Community Disruption and Relocation | 4.3 Air Quality; Climate; 4.5.5 Coastal Systems and Low-lying Areas; 4.5.7 Industry, Settlements, and Society; 4.5.8 Human Health; 4.6 Environmental Justice |

### 4.1.1 Approach to Scientific Uncertainty and Incomplete Information

#### 4.1.1.1 CEQ Regulations

The CEQ regulations recognize that many Federal agencies confront limited information and substantial uncertainties when analyzing the potential environmental impacts of their actions under NEPA (40 CFR §1502.22). Accordingly, the regulations provide agencies with a means of formally acknowledging incomplete or unavailable information in NEPA documents. Where “information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known,” the regulations require an agency to include in its NEPA document:

1) a statement that such information is incomplete or unavailable;

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

3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

4) the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.

Relying on these provisions is appropriate where an agency is performing a NEPA analysis that involves potential environmental impacts resulting from carbon dioxide ($CO_2$) emissions (*e.g.*, *Mayo Found. v. Surface Transp. Bd.*, 472 F.3d 545, 555, 8th Cir. 2006). The CEQ regulations also authorize agencies to incorporate material into a NEPA document by reference in order to "cut down on bulk without impeding agency and public review of the action" (40 CFR § 1502.21).

Throughout this Draft Environmental Impact Statement (DEIS), the National Highway Transportation Safety Administration (NHTSA) uses these two mechanisms – acknowledging incomplete or unavailable information and incorporation by reference – to address areas where the agency is unable to estimate precisely the potential environmental impacts of the proposed standards or reasonable alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts of changes in emissions of $CO_2$ and other greenhouse gases (GHG) and associated changes in temperature, including those expected to result from the proposed rule, is incomplete. In this DEIS, NHTSA often relies on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) 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)).

### 4.1.1.2 Uncertainty within the IPCC Framework

The IPCC Reports communicate uncertainty and confidence bounds using descriptive words in italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This is briefly explained in the IPCC Fourth Assessment Synthesis Report[1] and the IPCC Fourth Assessment Report Summary for Policy Makers.[2] A more detailed discussion of the IPCC's treatment of uncertainty can be found in the IPCC's Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties.[3]

This DEIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and 4 when discussing qualitative environmental impacts on certain resources. The reader should refer to the documents referenced above to gain a full understanding of the meaning of those uncertainty terms, as they may be separate from the meaning of language describing uncertainty in the DEIS as required by the CEQ regulations discussed above.

## 4.1.2 Temporal and Geographic Boundaries

When evaluating cumulative effects, the analyst must consider expanding the geographic study area beyond that of the proposed action, as well as expanding the temporal (time) limits to consider past,

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[1] IPCC, 2007: Synthesis Report, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf .

[2] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf .

[3] IPCC, Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties, *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-uncertaintyguidancenote.pdf .

present, and reasonably foreseeable future actions that may affect the environmental resources of concern. The timeframe for this cumulative impacts analysis extends through year 2100 and considers potential cumulative impacts on a national, as well as global, basis.

## 4.2 ENERGY

The NEPA analysis must consider the cumulative impacts of the proposed action. In the case of the model year (MY) 2011-2015 passenger cars and light trucks this involves evaluating their lifetime fuel consumption.

### 4.2.1 Affected Environment

According to Energy Information Administration (EIA), net imports of total liquids, including crude oil and refined products, will fall to 51 percent in 2022 and then rise again to 54 percent in 2030. This change is attributed to both changes in the Corporate Average Fuel Economy (CAFE) standards and the greater use of biofuels. These imports will replace declining production in meeting the increasing demand for liquid fuels in the United States. The large volume of crude oil imports has a number of impacts on the domestic economy. Further decreases or increases in imports, likely under some of the CAFE alternatives, may well affect the world price of crude oil. However, over time the United States' share of global demand for liquid fuels will decline due to rapid increases in demand in developing economies, including China and India, reducing the relative impact of the CAFE standards on global markets.

Over time a larger share of liquid fuels is expected to be produced from unconventional sources such as biofuels, shale oil, coal-to-liquids, and gas-to-liquids. These alternate sources would affect $CO_2$ and other emission reductions from the CAFE alternatives. This shift would be driven by changes to the Renewable Fuels Standard in the Energy Independence and Security Act (EISA), which forecasts that 36 billion gallons of renewable fuels will be required by 2022 for use primarily in the transportation sector. The EIA Annual Energy Outlook 2008 forecasts that domestic production of non-hydro renewable energy will increase from less than 4 quadrillion British thermal units (BTUs) in 2006 to over 10 quadrillion BTUs in 2030[4]. In the United States, liquid fuels from gas, coal, and biomass are projected to increase from 0.0 quadrillion BTUs in 2006 to 0.53 quadrillion BTUs. Overall, NHTSA expects in the short-term, the impact from these changes would net out. Over the long-term, the impact of these changes remains uncertain.

Changes to the CAFE standards are unlikely to affect domestic production, given the level of crude oil imports. The domestic environmental impacts over the life of the MY 2011-2020 vehicles are unlikely to change, whatever the alternative elected. Impacts on production will occur outside of the United States, and will be determined by the balance between the decline in United States imports and the increase in demand from developing countries.Impacts on petroleum products will be mixed. United States imports of petroleum products and are often targeted for specific product requirements, or to optimize the inputs and outputs from refineries. Petroleum imports are dependent on specific product demands and the mix of crudes being processed in the refineries, which are projected change considerably over time. Consequently, any decline in demand for petroleum products is likely to have some effect on both overseas and domestic refineries.

### 4.2.2 Consequences

Implementing alternative CAFE standards would result in different future levels of fuel use, total energy, and petroleum consumption, which would in turn have an impact on emissions of GHG and criteria air pollutants. An important measure of the impact of alternative CAFE standards is the impact on total fuel consumption over the expected lifetimes of passenger cars and light trucks produced during the

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[4] EIA Annual Energy Outlook 2008, http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html

model years to which those standards apply. The impact of alternative CAFE standards, by affecting petroleum consumption, total energy, and emissions, ultimately would determine many of the indirect environmental impacts of adopting higher CAFE standards.

Figure 4.2-1 shows the estimated lifetime fuel consumption of passenger cars and light trucks under the various CAFE standards. Figure 4.2.2-2 shows the savings in lifetime fuel consumption for passenger cars and light trucks depending on the CAFE alternative examined.

**Figure 4.2-1 Lifetime Fuel Consumption of Light Trucks and Passenger Cars under Alternative CAFE Standard**

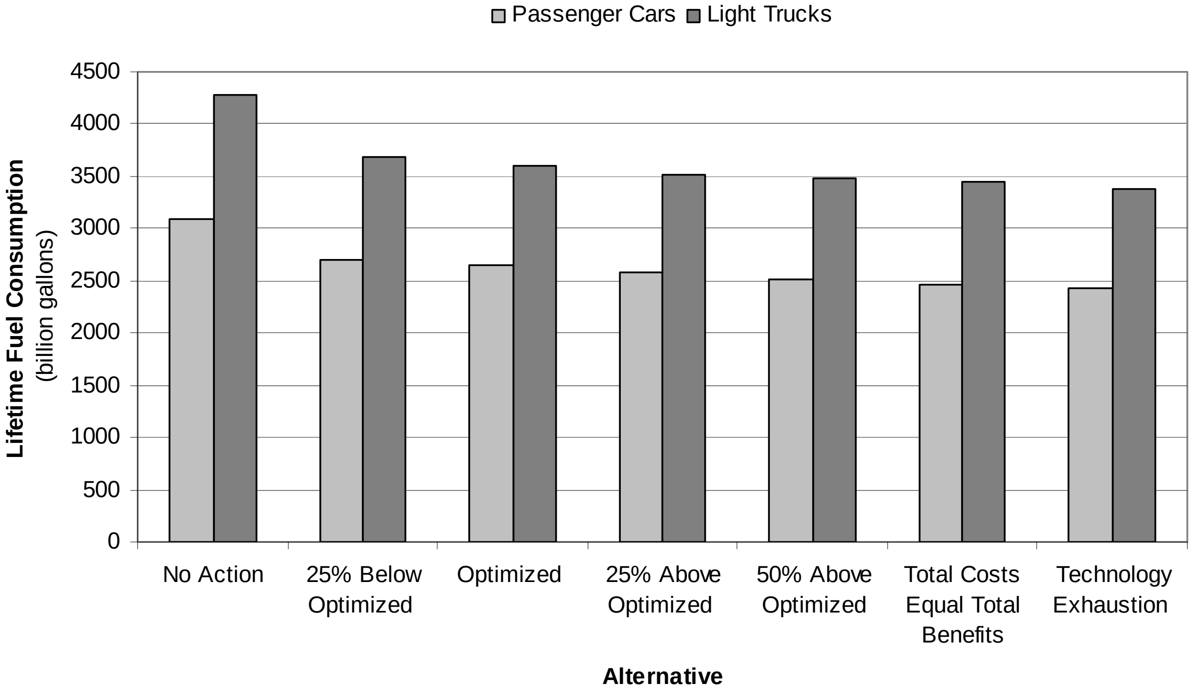
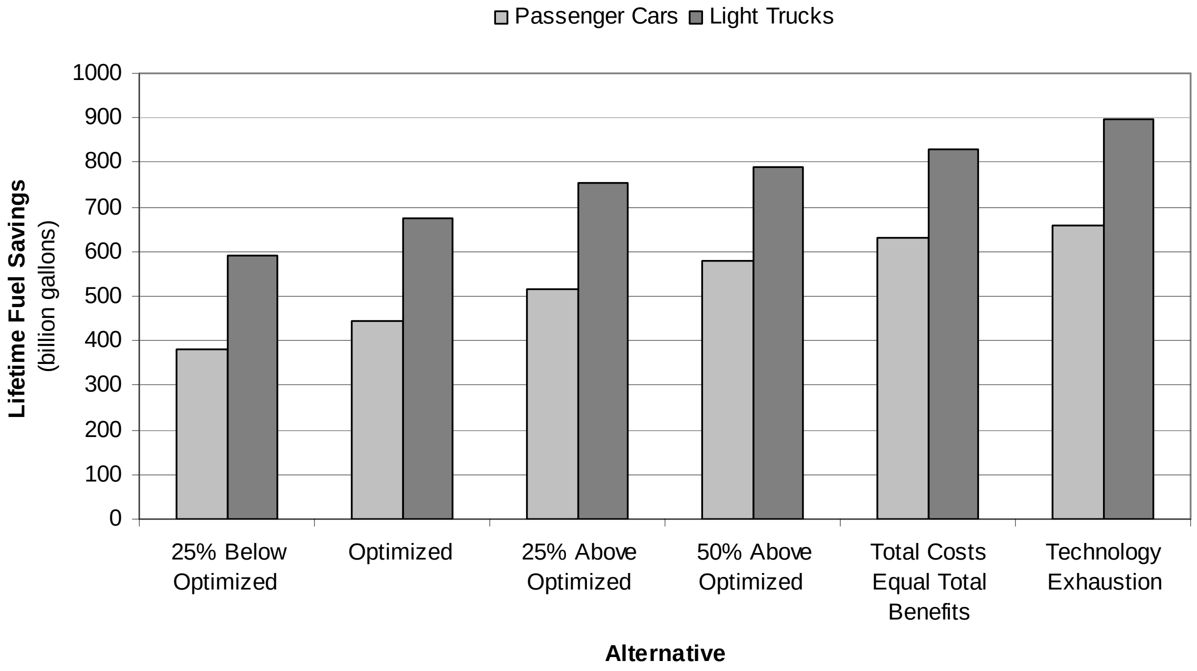


**Figure 4.2-2 Savings in Lifetime Fuel Consumption by Light Trucks and Passenger Cars under Alternative CAFE Standard**



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## 4.3 AIR QUALITY

### 4.3.1 Affected Environment

The air quality affected environment is described in Section 3.3.1.

### 4.3.2 Consequences

#### 4.3.2.1 Methodology

The analysis methodology for air quality cumulative impacts is the same as described in Section 3.3.2, except that the potential CAFE standards for MY 2016-2020 were added because the EISA requires that passenger cars and light trucks achieve an average of 35 miles per gallon (mpg) by 2020. The MY 2016-2020 standards are thus a reasonably foreseeable future action that must be considered.

The cumulative impacts analysis consists of three components analyzed together:

- CAFE implementation through MY 2010,
- The proposed MY 2011-2015 CAFE standard rules, and
- Assumed MY 2016-2020 rules based on EISA requirements for 35 mpg by 2020.

For comparison, the non-cumulative impacts analysis (Section 3.3.2) consists of only two components:

- CAFE implementation through MY 2010, and
- The proposed MY 2011-2015 CAFE standard rules.

For the calendar years 2016-2020, the non-cumulative impacts analysis (Ssection 3.3.2) assumes that MY 2016-2020 and later passenger cars and light trucks would continue to meet the MY 2015 standard under the proposed rules. By contrast, the cumulative impacts analysis assumes that MY 2016-2020 passenger cars and light trucks would meet the potential MY 2016-2020 standards and that MY 2021 and later passenger cars and light trucks would meet the potential MY 2020 standard.

##### 4.3.2.1.1 Treatment of Incomplete or Unavailable Information

As noted in Section 3.3.2, the estimates of emissions rely on models and forecasts that contain numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and economic factors. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). NHTSA has used the best available models and supporting data. The models used for the DEIS were subjected to scientific review and have received the approval of the agencies that sponsored their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain conditions reflect the best available information and are valid and sufficient for this analysis

##### 4.3.2.1.2 Results of the Emissions Analysis

The Clean Air Act (CAA) has been a success in reducing emissions from on-road mobile sources. As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and U.S. Environmental Protection Agency (EPA) projects that they will continue to decline. This trend will continue regardless of the alternative that is chosen for future CAFE standards. The analysis by alternative in this section shows that the alternative CAFE standards would lead to further reductions in emissions from passenger cars and light trucks. The amount of the reductions would vary by alternative CAFE standard. The more restrictive alternatives would result in greater emission reductions compared to the No Action Alternative. In no case is there an emission increase that would exceed any general conformity threshold.

#### 4.3.2.2 Alternative 1: No Action

With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in future years. Current trends in the levels of emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total vehicle-miles traveled (VMT). Therefore, there would be no cumulative impacts due to future actions. Table 4.3-2 summarizes the cumulative national emissions from passenger cars and light trucks. Appendix B-1 contains tables that present the cumulative emissions of criteria pollutants for each nonattainment area (NAA).

**TABLE 4.3-2**

**Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standard (tons/year), Cumulative Effects with MY 2011-2015 Standard and Potential MY 2016-2020 Standards**

| Pollutant and Year | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | |
| 2015 | 24,914,653 | 24,904,313 | 24,898,260 | 24,802,570 | 24,719,268 | 24,638,850 | 24,621,293 |
| 2020 | 23,046,827 | 22,996,192 | 22,937,251 | 22,323,981 | 21,956,890 | 21,675,925 | 21,544,933 |
| 2025 | 23,127,970 | 23,049,166 | 22,870,095 | 21,264,417 | 20,410,943 | 19,860,523 | 19,474,885 |
| 2035 | 26,446,292 | 26,392,554 | 25,928,187 | 22,327,626 | 20,563,462 | 19,584,601 | 18,665,921 |
| **NOx** | | | | | | | |
| 2015 | 2,902,481 | 2,881,782 | 2,874,864 | 2,856,203 | 2,841,353 | 2,826,752 | 2,821,727 |
| 2020 | 2,521,207 | 2,449,428 | 2,428,746 | 2,352,648 | 2,306,203 | 2,270,572 | 2,250,423 |
| 2025 | 2,438,747 | 2,306,370 | 2,268,567 | 2,102,885 | 2,011,707 | 1,951,362 | 1,907,560 |
| 2035 | 2,720,799 | 2,508,200 | 2,437,802 | 2,093,950 | 1,921,291 | 1,822,258 | 1,730,923 |
| **PM** | | | | | | | |
| 2015 | 418,882 | 416,701 | 415,879 | 409,849 | 404,903 | 400,341 | 398,992 |
| 2020 | 445,866 | 438,866 | 435,602 | 412,007 | 397,777 | 387,983 | 381,703 |
| 2025 | 483,176 | 471,535 | 465,062 | 420,586 | 395,592 | 380,560 | 368,062 |
| 2035 | 583,318 | 565,632 | 554,564 | 481,268 | 441,564 | 419,680 | 398,490 |
| **SOx** | | | | | | | |
| 2015 | 449,551 | 438,803 | 435,211 | 426,220 | 419,282 | 412,510 | 409,948 |
| 2020 | 469,521 | 432,809 | 422,775 | 392,542 | 374,727 | 361,511 | 352,808 |
| 2025 | 503,641 | 436,184 | 419,879 | 366,902 | 337,981 | 319,274 | 304,086 |
| 2035 | 603,991 | 493,989 | 469,439 | 385,825 | 342,328 | 316,867 | 292,926 |
| **VOC** | | | | | | | |
| 2015 | 2,583,711 | 2,572,113 | 2,568,184 | 2,554,807 | 2,543,985 | 2,533,512 | 2,530,127 |
| 2020 | 2,277,973 | 2,237,938 | 2,225,320 | 2,168,079 | 2,133,081 | 2,106,687 | 2,091,886 |
| 2025 | 2,231,152 | 2,158,057 | 2,133,599 | 2,005,337 | 1,934,143 | 1,887,413 | 1,853,854 |
| 2035 | 2,477,999 | 2,362,124 | 2,311,540 | 2,022,160 | 1,874,970 | 1,790,100 | 1,713,463 |

Table 4.3-2 presents the net changes in nationwide cumulative emissions from passenger cars and trucks for the No Action Alternative for each of the criteria pollutants and analysis years. The action alternatives are presented in left-to-right order of increasing fuel economy requirements. In Table 4.3-3 the nationwide cumulative emissions reductions become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives.

**TABLE 4.3-3**

**Nationwide Criteria Pollutant Emission Changes from Passenger Cars and Light Trucks with Alternative CAFE Standard, Cumulative Effects with MY 2011-2015 Standard and Potential MY 2016-2020 Standards, Compared to the No Action Alternative (tons/year)**

| Pollutant and Year | No Action | 25% Below Optimized | Optimized | 25% Above Optimized | 50% Above Optimized | Total Costs Equal Total Benefits | Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | |
| 2015 | 0 a/ | -10,341 b/ | -16,393 | -112,083 | -195,385 | -275,803 | -293,360 |
| 2020 | 0 | -50,635 | -109,577 | -722,846 | -1,089,938 | -1,370,902 | -1,501,895 |
| 2025 | 0 | -78,804 | -257,875 | -1,863,553 | -2,717,028 | -3,267,447 | -3,653,085 |
| 2035 | 0 | -53,739 | -518,105 | -4,118,666 | -5,882,830 | -6,861,691 | -7,780,371 |
| **NOx** | | | | | | | |
| 2015 | 0 | -20,699 | -27,617 | -46,278 | -61,128 | -75,728 | -80,754 |
| 2020 | 0 | -71,779 | -92,461 | -168,559 | -215,005 | -250,635 | -270,784 |
| 2025 | 0 | -132,377 | -170,180 | -335,862 | -427,040 | -487,385 | -531,186 |
| 2035 | 0 | -212,599 | -282,997 | -626,848 | -799,508 | -898,540 | -989,876 |
| **PM** | | | | | | | |
| 2015 | 0 | -2,181 | -3,003 | -9,033 | -13,979 | -18,541 | -19,890 |
| 2020 | 0 | -7,000 | -10,264 | -33,859 | -48,089 | -57,883 | -64,163 |
| 2025 | 0 | -11,641 | -18,114 | -62,590 | -87,584 | -102,616 | -115,114 |
| 2035 | 0 | -17,685 | -28,753 | -102,050 | -141,754 | -163,637 | -184,827 |
| **SOx** | | | | | | | |
| 2015 | 0 | -10,748 | -14,340 | -23,331 | -30,269 | -37,041 | -39,603 |
| 2020 | 0 | -36,712 | -46,746 | -76,979 | -94,794 | -108,011 | -116,714 |
| 2025 | 0 | -67,457 | -83,762 | -136,739 | -165,659 | -184,367 | -199,555 |
| 2035 | 0 | -110,002 | -134,552 | -218,166 | -261,663 | -287,124 | -311,065 |
| **VOC** | | | | | | | |
| 2015 | 0 | -11,598 | -15,527 | -28,904 | -39,725 | -50,199 | -53,584 |
| 2020 | 0 | -40,035 | -52,654 | -109,894 | -144,893 | -171,286 | -186,087 |
| 2025 | 0 | -73,094 | -97,553 | -225,815 | -297,008 | -343,739 | -377,298 |
| 2035 | 0 | -115,875 | -166,459 | -455,839 | -603,029 | -687,900 | -764,537 |

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a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

#### 4.3.2.2.1 Air Toxics

As with the criteria pollutants, current trends in the levels of air toxics emissions from vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite a growth in total VMT. The No Action Alternative (Alternative 1) would not result in any other increase or decrease in toxic air pollutant emissions in nonattainment and maintenance areas throughout the United States

Table 4.3-4 summarizes the cumulative national toxic air pollutant emissions from passenger cars and light trucks for the No Action Alternative for each of the toxic air pollutants and analysis years. As with the criteria pollutants, the No Action Alternative has the highest emissions of all the alternatives for all toxic air pollutants except acrolein. Table 4.3-4 shows increases for acrolein with the action alternatives because data on upstream emissions reductions were not available. Thus, the emissions for acrolein in Table 4.3-4 reflect only the increases due to the rebound effect. Appendix B-1 contains tables that present the cumulative emissions of toxic air pollutants for each nonattainment area (NAA) for the No Action Alternative.

Table 4.3-5 presents the net changes in nationwide cumulative emissions from passenger cars and light trucks for the No Action Alternative for each of the air toxic pollutants and analysis years. The other alternatives (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy requirements. In Table 4.3-5 the nationwide emissions reductions become greater from left to right, reflecting the increasing fuel economy requirements that are assumed under successive alternatives, except for acrolein. Table 4.3-5 shows increases for acrolein with the action alternatives because data on upstream emissions reductions were not available. Thus, the emissions changes for acrolein in Table 4.3-5 reflect only the increases due to the rebound effect.

**TABLE 4.3-4**

**Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standard (tons/year), Cumulative Effects with MY 2011-2015 Standard and Potential MY 2016-2020 Standard**

| Pollutant and Year | Alt. 1 No Action | Alt. 2 25% Below Optimized | Alt. 3 Optimized | Alt. 4 25% Above Optimized | Alt. 5 50% Above Optimized | Alt. 6 Total Costs Equal Total Benefits | Alt. 7 Technology Exhaustion |
|---|---|---|---|---|---|---|---|
| Acetaldehyde | | | | | | | |
| 2015 | 15,753 | 15,741 | 15,738 | 15,722 | 15,705 | 15,688 | 15,685 |
| 2020 | 13,781 | 13,735 | 13,718 | 13,568 | 13,461 | 13,374 | 13,342 |
| 2025 | 13,168 | 13,086 | 13,027 | 12,524 | 12,237 | 12,044 | 11,924 |
| 2035 | 14,354 | 14,252 | 14,063 | 12,646 | 11,959 | 11,573 | 11,225 |
| Acrolein | | | | | | | |
| 2015 | 744 | 746 | 746 | 750 | 753 | 756 | 757 |
| 2020 | 643 | 649 | 652 | 664 | 672 | 678 | 682 |
| 2025 | 611 | 624 | 627 | 641 | 654 | 662 | 670 |
| 2035 | 663 | 687 | 688 | 687 | 702 | 712 | 722 |
| Benzene | | | | | | | |
| 2015 | 82,225 | 82,080 | 82,028 | 81,754 | 81,522 | 81,297 | 81,236 |
| 2020 | 72,284 | 71,758 | 71,525 | 69,971 | 69,027 | 68,296 | 67,943 |
| 2025 | 69,648 | 68,688 | 68,115 | 64,051 | 61,875 | 60,436 | 59,458 |
| 2035 | 76,355 | 74,938 | 73,498 | 63,637 | 58,866 | 56,161 | 53,696 |
| 1,3-Butadiene | | | | | | | |
| 2015 | 8,913 | 8,909 | 8,908 | 8,897 | 8,887 | 8,877 | 8,875 |
| 2020 | 7,819 | 7,803 | 7,791 | 7,691 | 7,634 | 7,586 | 7,568 |
| 2025 | 7,449 | 7,420 | 7,381 | 7,058 | 6,902 | 6,795 | 6,730 |
| 2035 | 8,062 | 8,034 | 7,911 | 7,008 | 6,619 | 6,400 | 6,204 |
| Diesel Particulate Matter (DPM) | | | | | | | |
| 2015 | 197,948 | 193,033 | 191,393 | 187,597 | 184,724 | 181,897 | 180,777 |
| 2020 | 206,542 | 189,754 | 185,208 | 172,561 | 165,396 | 160,020 | 156,460 |
| 2025 | 221,435 | 190,514 | 183,204 | 161,215 | 149,820 | 142,374 | 136,342 |
| 2035 | 265,474 | 214,961 | 204,045 | 169,501 | 152,605 | 142,653 | 133,315 |
| Formaldehyde | | | | | | | |
| 2015 | 21,385 | 21,327 | 21,311 | 21,296 | 21,281 | 21,263 | 21,259 |
| 2020 | 18,721 | 18,523 | 18,483 | 18,383 | 18,296 | 18,221 | 18,194 |
| 2025 | 18,021 | 17,663 | 17,580 | 17,196 | 16,972 | 16,816 | 16,727 |
| 2035 | 19,851 | 19,312 | 19,098 | 17,904 | 17,363 | 17,060 | 16,796 |

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a/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the increases due to the rebound effect.

**TABLE 4.3-5**

**Nationwide Changes in Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standard – Cumulative Effects with MY 2011-2015 Standard and Potential MY 2016-2020 Standard, Compared to the No Action Alternative (tons/year)**

| | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | Alt. 5 | Alt. 6 | Alt. 7 |
|---|---|---|---|---|---|---|---|
| **Pollutant and Year** | **No Action** | **25% Below Optimized** | **Optimized** | **25% Above Optimized** | **50% Above Optimized** | **Total Costs Equal Total Benefits** | **Technology Exhaustion** |
| **Acetaldehyde** | | | | | | | |
| 2015 | 0 | -12 | -15 | -31 | -48 | -66 | -68 |
| 2020 | 0 | -46 | -63 | -213 | -319 | -407 | -439 |
| 2025 | 0 | -83 | -141 | -644 | -931 | -1,125 | -1,245 |
| 2035 | 0 | -102 | -292 | -1,708 | -2,396 | -2,782 | -3,130 |
| **Acrolein** | | | | | | | |
| 2015 | 0 | 2 | 3 | 7 | 10 | 13 | 14 |
| 2020 | 0 | 7 | 9 | 21 | 30 | 35 | 40 |
| 2025 | 0 | 13 | 16 | 30 | 44 | 52 | 59 |
| 2035 | 0 | 24 | 25 | 24 | 39 | 49 | 59 |
| **Benzene** | | | | | | | |
| 2015 | 0 | -144 | -196 | -471 | -702 | -927 | -989 |
| 2020 | 0 | -527 | -759 | -2,313 | -3,257 | -3,988 | -4,341 |
| 2025 | 0 | -961 | -1,533 | -5,597 | -7,773 | -9,212 | -10,190 |
| 2035 | 0 | -1,417 | -2,857 | -12,718 | -17,489 | -20,194 | -22,659 |
| **1,3-Butadiene** | | | | | | | |
| 2015 | 0 | -4 | -6 | -17 | -26 | -36 | -38 |
| 2020 | 0 | -16 | -28 | -128 | -186 | -233 | -251 |
| 2025 | 0 | -29 | -68 | -390 | -547 | -654 | -719 |
| 2035 | 0 | -28 | -152 | -1,055 | -1,444 | -1,662 | -1,858 |
| **Diesel Particulate Matter (DPM)** | | | | | | | |
| 2015 | 0 | -4,915 | -6,555 | -10,350 | -13,223 | -16,051 | -17,171 |
| 2020 | 0 | -16,788 | -21,334 | -33,981 | -41,146 | -46,522 | -50,082 |
| 2025 | 0 | -30,921 | -38,231 | -60,220 | -71,615 | -79,061 | -85,093 |
| 2035 | 0 | -50,513 | -61,429 | -95,972 | -112,868 | -122,821 | -132,159 |
| **Formaldehyde** | | | | | | | |
| 2015 | 0 | -58 | -74 | -89 | -105 | -122 | -126 |
| 2020 | 0 | -198 | -238 | -338 | -425 | -500 | -527 |
| 2025 | 0 | -358 | -441 | -825 | -1,048 | -1,205 | -1,294 |
| 2035 | 0 | -539 | -753 | -1,947 | -2,488 | -2,790 | -3,055 |

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a/ Emissions changes for the No Action Alternative are shown as zero because the No Action Alternative is the baseline to which the emissions for the other alternatives are compared.

b/ Negative emissions changes indicate reductions; positive emissions changes are increases.

c/ Data on upstream emissions reductions were not available for acrolein. Thus, the emissions for acrolein reflect only the increases due to the rebound effect.

### 4.3.2.3 Alternative 2: 25 Percent Below Optimized

#### 4.3.2.3.1 Criteria Pollutants

With the 25 Percent Below Optimized Alternative, the CAFE standards would require increased fuel economy compared to the No Action Alternative. In order to meet the MY 2016-2020 standards, the agency anticipates that vehicle manufacturers could increase the number of diesel-fueled vehicles. Because diesel vehicles have different emissions characteristics from gasoline vehicles the pattern of changes in emissions would be different for cumulative impacts compared to non-cumulative impacts. With Alternative 2, cumulative emissions would be higher than non-cumulative emissions for carbon monoxide (CO) by 19.7 percent in 2020, 47.3 percent in 2025, and 81.4 percent in 2035. Cumulative emissions of all other criteria pollutants (nitrogen oxides [NOx], sulfur oxides [Sox], particulate matter [PM], and for CO in 2035) in all years would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.3.2 Air Toxics

For the same reason as for the criteria pollutants, toxic air pollutant emissions would be different for cumulative impacts compared to non-cumulative impacts. With Alternative 2, cumulative emissions would be slightly higher than non-cumulative emissions for acetaldehyde by 34.5 percent in 2035; and for 1,3-butadiene by 15.1 percent in 2025 and by 60.8 percent in 2035. Cumulative emissions of acrolein for all years, benzene for all years, diesel particulate matter (DPM) for all years, formaldehyde for all years, and 1,3-butadiene in 2015 and 2020 would be slightly lower than non-cumulative emissions, between 0.1 percent and 85.0 percent.

With the 25 Percent Below Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

### 4.3.2.4 Alternative 3: Optimized

#### 4.3.2.4.1 Criteria Pollutants

With the Optimized Alternative, the CAFE standards would increase fuel economy more than would the No Action Alternative and the 25 Percent Below Optimized Alternative by between 0.3 percent and 2.5 percent on average depending on pollutant and year but less than would Alternatives 4 through 7 by between 0.3 percent and 29.2 percent. As with Alternative 2, cumulative emissions of CO would be slightly higher than non-cumulative emissions in analysis years 2020, 2025, and 2035, while cumulative emissions of NOx, SOx, and volatile organic compounds (VOC) would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.4.2 Air Toxics

For the same reason as with the criteria pollutants, air toxics emissions would be different for cumulative impacts compared to non-cumulative impacts. With Alternative 3, cumulative emissions of acetaldehyde and benzene would be slightly higher in 2035 than non-cumulative emissions, and cumulative emissions of acrolein would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM, benzene, 1,3-butadiene, and formaldehyde would be slightly lower in all analysis years.

With the Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

### 4.3.2.5 Alternative 4: 25 Percent Above Optimized

#### 4.3.2.5.1 Criteria Pollutants

With the 25 Percent Above Optimized Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 3 but less than would Alternatives 5 through 7. As with Alternative 3, cumulative emissions of CO and PM would be slightly higher in all analysis years than non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.5.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the 25 Percent Above Optimized Alternative compared to Alternatives 1 through 3. With Alternative 4, cumulative emissions of benzene would be slightly higher in 2035 than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM and formaldehyde would be slightly lower in all analysis years.

With the 25 Percent Above Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein and DPM reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

### 4.3.2.6 Alternative 5: 50 Percent Above Optimized

#### 4.3.2.6.1 Criteria Pollutants

With the 50 Percent Above Optimized Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 4 but less than would Alternatives 6 and 7. As with Alternative 4, cumulative emissions of CO and PM would be slightly higher in all analysis years than non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.6.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the 50 Percent Above Optimized Alternative compared to Alternatives 1 through 4. With Alternative 4, cumulative emissions of benzene and formaldehyde would be slightly higher in 2035 than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would be slightly lower in all analysis years.

With the 50 Percent Above Optimized Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

### 4.3.2.7 Alternative 6: Total Costs Equal Total Benefits

#### 4.3.2.7.1 Criteria Pollutants

With the Total Costs Equal Total Benefits Alternative, the CAFE standards would increase fuel economy more than would Alternatives 1 through 5 but less than would Alternative 7. As with Alternative 5, cumulative emissions of CO and PM would be slightly higher in all analysis years than non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.7.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the Total Costs Equal Total Benefits Alternative compared to Alternatives 1 through 5. With Alternative 6, cumulative emissions of benzene and formaldehyde would be slightly higher in 2035 than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would be slightly lower in all analysis years.

With the Total Costs Equal Total Benefits Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

### 4.3.2.8 Alternative 7: Technology Exhaustion

#### 4.3.2.8.1 Criteria Pollutants

With the Technology Exhaustion Alternative, the CAFE standards would increase fuel economy the most of all the Alternatives. As with the Total Costs Equal Total Benefits Alternative, cumulative emissions of CO and PM would be slightly higher in all analysis years than non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower than non-cumulative emissions.

All individual NAAs would experience reductions in emissions of all criteria pollutants for all analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix B-1 contains tables that present the emission reductions for each NAA.

#### 4.3.2.8.2 Air Toxics

As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic air pollutants with the Technology Exhaustion Alternative than with any other alternatives. With Alternative 7, cumulative emissions of formaldehyde would be slightly higher in 2035 than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, benzene and 1,3-butadiene would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would be slightly lower in all analysis years.

With the Technology Exhaustion Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein and DPM reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be notable because the VMT and emission increases would be distributed throughout each NAA.

## 4.4 CLIMATE

While the proposed rule only covers model years up to 2015, the Energy Policy and Conservation Act (EPCA) has directed the Secretary, after consultation with the Secretary of the Department of Energy (DOE) and the Administrator of the EPA, to establish separate average fuel economy standards for passenger cars and for light trucks manufactured in each model year beginning with model year 2011 "to achieve a combined fuel economy average for model year 2020 of at least 35 miles per gallon for the total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that model year" (49 U.S.C. § 32902(b)(2)(A)).

In April 2008, NHTSA issued a supplemental notice of public scoping providing additional guidance for participating in the scoping process and additional information about the proposed standards and the alternatives NHTSA expected to consider in its NEPA analysis. In that notice, NHTSA stated that it would consider the cumulative impacts of the proposed standards for MY 2011-2015 automobiles together with estimated impacts of NHTSA's historic implementation of the CAFE program through MY 2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by EPCA, as amended by EISA.

Again, a cumulative impact is defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency … or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR § 1508.70.

This section, on the cumulative impacts on climate of the CAFE alternatives, covers many of the same topics as the corresponding section in Chapter 3 (Section 3.4). Chapter 4 is broader in that it compares foreseeable effects of the both the MY 2011-2015 and future MY 2016-2020 CAFE standards with the MY 2020 levels affecting all passenger cars and light trucks built from 2020-2100 (Chapter 3 covers only the effects of the MY 2011-2015 standards). Chapter 4 also addresses the consequences of emissions and effects on the climate system (both Section 4.4 and Section 3.4 address these topics), as well as the impacts of climate change on key resources (e.g., freshwater resources, terrestrial ecosystems, coastal ecosystems).

Understanding that many users of EIS documents do not read through in linear fashion, but instead focus on the sections of most interest, this section repeats some of the information presented earlier in Section 3.4 with only minor modifications reflecting the slightly different scope (cumulative impacts versus the direct and indirect effects of the alternatives).

### 4.4.1 Introduction - Greenhouse Gases and Climate Change

There have been a series of intensive and extensive analyses conducted by the IPCC, the scientific body tasked by the United Nations to evaluate the risk of human-induced climate change), the United States Climate Change Science Program (USCCSP), and many other government-, non-government organizations (NGO), and industry-sponsored programs. Our discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of global and United States climate change: the IPCC Fourth Assessment Report (*Climate Change 2007*), and reports by the USCCP that include the *Scientific Assessment of the Effects of Global Change on the United States* and Synthesis and Assessment Products. These sources and the studies they review are frequently quoted throughout this DEIS. Since new evidence is continuously emerging on the subject of climate change impacts, the discussions on climate impacts in this DEIS also draw on more recent studies, where possible.

Global climate change refers to long-term fluctuations in global surface temperatures, precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature and sea levels have risen, and most scientists attribute this to GHGs released by human activities, primarily the combustion of fossil fuels. The IPCC recently asserted that, "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations" (IPCC, 2007, p. 10).

The primary GHGs—$CO_2$, methane ($CH_4$), nitrous oxide ($N_2O$)—are created by both natural and human activities. Human activities that emit GHGs to the atmosphere include the combustion of fossil fuels, industrial processes, solvent use, land use change and forestry, agriculture production, and waste management. These gases trap heat in the earth's atmosphere, changing the climate, which then impacts resources such as ecosystems, water resources, agriculture, forestry, and human health. As the world population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions and their concentrations in the atmosphere are expected to grow substantially over the next century. For a more in depth discussion of the science of climate change, please refer to Section 3.4.1.

### 4.4.2 Affected Environment

The affected environment can be characterized in terms of GHG emissions and climate. Section 3.4.2 provides a discussion of both topics, including a description of both United States conditions and the global environment. As there is no distinction between the affected environment for purposes of the direct/indirect effects analysis and the cumulative impacts analysis, the reader is referred to Section 3.4.1.

### 4.4.3 Methodology

The methodology employed to characterize the effects of the alternatives on climate has two key elements:

1. Analyzing the effects of the alternatives on GHG emissions, and
2. Analyzing how the GHG emissions affect the climate system (climate effects).

Each element is discussed below.

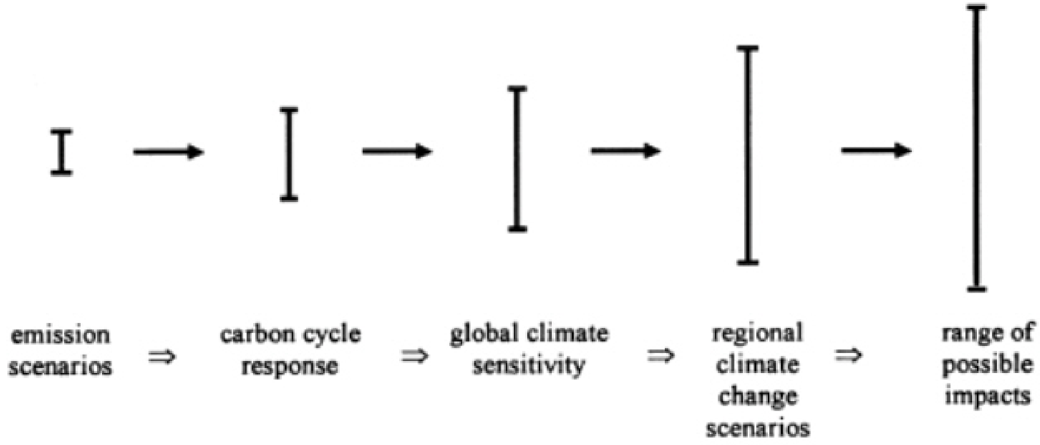
When using either method, this DEIS expresses results for each of the alternatives in terms of the environmental attribute being characterized (emissions, $CO_2$ concentrations, temperature, precipitation, sea level). It also expresses the change between the No Action Alternative and each of the other alternatives to illustrate the differences in environmental impacts across the CAFE alternatives.

The methods used to characterize emissions and climate change impacts involve considerable uncertainty. Sources of uncertainty include the pace and effects of technology change in both the transportation sector and other sectors that emit GHGs; changes in the future fuel supply that could affect emissions; the sensitivity of climate to increased GHG concentrations; the rate of change in the climate system in response to changing GHG concentrations; the potential existence of thresholds in the climate system (which could be difficult to predict and simulate); regional differences in the magnitude and rate of climate changes; and many other factors.

Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change simulations (Figure 4.4-1). As indicated in the figure, the emission estimates used in this DEIS have narrower bands of uncertainty than the global climate effects, which in turn have less uncertainty than the regional climate change effects. The effects on climate are in turn less uncertain than the impacts of climate changes on affected resources (e.g., terrestrial and coastal ecosystems, human health, and other sectors discussed in section 4.5).

Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). The understanding of the climate system is incomplete; like any analysis of complex, long-term changes to support decision making, the analysis described below involves many assumptions and uncertainties in the course of evaluating reasonably foreseeable significant adverse impacts on the human environment. The DEIS uses methods and data that represent the best available information on this topic, and which have been subject to peer review and scrutiny. In fact, the information cited throughout this section that is extracted from the IPCC and US Climate Change Science Program (USCCSP) has endured a more thorough and systematic review process than information on virtually any other topic in environmental science and policy. The Model for Assessment of Greenhouse Gas-induced Climate Change (MAGICC) model, the scaling approaches, and the IPCC emission scenarios described below are generally accepted in the scientific community.

**Figure 4.4-1. From Moss and Schneider (2000, p. 39): "Cascade of uncertainties typical in impact assessments showing the 'uncertainty explosion' as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social, and political impacts and policy responses."**



NHTSA notes that it is aware of the USCCSP's recent release for comment of a draft Synthesis and Assessment Product (SAP) 3.1 regarding the strengths and limitations of climate models.[5] The reader might find the discussions in this draft SAP useful in understanding the methodological limitations regarding modeling the environmental impacts of the proposed action and the range of alternatives on climate change.

### 4.4.3.1 Methodology for Greenhouse Gas Emissions Modeling

GHG emissions were estimated using the Volpe model, described earlier in Section 3.2. The Volpe model assumes that major manufacturers will exhaust all available technology before paying

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[5] U.S. Climate Change Science Program, Synthesis and Assessment Product 3.1 (Climate Models: An Assessment of Strengths and Limitations), Final (third) review draft (May 15, 2008)., *available at* http://www.climatescience.gov/Library/default.htm#sap.

noncompliance civil penalties. In the more stringent alternatives, the Volpe model predicts that increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to penalty payment. Setting standards this high may not be technologically feasible, nor may it serve the need of the nation to conserve fuel and/or reduce emissions.

Fuel savings from stricter CAFE standards also result in lower emissions of $CO_2$, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.[6] Lower fuel consumption reduces carbon dioxide emissions directly, because the primary source of transportation-related $CO_2$ emissions is fuel combustion in internal combustion engines. NHTSA estimates reductions in carbon dioxide emissions resulting from fuel savings by assuming that the entire carbon content of gasoline, diesel, and other fuels is converted to $CO_2$ during the combustion process.[7] Reduced fuel consumption also reduces $CO_2$ emissions that result from the use of carbon-based energy sources during fuel production and distribution. NHTSA currently estimates the reductions in $CO_2$ emissions during each phase of fuel production and distribution using $CO_2$ emission rates obtained from the Greenhouse Gases Regulated Emissions, and Energy Use in Transportation (GREET) model, using the previous assumptions about how fuel savings are reflected in reductions in each phase. The total reduction in $CO_2$ emissions from the improvement in fuel economy under each alternative CAFE standard is the sum of the reductions in emissions from reduced fuel use and from lower fuel production and distribution.

#### 4.4.3.2 Methodology for Estimating Climate Effects

This DEIS estimates and reports on four direct and indirect effects of climate change, driven by alternative scenarios of GHG emissions, including:

- Changes in $CO_2$ concentrations
- Changes in global temperature
- Changes in regional temperature and precipitation
- Changes in sea level

The change in $CO_2$ concentration is a direct effect of the changes in GHG emissions, and influences each of the other factors.

This DEIS uses two methods to estimate the key direct and indirect effects of the alternate CAFE standards.

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[6] For purposes of this rulemaking, NHTSA estimated emissions of vehicular $CO_2$, $CH_4$, and $N_2O$ emissions, but did not estimate vehicular emissions of hydrofluorocarbons. Methane and nitrous oxide account for less than 3 percent of the tailpipe GHG emissions from passenger cars and light trucks, and $CO_2$ emissions accounted for the remaining 97 percent. Of the total (including non-tailpipe) GHG emissions from passenger cars and light trucks, tailpipe $CO_2$ represents about 93.1 percent, tailpipe methane and nitrous oxide represent about 2.4 percent, and hydrofluorocarbons (i.e., air conditioner leaks) represent about 4.5 percent. Calculated from U.S EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006* (EPA, 2008)

[7] This assumption results in a slight overestimate of carbon dioxide emissions, since a small fraction of the carbon content of gasoline is emitted in the forms of carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimate is likely to be extremely small. This approach is consistent with the recommendation of the Intergovernmental Panel on Climate Change for "Tier 1" national GHG emissions inventories. *Cf.* Intergovernmental Panel on Climate Change, *2006 Guidelines for National Greenhouse Gas Inventories*, Volume 2, Energy, p. 3.16.

[7] See Notice of Proposed Rulemaking, Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 FR 24352, 24412-24413 (May 2, 2008).

1. Use a climate model, along with emission scenarios that correspond to each of the alternatives. For purposes of this DEIS, NHTSA chose to employ the simple climate model, the MAGICC version 4.1 (Wigley, 2003), to estimate changes in key direct and indirect effects. The application of MAGICC version 4.1 utilizes the emission estimates for $CO_2$, $CH_4$, and $N_2O$ from the Volpe Model.

2. Examine the reported relationship (in the IPCC Fourth Assessment Report [IPCC, 2007] and more recent peer reviewed literature) between various scenarios of global emission paths and the associated direct and indirect effects for each scenario. If one assumes that the relationships can be scaled through linear interpolation, these relationships can be used to infer the effect of the emissions associated with the regulatory alternatives on direct and indirect climate effects. The emission estimates used in these scaling analyses were based only on $CO_2$ emissions.

The MAGICC model, the scaling approach, and the emission scenarios used in the analysis are described in the three subsections below.

#### 4.4.3.3 MAGICC version 4.1

The selection of MAGICC for this analysis was driven by a number of factors:

- MAGICC has been used in peer-reviewed literature to evaluate changes in global mean surface temperature and sea level rise. In the IPCC Fourth Assessment for WG1 (IPCC, 2007) it was used to scale the results from the atmospheric-ocean general circulation models (AOGCMs)[8] to estimate the global mean surface temperature and the sea level rise for Special Report on Emission Scenarios (SRES) that the AOGCMs did not run.
- MAGICC is publicly available and is already populated with the SRES scenarios.
- MAGICC was designed for the type of sensitivity analysis performed in this study.
- 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 such as the B1 (low), A1B (medium), and A2 (high) scenarios.

For the analysis using MAGICC, NHTSA assumed that global emissions consistent with the No Action Alternative follow the trajectory provided by the SRES A1B (medium) scenario.

#### 4.4.3.4 Scaling Approach

The scaling approach uses information on relative changes in emissions to estimate relative changes in $CO_2$ concentrations, global mean surface temperature, precipitation, and sea level rise based on interpolation between the results provided for the three SRES scenarios (B1-low, A1B-medium, and A2-high) provided by the IPCC Work Group 1 (WG1) (IPCC, 2007). This approach uses the following steps to estimate these changes:

1. Assume that global emissions are consistent with the No Action Alternative and follow the trajectories provided by the three SRES scenarios. The results illustrate the uncertainty resulting from factors influencing future global emissions of GHGs.

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

2. Estimate $CO_2$ concentrations in 2100 for each of the three SRES scenarios and for each CAFE alternative based on the relative reduction in emissions for the CAFE alternative using the average share of emitted $CO_2$ that remains in the atmosphere for each of the SRES scenarios.

3. Determine the global mean surface temperature at equilibrium from $CO_2$ alone for each SRES scenario, each CAFE alternative, and different estimates of the climate sensitivity. See the following sections for definitions of the global mean temperature at equilibrium and the climate sensitivity.

4. Determine the global mean surface temperature for some of the cases described in step 3 above by using low and high estimates of the ratio of global mean surface temperature to global mean surface temperature at equilibrium.

5. Use the increase in global mean surface temperature and factors relating this increase to the increase in global average precipitation to estimate the increase in global averaged precipitation for each CAFE alternative for the A1B scenario.

6. Use the difference in 2100 global mean surface temperature between the SRES A1B scenario (No Action Alternative) and the SRES A1B (medium) scenario with each CAFE alternative relative to the difference between the global mean surface temperature in the SRES the A1B (medium) and B1 (low) as reported by the IPCC (2007) and apply this to the difference in the sea level rise between the SRES A1B (medium) and B1 (low) scenario in order to estimate the sea level rise for each CAFE alternative.

#### 4.4.3.5 Emission Scenarios

As described above, both the MAGICC modeling and the scaling approach use long-term emission scenarios representing different assumptions about key drivers of GHG emissions. All three of the scenarios used are based on IPCC's effort to develop a set of long-term (1990-2100) emission scenarios to provide some standardization in climate change modeling. The most widely used scenarios are those from SRES (Nakicenovic et al., 2000).

Both the MAGICC model and the scaling approach rely primarily on the SRES scenario referred to as "A1B" to represent a reference case emission scenario ( i.e., emissions for the No Action Alternative). NHTSA selected this scenario because it is regarded as a moderate emissions case and has been widely used in AOGCMs, including several AOGCM runs developed for the IPCC WG1 AR4 report (IPCC, 2007).

Separately, each of the other alternatives was simulated by calculating the difference in annual GHG emissions with respect to the No Action Alternative, and subtracting this change in the A1B (medium) scenario to generate modified global-scale emission scenarios, which each show the effect of the various regulatory alternatives on the global emissions path. For example, the emissions from United States passenger cars and light trucks in 2020 for the No Action Alternative are 1,617 million metric tons of carbon dioxide ($MMTCO_2$); the emissions in 2020 for the Optimized Alternative are 1,482 $MMTCO_2$. The difference is 135 $MMTCO_2$. Global emissions for the A1B (medium) scenario in 2020 are 46,339 $MMTCO_2$, and represent the No Action Alternative. Global emissions for the optimized scenario are 103 $MMTCO_2$ less, or 46,204 $MMTCO_2$.

The A1B (medium) scenario provides a global context for emissions of a full suite of GHGs and ozone precursors. There are some inconsistencies between the overall assumptions used by IPCC in its

SRES (Nakicenovic et al., 2000) to develop global emission scenario and the assumptions used in the Volpe model in terms of economic growth, energy prices, energy supply, and energy demand.

Where information in the analysis is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, despite the inconsistencies between the IPCC assumptions on global trends across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the Volpe model on the United States. transportation sector, the approach used is valid for this analysis; these inconsistencies affect all of the alternatives equally, and thus they do not hinder a comparison of the alternatives in terms of their relative effects on climate.

The approaches focus on the marginal climate effect of marginal changes in emissions. Thus, they generate a reasonable characterization of climate changes for a given set of emission reductions, regardless of the underlying details associated with those emission reductions. In the discussion that follows, projected climate change under the No Action Alternative is characterized, as well as the changes associated with each of the alternative CAFE standards.

The scaling approach also uses the B1 (low) and A2 (high) emission scenarios (Nakicenovic et al., 2000) as reference scenarios. This provides a basis for interpolating climate responses to varying levels of emissions. Some responses of the climate system are believed to be non-linear; by using a low- and high-emissions case, it is possible to estimate the incremental effects of the alternatives with respect to different reference cases.

#### 4.4.3.5.1 Tipping Points and Abrupt Climate Change

In a linear system, a system response is proportional to the change in a driver. Temperature and $CO_2$ are two key drivers of climate. However, the climate system is vastly complex; there are many positive and negative feedback mechanisms. Moreover, there may be thresholds in the response of the system. Below the thresholds, the response may be small or zero, and above the thresholds, the response could be much quicker than previously observed or had been expected. The term "tipping point" refers to a situation where the climate system reaches a point at which is there is a strong and amplifying positive feedback from only a moderate additional change in a driver, such as $CO_2$ or temperature increase. These tipping points could potentially result in abrupt climate change, as defined in Alley at al (2002) (cited in Meehl et al., 2007) to "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."

While climate models do take positive (and negative, i.e., dampening) feedback mechanisms into account, the magnitude of their effect and the threshold at which a tipping point is reached may not be well understood in some cases. In fact, MacCracken et al., (2008) note that existing climate models may not include some critical feedback loops, and Hansen et al., (2007a) states that the predominance of positive feedback mechanisms in the climate system have the potential to cause large rapid fluctuations in climate change effects. The existence of these mechanisms and other evidence has led some climate scientists including Hansen et al., (2007b) to conclude that a $CO_2$ level exceeding about 450 parts per million (ppm) is "dangerous".[9]

A number of these positive feedback loops may occur with the melting of land ice cover, including glaciers and the Greenland and West Antarctic ice sheets. As land ice cover melts, the ground underneath is exposed. This ground has a lower albedo (it reflects less infrared radiation back to the

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[9] Defined as more than 1 degreeCelsiusabove the level in 2000.

atmosphere) compared to the ice, and absorbs more heat, further raising temperatures. In addition, increased surface temperatures cause more precipitation to fall as rain instead of snow, increasing surface melt water, which may further increase ice flow (Meehl et al., 2007). The albedo effect is also relevant for sea ice melt, as darker open water absorbs the heat of the sun at a higher rate than the lighter sea ice does, with the warmer water leading to further melting.

Changes in ocean circulation patterns are also well documented as examples of potential abrupt climate change. The conveyor belt of circulation in the Atlantic Ocean, called the Meridional Overturning Circulation, brings warm upper waters into northern latitudes and returns cold deep waters southward to the Equator. There is concern that increasing ocean temperatures and reductions in salinity may cause this circulation to slow and possibly cease, as has happened in the past, triggering disastrous climate change. It is important to note that none of the AOGCMs show an abrupt change in circulation through 2100, though "some long-term model simulations suggest that a complete cessation can result for large forcings" (Stouffer and Manabe, 2003 as cited in Meehl et al., 2007). However, IPCC concludes that, "there is no direct model evidence that the Meridional Overturning Circulation could collapse within a few decades," and current simulations do not model out far enough to determine whether the cessation of this circulation would be irreversible (Meehl et al., 2007).

Another factor that may accelerate climate change at rates faster than those currently observed is the possible changing role of soil and vegetation as a carbon source, instead of a sink. Currently, soil and vegetation act as a sink, absorbing carbon in the atmosphere and translating this additional carbon to accelerated plant growth and soil carbon storage. However, around mid-century, increasing temperatures and precipitation could cause increased rates of transpiration, resulting in soil and vegetation becoming a potential source of carbon emissions (Cox et al., 2000 as cited in Meehl et al., 2007). There is also the potential for warming to thaw frozen arctic soils (permafrost) with the wet soils emitting more methane; there is evidence that this is already taking place (Walter et al., 2007). Therefore, a widespread change in soils, from a sink to a source of carbon, could further exacerbate climate change.

Overall, however, IPCC concludes that these abrupt changes are unlikely to occur this century (Meehl et al., 2007). Whether these tipping points exist, and the levels at which they occur, are still a matter of scientific investigation. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, the DEIS acknowledges that information on tipping points or abrupt climate change is incomplete, but the state of the science does not allow for a characterization how the CAFE alternatives influence these risks, other than to say that the greater the emission reductions, the lower the risk of abrupt climate change.

### 4.4.4 Consequences

This subsection describes the consequences of the MY 2011-2015 CAFE standards in terms of (1) GHG emissions and (2) climate effects.

#### 4.4.4.1 Greenhouse Gas Emissions

To estimate the emissions resulting from changes in passenger car and light truck CAFE standards, NHTSA uses the Volpe Model (see Section 3.1.3 for a discussion of the model). The change in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total and petroleum energy use, which in turn affects the amount of $CO_2$ emissions, These $CO_2$ emission estimates also include upstream emissions, which occur from the use of carbon-based energy during crude oil extraction, transportation, and refining, as well in the transportation, storage and distribution of refined fuel. Because $CO_2$ accounts for such a large fraction of total GHG emitted during fuel production and use

– more than 95 percent, even after accounting for the higher global warming potentials of other GHG – NHTSA's consideration of GHG impacts focuses on reductions in $CO_2$ emissions resulting from the savings in fuel use that accompany higher fuel economy.[10]

NHTSA considers three measures of the cumulative impact of alternative CAFE standards (for MY 2011-2015 *and* using the assumption of getting to 35 mpg by 2020 to estimate the foreseeable MY 2016-2020) on $CO_2$ emissions:

1. $CO_2$ emissions from the vehicles they would affect, namely, model year 2011-2020 passenger cars and light trucks;
2. $CO_2$ emissions by the entire United States passenger car and light truck fleets that would result during future years (2021-2100) from each alternative increase in CAFE standards; and
3. Cumulative emission reductions over the history of the CAFE program, including those projected to result from each alternative increase in CAFE standards considered for the agency's proposed action. Emission reductions represent the differences in total annual emissions by all cars or light trucks in use between their estimated future levels under the No Action Alternative (baseline), and with each alternative CAFE standard in effect.

Under NEPA the assessment of cumulative impacts must include the impact on the environment resulting from "the incremental impact of the action when added to other past, present, and reasonable foreseeable future actions" (40 CFR § 1508.7). Thus, the agency evaluated the effect of CAFE standards to date, as well as potential CAFE standards for MY 2016-2020 because they are considered a reasonably foreseeable action. With the potential MY 2016-2020 standards, model years after 2020 would continue to meet the MY 2020 standards.

NHTSA estimates that the cumulative $CO_2$ reductions from CAFE to date, from 1978-2007, have been 8,911 $MMTCO_2$, according to DOT's Volpe model. Assuming no further increases in fuel economy standards, i.e., the standards for MY 2010 vehicles remain in force through 2100, NHTSA estimates that continuation of the MY 2010 standard would result in further emission reductions of 130,904 $MMTCO_2$ as compared to a reference scenario of no CAFE standards.

Emission reductions resulting from the CAFE standard for MY 2011-2020 cars and light trucks were estimated from 2010 to 2100. Reductions begin in the year 2010, the first year that MY 2011 vehicles are on the road. For each alternative, all vehicles after MY 2020 were assumed to meet the MY 2020 CAFE standard. Emissions were estimated for all alternatives through 2100, and these emissions were compared against the Notice of Proposed Rulemaking (NPRM) baseline (which assumes all vehicles post-MY 2010 meet the MY 2010 standard) to estimate emission reductions. The Volpe model estimates emissions through the year 2060. As a simplifying assumption, annual emission reductions from 2061-2100 were held constant at 2060 levels.

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[10] While this section does not discuss $CH_4$ and $N_2O$ emissions (since they are very small compared to $CO_2$) the climate modeling described elsewhere in the DEIS does incorporate $CH_4$ and $N_2O$ emissions.

Total emission reductions from 2010-2100 new passenger cars and light trucks from for each of the seven alternatives are shown below in Table 4.4-1. Projections of emission reductions over the 2010 to 2100 timeframe due to the MY 2011-2020 CAFE standard ranged from 38,294 to 53,365 $MMTCO_2$. Compared against global emissions of 4,850,000 $MMTCO_2$ over this period (projected by the A1B-medium scenario), the incremental impact of this rulemaking is expected to reduce global $CO_2$ emissions by about 0.8 to 1.1 percent.

**TABLE 4.4-1**

**Emissions and Emission Reductions (compared to the No Action Alternative) Due to the MY 2011-2015 Standard and Potential MY 2011-2020 CAFE Standard, from 2010-2100 ($MMTCO_2$)**

| Alternative | Emissions | Emission Reductions Compared to No Action Alternative |
|---|---|---|
| No Action | 247,890 | 0 |
| 25 Percent Below Optimized | 209,596 | 38,294 |
| Optimized | 204,487 | 43,403 |
| 25 Percent Above Optimized | 202,075 | 45,815 |
| 50 Percent Above Optimized | 199,933 | 47,958 |
| Total Costs Equal Total Benefits | 197,434 | 50,456 |
| Technology Exhaustion | 194,525 | 53,365 |

To gain a sense of the relative impact of these reductions, it can be helpful to compare them against emission projections from the transportation sector, as well as expected or stated goals from existing programs designed to reduce $CO_2$ emissions. For ease of comparison, NHTSA focuses on the Optimized, or preferred alternative for this discussion.

In their *Annual Energy Outlook 2007*, the EIA projects United States transportation $CO_2$ emissions will increase from 2,037 $MMTCO_2$ in 2010 to 2,682 $MMTCO_2$ in 2030, with cumulative emissions from transportation over this period reaching 49,287 $MMTCO_2$. Over this same timeframe, the emissions reductions from this rulemaking are projected to be 2,595 to 4,002 $MMTCO_2$, which would yield a 5 to 8 percent emissions reduction from the transportation sector. The environmental impact from increasing fuel economy standards would grow as new vehicles enter the fleet and older vehicles are retired. For example, in 2030, projected emission reductions would be 287 to 407 MMTCO2, an 11 to 15 percent decrease from projected United States transportation emissions of 2,682 $MMTCO_2$ in 2030. It is important to note that the EIA did not take into account the expected effects of this rulemaking into their forecast (EIA, 2007), thus allowing a comparison of the impact of this rulemaking to United States transportation emissions under the No Action Alternative.

As another measure of the relative environmental impact of this rulemaking, these emission reductions can be compared to existing programs designed to reduce GHG emissions within the United States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate Initiative (WCI) to develop regional strategies to address climate change. The WCI has a stated goal of reducing 350 $MMTCO_2$ equivalent over the period from 2009-2020 (WCI, 2007). By comparison, this rulemaking is expected to reduce $CO_2$ emissions by 455-830 $MMTCO_2$ over the same time period. In the northeast, nine northeast and Mid-Atlantic States have formed the Regional Greenhouse Gas Initiative (RGGI, 2006) to reduce $CO_2$ emissions from power plants in that region. Emission reductions from 2006-

2024 are estimated at 268 $MMTCO_2$.[11] By comparison, NHTSA forecasts that this rulemaking will reduce $CO_2$ emissions by 1,100-1,834 $MMTCO_2$ over this timeframe. It is, important to note, however, that these projections are only estimates, and the scope of these climate programs differs from this rulemaking in geography, sector, and purpose.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, the comparison of emission reductions from the CAFE alternatives to emission reductions associated with other programs is intended to assist decision makers by providing relative benchmarks, rather than absolute metrics for selecting among alternatives. In summary, the alternatives analyzed here deliver GHG emission reductions that are on the same scale as many of the most progressive and ambitious GHG emission reduction programs underway in the United States.

### 4.4.4.2 Direct and Indirect Effects on Climate Change

The approach to estimating the cumulative effects of climate change from the MY 2011-2020 CAFE alternatives mirrors that used to estimate the direct and indirect effects of the MY 2011-2015 CAFE alternatives. Again, because EISA requires average fuel economy of the passenger car and light truck fleet to reach a combined 35 mpg by 2020, the MY 2016-2020 CAFE standards are a reasonably foreseeable future action. Accordingly, the cumulative impacts analysis assumes the minimum MY 2016-2020 CAFE standards necessary to get to 35 mpg by 2020, based on where the alternatives are at 2015 for purposes of analyzing the cumulative environmental impacts of the range of alternatives. Overall, the emission reductions for the MY 2011-2015 CAFE alternatives have a small impact on climate change. The emission reductions and resulting climate impacts for the MY 2011-2020 CAFE standards are larger, though they are still relatively small in absolute terms.

The direct and indirect effects of the alternatives on climate change are described in the following section in terms of (1) atmospheric $CO_2$ concentrations, (2) temperature, (3) precipitation, and (4) sea level rise. Within each section, the MAGICC results are reported first, followed by the results of the scaling approach. An explanation of the methodology and purpose of the scaling approach is discussed in Section 3.4.3.

#### 4.4.4.2.1 Atmospheric Carbon Dioxide Concentrations

<u>MAGICC Results</u>

The MAGICC model is a simple climate model that is well calibrated to the mean of the multi-model ensemble results for three of the most commonly used emission scenarios – B1 (low), A1B (medium), and A2 (high) from the IPCC SRES series – as shown in Table 4.4-2.[12] As the table indicates, the model runs developed for this analysis achieve relatively good agreement with IPCC Work Group 1 (WG1) estimates in terms of both $CO_2$ concentrations and surface temperature.

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[11] 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.

[12] The default climate sensitivity in MAGICC of 2.6 degrees Celsius was used.

**TABLE 4.4-2**

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

| | $CO_2$ Concentration (ppm) | | Radiative Forcing ($W/m^2$) | | Global Mean Increase in Surface Temperature ($^oC$) | |
|---|---|---|---|---|---|---|
| **Scenario** | **IPCC WG1 (2100)** | **MAGICC (2100)** | **IPCC WG1 (2080-2099)** | **MAGICC (2090)** | **IPCC WG1 (2080-2099)** | **MAGICC (2090)** |
| B1 | 550 | 537 | N/A | 3.22 | 1.79 | 1.82 |
| A1B | 715 | 709 | N/A | 4.85 | 2.65 | 2.60 |
| A2 | 836 | 854 | N/A | 6.09 | 3.13 | 3.01 |

The mid-range results of MAGICC model simulations for the No Action Alternative and the six alternative CAFE levels, in terms of $CO_2$ concentrations and increase in global mean surface temperature in 2030, 2060, and 2100 are presented in Table 4.4-3 and Figures 4.4-2 to 4.4-5. As Figures 4.4-2 and 4.4-3 show, the impact on the growth in $CO_2$ concentrations and temperature is just a fraction of the total growth in $CO_2$ concentrations and global mean surface temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in growth of both $CO_2$ concentrations and temperature in the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized Alternative, as shown in Figures 4.4-4 to 4.4-5.

As shown in the table and figures, there is a fairly narrow band of estimated $CO_2$ concentrations as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. As $CO_2$ concentrations are the key driver of all the other climate effects, this narrow range implies that the differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global surface air temperature increases are also shown below in Table 4.4-5. For all alternatives, the temperature increase is about 0.8°C as of 2030, 1.8°C as of 2060, and 2.8°C as of 2100. The differences among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.012°C to 0.018°C. These estimates include considerable uncertainty due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid-point of 3.0 degrees C which directly relates to the uncertainty in the estimated global mean surface temperature.

To supplement the modeled estimates (generated by applying MAGICC) in Table S-11, a scaling approach was used to (1) validate that the modeled estimates are consistent with recent IPCC AR4 estimates and (2) characterize the sensitivity of the $CO_2$ and temperature estimates to different assumptions about (a) global emissions from sources other than United States passenger cars and light trucks and (b) climate sensitivity (i.e., the equilibrium warming associated with a doubling of atmospheric $CO_2$ concentrations compared to pre-industrial levels). The scaling analysis showed that the results for $CO_2$ concentration and temperature are in good agreement with recent estimates from IPCC AR4. The analysis also indicates that the estimates for $CO_2$ concentrations and global mean surface temperature vary considerably, depending on which global emissions scenario is used as a reference case. Furthermore, temperature increases are sensitive to climate sensitivity. Regardless of the choice of reference case or climate sensitivity, the differences among CAFE alternatives are small: $CO_2$ concentrations as of 2100 are within 4 ppm across alternatives, and temperatures are within 0.03°C across alternatives (consistent with the MAGICC modeling results). The scaling results illustrate the uncertainty in $CO_2$ concentrations and temperatures related to reference case global emissions and climate sensitivity.

## TABLE 4.4-3

## MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standards Impact on $CO_2$ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC

|  | $CO_2$ Concentration (ppm) |  |  | Global Mean Surface Temperature Increase ($^oC$) |  |  |
|---|---|---|---|---|---|---|
|  | **2030** | **2060** | **2100** | **2030** | **2060** | **2100** |
| **Totals by Alternative** |  |  |  |  |  |  |
| No Action (A1B – AIM) a/ | 458.4 | 575.2 | 708.6 | 0.789 | 1.837 | 2.763 |
| 25 Percent Below Optimized | 458.2 | 573.7 | 705.1 | 0.788 | 1.832 | 2.751 |
| Optimized | 458.1 | 573.4 | 704.6 | 0.788 | 1.831 | 2.749 |
| 25 Percent Above Optimized | 458.1 | 573.3 | 704.4 | 0.788 | 1.83 | 2.748 |
| 50 Percent Above Optimized | 458.1 | 573.3 | 704.2 | 0.787 | 1.829 | 2.747 |
| Total Costs Equal Total Benefits | 458.0 | 573.2 | 703.9 | 0.787 | 1.829 | 2.746 |
| Technology Exhaustion | 458.0 | 573.0 | 703.7 | 0.787 | 1.828 | 2.745 |
| **Reduction from CAFE Alternatives** |  |  |  |  |  |  |
| 25 Percent Below Optimized | 0.2 | 1.5 | 3.5 | 0.001 | 0.005 | 0.012 |
| Optimized | 0.3 | 1.8 | 4 | 0.001 | 0.006 | 0.014 |
| 25 Percent Above Optimized | 0.3 | 1.9 | 4.2 | 0.001 | 0.007 | 0.015 |
| 50 Percent Above Optimized | 0.3 | 1.9 | 4.4 | 0.002 | 0.008 | 0.016 |
| Total Costs Equal Total Benefits | 0.4 | 2.0 | 4.7 | 0.002 | 0.008 | 0.017 |
| Technology Exhaustion | 0.4 | 2.2 | 4.9 | 0.002 | 0.009 | 0.018 |

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a/ The A1B-AIM scenario is the SRES marker scenario used by the IPCC WG1 to represent the SRES A1B (medium) storyline.

**Figure 4.4-2 CO$_2$ Concentrations for the A1B scenario and MY 2011-2015 Standard and Potential 2016-2020 Standard**

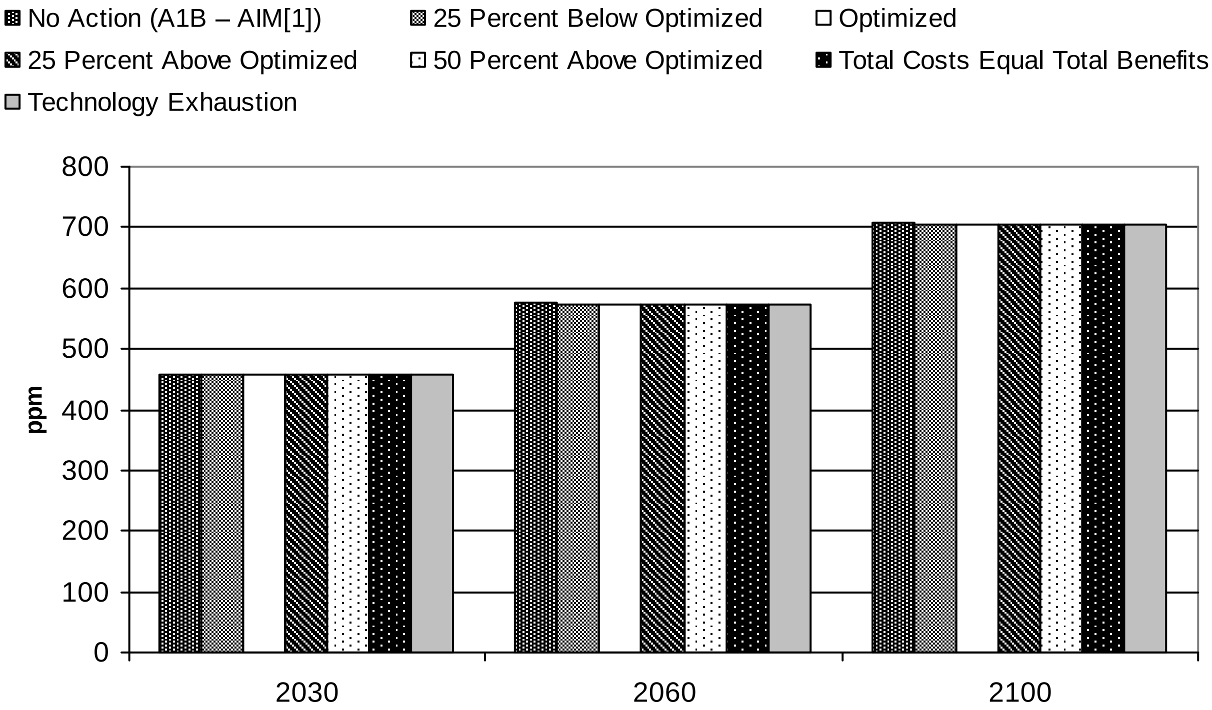


**Figure 4.4-3 Increase in Global Mean Surface Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential 2016-2020 Standard**

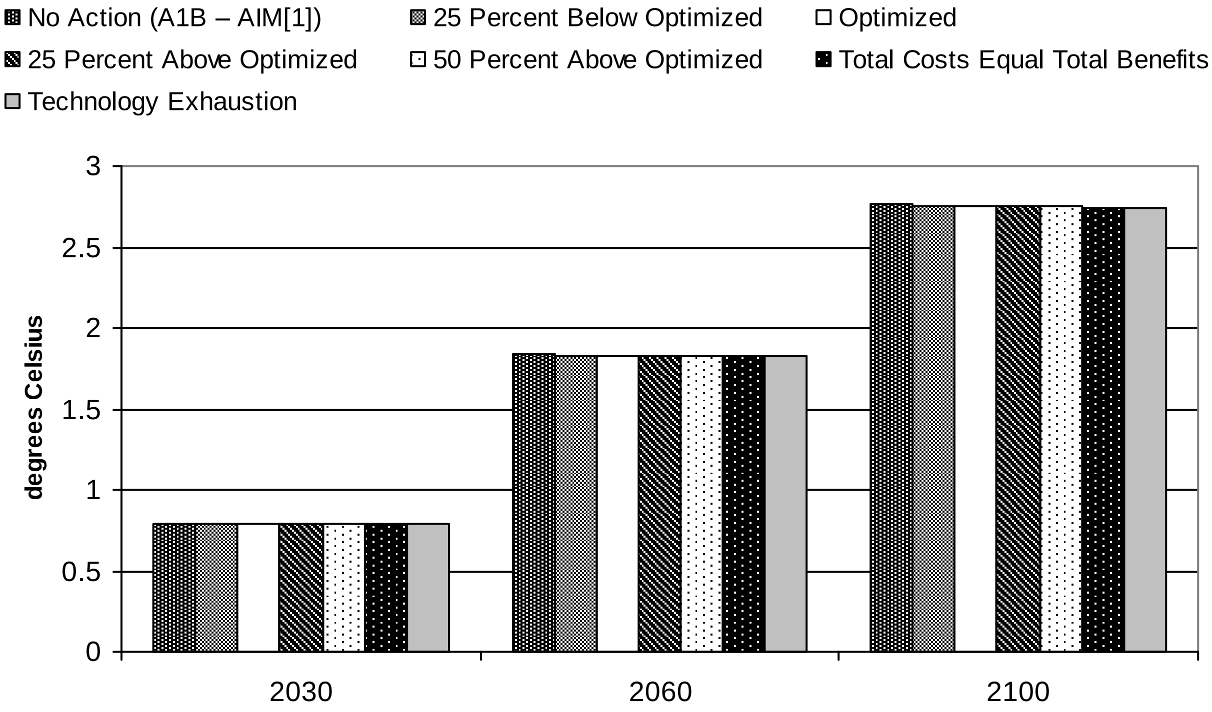


**Figure 4.4-4 Reduction in the Growth of $CO_2$ Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential 2016-2020 Standard**

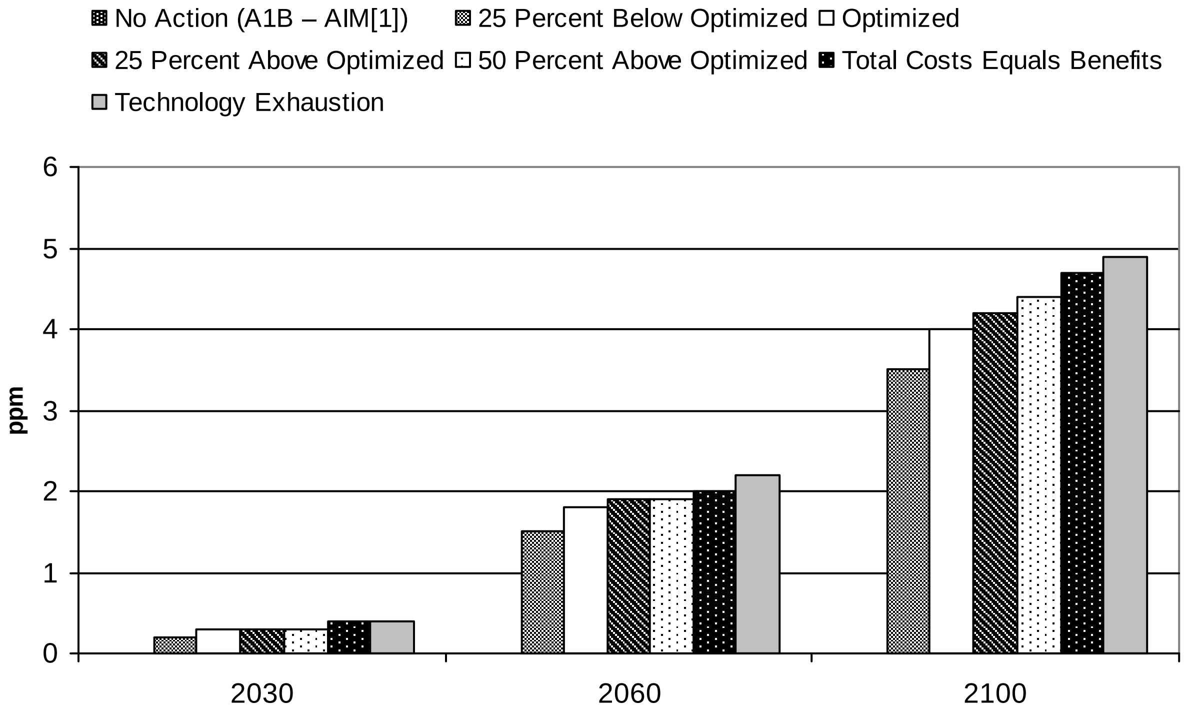
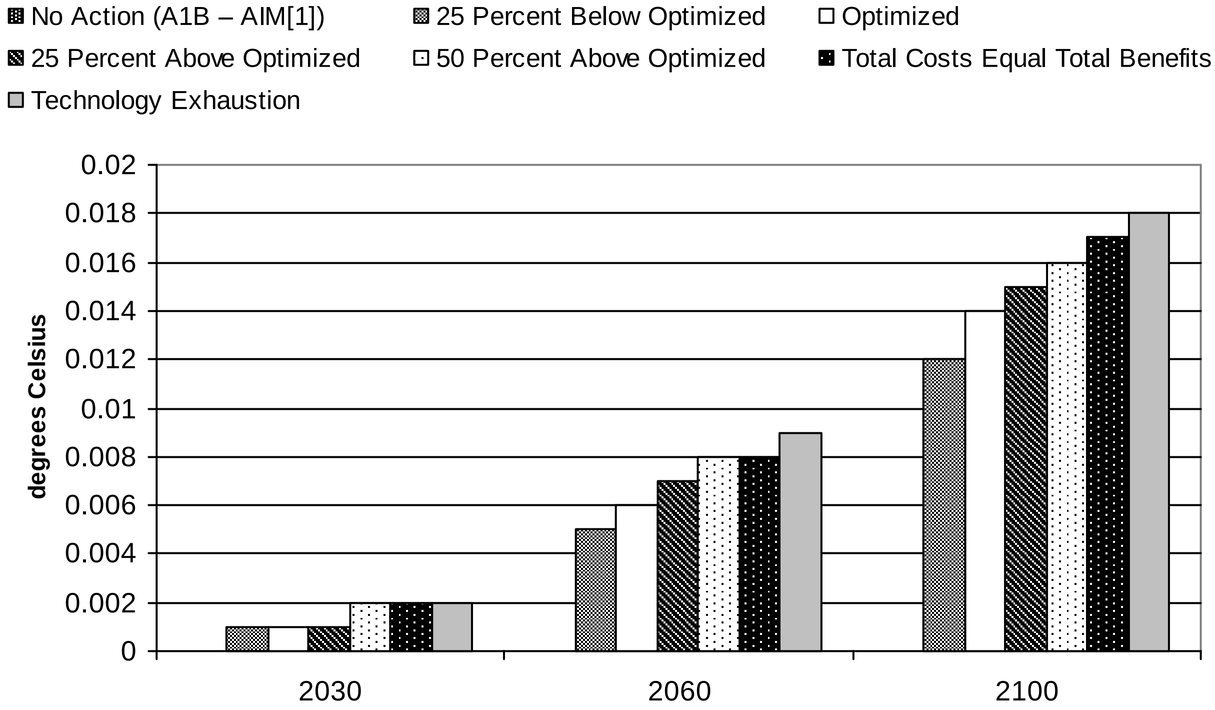


**Figure 4.4-5 Reduction in the Growth of Global Mean Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential 2016-2020 Standard**



As shown in the table and figures, there is a fairly narrow range of estimated $CO_2$ concentrations as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. For earlier years, the range is even tighter. As $CO_2$ concentrations are the key driver of all the other climate effects (which in turn act as drivers on the resource impacts discussed in this chapter), this narrow range implies that the differences among alternatives are difficult to distinguish.

### Scaling Results

The global emission scenarios developed by the IPCC in the SRES (Nakicenovic et al., 2000), showed ranges of cumulative emissions from 1990 to 2100 of $CO_2$ from 770 Gt[13] Carbon to 2,450 Gt C (2,825 to 8,985 billion metric tons of $CO_2$). The three scenarios used in the IPCC WG1 Fourth Assessment Report (IPCC, 2007) have the following emissions of $CO_2$ from 2005 to 2100[14]:

- Low – B1: 3,145 Gt $CO_2$
- Mid – A1B: 5,020 Gt $CO_2$
- High – A2: 6,640 Gt $CO_2$

As indicated earlier in Table 4.4-3, for these emission scenarios, $CO_2$ concentrations increase from 379 ppm in 2005 to mid-range estimates in 2100 of 550 ppm for the B1 (low) scenario, 715 ppm for the A1B (medium) scenario, and 836 ppm for the A2 (high) scenario (IPCC, 2007). This implies that 42 percent, 52 percent, and 53 percent of the emitted $CO_2$ from 2005 to 2100 in the SRES B1 (low), A1B (medium), and A2 (high) scenarios, respectively, is still in the atmosphere in 2100[15] (these percentages can be used in the agency's scaling approach). The amount of emitted $CO_2$ that remains in the atmosphere as of 2100 varies considerably depending upon when the $CO_2$ is emitted, which determines the length of time it is subject to land and ocean uptake.

By applying the scaling factors developed above, the emission reductions for the seven MY 2011-2020 CAFE alternatives yield $CO_2$ concentrations, as of 2100, as shown in Table 4.4-4. The results for scenario A1B (medium) in this table (712-715 ppm) agree relatively well with the MAGICC results in Table 4.4-3 (704-709 ppm). These concentrations are considerably higher than current concentrations, which were approximately 379 ppm in 2005 (IPCC, 2007).

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[13] Gt C is Gigaton or billion metric tons of carbon.

[14] Calculated by averaging cumulative emissions from 2000 to 2010 from the SRES scenario results (Nakicenovic et al, 2000)

[15] 1 ppm of $CO_2$ equals 2.13 Gt C (ORM/CIDAC, 1990) = 7.81 Gt $CO_2$

[15] The agency estimates emissions from 2005 to be consistent with calculations using the increase in $CO_2$ concentrations where estimates for 2005 exist.

**TABLE 4.4-4**

**Emissions and Estimated $CO_2$ Concentrations in 2100 for the MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard for Low (B1), Mid (A1B), and High (A2) Emission Scenarios**

| | $CO_2$ Emissions 2005-2100 a/ (Bt $CO_2$) | | | $CO_2$ Concentrations in 2100 (ppm) b/ | | |
|---|---|---|---|---|---|---|
| | **B1** | **A1B** | **A2** | **B1** | **A1B** | **A2** |
| **Totals by Alternative** | | | | | | |
| No Action | 3144 | 5022 | 6642 | 550.0 | 715.0 | 836.0 |
| 25 Percent Below Optimized: Reductions by 2100 | 3106 | 4984 | 6604 | 547.9 | 712.5 | 833.4 |
| Optimized | 3101 | 4979 | 6599 | 547.7 | 712.1 | 833.0 |
| 25 Percent Above Optimized | 3098 | 4976 | 6596 | 547.5 | 711.9 | 832.8 |
| 50 Percent Above Optimized | 3096 | 4974 | 6594 | 547.4 | 711.8 | 832.7 |
| Total Costs Equal Total Benefits | 3094 | 4972 | 6592 | 547.3 | 711.7 | 832.6 |
| Technology Exhaustion | 3091 | 4969 | 6589 | 547.1 | 711.5 | 832.4 |
| **Reduction from CAFE Alternatives** | | | | | | |
| 25 Percent Below Optimized: Reductions by 2100 | 38 | 38 | 38 | 2.1 | 2.5 | 2.6 |
| Optimized | 43 | 43 | 43 | 2.3 | 2.9 | 3.0 |
| 25 Percent Above Optimized | 46 | 46 | 46 | 2.5 | 3.1 | 3.2 |
| 50 Percent Above Optimized | 48 | 48 | 48 | 2.6 | 3.2 | 3.3 |
| Total Costs Equal Total Benefits | 50 | 50 | 50 | 2.7 | 3.3 | 3.4 |
| Technology Exhaustion | 53 | 53 | 53 | 2.9 | 3.5 | 3.6 |

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a/ The agency estimate emissions from 2005 to be consistent with calculations using the increase in $CO_2$ concentrations where estimates for 2005 exist.

b/ Concentration reduction estimates are based on the share of emitted $CO_2$ still in atmosphere from IPCC, 2007.

#### 4.4.4.2.2 Temperature

MAGICC Results

The MAGICC simulations of mean global surface air temperature increases are shown above in Table 4.4-3. For all alternatives, the cumulative global mean surface temperature increase is about 0.8 degree Celsius as of 2030, 1.8 degree Celsius as of 2060, and 2.8 degree Celsius as of 2100 (Table 4.4-3). The projected differences regarding reductions in temperature increase alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.012 degree Celsius to 0.018 degree Celsius.

### Scaling Results

The relationship between emissions and temperature is a dynamic one, given all of the feedback loops and transient phenomena involved in the climate system. The scaling approach used here is based on the relationship between emissions and the global mean surface temperature at equilibrium (GMSTE), i.e., the temperature increase if $CO_2$ concentrations were to equilibrate at levels reached as of 2100.

Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, the methodology uses three different emission scenarios (B1-low, A1B-medium, and A2-high) to provide a range of values to address uncertainty in the factors that drive global GHG emissions.

According to IPCC (2007), temperature change can be estimated using the following equation:

$$\Delta T = S \times \log(\mathrm{CO2} / 280\ \mathrm{ppm}) / \log(2)$$

Where:
T = Temperature (ºC)
S = Climate sensitivity
$CO_2$ = $CO_2$ concentration (ppm)

Using this equation, the impact of the emission reductions from the MY 2011-2020 CAFE alternatives for the range of climate sensitivities provided by the IPCC (IPCC, 2007a) are estimated and shown in Table 4.4-5, below. These are shown for three different levels of "climate sensitivity," i.e., the mean temperature increase resulting from a sustained doubling, over pre-industrial levels, of atmospheric $CO_2$ concentrations (IPCC 2007a). The calculations are also shown for three different emission scenarios: B1 (low), A1B (medium), and A2 (high). The range of GMSTE reductions (with respect to the No Action Alternative) due to the different CAFE alternatives ranges from 0.011 °C to 0.034 °C depending upon the climate sensitivity and the CAFE alternative.

The IPCC estimates that for the A1B (medium) and B1 (low) scenarios, the average warming from the AOGCMs as of 2100 is 65 to 70 percent of the estimated eventual equilibrium warming in the 21st century. With this information, and the data in Table 4.4-5, the agency constructed a bounding analysis on the effects of the CAFE alternatives on average warming by 2100. The lower bound combines the lower ends of the ranges on (a) the proportion of warming as of 2100 compared to eventual warming (viz., 65 percent), (b) the lowest value for the reduction in temperature for a CAFE alternative compared to the No Action Alternative from the table (viz., 0.011 degree C, the value for the 25 Percent Below Optimized Alternative, A2 (high) emission scenario, and climate sensitivity at 2.5 degrees C). This yields an estimate of a lower bound temperature effect (compared to the No Action Alternative) of 65%* 0.011°C = 0.007°C. The upper bound, derived by the same approach but using high end values, is 70% * 0.034°C = 0.024°C for the Technology Exhaustion Alternative using a climate sensitivity of 4.5 degrees C.

The range of 0.007 degree Celsius to 0.024 degree Celsius from the scaling approach encompasses the range of MAGICC values (in Table 4.4-5) of 0.012 degree Celsius to 0.018 degree C. Note that the scaling approach uses three different values for climate sensitivity, whereas MAGICC only uses one (2.6 degrees C, the middle value used for the scaling analysis), and so the greater range with the scaling approach is to be expected. The use of the scaling approach illustrates that the alternatives' effectiveness in reducing temperature increases is somewhat broader than the range projected in this DEIS using the MAGICC model, and that the results are sensitive to the value of climate sensitivity.

**TABLE 4.4-5**

**Atmospheric $CO_2$ Concentrations and Reductions for the 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard, and Estimated Impact on Global Mean Surface Temperature at Equilibrium by 2100**

| | | | | Global Mean Surface Temperature at Equilibrium from $CO_2$ Only (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Concentration (ppm) | | | GMEST – CS = 2.5 °C | | | GMEST – CS = 3 °C | | | GMEST – CS = 4.5 °C | | |
| | B1 | A1B | A2 | B1 | A1B | A2 | B1 | A1B | A2 | B1 | A1B | A2 |
| **Totals by Alternative** | | | | | | | | | | | | |
| No Action | 550 | 715 | 836 | 2.435 | 3.381 | 3.945 | 2.922 | 4.058 | 4.734 | 4.383 | 6.086 | 7.101 |
| 25% Below Optimized Alternative | 547.9 | 712.5 | 833.4 | 2.421 | 3.368 | 3.934 | 2.906 | 4.042 | 4.721 | 4.359 | 6.063 | 7.081 |
| Optimized Alternative | 547.7 | 712.1 | 833.0 | 2.420 | 3.367 | 3.932 | 2.904 | 4.040 | 4.719 | 4.355 | 6.060 | 7.078 |
| 25% Above Optimized Alternative | 547.5 | 711.9 | 832.8 | 2.419 | 3.366 | 3.932 | 2.902 | 4.039 | 4.718 | 4.353 | 6.058 | 7.077 |
| 50% Above Optimized Alternative | 547.4 | 711.8 | 832.7 | 2.418 | 3.365 | 3.931 | 2.901 | 4.038 | 4.717 | 4.352 | 6.057 | 7.076 |
| Total Costs Equal Total Benefits Alternative | 547.3 | 711.7 | 832.6 | 2.417 | 3.364 | 3.930 | 2.901 | 4.037 | 4.716 | 4.351 | 6.056 | 7.075 |
| Technology Exhaustion Alternative | 547.1 | 711.5 | 832.4 | 2.416 | 3.363 | 3.929 | 2.899 | 4.036 | 4.715 | 4.349 | 6.054 | 7.073 |
| **Reduction from CAFE Alternatives (with respect to No Action Alternative)** | | | | | | | | | | | | |
| 25% Below Optimized Alternative | 2.1 | 2.5 | 2.6 | 0.014 | 0.013 | 0.011 | 0.016 | 0.015 | 0.014 | 0.024 | 0.023 | 0.020 |
| Optimized Alternative | 2.3 | 2.9 | 3.0 | 0.015 | 0.015 | 0.013 | 0.018 | 0.017 | 0.015 | 0.028 | 0.026 | 0.023 |
| 25% Above Optimized Alternative | 2.5 | 3.1 | 3.2 | 0.016 | 0.016 | 0.014 | 0.020 | 0.019 | 0.016 | 0.030 | 0.028 | 0.025 |
| 50% Above Optimized Alternative | 2.6 | 3.2 | 3.3 | 0.017 | 0.016 | 0.014 | 0.021 | 0.019 | 0.017 | 0.031 | 0.029 | 0.026 |
| Total Costs Equal Total Benefits Alternative | 2.7 | 3.3 | 3.4 | 0.018 | 0.017 | 0.015 | 0.021 | 0.020 | 0.018 | 0.032 | 0.030 | 0.027 |
| Technology Exhaustion Alternative | 2.9 | 3.5 | 3.6 | 0.019 | 0.018 | 0.016 | 0.023 | 0.022 | 0.019 | 0.034 | 0.032 | 0.028 |

Table 4.4-6 summarizes the regional changes to warming and seasonal temperatures from the IPCC Fourth Assessment Report. It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives (40 CFR § 1502.22(b)).[16] Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information. In this case, the IPCC (2007) summary of regional changes to warming and seasonal temperatures represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in regional temperature relative to the reduction in global mean surface temperature.

**TABLE 4.4-6**
**Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment (IPCC, 2007)**

| Land Area | Sub-region | Mean Warming | Maximum Summer Temperatures |
|---|---|---|---|
| Africa | Mediterranean area and northern Sahara | *Likely* larger than global mean throughout continent and in all seasons | |
| | Southern Africa and western margins | | |
| | East Africa | | |
| Mediterranean and Europe | Northern Europe | *Likely* to increase more than the global mean with largest warming in winter | Maximum Summer Temperatures *likely* to increase more than average |
| | Southern and Central Europe | | |
| | Mediterranean area | | |
| Asia | Central Asia | *Likely* to be well above the global mean | |
| | Tibetan Plateau | *Likely* to be well above the global mean | |
| | Northern Asia | *Likely* to be well above the global mean | |
| | Eastern Asia | *Likely* to be above the global mean | *Very likely* that heat waves/hot spells in summer will be of longer duration, more intense and more frequent<br>*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 | |

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[16] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited June 20, 2008) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

**TABLE 4.4-6**

**Summary of Regional Changes to Warming and Seasonal Temperatures Extracted from the IPCC Fourth Assessment (IPCC, 2007)**

| Land Area | Sub-region | Mean Warming | Maximum Summer Temperatures |
|---|---|---|---|
| North America | Northern regions/Northern North America | *Likely* to exceed the global mean warming | Warming is *likely* to be largest in winter<br>Minimum winter temperatures are *likely* to increase more than the average |
| | Southwest | | Warming is *likely* to be largest in summer<br>Maximum summer temperatures are *likely* to increase more than the average |
| | Northeast USA | | |
| | Southern Canada | | |
| | Canada | | |
| | Northernmost part of Canada | | |
| Central and South America | Southern South America | *Likely* to be similar to the global mean warming | |
| | Central America | *Likely* to be larger than global mean warming | |
| | Southern Andes | | |
| | Tierra del Fuego | | |
| | Southeastern South America | | |
| | Northern South America | | |
| Australia and New Zealand | Southern Australia | *Likely* comparable to the global mean but less than in the rest of Australia | Increased frequency of extreme high daily temperatures and a decrease in the frequency of cold extremes is *very likely* |
| | Southwestern Australia | *Likely* comparable to the global mean | |
| | Rest of Australia | *Likely* comparable to the global mean | |
| | New Zealand, South Island | *Likely* less than the global mean | |
| | Rest of New Zealand | *Likely* comparable to the global mean | |
| Polar Regions | Arctic | *Very likely* to warm during this century more than the global mean. | Warming largest in winter and smallest in summer |
| | Antarctic | *Likely* to warm | |
| Small Islands | | *Likely* to be smaller than the global annual mean | |

#### 4.4.4.2.3 Precipitation

MAGICC Results

According to the IPCC WG1 (IPCC, 2007), global mean precipitation is expected to increase under all the scenarios. Generally, precipitation increases occur in the tropical regions and high latitudes, with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in future precipitation for the three SRES scenarios. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)). In this case, the IPCC (2007) summary of precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in proportion to their effects on temperature.

The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium), and B1 (low) scenarios (IPCC, 2007a) is given as the scaled change in precipitation (as a percentage change from 1980-1999 averages) divided by the increase in global mean surface warming for the same period (per degree C) as shown in Table 4.4-7 below. IPCC provided scaling factors in the year ranges 2011-2030; 2046-2065; and 2080-2099. The scaling factors for the A1B (medium) scenario were used in our analysis since MAGICC does not directly estimate changes in global mean rainfall.

**TABLE 4.4-7**

**Global Mean Precipitation Change (IPCC 2007)**

| Global Mean Precipitation Change (scaled, % per degree C) | 2011–2030 | 2046–2065 | 2080–2099 | 2180–2199 |
|---|---|---|---|---|
| A2 | 1.38 | 1.33 | 1.45 | NA |
| A1B | 1.45 | 1.51 | 1.63 | 1.68 |
| B1 | 1.62 | 1.65 | 1.88 | 1.89 |

Applying these to the reductions in global mean surface warming provides estimates of changes in global mean precipitation. Given that the CAFE alternatives would reduce temperature increases slightly with respect to the No Action Alternative, they also would reduce predicted increases in precipitation slightly, as shown in Table 4.4-8 (again, based on the A1B (medium) scenario).

**TABLE 4.4-8**

**MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard: Impact on Reductions in Global Mean Precipitation based onA1B SRES Scenario (% change), Using Increases in Global Mean Surface Temperature Simulated by MAGICC**

| Scenario | 2011–2030/2020 | 2046–2065/2055 | 2080–2099/2090 |
|---|---|---|---|
| **Global Mean Precipitation Change (scaled, % K-1)** | | | |
| | 1.45 | 1.51 | 1.63 |
| **Global Temperature above average 1980-1999 levels ($^oC$) for the A1B scenario by 2100, mid-level results** | | | |
| No Action | 0.690 | 1.750 | 2.650 |
| 25 Percent Below Optimized Alternative | 0.690 | 1.745 | 2.639 |
| Optimized Alternative | 0.690 | 1.744 | 2.638 |
| 25 Percent Above Optimized Alternative | 0.690 | 1.744 | 2.636 |
| 50 Percent Above Optimized Alternative | 0.690 | 1.743 | 2.636 |
| Total Costs Equal Total Benefits Alternative | 0.690 | 1.743 | 2.635 |
| Technology Exhaustion Alternative | 0.690 | 1.742 | 2.634 |
| ***Reduction in Global Temperature ($^oK$) for the A1B scenario, mid-level results*** | | | |
| 25 Percent Below Optimized Alternative | 0.000 | 0.005 | 0.011 |
| Optimized Alternative | 0.000 | 0.006 | 0.012 |
| 25 Percent Above Optimized Alternative | 0.000 | 0.006 | 0.014 |
| 50 Percent Above Optimized Alternative | 0.000 | 0.007 | 0.014 |
| Total Costs Equal Total Benefits Alternative | 0.000 | 0.007 | 0.015 |
| Technology Exhaustion Alternative | 0.000 | 0.008 | 0.016 |
| **Mid Level Global Mean Rain Fall Change by 2100 (%)** | | | |
| No Action | 1.00 | 2.64 | 4.32 |
| 25 Percent Below Optimized Alternative | 1.00 | 2.63 | 4.30 |
| Optimized Alternative | 1.00 | 2.63 | 4.30 |
| 25 Percent Above Optimized Alternative | 1.00 | 2.63 | 4.30 |
| 50 Percent Above Optimized Alternative | 1.00 | 2.63 | 4.30 |
| Total Costs Equal Total Benefits Alternative | 1.00 | 2.63 | 4.30 |
| Technology Exhaustion Alternative | 1.00 | 2.63 | 4.29 |
| **Reduction in Global Mean Precipitation (%)** | | | |
| 25 Percent Below Optimized Alternative | 0.00 | 0.01 | 0.02 |
| Optimized Alternative | 0.00 | 0.01 | 0.02 |
| 25 Percent Above Optimized Alternative | 0.00 | 0.01 | 0.02 |
| 50 Percent Above Optimized Alternative | 0.00 | 0.01 | 0.02 |
| Total Costs Equal Total Benefits Alternative | 0.00 | 0.01 | 0.02 |
| Technology Exhaustion Alternative | 0.00 | 0.01 | 0.03 |

In addition to changes in mean annual precipitation, climate change is anticipated to affect the intensity of precipitation as described below (IPCC, 2007, p. 750):

> *"Intensity of precipitation events is projected to increase, particularly in tropical and high latitude areas that experience increases in mean precipitation. Even in areas where mean precipitation decreases (most subtropical and mid-latitude regions), precipitation*

> *intensity is projected to increase but there would be longer periods between rainfall events. There is a tendency for drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes increase more than does the mean in most tropical and mid- and high-latitude areas."*

Regional variations and changes in the intensity of precipitation events cannot be quantified further. This is due primarily to the availability of AOGCMS required to estimate these changes. These models are typically used to provide results between scenarios with very large changes in emissions such as the SRES B1 (low), A1B (medium), and A2 (high) scenarios and very small changes in emission profiles would produce results that would be difficult to resolve between scenarios with relatively small changes in emissions. In addition, the multiple AOGCMs produce results that are regionally consistent in some cases but are inconsistent in other areas.

### Scaling Results

Given that the MAGICC modeling approach is based on a scaling methodology (per Table 4.4-7), a separate scaling calculation was not employed to characterize precipitation.

Table 4.4-9 summarizes the regional changes to precipitation from the IPCC Fourth Assessment. It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives but it is expected that they would reduce the changes relative to the reduction in global mean surface temperature.[17]

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[17] *See* 42 U.S.C. § 4332 (requiring federal agencies to "identify and develop methods and procedures … which will insure that presently unquantified environmental amenities and values may be given appropriate consideration"); 40 CFR § 1502.23 (requiring an EIS to discuss the relationship between a cost-benefit analysis and any analyses of unquantified environmental impacts, values, and amenities); CEQ, *Considering Cumulative Effects Under the National Environmental Policy Act* (1984), *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm (last visited June 20, 2008) (recognizing that agencies are sometimes "limited to qualitative evaluations of effects because cause-and-effect relationships are poorly understood" or cannot be quantified).

**TABLE 4.4-9**

**Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (IPCC, 2007a)**

| 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 | |
| | East Africa | *Likely* to be an increase in annual mean precipitation | |
| Mediterranean and Europe | Northern Europe | *Very likely* to increase and extremes are *likely* to increase | *Likely* to decrease |
| | Southern and Central Europe | | |
| | Mediterranean area | *Very likely* to decrease and precipitation days are *very likely* to decrease | |
| Asia | Central Asia | Precipitation in summer is *likely* to decrease | |
| | Tibetan Plateau | Precipitation in boreal winter is *very likely* to increase | |
| | Northern Asia | Precipitation in boreal winter is *very likely* to increase<br>Precipitation in summer is *likely* to increase | |
| | Eastern Asia | Precipitation in boreal winter is *likely* to increase<br>Precipitation in summer is *likely* to increase<br>*Very likely* to be an increase in the frequency of intense precipitation<br>Extreme precipitation and winds associated with tropical cyclones are *likely* to increase | |
| | South Asia | Precipitation in summer is *likely* to increase<br>*Very likely* to be an increase in the frequency of intense precipitation<br>Extreme precipitation and winds associated with tropical cyclones are *likely* to increase | |
| | Southeast Asia | Precipitation in boreal winter is *likely* to increase in southern parts<br>Precipitation in summer is *likely* to increase in most parts of southeast Asia<br>Extreme precipitation and winds associated with tropical cyclones are *likely* to increase | |

**TABLE 4.4-9**

**Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (IPCC, 2007a)**

| 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 | |
| | Northeast USA | Annual mean precipitation is *very likely* to increase | |
| | Southern Canada | | |
| | Canada | Annual mean precipitation is *very likely* to increase | |
| | Northernmost part of Canada | | Snow season length and snow depth are *likely* to increase |
| Central and South America | Southern South America | | |
| | Central America | Annual precipitation is *likely* to decrease | |
| | Southern Andes | Annual precipitation is *likely* to decrease | |
| | Tierra del Fuego | Winter precipitation is *likely* to increase | |
| | Southeastern South America | Summer precipitation is *likely* to increase | |
| | Northern South America | Uncertain how precipitation will change | |

**TABLE 4.4-9**

**Summary of Regional Changes to Precipitation Extracted from the IPCC Fourth Assessment (IPCC, 2007a)**

| Land Area | Sub-region | Precipitation | Snow Season and Snow Depth |
|---|---|---|---|
| Australia and New Zealand | Southern Australia | Precipitation *likely* to decrease in winter and spring | |
| | Southwestern Australia | Precipitation is *very likely* to Decrease in winter | |
| | Rest of Australia | | |
| | New Zealand, South Island | Precipitation is *likely* to increase in the west | |
| | Rest of New Zealand | | |
| Polar Regions | Arctic | Annual precipitation is *very likely* to increase. It is *very likely* that the relative precipitation increase will be largest in winter and smallest in summer. | |
| | Antarctic | Precipitation is *likely* to increase | |
| Small Islands | | Mixed depending on the region | |

#### 4.4.4.2.4 Sea Level Rise

IPCC identifies four primary components to sea level rise: thermal expansion of ocean water; melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in Greenland (IPCC, 2007). Ice sheet discharge is an additional factor that could influence sea level over the long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise, using a non-linear temperature- and pressure-dependent expansion coefficient (Wigley, 2003). It also addresses the other three primary components through ice-melt models for small glaciers and the Greenland and Antarctic ice sheets.

The state-of-the-science reflected in the IPCC Fourth Assessment Report (IPCC, 2007) projects sea level to rise of 18 to 59 centimeters (cm) by 2090-2099 (Parry, 2007 in National Science and Technology Council, 2008). This projection does not include all changes in ice sheet flow or the potential for rapid acceleration in ice loss (Alley et al., 2005; Gregory and Huybrechts, 2006; Hansen, 2005 in Pew, 2007). Several recent studies have found the IPCC's projections of potential sea level rise may underestimate ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wignham, 2007; Csatho, et al., 2008) and ice loss from mountain glaciers (Meier et al., 2007). Further, IPCC may underestimate sea level rise that would be gained through changes in global precipitation (Wentz et al., 2007; Zhang et al., 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea level rise. The approach yielded a proportionality coefficient of 3.4 millimeters (mm) per year per °C of warming, and a projected sea level rise of 0.5 to 1.4 meter (m) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that, "A rise over 1 m by 2100 for strong warming scenarios cannot be ruled out."

Sea level rise is discussed in more detail in Section 4.5.5, Coastal Systems and Low-lying Areas.

### MAGICC Results

MAGICC reports sea level rise in increments of 0.1 centimeter (cm) (i.e., 1 millimeter [mm]). The impact on sea level rise from the scenarios is at the threshold of the model's reporting: the alternatives reduce sea level rise by 0.1 to 0.2 cm (Table 4.4-10). Although the model does not report enough significant figures to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above); and the lower the temperature, the lower the sea level. Thus, the more stringent alternatives are likely to result in slightly less sea level rise.

### Scaling Results

One of the areas of climate change research where there have been many recent developments is the science underlying the projection of sea level rise. As noted above, there are four key components of sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-the-science, so the scaling approach is an important supplement.

**TABLE 4.4-10**

**MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard: Impact on Sea Level Rise based on A1B SRES Scenario, Simulated by MAGICC**

| Alternative | Sea Level Rise with Respect to 1990 Level, cm |
|---|---|
| No Action | 37.9 |
| 25 Percent Below Optimized | 37.8 |
| Optimized | 37.8 |
| 25 Percent Above Optimized | 37.8 |
| 50 Percent Above Optimized | 37.8 |
| Total Costs Equal Total Benefits | 37.7 |
| Technology Exhaustion | 37.7 |
| **Reduction in Sea Level Rise for the CAFE alternatives (compared to No Action Alternative)** | |
| 25 Percent Below Optimized | 0.1 |
| Optimized | 0.1 |
| 25 Percent Above Optimized | 0.1 |
| 50 Percent Above Optimized | 0.1 |
| Total Costs Equal Total Benefits | 0.2 |
| Technology Exhaustion | 0.2 |

Table 4.4-11 presents estimates of sea level rise provided by the IPCC WG1, excluding the effect of scaled-up ice sheet discharge, where further accelerations have been observed but could not be quantified with confidence (IPCC, 2007). Note that "for each scenario the lower/upper bound for sea level rise is larger/smaller/ than the total of the lower/upper bounds of the contributions, since the uncertainties of the contributions are largely independent" (IPCC, 2007, p. 820). The midpoint value for the A1B (medium) scenario is 0.35 m or 35 cm, in good agreement with the MAGICC estimate of 38 cm. The midpoints for the B1 (low) and A2 (high) scenarios are 28 cm and 37 cm, respectively.

**TABLE 4.4-11**

**IPCC Sea Level Rise Estimates for 21st Century Compared to 1990 (IPCC, 2007a)**

| Scenario | Increase from Thermal Expansion (meters) | Increase from glaciers and ice caps, Greenland Ice Sheet; Antarctic Ice Sheet | Total Sea Level Rise (meters) |
|---|---|---|---|
| B1 | 0.10 to 0.24 | 0.04 to 0.18 | 0.18 to 0.38 |
| A1B | 0.13 to 0.32 | 0.04 to 0.20 | 0.21 to 0.48 |
| A2 | 0.14 to 0.35 | 0.04 to 0.20 | 0.23 to 0.51 |

The scaling approach to estimate the impact of changes in sea level rise involved the following steps:

1. Changes in global mean temperature due to the alternative CAFE standards were compared with the difference between the global mean temperature increase from B1 (low) to A1B (medium). These values were taken from Table 4.4-5.

2. The change in sea level between scenarios B1 (low) and A1B (medium) was calculated (the simple difference in cm).

3. The resulting temperature ratios were used to interpolate within the interval of sea level estimates for the B1 (low) and A1B (medium) scenarios, reported by the IPCC.

This approach captures two effects which could overstate the impacts by just scaling the sea level rise by changes in global temperature. The first effect is the current "commitment" (i.e., the inertia in the climate system that would result in climate change even if concentrations did not increase in the future) to global warming, which will occur despite the emission reduction from the CAFE alternatives. The second is the current commitment to sea level rise similar to the current commitment to global warming. By examining the difference between the low (B1) scenario and the mid-level (A1B) scenario, these terms, which will be the same in both scenarios, are eliminated.

The commitment to increases in temperature, precipitation, and sea level rise is described in the IPCC WG1 Fourth Assessment Report (IPCC, 2007), which indicates that if concentrations of GHGs were to stabilize at current levels then an additional warming of 0.5 degree Celsius would occur along with an additional increase of global averaged precipitation would increase 1 to 2 percent, and sea level would rise due to thermal expansion by an additional 0.3 to 0.8 meters by 2300 relative to the 1980 to 1999 period.

Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In this case, the approach seeks to apply some of the results from state-of-the-art models to address the complex issues of climate system commitment and sea level rise commitment. NHTSA believes this approach provides a valid approximation, while recognizing that the recent developments in the science of sea level rise suggest that these estimates may be understated (as noted earlier).

The results are shown below in Table 4.4-12 for scenario A1B (medium). Across the CAFE alternatives, the mean change in the global mean surface temperature, as a ratio of the increase in warming between the B1 (low) to A1B (medium) scenarios, ranges from 1.2 percent to 1.7 percent. The resulting change in sea level rise (compared to the No Action Alternative) ranges across the alternatives from 0.08 cm to 0.11 cm. This compares well, but is less, than the MAGICC results of 0.1-0.2 cm. Thus, despite the fact that MAGICC does not reflect some of the more recent developments in the state-of-the-science, the results are of the same magnitude.

### TABLE 4.4-12

### The Estimated Impact on Sea Level Rise in 2100 From the MY 2011-2015 Standard and Potential MY 2016-2020 CAFE Standard for SRES Scenario A1B; Scaling Approach

| Alternative | Reduction in Equilibrium Warming for the 3.0 $^{o}$C Climate Sensitivity ($^{o}$C) | Reduction in Global Mean Surface Temperature for the 3.0 $^{o}$C Climate Sensitivity ($^{o}$C) | Reduction in Global Mean Warming as Share of B1 - A1B Increase in Warming (%) | Mid Range of Sea Level Rise (cm) |
|---|---|---|---|---|
| No Action | NA | 2.65 | 0.00 | 28.00 |
| 25 Percent Below Optimized | NA | 2.640 | 0.50 | 27.92 |
| Optimized | NA | 2.638 | 0.80 | 27.91 |
| 25 Percent Above Optimized | NA | 2.637 | 0.90 | 27.90 |
| 50 Percent Above Optimized | NA | 2.637 | 0.90 | 27.90 |
| Total Costs Equal Total Benefits | NA | 2.636 | 1.00 | 27.90 |
| Technology Exhaustion | NA | 2.635 | 1.10 | 27.89 |
| **Reduction from CAFE Alternatives** | | | | |
| 25 Percent Below Optimized | 0.015 | 0.010 | 1.2 | 0.08 |
| Optimized | 0.017 | 0.012 | 1.4 | 0.09 |
| 25 Percent Above Optimized | 0.019 | 0.013 | 1.5 | 0.10 |
| 50 Percent Above Optimized | 0.019 | 0.013 | 1.5 | 0.10 |
| Total Costs Equal Total Benefits | 0.020 | 0.014 | 1.6 | 0.10 |
| Technology Exhaustion | 0.022 | 0.015 | 1.7 | 0.11 |

In summary, the impacts of the MY 2011-2020 CAFE alternatives on global mean surface temperature, sea level rise, and precipitation are relatively small in the context of the expected changes associated with the emission trajectories in the SRES scenarios. This is due primarily to the global and multi-sectoral nature of the climate problem. Emissions of $CO_2$, the primary gas driving the climate effects, from the United States automobile and light truck fleet represented about 2.5 percent of total global emissions of $CO_2$ in the year 2000 (EPA, 2008; WRI, 2008). While a significant source, this is a still small percentage of global emissions, and the relative contribution of $CO_2$ emissions from the United States light vehicle fleet is expected to decline in the future, due primarily to rapid growth of emissions from developing economies (which are due in part to growth in global transportation sector emissions). In the SRES A1B (medium) scenario (Nakicenovic et al., 2000), the share of liquid fuel use, mostly petroleum and biofuels, from the Organization for Economic Cooperation and Development (OECD) countries declines from 60 percent in 2000 to 17 percent in 2100.

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# 4.5 RESOURCE IMPACTS OF CLIMATE CHANGE

## 4.5.1 Introduction

The effects of the CAFE alternatives on climate as described in Section 4.4 – $CO_2$ concentrations, temperature, precipitation, and sea level rise – can translate into impacts on key natural and human resources, including freshwater resources; terrestrial ecosystems; coastal systems and low-lying areas; managed ecosystems that produce food, fiber and forest products; industry, settlements, society, and other aspects of the built environment; and human health. This section describes the impacts on each of the resources associated with climate change.

After a discussion of methodology, Section 4.5 is divided into six subsections, one for each of the resource areas. Each subsection discusses the affected environment, provides an overview of the resource globally and in the United States, and addresses the consequences of climate change on that resource. Observed changes are also reported. In each subsection, an attempt has been made to present both positive and negative effects of climate change, as they are represented in the literature. The subsections are:

- Freshwater resources
- Terrestrial ecosystems
- Coastal systems and low-lying areas
- Food, fiber, and forests
- Industry, settlements, and society
- Human health

The subsections generally follow the organization of topic areas in the climate literature, notably by IPCC, which is a key source for much of the information presented in this section, and by USCCSP. These categories do not follow the classification of resources typically found in an EIS. Please refer to the chart in Section 4.1 to find where specific NEPA topics are covered.

As shown in Section 4.4, although the alternatives have the potential to substantially decrease GHG emissions, they do not prevent climate change from occurring, but only result in small reductions in the anticipated increases in $CO_2$ concentrations, temperature, precipitation, and sea level. As discussed below, NHTSA's assumption is that these reductions in climate effects will be reflected in reduced impacts on affected resources. However, the magnitude of the changes in these climate effects that the alternatives produce – a few ppm of $CO_2$, a hundredth of a degree Celsius difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2 mm of sea level – are too small to address quantitatively in terms of their impacts on resources. Given the enormous resource values at stake, these distinctions may be important – very small percentages of huge numbers can still yield substantial results – but they are too small for current quantitative techniques to resolve. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.

## 4.5.2 Methodology

Various reports were reviewed in order to assess the cumulative impacts of the proposed action. The key reports consulted for material include IPCC's Fourth Assessment Report by Working Group II entitled *Climate Change 2007- Impacts, Adaptation and Vulnerability* (IPCC, 2007), and the USCCSP SAP reports. Multiple SAP reports were reviewed such as, *Scientific Assessment of the Effects of Global*

*Climate Change on the United States and SAP reports 4.1-4.7*. More information on the SAP reports can be found at www.climatescience.gov/Library/sap.

The SAP report titles include: SAP 4.1 (*Coastal Elevations and Sensitivity to Sea Level Rise*), SAP 4.2 (*Thresholds of Change in Ecosystems*)*, SAP 4.3 (*The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity)*, SAP 4.4 (*Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources*, SAP 4.5 (*Effects of Climate Change on Energy Production and Use in the United States*), SAP 4.6 (*Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*) and SAP 4.7 (Impacts of Climate Variability and Change on Transportation Systems and Infrastructure -- Gulf Coast Study*). Note that not all of the SAP reports have been finalized; although publicly available and generally in later stages of review and revision, some were still in draft form at the time of the preparation of this document. Researchers also referenced additional studies published since the release of the IPCC and SAP reports.

Research was compiled on the following sectors: freshwater resources; ecosystems and biodiversity; coastal and low lying areas; industry, settlement and society; food, fiber, and forest products; and human health. Each sector provided an introduction to what is included in the section and addressed the impacts and adaptations anticipated for both the United States and global spheres. In order to assess the impacts of climate change on the United States, NHTSA first consulted the SAP reports for their respective sector and then examined more recent materials of relevance such as the Natural Resources Defense Council's (NRDC) *Cost of Climate Change* (May 2008), Union of Concerned Scientists (UCS) *Confronting Climate Change in the U.S. Northeast* (Frumhoff et al., 2007), and the University of Maryland's (UMD) *The US Economic Impacts of Climate Change and the Costs of Inaction* (CIER, 2007). The global impacts sections focused on the IPCC report as it is the most recent, comprehensive, and peer reviewed material on this topic. Articles and studies cited within the IPCC's report were consulted for additional information on various topics.

In order to accurately reflect the likelihood of climate change impacts for each sector, NHTSA referenced the IPCC's uncertainty guidelines. This provides a consistent approach to defining the levels of confidence that a predicted impact will occur and the probability of an outcome or result in terms of percentages. More information on the uncertainty guidelines can be found in the *Treatment of Uncertainties in the IPCC's Working Group II Assessment* in Solomon et al., 2007.

### 4.5.2.1 Cumulative Climate Impacts of Alternative CAFE Standards

As described in Chapter 3, the alternative CAFE options under consideration result in different time streams of $CO_2$ emissions associated with the operation of United States vehicles. These emissions, in combination with United States GHG emissions from other sources (such as power plants, natural gas use, and agricultural production) and with emissions of all GHGs globally, will alter atmospheric concentrations of GHGs. As the modeling results presented in Section 4.4 display, different atmospheric concentrations of GHGs will be associated with long-term changes in global climate variables, including global average temperature, precipitation, and rising sea level. In turn, these climate changes will result in changes to a range of natural and human resources and systems, including water supplies, human health, the built environment, and a host of others.

The most common approach to assessing the impacts of climate change is to construct future scenarios that represent combinations of changes in levels, and sometimes patterns or variability, of temperature, precipitation, sea level rise, and other relevant climatic and related variables (IPCC, WGII, p.31). In some case these scenarios will represent the results of specific climate modeling (i.e., the output of General Circulation Models [GCMs]), often downscaled to provide results at a finer level of geographic resolution). In other cases, scenarios may be designed to be representative of the *types and* *range* of effects that are expected to occur under climate change, and not the results of specific models (Parsons et al., 2007). Impacts associated with these scenarios are then estimated using a variety of techniques, including models of individual systems (e.g., specific ecosystems or geographic areas, such as a park) and examination of performance under similar historical conditions.

The impacts literature suggests that some regions and sectors will experience positive effects of future climate change, particularly at lower levels of temperature change (less than 1 to 3 degrees Celsius above 1990 levels), while others will experience negative effects (Policy Makers Summary, WGII report). Working Group II of AR4 found that, at higher levels of temperature, on balance the net global effects are expected to be negative: "while developing countries are expected to experience larger percentage losses, global mean losses could be 1 to 5 percent gross domestic product (GDP) for 4°C of warming" (WGII report, p. 17). To put these numbers in context, the IPCC has projected longer-term warming (associated with a doubling of $CO_2$ concentrations) in the range of 2 degrees Celsius to 4.5 degrees Celsius (IPCC WGI). The modeling results presented in Section 4.4 suggest that, for the CAFE alternatives, the cumulative climate effects under a moderate emissions scenario lie in the range of 2.7 to 2.8 degrees Celsius as of 2100.

NHTSA's presumption, consistent with the general literature cited above and reviewed for Section 4.5, is that reducing emissions and concomitant climate effects will reduce the net negative long term effects that have been projected for climate change. NHTSA has not, however, conducted a quantitative comparison of the climate impacts of the CAFE alternatives, for several reasons.

First, as indicated above, analyses of impacts often focus on discrete climate scenarios, rather than a continuum of climate outcomes; the information to analyze small changes in climate variables is not, therefore, generally available in the literature. Moreover, as the global climate changes, so will regional and local climates. Changes in global climate variables will be reflected in regional and local changes in average climate variables, as well as in the variability and patterns of climate, such as seasonal and annual variations, the frequency and intensity of extreme events, and other physical changes, such as the timing and amount of snowmelt. Impacts assessments often rely on highly localized data for both climate and other conditions and circumstances (Gamble et al., 2005). Thus, changes in impacts due to changes in global average climate, as projected in this analysis, will likely not be adequately represented by a simple scaling of results. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (s*ee* 40 CFR § 1502.22(b)). Information on the effect of very small changes in temperature, precipitation, and sea level rise (at the scale of the distinctions between the CAFE alternatives) is not currently available. Nevertheless, NHTSA's qualitative characterization – viz. that the greater the reductions in GHG emissions, the lower the environmental impact – is consistent with theoretical approaches and research methods generally accepted in the scientific community.

Second, there is considerable debate about the likely shape of a global climate impacts damage function; although many believe it to be upwardly sloped (so that marginal net damages rise with increasing levels of climate change), there is less agreement on the shape, i.e., how *rapidly* net climate damages rise as temperature and other variables increase (IPCC WGII). There is also the important question of whether thresholds exist, e.g., stress points at which ecosystems collapse, or negative impacts rapidly accelerate—a topic important enough to warrant attention in a SAP on which the U.S. Geological Survey (USGS) is the lead agency. Finally, much of the work on impacts—both globally and more localized—is, in and of itself, qualitative, rather than quantitative, and so does not lend itself to further quantification.

NHTSA's presumption is that reductions in climate effects due to the CAFE alternatives will be reflected in reduced impacts on affected resources. However, the magnitudes of the changes in these climate effects that the alternatives produce – a few ppm of $CO_2$, a hundredth of a degree Celsius difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2 mm of sea level – are too small to address quantitatively in terms of their impacts on resources. Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but rather provides an overview of climate impacts and therefore a qualitative review of the benefits of reducing GHG emissions and the magnitude of the risks involved in climate change.

NHTSA's presumption is that reductions in emissions and, therefore, climate effects will be reflected in reduced impacts on affected resources. However, the magnitudes of the changes in these climate effects that the CAFE alternatives produce are too small to address quantitatively in terms of their impacts on resources. Consequently, as discussed further in Section 4.5.2, the discussion of resource impacts does not distinguish among the CAFE alternatives. Where information in the analysis included in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). Information on the effect of very small changes in temperature, precipitation, and sea level rise (at the scale of the distinctions between the CAFE alternatives) is not currently available. Nevertheless, NHTSA's qualitative characterization – viz., that the greater the reductions in GHG emissions, the lower the environmental impact – is consistent with theoretical approaches and research methods generally accepted in the scientific community.

#### 4.5.2.2 Treatment of Uncertainties in the Working Group I Assessment

Uncertainties can be classified in several different ways. "Value uncertainties" and "structural uncertainties" are two primary types of uncertainties. When data are inaccurate or do not fully represent the phenomenon of interest, value uncertainties arise. These types of uncertainties are usually estimated with statistical techniques, and are 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 giving the authors' collective judgment of their confidence in the correctness of a result." As stated in the Working Group I Assessment, a "careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results" are drawn in the uncertainty guidance provided for the Fourth Assessment Report.

The standard terms used to define levels of confidence are:

| Confidence Terminology | Degree of Confidence in Being Correct |
|---|---|
| Very high confidence | At least 9 out of 10 chance |
| High confidence | About 8 out of 10 chance |
| Medium confidence | About 5 out of 10 chance |
| Low confidence | About 2 out of 10 chance |
| Very low confidence | Less than 1 out of 10 chance |

The standard terms used to define the likelihood of an outcome or result where this can be estimated probabilistically are:

| Likelihood Terminology | Likelihood of the Occurrence/Outcome |
|---|---|
| Virtually certain | >99% probability |
| Extremely likely | >95% probability |
| Very likely | >90% probability |
| Likely | >66% probability |
| More likely than not | >50% probability |
| About as likely as not | 33 to 66% probability |
| Unlikely | <33% probability |
| Very unlikely | <10% probability |
| Extremely unlikely | <5% probability |
| Exceptionally unlikely | <1% probability |

### 4.5.3 Freshwater Resources

This section addresses climate-related impacts on freshwater resources. Water is necessary to support life, societal welfare, and economic activity. "Given water's importance, plant, animal, and human communities are all sensitive to variations in the availability, storage, fluxes, and quality of surface and groundwater. These, in turn, are sensitive to climate change" (USCCSP, 2008, p.145).

#### 4.5.3.1 Affected Environment

This affected environment section was derived from World Water Resources at the Beginning of the 21st Century (Shiklomanov and Rodda, 2003), United Nations Educational, Scientific and Cultural Organization – World Water Assessment Program (UNESCO-WWAP) World Water Development Report 2 (UNESCO et al., 2006), and Pilot Analysis of Global Ecosystems: Freshwater Systems (Revenga et al., 2000).

Water supports all life on Earth. While about 70 percent of the Earth's surface is covered by water, most (97.5 percent) is contained in the oceans. Freshwater refers to the 2.5 percent of the Earth's hydrosphere that is not saline. Freshwater is portioned between glaciers (68.7 percent), groundwater (30.1 percent), permafrost (0.8 percent), and surface and atmospheric water (0.4 percent). This 0.4 percent is portioned between freshwater lakes (67.4 percent) and wetlands (8.5 percent); rivers (1.6 percent); soil moisture (12.2 percent); water in the atmosphere (9.5 percent); and water in living organisms (0.8 percent) (Shiklomanov and Rodda, 2003 in UNESCO et al., 2006).

The largest volume of freshwater is stored in a frozen state in the planet's glaciers and ice sheets, most of which are in Antarctica (almost 90 percent), while the remainder are found in Greenland (almost 10 percent) and in mountain glaciers. Permafrost extends over northeast Europe and the north and northeastern parts of Asia, including the Arctic islands, northern Canada, and the fringes of Greenland and Antarctica, as well as high-altitude areas of South America.

Groundwater is the second largest source of freshwater. Groundwater is found across the world in the pores of soils and fractures of rocks and is the largest source of unfrozen freshwater. Groundwater feeds springs, streams, and lakes, supports wetlands, and is a critical source of water for human consumption. Groundwater also includes aquifers (underground strata of water) bearing permeable rock or unconsolidated materials (e.g., sand, gravel, and some silts and clays) from which water can be extracted using well systems.

Lakes, which can be broadly defined as bodies of water collected in depressions in the Earth's surface, are widespread (there are around 15 million) and store the largest volume of fresh surface waters. Reservoirs, which could be considered a lake, are enclosed areas constructed for the storage of water, and are typically created by damming a river channel in a valley.

Wetlands, such as marshes, swamps, bogs, and estuaries are transitional zones between land and water environments where the soil is frequently or permanently waterlogged. Wetlands of various types exist all over the world, and it is estimated that during the 20th century, half of them were lost as land was converted to agriculture and urban use or filled to combat disease.

Rivers are bodies of flowing water that drain surface runoff from land into the seas and oceans. They begin in higher elevations such as mountains and hills where rainwater and snowmelt collect forming small tributary streams that flow into larger streams and rivers.

Soil moisture is water that drains into the soil, mainly the top two meters, and becomes part of the soil water store, where it is used by plants. Water exists in the atmosphere in the form of water vapor, water drops, and ice crystals, and falls as precipitation, which occurs as rain, snow, sleet, hail, frost, or dew. Biological water is the water contained in living organisms such as plants and animals.

Much of the discussion that follows below is drawn from the following studies and their citations: the IPCC *Freshwater Resources and their Management* (Kundzewicz et al., 2007), the USCCSP *Scientific Assessment of the Effects of Global Change on the United States* (USCCSP, 2008), and *World Water Resources at the Beginning of the 21st Century* (Shiklomanov and Rodda, 2003), *Pilot Analysis of Global Ecosystems: Freshwater Systems* (Revenga et al., 2000), and *Threats to the World's Freshwater Resources* (Gleick et al., 2001).

#### 4.5.3.2 Non-climate Threats to Freshwater Resources

Pressure on global freshwater resources during recent decades has come from non-climatic as well as climatic drivers. The non-climate threats include changes in population, economy, and technology. Population growth and economic development create increasing demands from the industrial, municipal, and agricultural sectors. For example, irrigated agriculture to support the demand for food accounts for nearly 70 percent of global freshwater withdrawals and for more than 90 percent of global consumptive use (Shiklomanov and Rodda, 2003 in Kundzewicz et al., 2007). The extent of irrigated areas, which is expected to expand in areas that are already water-stressed, will determine the effect that this use will have on global water use in the future.

The driving threats to the world's supply of freshwater resources are consistently reported in the literature: population growth and increased demand; infrastructure development (e.g., dams, dikes, levees, and river diversions); poor land use (e.g., urbanization, conversion to crop or grazing lands, wetland removal or reduction, deforestation); overexploitation (e.g., groundwater aquifer depletion and reduced water levels in lakes, rivers, and wetlands); and water pollution from industrial, municipal, and agricultural sources (e.g. phosphorus and nitrogen from fertilizers, pesticides, pathogens and microbial contaminants, heavy metals, toxic organic compounds and micro-organic pollutants; silt and suspended particles; acidification (from air pollution); and thermal pollution (from industrial discharges and slow flows caused by dams and reservoirs).

Shiklomanov and Rodda (2003) state that "Every year human influences grow and cause more and more changes to natural processes…These changes bring about alterations to the water balance and to water resources and their availability. The rapid growth of population, the development of industrial production and the rise of agriculture have resulted in the increased use of water…Human activities have also changed the character of groundwater…more often the water table has been lowered to provide water for drinking…The construction of reservoirs has led to the slowing down of the movement of river waters. Slowing the movement of water can influence its quality particularly by the accumulation of pollutants" (p. 17).

The freshwater resources in the United States are affected by the same non-climate threats discussed above. The USCCSP (2008) found that "most water quality changes observed so far across the continental United States are likely attributable to causes other than climate change" (p. 14). The EPA cites siltation, nutrients, and metals (e.g. mercury) as the main sources of pollution in United States waters, mostly as a result of nonpoint source pollution from urban and agricultural lands (EPA, 2000; EPA, 2002).

Ecosystem integrity, as defined by Gleick et al., (2001), is the interaction between the biological and chemical processes that support the functioning of an ecosystem and the health of the species supported by it. Water withdrawal and consumption by humans is directly connected to the integrity of freshwater ecosystems, because it competes with natural systems for water and leads to pollution, disrupting the natural processes that take place. As a result, the health of habitats, and the species that live in them, is affected. Revenga et al., (2000) found that between 1900 and 1995, world water withdrawals increased six-fold, more than twice the rate of population growth. As water withdrawals increase, more stress will be put on freshwater ecosystems.

#### 4.5.3.3 Consequences

Much of the discussion that follows is drawn from the following studies including the citations therein: IPCC's *Freshwater Resources and their Management* (Kundzewicz et al., 2007), *Scientific Assessment of the Effects of Global Change on the United States* (USCCSP, 2008), and *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* (Lettenmaier et al., 2008). Additional recent studies from peer-reviewed literature are also cited.

Non-climate-related impacts on freshwater resources have received more attention than climate-related impacts to date. However, "climate change is expected to result in increasing effects in the future" (USCCSP, 2008, p. 154). Climate change effects are especially relevant to freshwater resource management for the future. Freshwater resource infrastructure has been designed to accommodate the variability in water supply based on the historical record. This assumption that, on average, the future will be the same as the past is referred to as the stationarity assumption (Lettenmaier et al., 2008 in USCCSP, 2008). However, this assumption is now challenged by the demonstrated occurrence of climate change (Arnell, 2002; Lettenmaier, 2003; and Milly et al., 2008 in USCCSP, 2008). As a result, "the global population is highly vulnerable to climate change impacts on freshwater resources" (USCCSP, 2008, p. 154).

Global warming resulting from the enhanced greenhouse effect causes changes in temperature, precipitation, and ice melt, as well as other climate change effects. Evaporation, transpiration, and the water-holding capacity of the atmosphere all increase at higher temperatures. Increased atmospheric water content favors increased climate variability—more intense droughts and more intense precipitation (Trenberth et al., 2003 in Kundzewicz et al., 2007).

"While temperatures are expected to increase everywhere over land and during all seasons of the year, although by different increments, precipitation is expected to increase globally and in many river basins, but to decrease in many others" (Kundzewicz et al., 2007, p. 176). Precipitation may also increase in one season and decrease in another (Meehl et al., 2007, Section 10.3.2.3 in Kundzewicz et al., 2007). Changes in temperature and precipitation are the main climatic drivers observed to affect freshwater availability, quality, and water use.

#### 4.5.3.3.1 Globally Observed Climate Effects

General climate change impacts on hydrology and freshwater resources identified to date include the following (Arnell et al., 2001in Kundzewicz et al., 2007):

- Changes in streamflow volume—increases and decreases
- Variation in streamflow and groundwater recharge—largely following precipitation
- Shifts in peak streamflow timing—earlier snowmelt
- Lower streamflow in summer and autumn
- Glacier retreat and disappearance of small glaciers
- Water quality degradation—higher water temperatures
- Increases in flood magnitude and frequency

Climate-related trends have already been observed in various inputs, throughputs, and outputs to the freshwater system, including the following (Kundzewicz et al., 2007):

- Precipitation – increasing over northern (30°N) latitudes; decreasing over middle latitudes (10°S to 30°N); increasing in intensity.

- Snow cover – decreasing in most regions

- Glaciers – decreasing almost everywhere

- Permafrost – thawing between 0.08 inch per year (Alaska) and 1.8 inches per year (Tibetan plateau)

- Streamflow – increasing in Eurasian Arctic, significant increases or decreases in some river basins; earlier spring peak flows and increased winter-based flows in North America and Eurasia

- Evapotranspiration – increased actual evapotranspiration in some areas

- Lakes – warming, significant increases and decreases in some lake levels, and reduction in ice cover

For other anticipated changes in the freshwater system, data are insufficient to observe a climate trend, especially when compared to the non-climatic pressures mentioned previously. The absence of an observed trend does not indicate that freshwater resources will not be sensitive to future climate trends. As described in the section on impacts below, changes are also anticipated for groundwater levels, floods, droughts, water quality, erosion and sediment transport, and irrigation water demand (Kundzewicz et al., 2007):

#### 4.5.3.3.2 Observed and Projected Impacts of Climate Change on Freshwater Resources in the United States

Most of the freshwater resource analyses are keyed either to climate scenarios (e.g., what happens if temperature increases by 6°F, and precipitation declines by 10 percent) or to global climate model outputs pegged to IPCC-reported emission scenarios. The projected impacts resulting from such analyses, current sensitivities, and potential vulnerabilities (including extreme events) are summarized in this section, first for the United States and then, in the next section, globally.

The climate change impacts on freshwater resources in the United States are described by the USCCSP (USCCSP, 2008; Backlund et al., 2008), Lettenmaier et al., (2008), and Field et al., (2007).

"In regards to the hydrologic observing systems on which these sections are based, Lettenmaier et al., (2008) found that the current hydrologic observing system was not designed specifically for the purpose of detecting the effects of climate change on water resources. In many cases, the resulting data are unable to meet the predictive challenges of a rapidly changing climate" (USCCSP, 2008, p. 151).

Several recent State and regional studies have examined specific climate change impacts on freshwater resources. For example, many impacts on freshwater resources described above have been predicted for New Mexico (D'Antonio, 2006), New Jersey (EPA, 1997); and the West (Saunders, 2008).

"Projections for the western mountains of the United States suggest that warming, and changes in the form, timing, and amount of precipitation will *very likely* lead to earlier melting and significant reductions in snowpack by the middle of the 21st century" (*high confidence*). "In mountainous snowmelt-dominated watersheds, projections suggest advances in the timing of snowmelt runoff, increases in winter and early spring flows (raising flooding potential), and substantially decreased summer flows. Heavily utilized water systems of the western United States that rely on capturing snowmelt runoff, such as the Columbia River system, will be especially vulnerable" (Field et al., 2007 in USCCSP, 2008, p. 153). Trends in declining snowpack are perhaps best illustrated from studies conducted for California. Reduced snowpack has been identified as a major concern for the State (California Energy Commission, 2006 in USCCSP, 2008). Several authors anticipate a coming crisis in water supply for the western United States (Barnett et al., 2008), and have projected that Lake Mead (on the Colorado River system) might go dry (Barnett and Pierce, 2008). While these studies focus on issues already identified in the literature, their findings suggest that freshwater resources may in fact be more sensitive to climate change than previously projected.

#### 4.5.3.3.3 Precipitation

Precipitation is the primary driver of the land surface hydrological system. Precipitation variability, and subsequent surface water availability varies regionally across the United States depending on a catchment's physical, hydrological, and geological characteristics (USCCSP, 2008). In general, conditions become increasingly dry from east to west. Upslope areas in the Cascade and coastal mountain ranges are more humid with relatively low precipitation variability. The Intermountain West and Southwest are driest, and the greatest precipitation variability is in the arid and semi-arid West (Lettenmaier et al., 2008 in USCCSP, 2008). Stream gauge data (Mauget, 2003 in Lettenmaier et al., 2008) showed increases in streamflow from 1939 through 1998 in the eastern United States and a more or less reverse pattern in the western United States (USCCSP, 2008).

#### 4.5.3.3.4 Surface Water

The observed impacts on surface water (Field et al., 2007 in USCCSP, 2008) include the following:

- Streamflow in the eastern United States has increased 25 percent in the last 60 years (Groisman et al., 2004), but over the last century has decreased by about 2 percent per decade in the central Rocky Mountain region (Rood et al., 2005).

- Since 1950, stream discharge in both the Colorado and Columbia River Basins has decreased, while over the same time period annual evapotranspiration from the conterminous United States increased by 2.2 inches (Walter et al., 2004).

- In regions with winter snow, warming has shifted the magnitude and timing of hydrologic events (Mote et al., 2005; Regonda et al., 2005; Stewart et al., 2005). From 1949 to 2004, the fraction of annual precipitation falling as rain (rather than snow) increased at 74 percent of the weather stations studied in the western mountains of the United States (Knowles et al., 2006).

- Spring and summer snow cover has decreased in the western United States (Groisman et al., 2004). April snow water equivalent has declined 15 to 30 percent since 1950 in the western mountains of North America, particularly at lower elevations and primarily due to warming rather than changes in precipitation (Mote et al., 2003, 2005; Lemke et al., 2007).

- Streamflow peaks in the snowmelt-dominated western mountains of the United States occurred 1 to 4 weeks earlier in 2002 than in 1948 (Stewart et al., 2005).

Lettenmaier et al., (2008) assessed the following potential impacts on surface water in the United States (USCCSP, 2008):

- There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks across much of the western United States. Evidence suggests this trend is *very likely* attributable, at least in part, to long-term warming, although some part may have been played by decadal-scale variability, including a shift in the Pacific decadal oscillation in the late 1970s. Where shifts to earlier snowmelt peaks and reduced summer and fall low flows have already been detected, continuing shifts in this direction are expected and may have substantial impacts on the performance of reservoir systems.

- Recent climate model simulations reported in the IPCC Fourth Assessment Report project increased runoff over the eastern United States, gradually transitioning to little change in the Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior of the West (Colorado and Great Basin). The projected drying in the interior of the West is quite consistent among models. These changes are, very roughly, consistent with observed trends in the second half of the 20th century, which show increased streamflow over much of the United States, but sporadic decreases in the West.

- Snowpacks in the mountainous headwaters regions of the western United States generally declined over the second half of the 20th century, especially at lower elevations and in locations where average winter temperatures are close to or above 0°C. These trends toward reduced winter snow accumulation and earlier spring melt are also reflected in a tendency toward earlier runoff peaks in the spring, a shift that has not occurred in rainfall-dominated watersheds in the same region.

- Climate model projections of increased temperatures and slight precipitation increases indicate that modest streamflow increases are expected in the East, but that larger (in absolute value) declines are expected in the West, where the balance between precipitation and evaporative demand will shift toward increased evaporative demand. However, because of the uncertainty in climate model projections of precipitation change, future projections of streamflow are highly uncertain across most of the United States. One exception is watersheds that are dominated by spring and summer snowmelt, most of which are in the western United States. In these cases, where shifts to earlier snowmelt peaks and reduced summer and fall low flows have already begun to be detected, continuing shifts in this direction are generally expected and may have substantial impacts on the performance of reservoir systems.

#### 4.5.3.3.5 Groundwater

The effects of climate on groundwater—especially groundwater recharge—is an area that requires further research to determine any effects resulting from climate change. The available literature (Vaccaro, 1992; Loaiciga et al., 2000; Hanson and Dettinger, 2005; Scibek and Allen, 2006; and Gurdak et al., 2007 in Lettenmaier et al., 2008) implies that groundwater systems generally respond more slowly to climate change than surface water systems. Groundwater levels correlate most strongly with precipitation. Temperature is a more important factor for shallow aquifers during warm periods (USCCSP, 2008).

Groundwater and surface water may also be affected by sea level rise. Saltwater intrusion into aquifers may occur in coastal areas, and increased salinity of ground and estuary water may reduce freshwater availability.

#### 4.5.3.3.6 Water Quality

Chemical and microbial inputs, biogeochemical processes, water temperature, and water levels control water quality. Water temperature and water quantity are sensitive to climate change. However, pollution from land use—especially agricultural runoff, urban runoff, and thermal pollution from energy production—have caused most of the observed changes in water quality (USCCSP, 2008).

Rising water temperatures negatively affect aquatic biota, especially certain fish species such as salmon (Bartholow, 2005; Crozier and Zabel, 2006 in Lettenmaier et al., 2008). Rising temperatures also affect dissolved oxygen, redox potentials, lake stratification, and mixing rates. However, the direction of climate change effects associated with water quantity on water quality is not as evident. Increased streamflow can dilute pollutant concentrations or transport additional pollutants into surface water sources. Extreme events—floods and droughts—generally exacerbate water quality problems.

Region-specific studies conducted for the United States were reviewed by IPCC (Field et al., 2007; Kundzewicz et al., 2007). Projected impacts on water quality include the following (USCCSP, 2008):

- Changes in precipitation may increase nitrogen loads from rivers in the Chesapeake and Delaware Bay regions by up to 50 percent by 2030 (Kundzewicz et al., 2007).

- Decreases in snow cover and increases in winter rain on bare soil will *likely* lengthen the erosion season and enhance erosion intensity. This will increase the potential for sediment related water quality impacts in agricultural areas (Field et al., 2007).

- Increased precipitation amounts and intensities will lead to greater rates of erosion in the United States and in other regions unless protection measures are taken (Kundzewicz et al., 2007). Soil management practices (e.g., crop residue, no-till) in some regions (e.g., the Corn Belt) may not provide sufficient erosion protection against future intense precipitation and associated runoff (Field et al., 2007).

- For the Midwest, in simulated low flows used to develop pollutant discharge limits (Total Maximum Daily Loads) flows decrease over 60 percent with a 25 percent decrease in mean precipitation, declining by 100 percent with the incorporation of irrigation demands (Eheart et al., 1999).

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

- Based on simulations, phosphorus remediation targets for the Bay of Quinte (Lake Ontario) and the surrounding watershed could be compromised as 5.4 to 7.2 degrees Fahrenheit warmer water temperatures contribute to 77 to 98 percent increases in summer phosphorus concentrations in the bay (Nicholls, 1999), and as changes in precipitation, streamflow, and erosion lead to increases in average phosphorus concentrations in streams of 25 to 35 percent (Walker, 2001).

Kundzewicz et al., (2007) also concluded (*high confidence*) that climate change is *likely* to make it more difficult to achieve existing water quality goals for North America (USCCSP, 2008).

#### 4.5.3.3.7 Extreme Events—Floods and Drought

Extreme events such as floods and drought affect the freshwater resources sector. Climatic phenomena—intense/long-lasting precipitation, snowmelt, ice jams—and non-climatic phenomena—dam failure, landslides—can exacerbate floods and/or drought.

As previously mentioned, research to date has not provided clear evidence for a climate-related trend in floods during the last decades. However, there is suggestive evidence that floods may have been affected by the observed increase in precipitation intensity and other observed climate changes (USCCSP, 2008, p. 152).

Since the intensity and mean amount of precipitation will increase across the United States at middle and high latitudes, the risk of flash flooding and urban flooding will increase in these areas (Kundzewicz et al., 2007 in USCCSP, 2008). At the same time, greater temporal variability in precipitation increases the risk of drought (Christensen et al., 2007 in USCCSP, 2008).

There is some evidence of long-term drying and increase in drought severity and duration in the West and Southwest (USCCSP, 2008) that is probably a result of decadal-scale climate variability and long-term change (Lettenmaier et al., 2008 in USCCSP, 2008).

Over-allocation and continuing competition for freshwater resources for agriculture, cities, and industry increases vulnerability to extended drought in North America (Field et al., 2007) despite the fact that per capita water consumption has declined over the past two decades in the United States (Lettenmaier et al., 2008). Reducing water consumption will mitigate the impacts of climate change on freshwater resources.

#### 4.5.3.4 Projected Impacts of Climate Change on Global Fresh Water Resources

The IPCC report is the most recent, comprehensive, and peer reviewed summary of impacts on global freshwater resources that is available. Kundzewicz et al., (2007) summarized the conclusions from the freshwater resources and management chapter as follows:

- The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level, and precipitation variability (*very high confidence*).

- More than one-sixth of the world's population live in glacier- or snowmelt-fed river basins and will be affected by the seasonal shift in streamflow, an increase in the ratio of winter to annual flows, and possibly the reduction in low flows caused by decreased glacier extent or snow water storage (*high confidence*).

- Sea-level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas (*very high confidence*).

- Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas (*high confidence*).

- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (*high confidence*).

- Many of these areas (e.g., Mediterranean basin, western United States, southern Africa, and northeastern Brazil) will suffer a decrease in water resources due to climate change (*very high confidence*).

- Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed regions (*high confidence*), where vulnerability is often exacerbated by the rapid increase in population and water demand (*very high confidence*).

- Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability, and operating costs (*high confidence*).

- These pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt, and thermal pollution.

- Climate change affects the function and operation of existing water infrastructure as well as water management practices (*very high confidence*).

- Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land use change, and urbanization (*very high confidence*).

- Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence; regionally, large changes in irrigation water demand as a result of climate change are *likely* (*high confidence*).

- Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems (*very high confidence*).

- Improved incorporation of current climate variability into water-related management would make adaptation to future climate change easier (*very high confidence*).

- Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g., Caribbean, Canada, Australia, Netherlands, United Kingdom, United States, and Germany) that have recognized projected hydrological changes with related uncertainties (*very high confidence*).

- Since the IPCC Third Assessment, uncertainties have been evaluated, their interpretation has improved, and new methods (e.g., ensemble-based approaches) are being developed for their characterization (*very high confidence*).

- Nevertheless, quantitative projections of changes in precipitation, river flows, and water levels at the river-basin scale remain uncertain (*very high confidence*).

- The negative impacts of climate change on freshwater systems outweigh its benefits (*high confidence*).

- All IPCC regions (see Chapters 3–16 of the IPCC report) show an overall net negative impact of climate change on water resources and freshwater ecosystems (*high confidence*).

- Areas in which runoff is projected to decline are *likely* to face a reduction in the value of the services provided by water resources (*very high confidence*).

- The beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (*high confidence*).

Observed global climate-related trends affecting freshwater resources were identified previously. The following discussion identifies key projected impacts on surface waters, groundwater, extreme events, and water quality.

#### 4.5.3.4.1 Surface Water

Data from 24 climate model runs generated by 12 different general circulation models (Milly et al., 2005 in Kundzewicz et al., 2007) generally agreed that by 2050:

- Annual average river runoff and water availability will increase by 10 to 40 percent at high latitudes [North America, Eurasia] and in some wet tropical areas,

- Annual average river runoff and water availability will decrease by 10 to 30 percent over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas [Mediterranean, southern Africa, and western United States/northern Mexico].

Hydrological impact studies have shown that warming leads to changes in the seasonality of river flows where much winter precipitation currently falls as snow, including the European Alps, the Himalayas, western North America, central North America, eastern North America, the Russian territory, Scandinavia, and Baltic regions. Winter flows will increase, summer flows will decrease, and peak flow will occur at least one month earlier in many cases (Kundzewicz et al., 2007).

Higher temperatures increase glacier melt. Glacier melt sustains many rivers during the summer in the Hindu Kush Himalaya and the South American Andes (Singh and Kumar, 1997; Mark and Seltzer, 2003; Singh, 2003; and Barnett et al., 2005 in Kundzewicz et al., 2007). The mass of some northern hemisphere glaciers is projected to decrease up to 60 percent by 2050 (Schneeberger et al., 2003 in Kundzewicz et al., 2007).

Predictions for rain-fed basins describe higher flows in peak flow season with either lower flows in low flow season or extended dry periods (Kundzewicz et al., 2007).

Lake levels are determined by river and rain water inputs and evaporation outputs. By the end of the 21st century, water levels are predicted to change between −4.5 feet and +1.15 feet in the Great Lakes (Lofgren et al., 2002; and Schwartz et al., 2004 in Kundzewicz et al., 2007) and to drop about 29.5 feet in the Caspian Sea (Elguindi and Giorgi, 2006 in Kundzewicz et al., 2007).

In 2010 to 2015, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it did from 1950 to 1979. The maximum ice cover is also expected to be 20 to 40 percent thinner (Vuglinsky and Gronskaya, 2005 in Kundzewicz et al., 2007).

Annual runoff may be affected by a combination of land use changes and climate change. Land use changes are predicted by model studies to have a small effect compared to climate change in the Rhine basin, southeast Michigan, Pennsylvania, and central Ethiopia. In southeast Australia and southern India, predictions are comparable, with climate change having the potential to exacerbate reductions in runoff caused by afforestation (Kundzewicz et al., 2007).

Evapotranspiration—water loss from plant leaves—responds to increases in carbon dioxide in two distinct ways. First, higher $CO_2$ concentrations cause leaf stomata to close, reducing evapotranspiration. On the other hand, $CO_2$ fertilization encourages plant growth, increasing total leaf area and subsequent evapotranspiration. Considering these vegetation effects, global mean runoff has been predicted to increase by 5 percent for a doubling of $CO_2$ concentration (Betts et al., 2007; and Leipprand and Gerten, 2006 in Kundzewicz et al., 2007) compared to a 5 to 17 percent increase under climate change alone (Kundzewicz et al., 2007).

#### 4.5.3.4.2 Groundwater

Climate change will mainly affect groundwater recharge rates, although there has been very little research on the issue. Groundwater levels may change as a result of thawing permafrost, vegetation changes, changes in river level (where there is adequate hydraulic connection), and changes in floods. Global hydrological models predict that globally averaged groundwater recharge will increase less (2 percent) than total runoff (9 percent) in the 2050s compared to recharge and runoff rates from 1961 to 1990. In northeastern Brazil, southwest Africa, and the southern Mediterranean coast groundwater recharge is predicted to decrease by more than 70 percent. In contrast, recharge is predicted to increase by more than 30 percent in the Sahel, Near East, northern China, Siberia, and the western United States (Döll and Flörke, 2005 in Kundzewicz et al., 2007). Projected impacts on individual aquifers return very site-specific results.

Any decrease in groundwater recharge will exacerbate the effect of saltwater intrusion. Saltwater intrusion has been projected for a sea level rise of 0.33 feet on two coral islands off the Indian coast—the thickness of the freshwater lens decreasing from 82 feet to 32 feet and from 118 feet to 92 feet (Bobba et al., 2000 in Kundzewicz et al., 2007). Saltwater intrusion from sea level rise may also affect groundwater/aquifer water supplies on similar small islands.

#### 4.5.3.4.3 Extreme Events—Floods and Droughts

As discussed earlier, increased climate variability increases the risks of both floods and droughts depending on climatic and non-climatic variables. Extreme floods and extreme droughts are predicted to become more frequent in the future under various climate models (Kundzewicz et al., 2007). However, climate change impacts on flood magnitude and frequency can be both positive and negative depending on the global climate model used, snowmelt contributions, catchment characteristics, and location (Reynard et al., 2004 in Kundzewicz et al., 2007).

By the 2090s, the proportion of the total land surface in extreme drought is predicted to increase from the current rate of 1 to 3 percent to 30 percent; extreme drought events per 100 years are predicted to double; and mean drought duration is predicted to increase by a factor of six (Burke et al., 2006 in Kundzewicz et al., 2007).

More floods are predicted for northern and northeastern Europe, while more drought is predicted for southern and southeastern Europe (Lehner et al., 2005 in Kundzewicz et al., 2007).

The area flooded in Bangladesh is projected to increase by 23 to 29 percent for a global temperature rise of 3.6°F (Mirza, 2003 in Kundzewicz et al., 2007). Up to 20 percent of the world's population lives in river basins at risk from increased flooding (Kleinen and Petschel-Held, 2007 in Kundzewicz et al., 2007).

#### 4.5.3.4.4 Water Quality

Higher water temperatures and runoff variations are *likely* to affect water quality negatively (Patz, 2001; Lehman, 2002; O'Reilly et al., 2003; and Hurd et al., 2004 in Kundzewicz et al., 2007). Negative impacts on water quality from changes in water quantity include resuspension of bottom sediments, increased turbidity (i.e., suspended solids), pollutant introduction, and reduced dilution. Negative impacts from water temperature include algal blooms, increased microbial concentrations, and out-gassing of volatile and semi-volatile compounds like ammonia, mercury, dioxins, and pesticides (Kundzewicz et al., 2007).

Acidic atmospheric deposition is projected to increase acidification in rivers and lakes (Ferrier and Edwards, 2002; Gilvear et al., 2002; and Soulsby et al., 2002 in Kundzewicz et al., 2007).

Salt concentration is expected to increase in estuaries and inland reaches under decreasing streamflows. For example, salinity is projected to increase in the tributary rivers above irrigation areas in Australia's Murray-Darling Basin by 13 to 19 percent by 2050 and by 21 to 72 percent by 2100 (Kundzewicz et al., 2007).

No quantitative studies projecting the impact of climate change on microbiological water quality for developing countries are cited by the IPCC. However, climate change will be an additional stressor affecting water quality and public health. Potential impacts include increased waterborne disease with increases in extreme rainfall, and great incidence of diarrheal and water-related diseases in regions with increased drought (Kundzewicz et al., 2007). A brief overview of the effects of climate change on the availability and quality of drinking water is provided by Anderson et al. (2005).

Developed countries are also experiencing water quality issues in their water and wastewater treatment plants. Increased filtration is required in drinking water plants to address micro-organism outbreaks following intense rain, thus increasing some operating costs by 20 to 30 percent (AWWA, 2006 in Kundzewicz et al., 2007). Other stressors on water quality include the following (Kundzewicz et al., 2007):

- More water impoundments for hydropower (Kennish, 2002; Environment Canada, 2004).
- Stormwater drainage operation and sewage disposal disturbances in coastal areas resulting from sea level rise (Haines et al., 2000).
- Increasing water withdrawals from low-quality sources.
- Greater pollutant loads resulting from increased infiltration rates to aquifers or higher runoff to surface waters (resulting from high precipitation).
- Water infrastructure malfunctioning during floods (GEO-LAC, 2003; DFID, 2004).
- Overloading the capacity of water and wastewater treatment plants during extreme rainfall (Environment Canada, 2001).
- Increased amounts of polluted storm water.

In many regions, there is no alternative supply even as water quality declines, and reusing wastewater (i.e., to irrigate crops) can introduce other public health problems.

Global adaptation to freshwater resource stressors will require the availability of relevant information, more water resource options (e.g., storage), and proactive responses in the face of climatic changes. These responses will include effluent disposal strategies accounting for reduced biodegradation; water and wastewater treatment plant design accounting for extreme climate conditions; and reducing, reusing and recycling water (Luketina and Bender, 2002; Environment Canada, 2004; and Patrinos and Bamzai, 2005 in Kundzewicz et al., 2007).

### 4.5.4 Terrestrial Ecosystems

This section addresses climate-related impacts on terrestrial ecosystems. An ecosystem is defined as a complex of biological communities (plants, animals, and microorganisms) and their non-living environments, which act together as a unit (MA, 2005, and Reid, et al., 2005, in Fischlin, et al., 2007). By definition, relationships within an ecosystem are strong while relationships with components outside the ecosystem boundaries are weak (Reid, et al., 2005, part 2, in Fischlin, et al., 2007).

#### 4.5.4.1 Affected Environment

Earth’s biosphere is an interconnected network of individuals, populations, and interacting natural systems, referred to as ecosystems. Ecosystems are critical, in part, because they supply humans with services that sustain life and are beneficial to the functioning of society (Fischlin, et al., 2007). Ecosystems include:

- terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra;
- aquatic communities, such as rivers, coral reefs, lakes, and estuaries; and
- wetlands, such as marshes, swamps, and bogs (Noss, et al., 1995).

The focus of this section is on terrestrial ecosystems.

### 4.5.4.1.1 Global Terrestrial Ecosystems

The World Wildlife Fund (WWF) has developed a widely accepted global ecosystem classification that consists of what are referred to as ecozones, biomes, and ecoregions. Similar to the classification of Miklos Udvary's (1975) biogeographical realm, the ecozone is the biogeographic division of the earth's surface at the largest scale. Terrestrial ecozones follow the floral and faunal boundaries that separate the world's major plant and animal communities. The WWF has identified eight ecozones, as indicated in Figure 4.5-1.

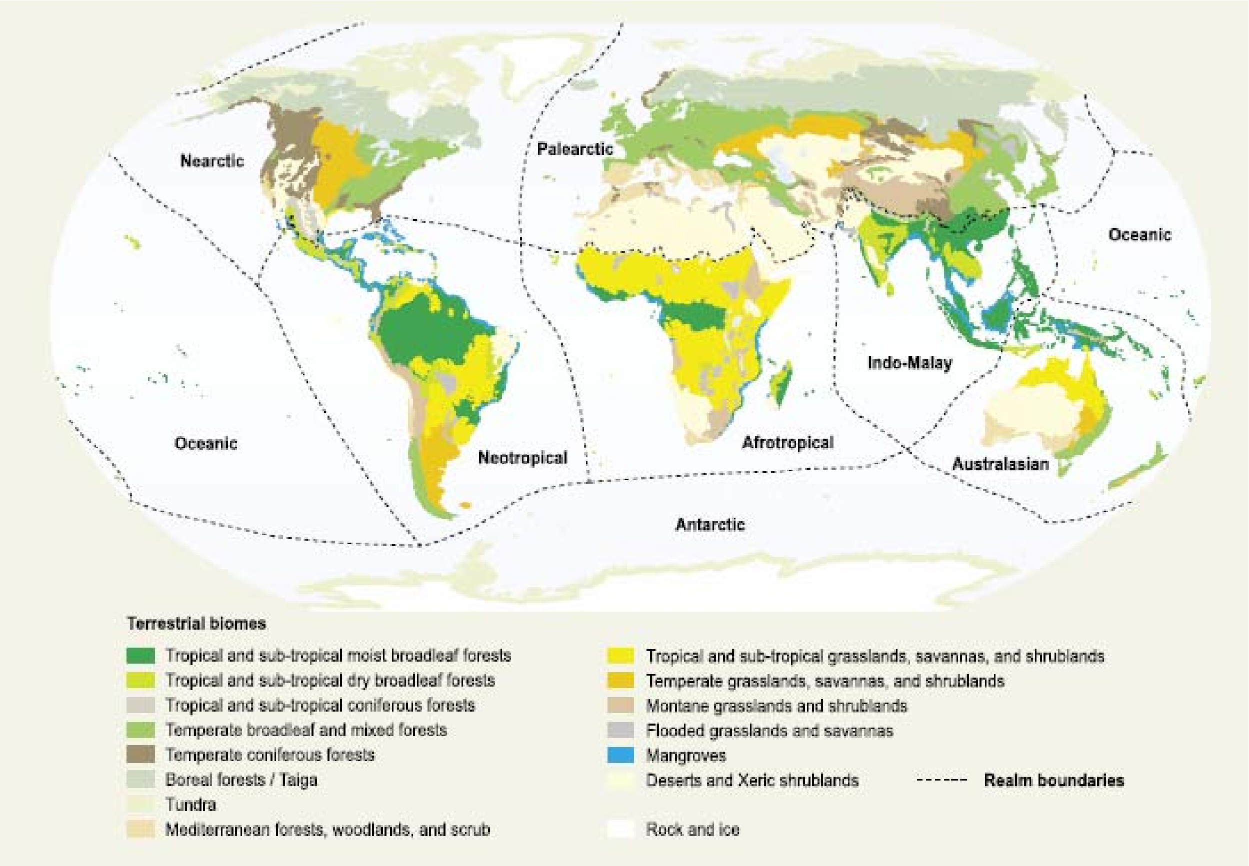

**Figure 4.5-1 Ecozones and Biomes of the World (source: MA, 2005)**

Biomes are climatically and geographically defined areas of ecologically-similar communities of plants, animals, and microorganisms. These habitat types are defined by factors such as plant structures, leaf types, plant spacing, and climate. The land classification system developed by WWF identifies 14 major terrestrial habitat types, which can be further divided into 825 smaller, more distinct terrestrial ecoregions (WWF, 2008a). The primary terrestrial habitats recognized by WWF are:

**Tundra** is a treeless polar desert found at high latitudes in the polar regions, primarily in Alaska, Canada, Russia, Greenland, Iceland, and Scandinavia, as well as sub-Antarctic islands. These regions are characterized by long, dry winters, months of total darkness, and extremely frigid temperatures. The vegetation is composed of dwarf shrubs, sedges and grasses, mosses, and lichens. A wide variety of animals thrive in the tundra, including herbivorous and carnivorous mammals and migratory birds (Chapin et al., 2005).

**Boreal Forests and Taiga** are forests found at northerly latitudes in inland Alaska, Canada, Sweden, Finland, Norway, and Russia, as well as parts of the extreme northern continental United States, northern Kazakhstan, and Japan. Annual temperatures are low and precipitation ranges from 15 to 40 inches per year and may fall mainly as snow. Vegetation includes coniferous and deciduous trees, lichens, and mosses. Herbivorous mammals and small rodents are the predominant animal species; however, predatory birds and mammals also occupy this habitat type.

**Temperate coniferous forests** are found predominantly in areas with warm summers and cool winters. Plant life varies greatly across temperate coniferous forests. In some forests, needleleaf trees dominate, while others consist of broadleaf evergreen trees or a mix of both tree types. Typically, there are two vegetation layers in a temperate coniferous forest: an understory dominated by grasses and shrubs, and an overstory of large tree species.

**Temperate broadleaf and mixed forests** experience a wide range of variability in temperature and precipitation. In regions where rainfall is distributed throughout the year, deciduous trees mix with evergreens. Species such as oak, beech, birch, and maple typify the tree composition of this habitat type. Diversity is high for plants, invertebrates, and small vertebrates.

**Mediterranean forests, woodlands, and shrub** ecoregions are characterized by hot and dry summers, while winters tend to be cool and moist. Most precipitation arrives during winter. Only five regions in the world experience these conditions: the Mediterranean, south-central and southwestern Australia, the fynbos of southern Africa, the Chilean matorral, and the Mediterranean ecoregions of California. These regions support a tremendous diversity of habitats and species.

**Tropical and subtropical coniferous forests** are found predominantly in North and Central America and experience low levels of precipitation and moderate variability in temperature. These forests are characterized by diverse species of conifers, whose needles are adapted to deal with the variable climate conditions. These forests are wintering ground for a variety of migratory birds and butterflies.

**Tropical and subtropical moist broadleaf forests** are generally found in large, discontinuous patches centered on the equatorial belt and between the Tropics of Cancer and Capricorn. They are characterized by low variability in annual temperature and high levels of rainfall. Forest composition is dominated by semi-evergreen and evergreen deciduous tree species. These forests are home to more species than any other terrestrial ecosystem. A square kilometer may support more than 1,000 tree species. Invertebrate diversity is extremely high, and dominant vertebrates include primates, snakes, large cats, amphibians, and deer.

**Tropical and subtropical dry broadleaf forests** are found in southern Mexico, southeastern Africa, the Lesser Sundas, central India, Indochina, Madagascar, New Caledonia, eastern Bolivia, central Brazil, the Caribbean, valleys of the northern Andes, and along the coasts of Ecuador and Peru. Deciduous trees predominate in most of these forests and they are home to a wide variety of wildlife, including monkeys, large cats, parrots, various rodents, and ground-dwelling birds.

**Temperate grasslands, savannas, and shrublands** are known as prairies in North America, pampas in South America, veld in southern Africa and steppe in Asia. They differ from tropical grasslands in species composition and the annual temperature regime under which they thrive. These regions are devoid of trees, except for riparian or gallery forests associated with streams and rivers. Biodiversity in these habitats includes a number of large grazing mammals and associated predators, burrowing mammals, numerous bird species, and a diversity of insects.

**Tropical and subtropical grasslands, savannas, and shrublands** are found in the large expanses of land in the tropics that do not receive enough rainfall to support extensive tree cover. However, there may be great variability in soil moisture throughout the year. Grasses dominate the species composition of these ecoregions, although scattered trees may be common. Large mammals that have evolved to take advantage of the ample forage typify the biodiversity associated with these habitats.

**Montane grasslands and shrublands** include high elevation grasslands and shrublands such as the puna and paramo in South America, subalpine heath in New Guinea and East Africa, steppes of the Tibetan plateaus, and other similar subalpine habitats around the world. Montane grasslands and shrublands are tropical, subtropical, and temperate. Mountain ecosystem services such as water purification and climate regulation extend beyond the geographical boundaries of the grasslands and shrublands and affect all continental mainlands (Woodwell, 2004). Characteristic plants of these habitats display features such as rosette structures, waxy surfaces, and abundant pilosity (WWF, 2008b).

**Deserts and xeric shrublands** across the world vary greatly with respect to precipitation and temperature. Generally, rainfall is less than 10 inches annually and evaporation exceeds precipitation. Temperature variability is also extremely diverse in these remarkable lands. Many deserts, such as the Sahara, are hot year-round but others, such as Asia's Gobi, become quite cold in winter. Woody-stemmed shrubs and plants evolved to minimize water loss characterize vegetation in these regions. Animal species are equally well-adapted to the dry conditions, and species are quite diverse.

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

**Flooded grasslands and savannas** are common to four continents. These vast areas support numerous plants and animals adapted to the unique hydrologic regimes and soil conditions. Large congregations of migratory and resident waterbirds may be found in these regions. Ecosystem services include breeding habitat and buffering inland areas from the effects of wave action and storms (MA 2005).

#### 4.5.4.1.2 Terrestrial Ecosystems in the United States

Published in 1976, *Ecoregions of the United States* was one of the first attempts to divide the nation into ecosystem regions systematically. Subsequently, Bailey (1980) provided, for each region, a brief description of the dominant physical and biological characteristics based on land-surface form, climate, vegetation, soils, and fauna. Bailey defined four major domains, 12 divisions, and 30 provinces. Since then, the ecoregions of North America have been further refined by the international working group of the Commission of Environmental Cooperation (CEC, 1997). Their system divides the continent into 15 broad level I ecoregions, 52 level II ecoregions and approximately 200 level III ecoregions. The level I ecoregions present in the United States include tundra, taiga, northern forests, northwestern forested mountains, marine west coast forests, eastern temperate forests, great plains, North American deserts, Mediterranean California, southern semi-arid highlands, temperate sierras, and tropical humid forests (Figure 4.5-2).

Ecosystems are dynamic and may change naturally over time as a result of drivers such as climate change (natural or anthropogenic), geological processes (volcanic eruptions, earthquakes, landslides), fire, disease or pest outbreaks, and evolution. All organisms modify their environment to some extent; however, in the last century and especially in the last 50 years, human population growth and technological innovations have affected ecosystems drastically (Vitousek et al., 1997). In fact, the structure of the world's ecosystems have changed more rapidly in the second half of the 20th century than in any time in recorded human history (MA, 2005). It is expected that during the course of this century, the resilience of many ecosystems is likely to be exceeded by anthropogenic pressures (Fischlin et al., 2007).

#### 4.5.4.1.3 Non-Climate Threats to Global Terrestrial Ecosystems

The Millennium Ecosystems Assessment (MA), a United Nations research project, focuses on identifying the current inventory and conditions of 10 categories of global ecosystems (including five categories of natural terrestrial ecosystems) and projecting changes and trends into the future.

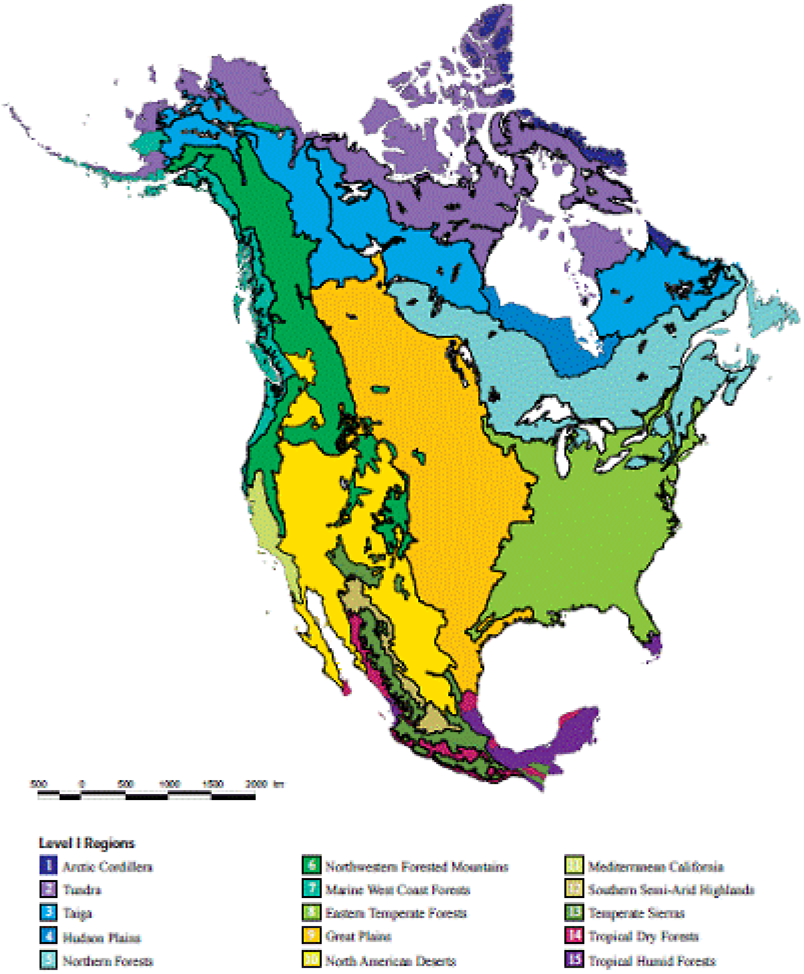

**Figure 4.5-2 Level I Ecoregions in the North America (source: CEC, 1997)**

In 2005, the MA released five technical volumes and six synthesis reports, providing a scientific appraisal of the condition and trends in the world's ecosystems and the services they provide. From 2001 to 2005, the MA involved the work of more than 1,360 experts worldwide. The MA included the following conclusions regarding the current state of global ecosystems (MA, 2005):

- Cultivated systems now cover one quarter of Earth's terrestrial surface. More than two thirds of the area of two of the world's 14 major terrestrial biomes and more than half of the area of four other biomes had been converted by 1990, primarily to agriculture.
- Across a range of taxonomic groups, for most species, either the population size or range or both is currently declining.
- The distribution of species on Earth is becoming more homogenous; in other words, the set of species in any one region of the world is becoming more similar to the set in other regions primarily as a result of introductions of species, both intentionally and inadvertently in association with increased travel and shipping.
- The number of species on the planet is declining. Over the past few hundred years, humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the Earth's history. Some 10 to 30 percent of mammal, bird, and amphibian species are currently threatened with extinction.
- Only four of the 24 ecosystem services examined in this assessment have been enhanced, while 15 have been degraded (Hassan, 2005).

The MA concluded that biodiversity changes due to human activities were more rapid in the past 50 years than at any time in human history. Moreover, the forces causing biodiversity loss and leading to changes in ecosystem services are either steady, show no evidence of declining over time, or are increasing in intensity. The MA examined four plausible future scenarios and projected that the rates of biodiversity change will continue or accelerate (MA, 2005). In one specific example, the United States Fish and Wildlife Service has indicated that the threats to certain endangered species such as the Yosemite toad in Sierra Nevada include disease, cattle grazing, timber harvesting, and climate change (FWS, 2006).

The changes in ecosystems identified in the MA can have impacts on ecological processes, species composition, and genetic diversity. Ecological processes, which include water, nitrogen, carbon, and phosphorous cycling, have all changed more rapidly in the second half of the 20th century than at any time in recorded human history (MA, 2005). Human actions have not only changed the structure of ecosystems, but the processes as functions of the ecosystems as well.

A change in ecosystem structure also affects the species within the system and vice versa. Historically, the natural processes of evolution and the combination of natural barriers to species migration and local adaptation resulted in significant phenotypic differences in plant and animal species of different ecosystems. These regional differences are now becoming rare.

Some ecosystem changes have been the inadvertent result of activities unrelated to the use of ecosystem services, such as the construction of roads, ports, and cities and the discharge of pollutants. But most ecosystem changes were the direct or indirect result of changes made to meet growing demands for food, water, timber, fiber, and fuel (MA, 2005). Ecosystems change can be affected by a variety of human and natural drivers, including climate change, land use, land degradation, urbanization, pollution, natural climate change, geological processes, and invasive species. These drivers can act independently or in concert with each other (Lepers et al., 2004), and are summarized below.

### Land Use Change

Land use change represents the anthropogenic replacement of one land use type by another, e.g., forest converted to cultivated land (or the reverse), as well as subtle changes of management practices within a given land use type, e.g., intensification of agricultural practices. Both forms of land use change are affecting 40 percent of the terrestrial surface (Foley et al., 2005). Land use change can lead to habitat loss and fragmentation and is an important driver in ecosystem change (Heywood and Watson, 1995; Fahrig, 2003). Overall, land transformation represents the primary driving force in the loss of biological diversity (Vitousek et al., 1997). In nine of the 14 terrestrial biomes studied by the MA, over one half of the area has been transformed, largely by agricultural cultivation (Hassan, 2005). Only the biomes that are less suitable for agriculture, such as deserts, boreal forests, and tundra, have remained largely untransformed by human activity.

Virtually all of Earth's ecosystems have now been significantly transformed through human actions (MA, 2005). Roughly 70 percent of original temperate grasslands and forests and Mediterranean forests were lost by 1950, chiefly from conversion to agricultural lands. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (MA, 2005a; Hassan, 2005).

Historically, terrestrial ecosystems that have been most significantly altered by human activity include temperate broadleaf forests, temperate grasslands, Mediterranean forests, and tropical dry forests (Hassan, 2005). Of these, more than two thirds of the temperate grasslands and Mediterranean forests, and more than half of tropical dry forests, temperate broadleaf forests, and tropical grasslands have been converted to agriculture (Hassan, 2005). Forest systems in general have been reduced by half over the past three centuries, and have effectively disappeared in 25 countries. Another 29 countries have lost 90 percent or more of their forest cover (Hassan, 2005).

Globally, the rate of ecosystem conversion has begun to decelerate, mainly because the rate of expansion of cultivated land has declined. Ecosystems are beginning to return to conditions and species compositions similar to their pre-conversion states. However, rates of ecosystem conversion remain high or are increasing for specific ecosystems and ecoregions (MA, 2005). Land use changes and land degradation are significant drivers of ecosystem change globally and in the United States. For example, between1982 and 1997, 11 million acres of nonfederal grasslands and shrublands were converted to other uses (SNE, 2002).

The increase in cultivated land, especially for the purpose of grazing, has led to an increase in desertification. Desertification involves the expansion of deserts into semi-arid and subhumid regions, and the loss of productivity in arid zones. Desertification is characterized by loss of groundcover and soils, replacement of palatable, mesophytic grasses by unpalatable xerophytic shrubs, or both (Ryan et al., 2008). Desertification affects the livelihoods of millions of people, including a large portion of the poor residents of drylands (Hassan, 2005). While desertification can certainly be exacerbated by changes in climate, there has been long-standing controversy over the relative contributions of climatic and anthropogenic factors as drivers of desertification (National Science and Technology Council, 2008).

### Fire

Fire influences ecosystem structure by promoting species that tolerate fire or even enhance fire spread, resulting in a relationship between the relative flammability of a species and its relative abundance in a particular community (Bond and Keeley, 2005). Intensified and increasing wildfire occurrences appear to be changing vegetation structure and composition in some ecoregions. In the forest-tundra transition in eastern Canada, this transition is observed in a shift from Picea- to Pinus-dominated communities and 75 to 95 percent reductions in tree densities (Lavoie and Sirois, 1998). Across the boreal forests of North America, total burned areas increased by a factor of 2.5 between the 1960s and the 1990s (Kasischke and Turetsky, 2006).

#### Insect Outbreaks

Invasive alien species represent a major threat to endemic or native biodiversity in terrestrial and aquatic systems. Alien species invasions also interact with other drivers, sometimes resulting in unexpected outcomes. The impact of insect damage is significant and can exceed the impacts of fire in some ecosystems, but especially in boreal forests (Logan et al., 2003). For example, spruce budworm defoliated over 20 times the area burned in eastern Ontario between 1941 and 1996 (Fleming et al., 2002). Fires tended to occur 3 to 9 years after a spruce budworm outbreak (Fleming et al., 2002), suggesting that insect outbreaks can be a driver of increased fire events. Forest impacts by the forest tent caterpillar have also increased in western Canada over the past 25 years (Timoney, 2003).

#### Species Decline and Extinction

Although extinction is a natural part of Earth's history, observed modern rates of extinction are not part of natural cycles. Over the past few hundred years, humans have increased the extinction rate by as much as 1,000 times over the rate expected based on natural history (Hassan, 2005). A decrease in global genetic diversity is linked to extinction. The loss of unique populations has resulted in the loss of genetic diversity. The loss of genetic diversity has also declined among cultivated species as farmers have shifted from locally adapted crop populations to more widely adapted varieties produced through formal breeding practices. Currently, for most species across a wide range of taxonomic groups, either the population size, population range, or both is in decline (MA, 2005).

#### Pollution

Pollution is another significant threat to terrestrial ecosystems. Over the past four decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine systems. A significant cause is the use of increasing amounts of synthetic nitrogen and phosphorous fertilizers, which may be lost to the environment after application. Consumption of nitrogen fertilizer grew nearly 800 percent between 1960 and 2003 (MA, 2005). In terrestrial ecosystems, excessive nitrogen flows contribute to acidification. Nitrogen also plays a role in ground-level ozone, which can lead to a loss of forest productivity (MA, 2005).

### 4.5.4.2 Consequences

This section discusses current climate change impacts that have already been observed and projected impacts (including the potential for adaptation to climate changes). Climate change impacts are discussed generally, and with specific attention to impacts in the United States. The IPCC WKGI Fourth Assessment Report (Fischlin et al., 2007) was released in 2007, and in 2008 the USCCSP report on climate sensitive ecosystems was released (USCCSP, 2008). The 2007 IPCC report is the most comprehensive, recent summary of projected impacts of global climate change. Many of the impacts discussed in this section were gathered from the 2007 IPCC report, which provides an analysis and discussion on a global scale. Information about impacts specific to ecosystems in the United States was obtained primarily from the 2008 USCCSP report. The projected impacts reported below were forecast with varying degrees of certainty. The level of certainty, as defined by IPCC, is noted in this report where relevant.

#### 4.5.4.2.1 Observed Climate Change Impacts

Because terrestrial ecosystems are defined by the interactions of biotic (plants, animals, and microorganisms) and abiotic factors (geology, hydrology, weather), climate is a key factor in determining the different characteristics and distributions of natural systems.

##### Observed Impacts on Terrestrial Ecosystems Globally

Studies have noted the response of biological and chemical characteristics of ecosystems to climate conditions, especially temperature change. Substantial research has examined the effects of climate change on vegetation and wildlife, leading to the conclusion that the changing climate is already having a real and demonstrable effect on a variety of ecosystem types (Janetos et al., 2008). As noted in the IPCC report, plants and animals can reproduce, grow, and survive only within specific ranges of climate and environmental conditions (Fischlin et al., 2008). Changes in climate can affect terrestrial ecosystems in the following ways (Rosenzweig et al., 2007):

- shifting the timing of life cycle events such as blooming or migration;
- shifting range boundaries or densities of individuals within their ranges;
- changing species morphology (body size, egg size), reproduction, or genetics; or
- causing extirpation or extinction.

These changes are a result of many factors. Phenology – the timing of seasonal activities of animals and plants – is perhaps the simplest process by which to track changes in the ecology of species in response to climate change (Rosenzweig et al., 2007). Observed phenological events include leaf unfolding, flowering, fruit ripening, leaf coloring, leaf fall of plants, bird migration, chorusing of amphibians, and appearance or emergence of butterflies. Global daily satellite data, available since 1981, indicate an earlier onset of spring by 10 to 14 days over 19 years, particularly across temperate latitudes of the northern hemisphere (Zhou et al., 2001; Lucht et al., 2002). Leaf unfolding and flowering in spring and summer have, on average, advanced by 1 to 3 days per decade in Europe, North America, and Japan over the last 30 to 50 years (Fischlin et al., 2007). The seasonal timing of bird migration and egg laying has also changed, associated with the increase of temperature in breeding grounds and migration routes. Many small mammals have been observed to come out of hibernation and to breed earlier in the spring than they did a decade ago (Inouye et al., 2000; Franken and Hik, 2004) and even larger mammals such as reindeer are showing phenological changes (Post and Forchhammer, 2002), as are butterflies, crickets, aphids, and hoverflies (Forister and Shapiro, 2003; Stefanescu et al., 2003; Hickling et al., 2005; Newman, 2005). Increasing regional temperatures are also associated with earlier calling and mating and shorter time to maturity of amphibians (Gibbs and Breisch, 2001; Reading, 2003; Tryjanowski et al., 2003).

Rapid global warming can directly affect the size of a species' range, the density of individuals within the range, and the abundance of preferred habitat within the range. Climate changes have affected the location of suitable habitat for several species of plants and animals. Changes in the distribution of species have occurred across a wide range of taxonomic groups and geographical locations (Rosenzweig et al., 2007). Several different bird species no longer migrate out of Europe in the winter as the temperature continues to warm (Rosenzweig et al., 2007). Over the past decades, a poleward extension of various species has been observed, which is probably attributable to increases in temperature (Parmesan and Yohe, 2003). Many Arctic and tundra communities are affected and have been replaced by trees and dwarf shrubs (Kullman, 2002; ACIA, 2005). In several northern hemisphere mountain systems, tree lines have markedly shifted to higher elevations during the 20th century, including those of Alaska (Sturm et al., 2001).

Decreases in the size of a species' range, the density of individuals within the range, and the abundance of its preferred habitat factors can lower species population size (Wilson et al., 2004) and increases the risk of extinction. Examples of declines in populations and subsequent extinction or extirpation are found in amphibians around the world (Alexander and Eischeid, 2001; Middleton et al., 2001; Ron et al., 2003; Burrowes et al., 2004).

Changes in morphology and reproduction rates have been attributed to climate change. For example, the egg sizes of many bird species are changing with increasing regional temperatures (Jarvinen, 1994, 1996; Tryjanowski et al., 2004). Studies from eastern Poland, Asia, Europe, and Japan have found that various birds and mammals exhibit trends toward larger body size with regionally increasing temperatures, probably due to increasing food availability (Nowakowski, 2002; Yom-Tov, 2003; Kanuscak et al., 2004; Yom-Tov and Yom-Tov, 2004). Many northern insects have a 2-year life cycle, and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. The mountain pine beetle has expanded its range in British Columbia into areas previously considered too cold (Carroll et al., 2003).

### Observed Changes on Terrestrial Ecosystems in the United States

Changes and impacts on United States ecosystems are similar to those occurring globally. During the 20th century, the United States already began to experience the effects of climate change. Precipitation over the contiguous United States increased 6.1 percent over long-term averages (USCCSP, 2008) while a sea level rise of 0.06 to 0.12 inch per year has occurred at most of the country's coastlines; the Gulf coast has experienced an even greater rise in sea level at a rate of 0.2 to 0.4 inch per year (USCCSP, 2008).

Examples of observed changes to terrestrial ecosystems in the United States attributable to anthropogenic climate change include the following:

- Many plant species are expanding leaves or flowering earlier - e.g., earlier flowering in lilac: 1.8 days per decade (Schwartz and Reiter, 2000), honeysuckle: 3.8 days per decade (Cayan et al., 2001), earlier leaf expansion in apple and grape: 2 days per decade (Wolfe et al., 2005), and trembling aspen: 2.6 days per decade (Wolfe et al., 2005).

- Warmer springs have led to earlier nesting for 28 migrating bird species on the east coast of the United States (Butler, 2003) and to earlier egg laying for Mexican jays (Brown et al., 1999) and tree swallows (Dunn and Winkler, 1999).

- Several frog species now initiate breeding calls 10 to 13 days earlier than a century ago (Gibbs and Breisch, 2001).

- In lowland California, 70 percent of 23 butterfly species advanced the date of first spring flights by an average of 24 days over 31 years (Forister and Shapiro, 2003).

- Many North American plant and animal species have shifted their ranges, typically to the north or to higher elevations (Parmesan and Yohe, 2003).

- Edith's checkerspot butterfly has become locally extinct in the southern, low-elevation portion of its western North American range but has extended its range 56 miles north and

394 feet higher in elevation (Parmesan, 1996; Crozier, 2003; Parmesan and Galbraith, 2004). Edith's checkerspot butterfly is important to the survival of its grassland and rocky outcrop habitat, and also provides essential ecosystem services because the adult butterflies pollinate various flowers (Scott, 1986 in Kayanickupuram, 2002).

- The frequency of large forest fires and the length of the fire season in the western United States have increased substantially since 1985. These phenomena are related to the advances in the timing of spring snowmelt and increases in spring and summer air temperatures (Westerling et al., 2006).
- In the Great Basin region, the onset of snow runoff is currently 10 to 15 days earlier than it was 50 years ago (Cayan et al., 2001).
- The vegetation growing season has increased on average by about 2 days per decade since 1948, with the largest increase happening in the west (Easterling, 2002; Feng and Hu, 2004).
- Recently, spruce budworm in Alaska has completed its lifecycle in 1 year, rather than the previous 2 years (Volney and Fleming, 2000). This allows many more individuals to survive the overwintering period with impacts on the boreal forests of North America.
- Over the past three to five decades, all the major continental mountain chains exhibited upward shifts in the height of the freezing level (Diaz et al., 2003).
- Populations of the American pika, a mountain-dwelling relative of the rabbit, are in decline (Beever et al., 2003). The pika may be the first North American mammal to become extinct as a result of anthropogenic climate change.
- Reproductive success in polar bears has declined as a result of melting Arctic Sea ice. Without ice, polar bears cannot hunt seals, their favorite prey (Derocher et al., 2004). On May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species, reflecting the loss of sea ice habitat that once encompassed over 90 percent of the polar bear's habitat range (FR 73:95,; May 15, 2009).

#### 4.5.4.2.2 Projected Impacts of Climate Change in the United States

The United States is projected to experience changes in average temperature and precipitation over the 21st century of an even greater magnitude than those experienced in the 20th century. Although the entire country is projected to experience some degree of change, particular regions of the United States could experience changes of a greater-than-average magnitude. For example, the greatest changes in temperature are projected for Alaska and the western continental United States (USCCSP, 2008). In northern Alaska, the average temperatures are projected to increase 5°C by the end of the 21st century. Areas near coasts are projected to witness an increase of approximately 2°C over the same period; summer temperatures nationwide could increase 3 to 5°C; and winter temperatures are projected to increase 7 to 10°C (USCCSP, 2008).

Additional expected changes in United States climate include:

- more frequent hot days and hot nights (USCCSP, 2008);

- heavier precipitation events, primarily in the form of rain rather than snow (USCCSP, 2008). Annual precipitation in the northeastern United States is projected to increase while precipitation in the Southwest is expected to decrease (Christensen et al., 2007); and

- a decline in spring snow cover, leading to decreased availability of water in reservoirs (USCCSP, 2008).

Ecosystems across the United States are projected to experience both positive and negative impacts from climate change over the next century. The degree of impacts will vary by region. Wildlife species have already responded to climate change and its effects on migration patterns, reproduction, and geographic ranges (Field et al., 2007 in National Science and Technology Council, 2008). Future, more substantial changes in climate are projected to affect many ecosystem services negatively (USCCSP, 2008). The Working Group II of IPCC has projected, with a high level of confidence, "that recent regional changes in temperature have had discernible impacts on many physical and biological systems" (National Science and Technology Council, 2008, p. 103).

The IPCC has determined that areas of the United States that experience temperature increases of 1.5 to 2.5 degrees Celsius are at highest risk for modifications to ecosystem structure and composition (IPCC, 2007 in USCCSP, 2008). Over the next century, it is projected that species could move northward and to higher elevations (Field et al., 2007 in National Science and Technology Council, 2008). In one example of possible future threats to ecosystem vegetation, the upward move in elevation of species as the snow and tree line advances suggests that alpine ecosystems could be endangered by the introduction of invasive species (National Science and Technology Council, 2008).

Rather than experiencing impacts of climate change directly, most animals could experience the effects of climate change indirectly via changes to their habitat, food sources, and predators (Schneider and Root, 1996 in National Science and Technology Council, 2008). A changing climate facilitates migration of certain species into non-native habitats, potentially affecting current goods and services (USCCSP, 2008).

Animals in ecosystems in the United States are projected to experience a variety of climate change impacts. For example:

- Changes in hydrology as a result of changes in precipitation patterns could interrupt the breeding cycles of amphibians, which depend on the ability to migrate to breeding ponds. The production of their eggs is also highly dependent on temperature and moisture availability (Fischlin et al., 2007 as cited in National Science and Technology Council, 2008).

- Changes in climate that occur over at least several years are likely to affect the reproductive success of migratory birds, as well as their ability to survive. A mismatch in timing between the migration and reproduction periods and peak food availability is the potential pathway for such impacts (Stenseth and Mysterud, 2002; Visser et al., 2004, 2006; Visser and Both, 2005 in National Science and Technology Council, 2008).

- The migration of butterflies is highly dependent on spring temperatures and anthropogenic climate change is likely to lead to earlier spring arrivals. As with migratory birds, an earlier butterfly migration may result in a mismatch with food supply, thus threatening reproduction and survival (Forister and Shapiro, 2003 in National Science and Technology Council, 2008).

- Shifts in migration ranges could result in disease entering new areas; e.g., avian malaria in Hawaii could move upslope as climate changes (USCCSP, 2008).

In one prominent example of mammals experiencing the effects of a warming climate, the polar bear is specifically adapted to conditions in a narrow ecological slot (an environment with cold temperatures and access to snow, ice, and open water), and spends much of its time on the frozen sea (Gunderson, 2008). As the climate warms and sea ice melts, the polar bear loses much of its natural habitat. If current trends in sea ice loss continue, the polar bear could become extirpated from most of their range within 100 years (IUCN, 2008). Polar bears were listed as threatened under the Endangered Species Act on May 15, 2008 due to the ongoing and projected loss of their sea-ice habitat from global warming (FR 73: 95; May 15, 2009, p 28212-28303).

The vegetation of terrestrial ecosystems in the United States is projected to experience a variety of direct impacts from climate change. For example, national forests, which harbor much of the United States' biodiversity, and national grasslands are expected to experience an exacerbation of pre-existing stressors, such as wildfires, invasive species, extreme weather events, and air pollution (USCCSP, 2008).

Warmer, dryer climates weaken trees' resistance to insect infestation, as they are more likely to be wilted and weakened under those conditions. In a healthy state, trees can typically fight off beetle infestation by drowning them with resin as they bore through the bark. Drought reduces the flow of resin and beetles that are able to penetrate the bark introduce decay-causing fungus. This problem has already been documented. Since 1994, winter mortality of beetle larvae in Wyoming has been cut due to mild winters (from 80 percent to less than 10 percent mortality). As a result, the beetles have been able to strip 4 million acres of forests (Egan, 2002 in Center for Health & the Global Environment, 2005). In the southwestern United States, high temperatures, drought, and the piñon ips bark beetle have had the cumulative effect of causing a mass die-back of piñon trees. From 2002-2003 alone, piñon mortality in Mesa Verde National Park in Colorado, and Bandelier National Monument in New Mexico exceeded 90 percent. Researchers determined that climate factors drove the die-off (Rocky Mountain Climate Organization, 2008). The United States Forest Service indicates that, by 2012, almost all of the mature lodgepole trees in northern Colorado and southern Wyoming will have been killed by bark beetles. This will affect watersheds, timber production, and wildlife habitats, along with other human activities (USFS website, accessed June 20, 2008).

Additional impacts on vegetation in ecosystems in the United States could include the following:

- Water management in the west would be complicated by increases in temperatures and changes in precipitation patterns, which lead to reduced snow pack, earlier snowmelt, and modified hydrology (USCCSP, 2008).

- High latitudes would experience increased vegetation productivity. Regions in the mid-latitudes would experience either increased or decreased productivity, depending on whether the primary impact is more precipitation or higher temperatures (increasing evaporation and dryness) (Bachelet et al., 2001; Berthelot et al., 2002; Gerber et al., 2004; Woodward and Lomas, 2004 in National Science and Technology Council, 2008).

- Ecosystems in the east would be statistically "likely to become carbon sources, while those in the west would be likely to remain carbon sinks" (Bachelet et al., 2004 in National Science and Technology Council, 2008).

- The jet stream would move northward with increasing atmospheric temperatures. The consequence of this shift is a drying of the southeast. Closed-canopy forest ecosystems could be converted to savanna ecosystems, woodlands, or grasslands, significantly increasing the threat of fire occurrence (USCCSP, 2008).

- Growing seasons would lengthen, according to several predictive models; this would beneficially act to sustain carbon sinks (Cox et al., 2000; Berthelot et al., 2002; Fung et al., 2005 in National Science and Technology Council, 2008).

- In the Olympic Range, a temperature increase of 2°C would move tree species upwards 0.20 to 0.38 mile. Temperate species would replace subalpine species over 300 to 500 years (Zolbrod and Peterson, 1999).

### Adaptation to Climate Change by Terrestrial Ecosystems

The ability or inability of ecosystems to adapt to change is referred to as adaptive capacity. There may be notable regional differences in the adaptive capacity of ecosystems, and adaptive capacity is moderated by anthropogenic influences and capabilities. The ultimate impact of climate change on ecosystems depends on the speed and extent to which these systems can adapt to a changing climate. Adaptation occurs naturally in a biological system to varying degrees, but it can also be a planned human response to anticipated challenges (USCCSP, 2008). Ecosystem managers could "proactively alter the context in which ecosystems develop… they can improve the resilience, i.e., the coping capacity, of ecosystems. Such ecosystem management involves anticipatory adaptation options" (Fischlin et al., 2007, p. 246).

Because the effectiveness of specific adaptation strategies is uncertain, a "no regrets" path consisting of practical adaptation options that account for current, known stressors along with the more uncertain future stressors (USCCSP, 2008) is typically sought by ecosystem managers. For example, invasive species pose a known threat to many ecosystems. Future climate change is likely to exacerbate this stressor, so an adaptation strategy to tackle current invasive species problems could also address projected impacts of more serious, future invasive species challenges (USCCSP, 2008). Another example of dual-purpose adaptation strategies lies with the construction of riparian buffer strips. These not only reduce agricultural runoff into freshwater systems, but also establish protective barriers against potential increases in both pollution and sediment loadings due to climate change in the future (USCCSP, 2008).

#### 4.5.4.2.3 Projected Impacts of Climate Change on Global Terrestrial Ecosystems

The IPCC concludes (*very high confidence*) that anthropogenic temperature rises have visibly altered ecosystems (Parry et al., 2007). The exact impacts of climate changes are difficult to discern, however, as they are mediated by other stressors and the capabilities of natural systems to adapt to changing climates to some degree (Parry et al., 2007).

Some regions of the world are more vulnerable to changes in climate than others. Regions of snow, ice, and tundra have been visibly altered by changes in global temperature. Observations of frozen regions already show larger glacial lakes and the destabilization of glacial debris that dam these lakes; changes in ecosystems at both poles; and increased melting of ice sheets, glaciers, and ice caps (Parry et al., 2007).

Ecosystems in all regions of the world are expected to respond to climate changes impacts with:

- poleward and upward shifts of plants and animals;
- earlier onset of migration of terrestrial species such as birds and butterflies; and
- localized disappearance of particular species (Parry et al., 2007).

Additional factors, such as projected growth in human populations, are expected to exacerbate the effects of climate change. For example, river basin ecosystems that are already experiencing high levels of stress are projected, with *medium confidence*, to witness growth in human populations from approximately 1.4 to 1.6 billion in 1995 to roughly 4.3 to 6.9 billion by 2050 (Parry et al., 2007). River basins experience the stress of increasing human populations as manifested in increasing demands for water, (USCCSP, 2008b) and more inputs of pollutants. A warmer, dryer climate could increase these stressors and reduce access to other water sources (USCCSP, 2008b).

Other projected global impacts of climate change include the following:

- The hardiness of the world's ecosystems is expected (*high confidence*) to be challenged over the 21st century with "an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, and ocean acidification), and other global change drivers (especially land use, pollution, and over-exploitation of resources) (Fischlin et al., 2007, p. 213).
- Carbon dioxide ($CO_2$) levels are projected to be much higher than any in the past 650,000 years, and temperatures are projected to be as high as any in the last 740,000 years. Both increases are very likely to impact ecosystems (*very likely*) (Fischlin et al., 2007).
- Global average temperature increases in excess of 1.5 to 2.5°C are statistically likely to threaten 20 to 30 percent of plant and animal species with extinction (Fischlin et al., 2007 in National Science and Technology Council, 2008).
- Carbon uptake by ecosystems such as forests and grasslands is statistically likely to peak during the 21st century and might ultimately even reverse (forests and grasslands would emit carbon, rather than taking it in), which would amplify climate change due to increased atmospheric $CO_2$ (Fischlin et al., 2007 in National Science and Technology Council, 2008).

In addition to other anthropogenic stressors, "such as extractive use of goods, and increasing fragmentation and degradation of natural habitats" (Bush et al., 2004 in Fischlin et al., 2007, p. 215), climate change poses a threat to the wellbeing of ecosystems. Although many ecosystems have been resilient to historical changes in climate, it is not clear whether their resilience is enough to withstand the more rapid and profound changes that are projected given the buildup of GHGs in the atmosphere (Chapin et al., 2004; Jump and Peñuelas, 2005 in Fischlin et al., 2007). Predicted climate change and other anthropogenic stressors are "virtually certain to be unprecedented" (Forster et al., 2007 in Fischlin et al., 2007, p. 215). While some of the impacts expected with climate change serve to exacerbate existing stressors on ecosystems, other expected impacts could be altogether new. For example, increasing temperatures could cause some current sinks for GHGs, such as forest vegetation, to actually become sources for these gases (including $CO_2$ and methane) (Fischlin et al., 2007).

Effects of anthropogenic climate change on ecosystems are anticipated at different levels of severity and over varying time scales (decades to centuries) (Lischke et al., 2002 in Fischlin et al., 2007). Some of the broad impacts on ecosystems associated with climate change are expected to include species extinctions, loss of habitat due to more severe tropical storms (Wiley and Wunderle, 1994 in Fischlin et al., 2007), changes in the types and abundance of vegetation present in an ecosystem (Schröter et al., 2005; Metzger et al., 2006 in Fischlin et al., 2007), and increased susceptibility of land to desertification (Burke et al., 2006 in Fischlin et al., 2007).

Foreseeable pathways of climate change-induced impacts on ecosystems include the following:

- $CO_2$ fertilization effects on vegetation (Baker et al., 2004; Lewis et al., 2004b; Malhi and Phillips, 2004 in Fischlin et al., 2007);

- higher atmospheric temperatures that could lead to more frequent insect and disease outbreaks (USCCSP, 2008); and

- increased radiation due to a projected decrease in tropical cloud cover (Nemani et al., 2003 in Fischlin et al., 2007). This is linked to warming, which can directly affect ecosystems, and increase the frequency and severity of storms originating in the tropics.

### 4.5.5 Coastal Systems and Low-lying Areas

This section addresses climate-related impacts on coastal ecosystems. Coastal zones are unique environments where land and water meet. There is no single definition for coastal zones, but what is certain is that all coastal zones include an area of land and an area that is covered by saltwater. Burke et al., (2001, p. 11f) defines coastal zones as the "intertidal and subtidal areas on and above the continental shelf (to a depth of about 650 feet)—areas routinely inundated by saltwater—and immediately adjacent lands."

#### 4.5.5.1 Affected Environment

Important ecosystems found in coastal zones can include estuaries, coral reefs, coastal lagoons, mangroves, seagrass meadows, upwelling areas, salt marshes, beaches, bays, deltas, kelp forests and barrier islands. A variety of terminology exists describing coastal zone ecosystems. Table 4.5-1 lists some of the more commonly described ecosystems found in coastal zones.

**TABLE 4.5-1**

**Common Coastal Ecosystem**

| Coastal Ecosystem | Description |
|---|---|
| Coastal Wetlands | The broadest definition of wetlands occurring along coastal zones. They include a number of natural communities that share the unique combination of aquatic, semi-aquatic, and terrestrial habitats that results from periodic flooding by tidal waters, rainfall, or runoff.[a] |
| Sandy Shorelines | Sandy areas along coastlines where high-energy wave actions deposit and move around sand and sediment. |
| Barrier Islands | Long narrow islands running parallel to the mainland that provide protection to the coast. |
| Tidal Wetlands | A type of coastal wetland that is affected by both tides and freshwater runoff. |
| Estuaries | Bodies of water and their surrounding coastal habitats typically found where rivers meet the ocean. |
| Mangroves | Coastal wetlands found in tropical and subtropical regions typically characterized by shrubs and trees with an affinity to saline tidal waters. |
| Tidal Salt Marshes | A type of coastal wetland frequently or continually inundated with water, characterized by soft-stemmed vegetation adapted to saturated soil conditions.[b] |
| Coral Reefs | A large underwater calcium carbonate formation that includes a diverse collection of biological communities. |
| Coastal Deltas | Typically a triangular deposit of silt and sand deposited at the mouth of a river along a coast. |

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a/ California Environmental Resources Evaluation Systems, 2000

b/ EPA, 2006

The world's coastal length is estimated to be 1,015,756 miles, with North America having the longest coastal length of all continents (Pruett and Cimino, 2000). Canada has the longest coastal length of any country in the world and the United States has the second longest, at 164,988 miles and 82,836 miles, respectively (Pruett and Cimino, 2000).

Coastal zones are areas of significant biological productivity that provide food, shelter, spawning grounds and nurseries for fish, shellfish, birds, and other wildlife. The interaction between aquatic and terrestrial components of coastal ecosystems creates a unique environment that is critical to the life cycles of many plant and animal species. In the United States, 85 percent of commercially harvested fish depend on estuaries and coastal waters at some state in their life cycle (Summers et al., 2004), while as much as 95 percent of the world's marine fish harvest are caught or reared in coastal waters (Sherman, 1993). Most historical information available on coastal ecosystems focuses on data related to fisheries. As more research is conducted on other increasingly important coastal ecosystems, new data and information are becoming available. For example, coral reefs alone, while representing only 0.2 percent of the total area of oceans, harbor more than 25 percent of all known marine fish (Bryant et al., 1998). In addition, some coral reefs can reach densities of 1,000 species per square meter (Tibbets, 2004). In the United States, 85 percent of the country's essential nesting, feeding, and breeding habitat for waterfowl and migratory birds is found in coastal ecosystems (Summers et al., 2004). Coastal zones have also been found to support a much higher percentage of the world's threatened and endangered species.

Because a disproportionate percentage of the world's population lives in coastal zones, the activities of humans have created environmental pressures that threaten the very resources that make the coastal zones desirable (Summers et al., 2004). The impact of these activities varies from place to place and depends on the types and sensitivity of coastal ecosystems involved. A wide range of pressures have been identified as causing adverse changes in coastal ecosystems, but the leading causes of coastal ecosystem degradation include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species (UNESCO and WWAP, 2006). In addition, climate change may compound these pressures through the effects of higher sea levels, warmer seawater, altered ocean circulation patterns, increased and extreme storm events, and increased carbon dioxide concentrations (UNESCO and WWAP, 2006; Burke et al., 2001).

#### 4.5.5.1.1 Coastal Conditions Globally and in the United States

The conditions of coastal ecosystems vary from place to place and depend on many factors. Attempts have been made to assess the global extent and distribution of aquatic habitats, but estimates vary considerably depending on the type and source of data (UNESCO and WWAP, 2006). While inventories of coastal zones exist, there are no high-quality data sets or indicators at the global level that track changes in condition over time (UNESCO and WWAP, 2006). Despite the lack of high-quality data, it is safe to assume that coastal zones with significant human populations are vulnerable to a range of human activities that can increase pressure and cause adverse changes to coastal ecosystems. As mentioned above, typical coastal ecosystem degradation would include physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-native species. The effects of sea level rise from climate change could compound these potential impacts.

The current overall coastal condition of the United States is considered fair by the EPA (Summers et al., 2004). Six geographic coastal regions (Great Lakes Coastal Area, Northeast Coastal Area, Southeast Coastal Area, Gulf Coast Coastal Area, West Coastal Area and Alaska, Hawaii, and Island Territories) were evaluated by the EPA using five ecological health indicators to assess estuarine coastal conditions as good, fair, or poor. The five indicators include water quality, sediment quality, benthic, coastal habitat, and fish tissue contaminants. Of the five indicators, only the coastal habitat index received an overall poor rating. The benthic and sediment quality indices rated fair to poor, while the water quality and fish tissue contaminants indices received fair ratings. Of the six coastal regions, the Southeast Coastal Area ranked highest with all indicators rating fair to good. The region with the worst coastal condition was the Northeast Coastal Area, with four of the five indicators rating poor or fair to poor. In terms of human and/or aquatic life use, 21 percent of the assessed coastal resources of the country are considered unimpaired (good condition), whereas 35 percent are impaired (poor condition) and 44 percent threatened (fair condition).

#### 4.5.5.1.2 Observed Trends in Coastal Zones Conditions

Impacts to coastal ecosystems are expected to continue as coastal populations increase and demand more coastal space and resources. Many coastal ecosystems around the globe have been significantly degraded, and many have been lost altogether. It is difficult to quantify the changes in coastal ecosystems because historical data describing the previous extent of coastal ecosystems is very limited. There is a need for more and higher-quality data characterizing the world's coastal zones. Burke et al., (2001) found the following trends in the conditions of coastal ecosystems:

- Many coastal habitats are disappearing at a fast pace, with extensive losses occurring in the last 50 years.
- Although some industrial countries have improved coastal water quality, chemical pollutant discharges are increasing overall as agriculture intensifies and new synthetic compounds are developed.
- Pollution filtering capacities are lost as coastal ecosystems are lost.
- Nutrient inputs to coastal waters appear to be increasing because of population increase and agricultural intensification.
- The frequency of harmful algal blooms resulting in mass mortality of marine organisms has increased significantly over the past few decades.
- Increased occurrences of hypoxia (shortage of oxygen in water) have been reported.
- More than 25 different coral reef diseases have been recorded since 1970, and reports of coral bleaching have increased significantly in recent years.
- Many commercial fish species and other marine wildlife have become threatened.
- Large-scale marine oil spills have been declining, but oil discharges from land-based sources are believed to be increasing.
- An increased number of invasive species is being reported throughout the world coastal ecosystems.
- There has been an increase in the number of protected marine and coastal areas, indicating greater awareness of the need to protect these environments.
- Global marine fish production has increased six fold since 1950.
- The capacity of coastal ecosystems to produce fish for human harvest has been highly degraded by overfishing, destructive trawling techniques, and loss of coastal nursery areas.
- Notable ecosystem changes have occurred over the last half-century in some fishery areas, such as the North Atlantic and Northeast Pacific.

There are a number of marine wildlife species that have been or may be adversely affected by environmental changes in temperature, availability of water and nutrients, runoff from land, wind patterns, and storminess that are associated with climate change (Kennedy et al., 2002). Marshes and mangroves are particularly susceptible to sea level rise affecting the feeding or nesting grounds of Black Rail, Clapper Rail, some terns and plovers (Kennedy et al., 2002). Over the short term, however, shrimp, menhaden, dabbling ducks and some shorebirds would benefit from the release of nutrients from the breakup of marshes (Kennedy et al., 2002). The southern sea otter, a keystone species, is listed as threatened by the Endangered Species Act where the population has declined as a result of the increased contaminants associated with high runoff produced by El Niño Southern Oscillation (ENSO)-induced Pacific Ocean storms (Environmental and Energy Study Institute, 2001). Marine turtles are affected by unusual changes in high/low temperatures, pollutants, infectious agents, and marine biotoxins, and have become threatened by an epidemic of fibropapollomatosis linked to polluted coastal areas, agricultural runoff, and biotoxins from algae (Environmental and Energy Study Institute, 2001). The full effect of marine birds and species inhaling or ingesting biotoxins produced by algal blooms is of concern and not fully understood (Environmental and Energy Study Institute, 2001).

There is strong evidence that temperature increases caused a rise in the global sea level during the 20th century (IPCC, 2007). Since each coastal area has its own unique geographic and environmental characteristics, consequences from adaptations to climate change are expected to differ for each community. Areas of critical sensitivity on the global scale include the major cities of Tokyo, Shanghai, and London, and the countries of Thailand, India, and Vietnam (USCCSP, 2008a quoting IPCC). These areas all share the characteristics of a coastal location, low elevation, large population, and currently stressed resources. Because of their proximity to the water's edge and the high level of infrastructure typical of many coastal communities, these urban centers are sensitive to changes in sea level rise (USCCSP, 2008a).

Recent data suggest that the rise in global sea level has had an effect on some coastal zones of the United States. Sea level data has shown a rise of 0.8 to 1.2 inches per decade since the beginning of the 20th century along most of the Atlantic and Gulf Coasts in the United States (USCCSP, 2008a). The majority of the Atlantic Ocean demonstrated a sea level rise over the past decade at a rate greater than 0.1 inch per year in an east-northeast band from the United States east coast (USCCSP, 2008a). Coastal wetland loss is occurring where these ecosystems are squeezed between natural and artificial landward boundaries and rising sea levels (Field et al., 2007 as cited in USCCSP, 2008a). Rises in sea levels may be contributing to coastal erosion across the eastern United States (USCCSP, 2008a). Sea level rise in the Chesapeake Bay has accelerated erosion rates resulting in wetland destruction (USCCSP, 2008a). In Mississippi and Texas, more than half of the shorelines have eroded at average rates of 8.5 to 10.2 feet per year since the 1970s, while 90 percent of the Louisiana shoreline has eroded at a rate of 39.4 feet per year (Nicholls et al., as cited in USCCSP, 2008a). Areas in Louisiana are experiencing barrier island erosion resulting in an increased height of waves (USCCSP, 2008a). Furthermore, regional sea level rise has contributed to increase storm surge impacts along the North American Eastern Coast (USCCSP, 2008a). Particularly since subsidence is occurring in parts of this area, areas such as the Louisiana and Gulf coasts are considered at high risk from erosion and storm surges, and any area along the coast with low elevations, large populations, and currently stressed resources could be expected to be at risk from any future sea level rises.

#### 4.5.5.2 Consequences

This section discusses the potential cumulative effects of climate change on coastal zones both in the United States and globally.

#### 4.5.5.2.1 Projected Impacts of Climate Change for the United States

According to the USCCSP Scientific Assessment, 50 percent of Americans live in coastal communities (National Science and Technology Council, 2008). Coastal urban centers are expected to experience a surge in population growth of an additional 25 million people over the next 25 years. This change in population is expected to compound the anticipated adverse effects of climate change on coastal communities, placing heavier demand on already-stressed resources (National Science and Technology Council, 2008). Data have confirmed an average rise in sea level of 0.8 to 1.2 inches per decade since the beginning of the 20th century along most coasts in the United States, with the Gulf Coast experiencing a rise of a few inches per decade (primarily due to land subsidence) and Alaskan coasts experiencing *decreases* in sea level of a few inches per decade (National Science and Technology Council, 2008). In one example, the Union of Concerned Scientists' report (Frumhoff et al., 2007) discusses the impacts of surging waters during a coastal storm in December 1992, when strong winds and rising water levels disrupted the New York City public transit system and required the evacuation of communities in New Jersey and Long Island. Sea level rise in the Chesapeake Bay has accelerated erosion rates, resulting in wetland destruction (National Science and Technology Council, 2008). Sea level rise in the 21st century is expected to exceed that of past years, causing great alarm for coastal communities and the infrastructures they support.

Although a range of adverse effects from climate change is expected in the United States, one of the most damaging is expected to be that of sea level rise. The IPCC predicts a sea level rise of 7 to 23 inches by 2090-2099 (Parry, 2007 in National Science and Technology Council, 2008). These figures do not include the anticipated sea level rise from melting ice sheets and glaciers in Greenland and Antarctica where scientists have already noted a decrease in the thickness and depth of sea ice (National Science and Technology Council, 2008) or the potential for rapid acceleration in ice loss (Alley et al, 2005; Gregory and Huybrechts, 2006; Hansen, 2005 in Pew, 2007). Recent studies have found the IPCC's estimates of ice loss from the Greenland and Antarctic ice sheets and from mountain glaciers may be underestimated (Shepherd and Wignham, 2007; Csatho et al., 2008; Meier et al., 2007). Further, IPCC may underestimate sea level rise that would be gained through changes in global precipitation (Wentz et al., 2007; Zhang et al., 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea level rise. The approach yielded a proportionality coefficient of 3.4 mm per year per degree Celsius of warming, and a projected sea level rise of 0.5 to 1.4 meters above 1990 levels in 2100 when applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise over 1 meter by 2100 for strong warming scenarios cannot be ruled out."

Some general effects associated with rising sea levels include:

- Loss of land area due to submergence and erosion of lands in the coastal zone;
- Changes to coastal environments;
- More flooding due to storm surges; and
- Salinization of estuaries and groundwater (National Science and Technology Council, 2008).

For islands such as those located in Hawaii and other United States territories in the Pacific, outcomes could include a reduction in island size and the abandonment of inundated areas (National Science and Technology Council, 2008). Approximately one-sixth of United States land that is close to sea level is located in the Mid-Atlantic region and, consequently, much of the reporting on effects focuses on this region (National Science and Technology Council, 2008).

Over the past century, the highest rate of sea level rise has been observed in the mid-Atlantic region, in part resulting from subsidence of the land surface (Gutierrez et al., 2007). For example, Virginia has observed sea level rise at 4.4 millimeters per year compared to 1.8 millimeters per year in

Maine (Zervas, 2001 cited in Gutierrez et al., 2007). New Jersey, with 60 percent of its population living along the 127 miles of coastline, has experienced coastline subsidence and beach erosion threatening communities and coastal wetlands (Union of Concerned Scientists, 2007; Aucott and Caldarelli, 2006; Metro East Coast Regional Assessment, 2000).

The effects of sea level rise on some coastal communities could be devastating with increased erosion and flooding. Extensive erosion has already been documented across the East Coast, as have notable decreases in the coastal wetlands of Louisiana, the mid-Atlantic region, New England, and New York (Rosenzweig et al., 2007 in National Science and Technology Council, 2008). Erosion is expected to be worse in sandy environments along the mid-Atlantic coast, Mississippi, and Texas (National Science and Technology Council, 2008; Nicholls et al., 2007 in National Science and Technology Council, 2008). The IPCC notes that sandy shorelines are already retreating. Furthermore, areas in Louisiana are experiencing barrier island erosion, resulting in increases in the height of waves that make it to shore (Nicholls et al., 2007 in National Science and Technology Council, 2008). A large storm can affect the shoreline position for weeks to a decade or longer (Morton et al., 1994; Zhang et al., 2004; List et al., 2006; Riggs and Ames, 2007 in Gutierrez et al., 2007). Tidal wetlands, estuarine beaches, marshes and deltas are expected to be inundated with water in areas such as the Mississippi River, Louisiana Delta, and the Blackwater River marshes in Maryland (Titus et al., 2008 in National Science and Technology Council, 2008). The "coastal squeeze" phenomenon where wetlands are trapped between natural and human-made land boundaries is causing wetland loss and habitat destruction (Field et al., 2007 in National Science and Technology Council, 2008). Freshwater resources are also at risk given the *likely* intrusion of saltwater into groundwater supplies, adversely affecting water quality and salinization rates (Kundzewicz et al., 2007 in National Science and Technology Council, 2008).

The height of storm surges will increase if sea level rises regardless of storm frequency and intensity increases; thus, a storm of similar behavior will cause greater damage with rising sea level (Fisher et al., 2000). One study suggests the 100-year flood may in fact occur every 25 to 30 years (Najjar et al., 2000 in Fisher et al., 2000). By mid-century, Boston and Atlantic City could experience a 100-year flood event every 2 to 4 years and annually by the end of the century (Frumhoff et al., 2007).

Cayan et al., (2006) projected future sea level rise and its implications for California. The study projected sea level rise, relative to 2000, to range from 11 to 54 centimeters (4.3 to 21 inches); 14 to 61 centimeters (5.5 to 24 inches); and 17 to 72 centimeters (6.7 to 28 inches) by 2070 to 2099 for B1, A2, and A1 GHG modeling scenarios, respectively. The mean sea level rise from a survey of several climate models was also determined to range from approximately 10 to 80 centimeters (3.9 to 3.15 inches) between 2000 and 2100. The historic rate of sea level rise observed at San Francisco and San Diego during the last 100 years was 15 to 20 centimeters (5.9 to 7.9 inches). Parts of the California coast are at risk for flood damage, which may further jeopardize levees in the City of Santa Cruz (California Environmental Protection Agency, 2006). Santa Cruz is 20 feet above sea level with levees built to contain the 100-year flood. If sea levels were to increase above 12 inches as predicted for the medium warming range of temperatures, then a flood associated with a storm surge event at the 100-year level may happen once every 10 years (California Climate Change Center, 2006a). The ENSO events of 1982-1983 and 1997-1998 corresponded to high sea level episodes (Flick, 1998 in California Climate Change Center, 2006b). These high sea level episodes may intensify in future ENSO events if rising sea level increases.

The frequency and intensity of storms are expected to become more prevalent at the same time as sea levels rise and sea surface temperatures increase. Some societal effects include the following:

- Infrastructure such as bulkheads, dams, and levees could be damaged by flooding and strong storms (Nicholls et al., 2007 in National Science and Technology Council, 2008).

- Coastal ports, roads, railways, and airports are at risk of disruption due to power outages, flooded routes, and poor travel conditions (Nicholls et al., 2007 in National Science and Technology Council, 2008).

- Industries reliant on coastal stability such as travel and recreation, fishing and hunting, and trade are expected to become increasingly sensitive to these temperature and precipitation changes in the coming decades (Nicholls et al., 2007 in National Science and Technology Council, 2008).

- The most at-risk State in the United States is expected to be Alaska because the indigenous communities residing there depend upon wildlife for hunting and fishing practices, living within floodplains and currently face water shortages (IPCC, 2007 in National Science and Technology Council, 2008).

Loss of coastal wetlands due to intense storms has been documented on many occasions. A prominent recent example is the loss of coastal lands as a result of Hurricane Katrina in 2005. In Louisiana alone, the loss of land during Hurricane Katrina was approximately 217 square miles. The Chandeleur Islands, which New Orleans relied on as a tropical storm buffer, lost 85 percent of their surface area (USCCSP, 2008b).

Increases in storm frequency and severity, as well as sea rise itself, have detrimental effects on coastal areas with sandy beaches. Many species are reliant on the wellbeing of, and accessibility to, beaches. Some examples:

- Diamondback terrapins and horseshoe crabs rely on beach sands to bury their eggs. The eggs not only act to propagate the species, but some shorebirds, such as the piping plover, rely on these eggs as a food source (USFWS, 1988 in Titus et al., 2008).

- Horseshoe crabs rarely spawn unless sand is at least deep enough to nearly cover their bodies, about 10 cm (4 inches) (Weber, 2001). Shoreline protection structures designed to slow beach loss can also block horseshoe crab access to beaches and can entrap or strand spawning crabs when wave energy is high (Doctor and Wazniak, 2005). (Titus et al., 2008). So, in this case, the loss of beach, as well as the adaptation strategy selected by the community, can result in harm to local species.

- A rare firefly, *Photuris bethaniensis*, is found only in areas between dunes on Delaware's barrier beaches. Its habitat is at risk due to beach stabilization and hardening of shorelines; this limits migration of dunes and the formation of the interdunal swales where the firefly is found (Titus et al., 2008).

#### 4.5.5.2.2 Adaptation to Climate Change

There are uncertainties regarding which effects of climate change could affect individual coastal and low-lying areas. However, because these areas are particularly sensitive to climate and hazardous weather events, adaptation to projected climate change remains a potentially attractive option. Adaptations can be preventative, taken before the arrival of an anticipated impact or reactive, taken in response to the actual changes. Many of the adaptations for coastal and low-lying areas can overlap between these two categories and might differ only by the timing in which they are implemented. The USCCSP (2008, in National Science and Technology Council, 2008) outlines seven approaches to adaptation:

- Protecting key ecosystem features;
- Reducing anthropogenic stresses;
- Representation (maintaining species diversity);
- Replication of ecosystems to maintain species diversity and habitable lands;
- Restoration of disturbed ecosystems;
- Refugia (using less affected areas to "seed" new areas); and
- Relocation.

Some examples of possible adaptation strategies in the United States include shifting populations and infrastructure from coastal communities along the East and Gulf Coasts and Mid-Atlantic region further inland (IPCC, 2007 in National Science and Technology Council, 2008). Other possible strategies include elevating infrastructure, introducing barriers such as levees and dams to hold off storm surges, reducing fertilizer and pesticide use in nearshore coastal communities (Epstein, P. and E. Mills, 2006), preserving contiguous interconnected water systems (including mangrove stands, spawning lagoons, upland forest and watershed systems, coastal wetlands) (Epstein, P. and E. Mills, 2006), and constructing watertight containment for essential equipment (NY DEP, 2008). While the options for adaptation in coastal and low-lying areas are many, the key is to consider the time frame in which these adaptations are proposed and implemented to best prepare communities. The IPCC in their 2007 Technical Summary has predicted that the costs of adaptation are *virtually certain* to be less than those of inaction (Parry et al., 2007).

Current government programs are in effect that assist in subsidizing protection for coastline development including shoreline protection and beach replenishment, Federal disaster assistance, and the National Flood Insurance Program (Fisher et al., 2000). In 2006, Maine developed and implemented shoreline regulations to address projected sea level rise due to climate change (Frumhoff et al., 2007). Maine is currently the only State in the nation with such a program.

#### 4.5.5.2.3 Projected Global Impacts of Climate Change

Globally, coastal systems and low-lying areas are experiencing adverse effects related to climate change and sea level rise such as coastal inundation, erosion, ecosystem loss, coral bleaching and mortality at low latitudes, thawing of permafrost and associated coastal retreat at high latitudes (*very high confidence*) (IPCC, 2007). To further exacerbate the stressors, human settlement and encroachment on coastal systems and low-lying areas have been increasing with an estimated 23 percent of the world's population living within about 60 to 65 miles of the coast and no more than about 330 feet above sea level (Small and Nichols, 2003 in National Science and Technology Council, 2008).

Though non-uniform around the world, it is estimated global sea level has risen by 0.07 ±0.02 inch per year over the past century with western Pacific and eastern Indian Ocean experiencing the greatest rise (IPCC, 2007). Sea level is anticipated to continue to increase 0.7 to 2.0 feet or more by the end of the 21st century (IPCC, 2007). This sea level rise coupled with both projected sea surface temperatures increasing 1 to 3°C and intensified cyclonic activity could lead to larger waves and storms surges impacting coastal systems and low-lying areas across the globe (IPCC, 2007). The loss or degradation of coastal ecosystems has a direct impact on societies that are dependent on coastal-related goods and services such as freshwater and fisheries with the potential to impact hundreds of millions of people (Parry et al., 2007).

There is variability in the projected effects from climate change and sea level rise on an international scale. For instance, if the global mean annual temperature increases above 1980 to 1999 levels, it is anticipated that coastal systems and low-lying areas will sustain increased damage due to floods and storms; an additional 2 degrees Celsius increase would lead to an increase of millions of people that could experience coastal flooding each year; and an increase by 3 degrees Celsius is estimated to lose 30 percent of the global coastal wetlands (*high confidence*; IPCC, 2007, Figure SPM.2). Coastal wetland ecosystems are at significant risk from sea level rise if they are sediment-starved or unable to migrate further inland. As sea water temperatures increase, it is *likely* that coral bleaching and mortality will rise unless corals demonstrate thermal adaptation (IPCC, 2007). These adverse impacts are expected to increase in severity as the global mean annual temperature increases.

Tide gauges have measured the average rate of sea level rise to be 0.07 ±0.02 inch per year from 1961 to 2003 and 0.07 ±0.02 inches per year (National Science and Technology Council, 2008) over the past century. These changes are attributed to thermal expansion associated with rising global temperature, thawing of permafrost, and loss of sea ice (IPCC, 2007). The global ocean temperature averaged from the surface to a depth of approximately 2,300 feet has increased by 0.10 degrees Celsius over the period from 1961 to 2003 contributing to an average increase in sea level of 0.02 ±0.004 inch per year (National Science and Technology Council, 2008). This contribution has increased for the period 1993 to 2003 with a rate of sea level rise of 0.06 ±0.02 inch per year. Melting of mountain glaciers, ice caps, and land ice have also contributed to the measured sea level rise. From 1961 to 2003, the melting of land ice has contributed approximately 0.03 ± 0.02 inch per year to sea level rise with an accelerated rate of 0.05 ±0.02 inch per year between 1993 and 2003 (Lemke et al., 2007 in National Science and Technology Council, 2008).

Sea level rise is non-uniform around the world. In some regions, rates of rise have been as much as several times the global mean, while other regions have experienced falling sea level. This might be the result of variations in thermal expansion and exchanges of water between oceans and other reservoirs, ocean and atmospheric circulation, and geologic processes (Bindoff et al., 2007 in National Science Technology Council, 2008). Satellite measurements provide unambiguous evidence of regional variability of sea level change for the period 1993 to 2003 with the largest sea level rise occurring in the western Pacific and eastern Indian oceans (National Science and Technology Council, 2007).

Sea level is projected to increase from 0.7 to 2.0 feet or more by the end of the 21st century (IPCC, 2007) with the possibility of additional significant sea level rise occurring resulting from the breakdown of West Antarctic and/or Greenland ice sheets. A temperature increase of 1.1 to 3.8 degrees Celsius would trigger the breakdown of the Greenland ice sheet, and is *likely* to occur by 2100 (Parry et al., 2007). An additional sea level rise of about 21 to 24 feet would result in the complete disappearance of the Greenland ice sheet (IPCC, 2007, Table 4.1; Epstein, P. and E. Mills, 2006). This scenario raises concern regarding the viability of coastal communities, salt marshes, corals, and mangroves. A sea level rise of about 14 inches from 2000 to 2080 is projected to reduce coastal wetlands by 33 percent with the largest impact on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic, and small-islands (IPCC, 2007).

IPCC SRES estimated that the coastal population could grow from 1.2 billion people in 1990 to between 1.8 billion and 5.2 billion people by the 2080s with this range dependent on coastal migration. Though the impact of sea level rise on a specific region can be difficult to quantify given regional and local variations (Parry et al. 2007), the IPCC describes the following coastal regions as the most vulnerable to the impact of climate change: South Asia, Southeast Asia, East Asia, Africa, and small islands (IPCC, 2007).

Many of the coastal cities that are most vulnerable to adverse impacts of climate change are at further risk due to human activities such as agriculture, aquaculture, silviculture, industrial uses, and residential uses that have degraded the natural protective qualities of the coastal systems (IPCC, 2007). Coastal countries at risk for shoreline retreat and flooding due to degradation associated with human activity include Thailand (Durongdej, 2001; Saito, 2001 in National Science and Technology Council, 2008), India (Mohanti, 2000 in National Science and Technology Council, 2008), Vietnam (Thanh et al., 2004 in National Science and Technology Council) and the United States (Scavia et al., 2002 in National Science and Technology Council, 2008) with emphasis on the seven Asian megadeltas with a combined population greater than 200 million (IPCC, 2007). Of particular concern are those highly coastal populated regions within countries with limited financial resources to protect or relocate its populations (IPCC, 2007).

Small islands are particularly vulnerable to climate change and sea level rise, especially those islands prone to subsidence (Parry et al., 2007). Beach erosion is projected to increase as sea level rises and sea water temperature increases. Arctic islands may experience increased erosion and volume loss as permafrost and ground ice warms in response to rising global temperatures (IPCC, 2007).

Positive impacts anticipated to be experienced in high latitudes include a longer tourist season and better navigability (IPCC, 2007). Without adaptation, IPCC model results suggest more than 100 million people could endure coastal flooding due to sea level rise every year by 2080 (IPCC, 2007).

#### 4.5.5.2.4 Adaptation to Climate Change

In some circumstances, the potential effects from climate change and sea level rise on coastal systems and low-lying areas can be reduced through widespread adaptation (IPCC, 2007). The IPCC modeled results of flood risk associated with rising sea level and storm surges projected to 2080 found significant benefit associated with upgrading coastline defenses (Nicholls et al., 2007). In addition, curtailing the current degradation in coastal systems by anthropogenic activities such as deforestation, fertilizer use, sewage dredging, sand mining, fish harvesting, and sea wall construction would provide a more robust coastal system resistant to extreme water levels during storms.

Small islands in the Indian Pacific Oceans and the Caribbean have much of their infrastructure in coastal locations (Parry et al., 2007). Under projected sea level rise levels, some infrastructure is *likely* to be at risk from inundation and flooding (IPCC, 2007). Small islands have limited adaptation choices to sea level rise and climate change impact on coastal sections.

### 4.5.6 Food, Fiber, and Forest Products

This section defines these resources and describes the existing conditions and potential vulnerability of each to climate change impacts. The primary resource used in this section is the IPCC Fourth Assessment Report (IPCC, 2007a); specifically, Chapter 5 for food, fiber, and forest products.

The food, fiber, and forest sector is a significant source of livelihood and food for large numbers of the world's population and a major land cover type at a global level. Cropland, pasture, or natural forests account for approximately 70 percent of the world's land cover. The United Nations Food and Agriculture Organization (FAO) estimates that approximately 450 million of the world's poorest people are entirely dependent on this sector for their livelihood (IPCC, 2007a).

According to IPCC, this sector includes agriculture, forestry, and fisheries. It also includes subsistence and smallholder agriculture, defined as rural producers who farm or fish primarily with family labor and for whom this activity provides the primary source of income (IPCC, 2007a).

#### 4.5.6.1 Affected Environment

It is estimated that 40 percent of the Earth's land surface is used for cropland and pasture (Foley et al., 2005, in IPCC, 2007a). The FAO estimates that natural forests cover another 30 percent of the land surface, and that 5 percent of that natural forest area generates 35 percent of global timber production (FAO, 2000, in IPCC, 2007a). Nearly 70 percent of people in lower-income countries around the world live in rural areas where agriculture is the primary source of livelihoods. Growth in agricultural incomes in developing countries fuels the demand for non-basic goods and services fundamental to human development. The FAO estimates that the livelihoods of roughly 450 million of the world's poorest people are entirely dependent on managed ecosystem services. Fish provide more than 2.6 billion people with at least 20 percent of their average per-capita animal protein intake, but 75 percent of global fisheries are currently fully exploited, overexploited, or depleted (FAO, 2004 in IPCC, 2007a).

### Terrestrial Systems

The distribution of crop, pasture, and forest species between the polar and equatorial latitudes is a function of current climatic and atmospheric conditions, as well as photoperiod. Agricultural, pastoral, and forestry systems are dependent on total seasonal precipitation and its pattern of variability, as well as wind and humidity. Crops exhibit threshold responses to their climatic environment, which affect their growth, development and yield (Porter and Semenov, 2005 in IPCC, 2007a). Short-term natural extremes, such as storms and floods, interannual and decadal climate variations, and large-scale circulation changes, such as ENSO, all have important effects on crop, pasture and forest production (Tubiello 2005 in IPCC 2007a).

For example, Europe experienced a particularly extreme climate event during the summer of 2003, with temperatures up to 6 degrees Celsius above long-term means, and precipitation deficits up to 12 inches (Trenberth et al., 2007 in IPCC, 2007a). Associated with this extreme climate event was a decline in corn yield of 36 percent in the Po River valley in Italy and 30 percent in France. In addition, French fruit harvests declined by 25 percent, winter wheat yields declined by 21 percent, and hay and other forage production declined on average by 30 percent (Ciais et al., 2005 in IPCC, 2007a). Moreover, African droughts between 1981 and 1999 caused livestock mortality from 20 percent to more than 60 percent in countries such as Botswana, Niger, Ethiopia, and Kenya (IPCC, 2007a).

Overall, climate change may benefit crop and pasture yields in mid- to high-latitude regions, while decreasing yields in dry and low-latitude regions. Total forest productivity may rise modestly, with considerable global variation. Local extinctions of fish species are expected, particularly at the edges of habitat ranges (IPCC, 2007a).

Agricultural and forest lands are experiencing multiple stresses that increase their vulnerability to climate change impacts. Examples include soil erosion, salinization of irrigated areas, overgrazing, over-extraction of groundwater, loss of biodiversity, and erosion of the genetic resource base in agricultural, forest and pasture areas. Overfishing, loss of biodiversity, and water pollution in aquatic areas serve as stresses that increase vulnerability to climate change to fishery resources (IPCC, 2007a).

The vulnerability of these resources is dependent on both the exposure to climate conditions and capacity to cope with changing conditions. Exposure to conditions is highly dependent on local geography and environment. Adaptive capacity is dynamic and dependent on wealth, human capital, information and technology, material resources and infrastructure, and institutions and entitlements (IPCC, 2007a).

Sub-Saharan Africa offers one example of a region that is currently highly vulnerable to food insecurity (Vogel, 2005 in IPCC, 2007a). Drought conditions, flooding, and pest outbreaks are some of the current stressors on food security that may be influenced by future climate change. Options for addressing food insecurity in this region (as well as overall development initiatives related to agriculture, fisheries, and forestry) may be constrained by health status, lack of information, and ineffective institutional structures. These constraints have the potential for limiting future adaptations to periods of heightened climate stress (Reid and Vogel, 2006 in IPCC, 2007a).

Aquatic Systems

Spatial adaptation of marine ecosystems to climate change is in some ways less geographically constrained than for terrestrial systems. The rates at which planktonic ecosystems have shifted their distribution have been very rapid over the past three decades, which can be regarded as natural adaptation to a changing physical environment (Beaugrand et al., 2002, in IPCC, 2007a). Most fishing communities use stocks that fluctuate due to interannual and decadal climate variability, and consequently have developed considerable coping capacity (King 2005, in IPCC, 2007a).

Research on the relationship between water temperature and the health of freshwater fishes indicates different impacts in summer and winter. While temperature increases may cause seasonal increases in growth in the winter, mortality risks to fish populations occur at the upper end of their thermal tolerance zone in the summer.

World capture production of finfish and shellfish in 2004 was more than twice that of aquaculture, but since 1997 capture production decreased by 1 percent, whereas aquaculture increased by 59 percent (IPCC, 2007a). The increasingly important aquaculture sector allows for the application of similar types of management adaptations to climate change suggested for crop, livestock, and forestry sectors. This is not the case, however, for marine capture fisheries, which are shared resources subject to varying degrees of effective governance. Adaptation options for marine capture fisheries include altering catch size and effort. Three-quarters of world marine fish stocks are currently exploited at levels close to or above their productive capacity (Bruinsma, 2003 in IPCC, 2007a). Reductions in the level of effort and harvest are required to sustain yields. Such a course of action may also benefit fish stocks that are sensitive to climate variability when their population age-structure and geographic sub-structure is reduced (Brander 2005 in IPCC, 2007a).

### 4.5.6.2 Consequences

The Earth's land surface is composed mostly of managed cropland and pasture (40 percent) and natural forests (30 percent) (Foley et al., 2005 in Easterling et al., 2007). These sectors provide important commodities that are produced in a variety of geographic and climatic regions (USCCSP, 2008). The continued growth and productivity of the world's agriculture and forests is necessary to sustain human economic and social development.

The discussion below is focused on impacts on food and industrial crops, fisheries, agricultural pastures, commercial forestry, and subsistence farming (Easterling et al., 2007). The key drivers for climate impacts in this sector are higher temperatures, changed precipitation and transpiration dynamics, the effects of increased $CO_2$ concentrations on vegetative growth and yield, greater frequency in extreme weather events, and increased stressors to forests and agriculture in the form of pests and weeds (Easterling et al., 2007).

The world's food crops, forests, and fisheries have evolved to be in tune with the present climatic environment. The productivity of these systems ultimately relies on the interaction of various climate factors including temperature, radiation, precipitation, wind speed, and water vapor pressure (Easterling et al., 2007). There are threshold climatic conditions for crops and forests that affect their growth and yield, and climatic conditions and their interaction influence the global distribution of agricultural and forest species (Porter and Semenov, 2005 in Easterling et al., 2007).

The sensitivity to climate change and exposure to various other stressors increases the vulnerability of the forest, food, and fiber systems (Easterling et al., 2007). Non-climate stressors such as soil erosion, overgrazing, loss of biodiversity, decreased availability of water resources, increased economic competition among regions, and the adaptive capacity of various species increase overall sensitivity to the climate and thus exacerbate the adverse effects of climate change (USCCSP, 2008).

Climate change could also benefit agriculture and silviculture through the $CO_2$ fertilization effect. $CO_2$ is essential for plant growth; some research suggests that higher atmospheric concentrations translate to higher productivity of some food, fiber, and forest crops. Milder winters and longer growing seasons could also increase productivity in some regions.

Important examples that highlight the link between large-scale climate changes and the sensitivity of the food, fiber, and forest systems include the effects of ENSO, a relatively well-known phenomenon, on crop yield. In Australia, during ENSO years there is increased probability of a decline in farmers' incomes by as much as 75 percent below the median income as compared to non-ENSO years (Tubiello, 2005 in Easterling et al., 2007). Another example is the extreme heat wave that occurred in Europe in 2003, which lowered maize yield by 36 percent in Italy and 30 percent in France (Cais et al., 2005 in Easterling et al., 2007). Uninsured losses for the entire European Union agriculture sector were estimated at 13 billion euros; 4 billion euros were lost in France alone (Senat, 2004 in Easterling et al., 2007). (This is discussed earlier in the chapter)

The most recent comprehensive and peer-reviewed literature on global climate impacts on the food and forestry sectors is from the IPCC Fourth Assessment Report. The SAP 4.3 report by USCCSP and the Subcommittee on Global Change Research provides an additional source of authoritative information on the impacts of climate change on agriculture, land resources, and biodiversity in the United States. Most of the evidence cited in this chapter focuses on the results of the IPCC report and the SAP 4.3. However, since new evidence is continuously emerging on the subject of climate change impacts on the agriculture and forest systems, the discussion below also draws on results reported in more recent studies.

#### 4.5.6.2.1 Projected Impacts of Climate Change for the United States

##### Forests

In the United States, the combination of human management and temperate climate has resulted in a productive and healthy forest system, as exemplified by the southern pine plantations (USCCSP, 2000). Forests are generally considered the most productive of the terrestrial ecosystems and provide important commodities like timber products. They are also key biodiversity sanctuaries and providers of ecosystem services. Presently, forests cover roughly one third of the land in the United States. Net growth of these forests (growth minus removals minus decomposition) accounts for removing about 883.7 $MMTCO_2$ per year, about 12.5 percent of gross national GHG emissions (EPA, 2008). Globally, forests account for the largest fraction of terrestrial ecosystem sequestered carbon, estimated to be roughly 1,640 petagrams of carbon (Sabine et. al, 2004 in USCCSP, 2008). Climate change may directly affect the ability of forests to provide these key services and commodities in a number of ways.

One key impact of climate change is the extended risk and increased burn area of forest fires coupled with pathogenic stressors that damage fragile forest systems (IPCC, 2007a). These impacts (i.e., forest fires, diseases, and pathogens) might potentially be greatest between 2050 and 2100. It is projected that the forest fire season (summer) could be extended by 10 to 30 percent as a result of warmer temperatures (Parry et al., 2007). In the western states, the anticipated warmer spring and summer temperatures are expected to reinforce longer fire seasons and increased frequency of large wildfires. In turn, the carbon pools within forests are expected to be affected by changes in forest composition and reduced tree densities (Westerling, 2006). More specifically, the Hadley and Canadian climate and ecological models project an increase in the fire season hazard by 10 percent in the 21st century in the United States, with small regional decreases in the Great Plains and a 30 percent increase in Alaska and the southeast (USCCSP, 2000). Highlighting the geographic differences even within a state, two climate models including the Geophysical Fluid Dynamics Laboratory and the Parallel Climate Model were run using "business as usual" (A2) and "transition to a low GHG emissions" (B1) IPCC SRES emissions scenarios. The results showed increases in fire risk in Northern California (15 to 90 percent), increasing with temperature whereas in Southern California, the change in fire risks ranged from a decrease of 29 percent to an increase of 28 percent. These results were largely driven by differences in precipitation between the different scenarios. In Southern California the drier conditions simulated in both the Geophysical Fluid Dynamics Laboratory model scenarios led to reduced fire risks in large parts of southern California, with fire risks increased in parts of the San Bernardino mountains (Westerling and Bryant, 2006).

Historical evidence indicates that the warmer periods in the past millennium correlated with increased frequency in wildfires, particularly in the western forests (USCCSP, 2008). General circulation models project increased wildfire activity in the western states, particularly from 2010 through 2029 (Flannigan et al., 2000; Brown et al., 2004 in USCCSP, 2008). In 2060, models have projected forest fire severity increases of 10 to 30 percent in the southeastern states and 10 to 20 percent in the northeastern states (Flannigan et al., 2000 in USCCSP, 2008). Some models have projected even larger increases in wildfire activity, particularly in the southeastern region of the United States (Bachelet et al., 2001 in USCCSP, 2008). Potential losses to North American producers from increased disturbances (including wildfires, insects, and diseases) coupled with climate change impacts have been estimated to range from $1 to $2 billion per year averaged throughout the 21st century (Sohngen and Sedjo, 2005 as cited in Field et al., 2007).

Ancillary consequences of the projected increase in wildfire frequency across the United States include an increase in emissions expected to affect air quality and continue to be a source of GHGs. Although the GHGs that are released through wildfires could eventually be sequestered by forest regrowth, this carbon release might not be fully recovered in the short term and thus might be an important source of $CO_2$ in the atmosphere (Kashian et al., 2006 in USCCSP, 2008). Particularly in forests in the western United States, "If wildfire trends continue, at least initially this biomass burning will result in carbon release, suggesting that the forests of the western United States may become a source of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature increase scenario" (Westerling et al., 2006, p. 943).

### Invasive Species

The increasing occurrence of forest fires, which is likely to continue with projected warming temperatures, would impact ecosystem services, reduce the potential for carbon storage via forest management, and provide increased potential habitat for invasive species and insect outbreaks (Parry et al., 2007).

Since invasive species and pests are not constrained by the need for pollinators or seed spreaders, these species are more adaptable to the warming climate (Vila et al., 2007 in USCCSP, 2008). The northward movement of weed species, especially invasive weeds, is likely to be a result of higher projected temperatures and increased $CO_2$ concentration. This movement northward could further be accelerated, as some studies that have shown that the responsiveness of weeds to glyphosate, an important herbicide used in the United States, diminishes with increases in $CO_2$ concentration levels (Ziska et. al, 1999 in USCCSP, 2008).

### Disease and Pathogens

Warming temperatures may be allowing for the migration of diseases and pathogens (USCCSP, 2008). More specifically, the increases in temperature are influencing the development of insect lifecycles, reducing winter mortality rates and "influence[ing] synchronization of mass attacks required to overcome tree defenses" (Ryan et al., 2008 in USCCSP, 2008, p. 82).

The warming trends in the United States have already allowed for earlier spring insect activity and the increased proliferation of certain species (USCCSP, 2008). These warming trends have also allowed for an increase in the survival rates of diseases and pathogens that affect crops, as well as plant and animal species. Recent research has linked the rising temperatures to increased outbreaks of the mountain pine beetle, the southern pine beetle, and the spruce beetle. Rising temperatures have also been correlated with the expansion of suitable range for the hemlock wooly adelgid and the gypsy moth (Ryan et al., 2008 in USCCSP, 2008). Not only are the boundaries of insects being shifted by climate change but "tree physiology and tree defense mechanisms" are being altered as well (Kirilenko, 2007). The damage to forests is expected to depend on seasonal warming: winter and spring increases in temperature might increase losses to insects such as the southern pine beetle (Gan, 2004 as cited in Field et al., 2007). In the western United States, particularly in Colorado, a recent significant decline in aspen trees has been linked to global warming. Unlike earlier episodes of aspen tree dieback, the current decline is occurring more rapidly and over larger areas. The dieback is caused by bark beetles that were not known to have existed in the area (Saunders et al., 2008). In effect, "the hotter, drier conditions recently present in Colorado's mountains have enabled these unexpected agents to so quickly kill so many aspen" (Saunders et al., 2008, p. 25). The forest disturbances such as insect outbreaks "are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons" (Field et al., 2007 in Saunders et al., 2008, p. 19). The control of increased insect populations, especially in the projected warmer winters and in the southern regions, may require increased applications of insecticides. It is important to control these insect populations because of their ability to spread other pathogens, especially the flea beetle, which is known to be a conduit for the corn damaging bacteria Stewart's Wilt (USCCSP, 2008).

### Migration

Under future climate warming scenarios, plant and animal species are expected to shift northward and to migrate to higher elevations, thus redistributing North American ecosystems (Parry et al., 2007). The southeast and northwest forests may experience carbon losses as a result of increased drought (USCCSP, 2000). However, the projected increases in precipitation over dry regions may encourage forest growth and displace some grasslands (USCCSP, 2008).

A marked change in forest composition and distribution has been noted in Alaska, as indicated by a northward migration of the subarctic boundary tree line by 6 miles, and the displacement of 2 percent of the Alaskan tundra in the past 50 years (Anisimov et al., 2007 in USCCSP, 2008). Also, as evidenced by remote sensing analysis, the growing season is increasing in length by roughly 3 days per decade (USCCSP, 2008). Arctic vegetation is expected to shift northward and cause forests to overtake tundra (ACIA, 2004 in USCCSP, 2008).

### Crops and Agriculture

In the early part of the 21st century, moderate climate change will increase crop yields on agricultural land by 5 to 20 percent (IPCC, 2007a). However, this is dependent on regional differences and for crops that rely on highly utilized water resources (Parry et al., 2007). Crops that are near the threshold of their productive temperature range (i.e., crops that are "near the warm end of their suitable range”), such as wine grapes in California, are expected to decrease in yield or quality based on moderate climate change scenarios (IPCC, 2007a, p. 631).

Grain crops in the United States are likely to initially benefit from the increased temperature and $CO_2$ levels. However, as temperatures continue to rise, sensitivity of these grain crops could increase. This sensitivity is expected to an even greater extent for horticultural crops such as tomatoes and onions, compromising their productive yield (USCCSP, 2008). Various studies have found differing thresholds for maize production in the United States, with one in particular showing a 17 percent reduction of maize yield per 1 degree Celsius increase in temperature (Lobel and Asner, 2003, in USCCSP, 2008). Other crops such as wheat are regionally and temporally dependent. Studies show that wheat yield in the Great Plains “is estimated to decline 7 percent per 1 degree Celsius increase in air temperature between 18 and 21 degrees Celsius and about 4 percent per 1 degree Celsius increase in air temperature above 21 degrees C” (Lobell and Field, 2007, in USCCSP, 2008, p. 124). Similarly, rice yields are projected to decline about 10 percent per 1 degree Celsius increase for temperature profiles that are above current summer mean air temperatures (USCCSP, 2008).

In the Great Lakes region, fruit production might benefit from climate change although there might be increased risk of winter thaws and spring frost (Belanger et al., 2002; Winkler et al., 2002 as cited in Field et al., 2007). In New Jersey, higher summer temperatures are expected to depress the yields of a number of other economically important crops adapted to cooler conditions (e.g., spinach, lettuce) by mid-century, while rising winter temperatures are expected to drive the continued northward expansion of agricultural pests and weeds (such as kudzu) (NECIA, 2007) . Cranberries are especially susceptible because of their requirement to be subjected to long periods of cold winter temperatures for development (NECIA, 2007).

### Extreme Weather Events

The negative impacts of increased frequency of extreme weather events on crop yield might temper the beneficial effects of increased $CO_2$ concentrations with associated temperature increases and longer growing seasons on crop growth (USCCSP, 2008).

In the United States, particularly in the north, the average increase in temperature is expected to lead to a longer growing season. However, temperature increases may also lead to increased climate sensitivity in the southeast and the Corn Belt (Carbone et. al, 2003 in USCCSP, 2008). The Great Plains region is not expected to experience increased climate sensitivity (Mearns et al., 2003 in USCCSP, 2008). In terms of species migration as a result of climate change, the United States has experienced an incursion of perennial herbaceous species that limit the soil moisture available for other crops throughout the growing season (USCCSP, 2008). The invasion of these nonnative species could impact how these regions adapt to climate change and could lead to the potential for more frequent wildfires by increasing vegetation density (Fenn et al., 2003; Wisdom et al., 2005 in USCCSP, 2008).

Multiyear droughts, which might have been a result of increased temperature conditions in lower-elevation forests in the southwestern region, have had a large impact on forest mortality rates (Breshears et al., 2005 in USCCSP, 2008). The morality rate continued to increase even though growth at the forest tree line had been increasing previously (Swetnam and Betancourt, 1998 in USCCSP, 2008). Forest productivity has decreased from climate change-induced warming in drought-prone regions (McKenzie et al., 2001 as cited in USCCSP, 2008) and in subalpine regions (e.g., Monson et al., 2005; Sacks et al., 2007, as cited in USCCSP, 2008).

### Livestock

The livestock production infrastructure in the United States is likely to be influenced by the climate change-induced distributional and productivity changes to plant species. Livestock production during the summer season may *very likely* be reduced due to higher temperatures, but livestock production during the winter months may increase, again due to the projected increase in temperatures (USCCSP, 2008).

The expected elevated $CO_2$ concentrations may diminish the grass feed quality. An increase in the carbon to nitrogen ratio would decrease the nutritional value of feed. In turn, grazing livestock that feed on lower quality grasses might be affected in terms of decreased weight and health (USCCSP, 2008). The average climate change conditions that are expected to occur in the future may have less effect on livestock productivity and potential livestock loss than the effects of increased climate variability (e.g., droughts and heat waves) (USCCSP, 2008).

Climate models have projected decreases in livestock productivity in the United States simply due to projected temperature increases. In 2050, climate models project an average decrease in swine, beef, and milk production of 0.9 to 1.2 percent, 0.7 to 2.0 percent, and 2.1 to 2.2 percent, respectively (Frank et. al, 2001, as cited in USCCSP, 2008). Indeed, higher temperatures directly affect animals' ability to maintain homeostasis and consequently livestock must engage in altered metabolic thermoregulatory processes (Mader et. al., 1997; Davis et al., 2003, as cited in USCCSP, 2008). The induced thermal stress on livestock often results in a reduction in physical activity and ultimately diminishes feed intake. Livestock production losses and associated economic losses may be attributed to increasing temperatures that are "beyond the ability of the animal to dissipate [and] result in reduced performance (i.e., production and reproduction), health, and well-being" (Hahn et al., 1992; Mader, 2003, as cited in USCCSP, 2008, p. 131).

The increased temperature expected as a result of climate change could allow for easier migration of animal pathogens and diseases, especially in the northward transition from the low to mid-latitudes, which would adversely affect livestock well-being in the United States (White et al., 2003; Anon, 2006; van Wuijckhuise et al., 2006, as cited in USCCSP, 2008).

### Fisheries

Although fisheries in cold freshwater regions are expected to be adversely affected, fisheries in warm freshwater regions could benefit from climate change. The effects of temperature increases have caused northward shifts of fisheries systems and this is expected to continue in the future (USCCSP, 2008). According to IPCC, "many warm-water and cool-water species will shift their ranges northward or to higher altitudes" (Clark et al., 2001 and Mohseni et al., 2003, as cited in Field et al., 2007, p. 631).

An example of negative impacts that result from large-scale species migration is the recent migration of two protozoan parasites from the Gulf of Mexico northward into the Delaware Bay. This parasitic incursion, possibly as a result of climate change, has led to a significantly increased mortality rate of oysters in the region (Hofmann et al., 2001, USCCSP, 2008).

According to IPCC, the survival of brook trout in the United States is directly correlated to its preferred cold groundwater seeps habitat. As temperatures increase, mortality rates also increase for certain species of trout (USCCSP, 2008). The salmonid species are likely also to be negatively affected by rising temperatures as they, too, are cold-water species (Gallagher and Wood, 2003, in Field et al., 2007). It is *likely* that other coldwater marine species may "disappear from all but the deeper lakes; cool-water species will be lost mainly from shallow lakes; and warm-water species will thrive, except in the far south, where temperatures in shallow lakes will exceed survival thresholds" (USCCSP, 2008, p. 134). Stocks of the river-spawning walleye will likely decline due to lower lake levels and climate change impacts in Lake Erie (Jones et al., 2006, as cited in Field et al., 2007). Coastal fisheries are also expected to experience the negative impacts of climate change, including coral reef bleaching, due to increased ocean temperatures (USCCSP, 2008). In Alaska, the spawning and migration behaviors of commercially fished species may be affected and increasing temperatures might cause an increase in the cooling needs for storage and processing of catch (CIER, 2007).

Adaptation

Motivation to engage in specific adaptation strategies because of the impacts of climate change on the forest, fiber, and food systems of the United States is expected. Adaptive practices in the forestry sector include cultivar selection, replanting tree species that are appropriate for the new climate regime, and utilizing dying timber (USCCSP, 2000). These and other potential strategies should be taken in the context of overall demand, population, and economic growth. Adaptive measures could be especially important to ensure the survival of forest, fisheries, and agriculture systems that are rich in biodiversity and productive value (USCCSP, 2000). It is possible that the current pace of climate change will make it difficult for many tree species to adapt as readily via migration as they have in previous periods of climate changes (Davis, 2001). It has been documented via pollen records that tree migration rates in the past have been roughly 20 to 40 km per century. In order to keep up with the projected climate changes in the future, tree migration rates would require migration patterns of roughly 300 to 500 km per century. Due to the projected pace of climate change, it is possible that "taxa that fail to adapt rapidly enough to tolerate these new and rapidly changing climate regimes will go extinct" (Davis, 2001, p. 678). It is also possible that climate change could result in extinctions of many tree species (Davis, 2001).

#### 4.5.6.2.2 Projected Global Impacts of Climate Change

Although the preceding section highlights anticipated climate change impacts in the United States, there are additional impacts that could affect forest and agriculture systems elsewhere in the world.

Crops

Globally, the agriculture and forest infrastructure will be affected by climate change. A recent Harvard report on Climate Change Futures states that a "changing climate will alter the hydrological regime, the timing of seasons, the arrival of pollinators and the prevalence, extent, and type of crop diseases and pests" (CCF, 2005, p. 77). Throughout the mid- to high-latitudinal regions, crop-specific productivity increases are projected for global mean temperature increases of 1 to 3 degrees Celsius. Beyond a 3-degrees Celsius increase in global mean temperature, crop productivity is expected to decrease in some regions (IPCC, 2007a). Depending on the crop type, experiments on the effects of increased $CO_2$ concentrations, namely 550 parts per million as opposed to current levels of roughly 380 parts per million, suggest that crop yields may increase by 0 to 20 percent (Parry et al., 2007).

In a modest warming climate scenario, adaptive practices such as using various cultivars and altering planting and harvesting times might maintain cereal crop yields and possibly allow for an increase in productivity in the high latitudinal and temperate regions (IPCC, 2007). The adaptive practice in regions with 1 to 2 degrees Celsius increases in temperatures corresponds to an avoidance of a 10 to 15 percent reduction in yield for cereal crops (Parry et al., 2007). However, in the lower latitude dry regions, cereal crop productivity is projected to decrease for 1 to 2 degrees Celsius temperature increases, thereby exacerbating hunger issues for the population living in these regions (Parry et al., 2007).

According to IPCC the, "projected changes in the frequency and severity of extreme climate events will have more serious consequences for food and forestry production, and food insecurity, than will changes in projected means of temperature and precipitation" (Easterling et al., 2007, p. 275). The low latitudinal regions may experience an increase in the frequency of extreme weather events like floods and droughts, which may adversely affect crop production, especially in the subsistence farming regions (IPCC, 2007a). Extreme weather events, "reduce crop yield and livestock productivity beyond the impacts due to changes in mean variables alone, creating the possibility for surprises" (Parry et al., 2007, p. 38). The reduced adaptive capacity of small-scale farmers such as subsistence and artisanal fisherfolk may result in increased vulnerability to extreme weather events, sea level rise, and the spread of human disease, which may negatively affect agricultural and fish yields (Parry et al., 2007). Current climate change models do not yet include recent findings on precipitation extremes that are expected to impact agricultural production in areas such as southern Asia, northern Europe, and eastern Australia. These areas are expected to experience an impact on agricultural productivity as a result of projected increased precipitation extremes such as floods and droughts (Christensen et al., 2007, in Easterling et al., 2007). Certain crops, such as wheat, are impacted by high precipitation events because wheat is, "susceptible to insects and diseases (especially fungal diseases) under rainy conditions" (Rosenzweig and Hillel, 2005, as cited in CCF, 2005). On the other hand, during droughts, certain fungi, such as *Aspergillus flavus*, are stimulated and will feed on drought-weakened crops (Anderson et. al, 2005 in CCF, 2005).

Decreases in crop and forest yields in moderate warming scenarios for the low latitudes will likely result in increased dependence on food imports in these typically the developing countries. As such, agricultural exports to lower latitude countries are likely to increase in the short term (Parry et al., 2007).

There may be a marginal increase in the population that is at risk of hunger due to climate change, but this will occur in the context of an overall decrease in the global population at risk of hunger, as a result of anticipated economic development (Parry et al., 2007).

### Forests

Globally, commercially grown forests for use in timber production are expected to increase modestly in the short term, depending on geographic region (IPCC, 2007). Large regional and local differences are anticipated as is a shift in terms of production increase from the lower latitudes to the higher latitudes (Parry et al., 2007). This poleward shift of forests and vegetation is estimated at roughly 500 km or more for the boreal zones for climate scenarios with $CO_2$ concentrations of double the current levels (Kirilenko, 2007). In terms of distributional production, net benefits will accrue to regions experiencing increased forest production, whereas regions with declining activity will likely face net losses (Kirilenko, 2007).

Due to increases in $CO_2$ concentration, there is potential for a carbon fertilization effect on the growth of trees with some experiments showing up to an 80 percent increase in wood production for orange trees (Kirilenko, 2007). There is evidence to support elevated growth for young, immature forests in response to higher $CO_2$ concentration levels (Parry et al., 2007). However, free-air $CO_2$ enrichment experiments indicate that mature forests show no appreciable response to elevated $CO_2$ concentrations. However, young, immature forests show elevated growth in response to higher $CO_2$ concentrations (Parry et al., 2007). It should be noted that there has been only one feasibility study regarding forest free air $CO_2$ enrichment (FACE) of 100-year-old tree stands in which little to no stem growth was recorded, but that this lack of growth might be explained by the relative difficulty of controlling for constant $CO_2$ levels (Kirilenko, 2007). Many GCMs have projected increases in forest production in certain geographic regions with notable exceptions. For example, the Terrestrial Ecosystem Model and the Center for International Trade in Forest Products Global Trade Model have simulated a future harvest increase of 2 to 11 percent in western North America, a 10 to 12 percent increase in New Zealand, a 10 to 13 percent increase in South America and a harvest decrease in Canada (Kirilenko, 2007).

It is important to contrast these possible short term benefits with the negative implications of a warming climate since, “continued warming favors more fungal and insect of forests, and more harsh weather will further weaken tree defenses against pests” (CCF, 2005, p. 68) The ability of forests to continue to function as providers of agriculture and energy as well as sequester carbon will be affected by climate change (CCF, 2005, p. 69). Overall, the “effects of future drought and decreased soil moisture on agriculture and natural vegetation (such as forests) are uncertain and may, at least in part, be temporarily offset by fertilization effects of higher atmospheric concentrations of $CO_2$” (Triggs et al., 2004 as cited in CIER, 2007, p. 10). These extreme weather events, in concert with increased damage from insect and pathogen outbreaks and wildfires, may result in large scale deforestation as evidenced by recent trends in the Amazon basin (Kirilenko, 2007). Climate-vegetation models have indicated that at $CO_2$ concentration levels of roughly three times current levels, the Amazon rainforests will eventually be lost due to climate change (Cox et al., 2004, in Kirilenko, 2007).

#### Fisheries

The aquaculture and fisheries sector are expected to incur negative development impacts as a result of the regional changes in the distribution and proliferation of various marine species (IPCC, 2007a). As the distribution of certain fish species continues to be regionally rearranged, there is the potential for notable extinctions in the fisheries system, especially in freshwater species, in temperature ranges at the margin (Parry et al., 2007). Recent evidence indicates that the Meridional Overturning Circulation, which supplies nutrients to the upper layers of the Pacific and Atlantic Oceans, is slowing and thus adversely affecting regional production of primary food supply for fisheries systems (McPhaden and Zhang, 2002; Curry and Mauritzen, 2005; Gregg et al., 2003; Lehodey et al., 2003, in Easterling et al., 2007). In the North Sea, a shift in the distribution of warm water species such as zooplankton has resulted in a shift of fish species from whiting to sprat (Beaugrand, 2004, in USCCSP, 2008).

The largest economic impacts associated with the fisheries sector as a result of climate change are expected to occur in coastal regions of Asia and South America (Allison et al., 2005 as cited in USCCSP, 2008). Specifically, species such as tuna and Peruvian anchovy may be the most affected by regional climate change (Barber, 2001; Lehodey et al., 2003 as cited in USCCSP, 2008).

Earlier spring ice melts in the Arctic and diminishing sea ice are affecting the distribution and productivity of marine species, particularly the upper-level sea organisms. In turn, fish harvests in the Arctic region are expected to change in the warming future. The freshwater species in the Arctic region are expected to be most affected by the increasing temperatures (Wrona et al., 2005, as cited in Field et al., 2007).

### 4.5.7 Industries, Settlements, and Society

This section defines these resources and describes the existing conditions and potential vulnerability of each to climate change impacts. In addition, this section briefly describes the potential vulnerability of cultural resources, including archaeological resources and buildings of historic significance to climate change impacts. The primary resource used in this section is the IPCC Fourth Assessment Report (IPCC, 2007a); specifically, Chapter 7 for industry, settlement, and society.

The industries, settlements, and society sector encompasses resources and activities that describe how people produce and consume goods and services, deliver and receive public services, and live and relate to each other in society.

As defined by IPCC, this sector includes the following:

- Industry: manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (IPCC, 2007a).
- Services: trade, retail, and commercial services, tourism, risk financing/insurance (IPCC, 2007a).
- Utilities/Infrastructure: systems designed to meet relatively general human needs, often through largely or entirely public utility-type institutions (IPCC, 2007a).
- Human Settlement: urbanization, urban design, planning, rural settlements (IPCC, 2007b).
- Social Issues: demography, migration, employment, livelihood, and culture (IPCC, 2007b).

#### 4.5.7.1 Affected Environment

The industry, settlements, and society sector covers a very broad range of human institutions and systems, including the industrial and services sectors, large and small urban areas and rural communities, transportation systems, energy production, and financial, cultural, and social institutions.

A principal objective of human societies is to reduce their sensitivity to weather and climate. Recent experience with storms such as Hurricane Katrina reveals the limits to human control over climate-related impacts on industries, settlements, and society. Systems that are sensitive to climate change include air and water quality, linkage systems (transportation and transmission networks), building structures, resource supplies, social networks, and economic systems (IPCC, 2007a).

This sector normally experiences and is generally resilient to variability in environmental conditions. Industries, settlements, and human society, however, can be vulnerable to extreme or persistent changes. Vulnerability increases when changes are unexpected or if resources or other factors inhibit the ability of this sector to respond to changes (IPCC, 2007a).

Together, industry and economic services account for more than 95 percent of gross domestic product in highly developed economies and between 50 and 80 percent of gross domestic product in less developed economies (World Bank 2006, cited in IPCC, 2007a). Industrial activities are vulnerable to temperature and precipitation changes. For example, in Canada weather-related road accidents translate into annual losses of at least $1 billion Canadian annually, while more than a quarter of air travel delays in the United States are weather related (Andrey and Mills, 2003, cited in IPCC 2007a). Buildings, linking systems, and other infrastructure are often located in areas vulnerable to extreme weather events (flooding, drought, high winds). Trapp et al. (2007) found a net increase in the number of days in which severe thunderstorm environmental conditions could occur during the late 21st century using global and high-resolution regional climate models. The analysis suggests a future increase in these conditions of 100 percent or more in Atlanta, Georgia, and New York, New York. Such extreme events that can threaten linkage infrastructures such as bridges, roads, pipelines or transportation networks may cause industry to experience substantial economic losses (IPCC, 2007a).

Institutional infrastructure is generally considered to be less vulnerable to weather and climate variation, as it embodies less fixed investment and is more readily adapted within the time scale of climate change. In some cases, experience with climatic variability can enhance the resilience of institutional infrastructure by triggering adaptive responses (IPCC, 2007 a).

Vulnerability to climate change impacts is determined by local geography and social context rather than large scale or aggregate factors (IPCC, 2007a). Risk factors associated with local geography and social context are briefly described below.

### Geography

Extreme weather events are more likely to pose risks to industry, settlements, and society than gradual climate change (IPCC, 2007a). Resources and activities that are located in areas with higher susceptibility to extreme weather events (high temperatures, high winds, and flooding) are more vulnerable to the impacts of climate change. Extreme weather events can damage transportation routes and other infrastructure, damage property, dislocate settlement patterns, and disrupt economic activity. Gradual climate change can change patterns of consumption, decrease or increase the availability of inputs for production, and affect public health needs. Such impacts are experienced locally, but can be linked to impacts on national and global systems (IPCC, 2007a).

Archaeological resources and buildings of historic significance are fixed in location and are therefore vulnerable to the effects of extreme weather events and gradual changes associated with local geography. Extreme weather events can expose archaeological resources and damage significant structures. Over time, gradual changes to weather patterns can also erode protective cover around archaeological resources and increase the rate of deterioration of historic buildings. Vulnerability of these resources to climate change impacts is tied to the susceptibility of location and local geography to extreme and gradual changes to weather.

### Social Context

Worldwide, many of the places where people live are under pressure from a combination of growth, social inequity, jurisdictional fragmentation, fiscal shortfalls, and aging infrastructure. These stresses can include scarcity of water, poor sanitation, inadequate governance structures, unmet resource requirements, economic inequities, and political instability. While these types of stresses vary greatly across localities, they can combine with climate change impacts to result in significant additional stress at local, national, and global levels (IPCC, 2007a).

The social impacts associated with climate change will be mainly determined by how the changes interact with economic, social, and institutional processes to minimize or magnify the stresses. From an environmental justice perspective, the most vulnerable populations include the poor, the very old and very young, the disabled, and other populations that have limited resources and ability to adapt to changes (IPCC, 2007a).

### Urbanization

It is estimated that one third of the world's urban population (nearly 1 billion people) lives in overcrowded and unserviced slums, and 43 percent of the urban population is in developing countries. More generally, human settlements are often situated in risk-prone regions such as steep slopes, ravines, and coastal areas. These risk-prone settlements are expected to experience an increase in population, urbanized area, and economic activity. The population in the near-coastal zone (i.e., within 330 feet elevation and 60 to 65 miles distance from the coast) has been estimated to be between 600 million and 1.2 billion, or 10 to 23 percent of the world's population (Adger et al., 2005; McGranahan et al., 2006 cited in IPCC, 2007a). Migration from rural to urban areas is a common response to calamities such as floods and famines (IPCC, 2007a).

#### 4.5.7.2 Consequences

Key climate change impacts on this set of human systems are likely to vary widely and depend on a range of location-specific characteristics and circumstances. Moreover, potential climate change impacts on this sector could be particularly challenging to determine because effects tend to be indirect rather than direct, for example changes in temperature—a direct effect of climate change—affect air pollution concentrations in urban areas thereby affecting human health and health care systems, which are all indirect effects (Wilbanks et al., 2007).

The human institutions and systems that comprise the industry, settlements, and society sector tend to be quite resilient to fluctuations in environmental conditions that are within the range of normal occurrence. However, when environmental changes are more extreme or persistent, these systems can exhibit a range of vulnerabilities "especially if the changes are not foreseen and/or if capacities for adaptation are limited" (Wilbanks et al., 2007, p. 359). For this reason industry, settlements, and society in developing countries are expected to be more vulnerable to direct and indirect climate change impacts than they are in industrialized countries (Wilbanks et al., 2007).

Climate change is expected to affect industry, settlements, and society via a range of physical effects, including the frequency and intensity of tropical cyclones and storms, extreme rainfall and floods, heat and cold waves, drought, temperature extremes, precipitation, and sea level rise. Following the approach in Wilbanks et al., 2007, the categories of human systems addressed in this section include industry, services, utilities and infrastructure, settlements, and social issues. Each category is described below, and potential climate impacts on each category are discussed. Key systems within these categories that are expected to experience impacts associated with climate change are then discussed in greater detail in subsequent sections.

**Industry.** Industry includes manufacturing, transport, energy supply and demand, mining, construction, and related informal production activities (Wilbanks et al., 2007). These activities can be vulnerable to climate change when (a) facilities are located in climate-sensitive areas such as coasts and floodplains, (b) the sector is dependent on climate-sensitive inputs such as food processing, or (c) the sector has long-lived capital assets (Ruth et al., 2004 in Wilbanks et al., 2007). For the energy sector, in addition to possible infrastructure damage or destruction from the effects of climate change (e.g., as could happen due to extreme weather events) effects could also include climate-driven changes in demands for energy. For example, demand for heating could decline in winter months while demand for cooling could rise in summer months (USCCSP, 2008).

**Services.** Services include trade, retail and commercial services, tourism, and risk financing or insurance (Wilbanks et al., 2007). Possible climate change impacts on trade include impacts on transportation from extreme weather events like snow and ice storms that could impede the ability to transport goods, or impacts on comparative advantage of a region or country due to temperature shifts that affect production. Climate change impacts on transportation could also affect retail and commercial services. Retail and commercial services could also be affected by climatic conditions that affect prices of raw materials and by potential damage to infrastructure such as facilities existing in climate sensitive areas like coastal regions. Extreme events such as hurricanes can also affect tourism infrastructure. Tourism services could also be affected by climate change impacts through temperature shifts and changes that affect the natural landscape of tourist destinations. Potential indirect effects of climate change on tourism include changes in availability of water and energy prices. With respect to the insurance sector, climate change impacts could lead to increasing risk, which could trigger higher premiums and more conservative coverage. A reduction in availability of or ability to afford insurance could in turn lead to impacts on local and regional economies.

**Utilities and Infrastructure.** Utilities and infrastructure includes systems that are "designed to meet relatively general human needs, often through largely or entirely public utility-type institutions" (Wilbanks et al., 2007, p. 370). This includes physical infrastructure such as water, transportation, energy, and communication systems, as well as institutional infrastructure such as shelters, public health care systems, and police, fire, and emergency services. "These infrastructures are vulnerable to climate change in different ways and to different degrees depending on their state of development, their resilience, and their adaptability" (Wilbanks et al., 2007, p. 370). In general, institutional infrastructure tends to be less vulnerable to climate change than physical infrastructure because it typically involves less investment in fixed assets and is more flexible over timeframes that are relevant to climate change. There are numerous points where impacts on different infrastructures interact and the failure of one system can put pressure on others. At the same time, however, "this means that measures to protect one sector can also help to safeguard the others" (Wilbanks et al., 2007, p. 370).

**Human Settlement.** Climate change interacts with other stresses in its impact on human settlements (Wilbanks et al., 2007). Potential impacts on human settlements could be experienced through several pathways. Sea level rise threatens populations in coastal areas by accelerating the inundation of coastal wetlands, threatening vital infrastructure and water supplies, augmenting summertime energy demand, and affecting public health (Wilbanks et al., 2007). Changes in precipitation patterns could alter the availability of potable water while changes in temperature could affect air quality and contribute to an increase in incidents of heat stress and respiratory illnesses (Wilbanks et al., 2007). In urban areas, the Urban Heat Island effect (Wilbanks et al., 2007), which relates to the "degree to which built and paved areas are associated with higher temperatures than surrounding rural areas" (USCCSP, 2008, p. 159) might affect the manner in which climate change affects these areas.

**Social Issues.** Within human settlements, society could also experience a variety of effects associated with climate change. For example, communities could experience increasing stress on management and budget requirements for public services, if demands on public health care and disaster risk reduction grow (USCCSP, 2008). There could be a loss of cultural and traditional groups of people, e.g. "indigenous societies in polar regions" (Wilbanks et al., 2007, p. 373). Societal concerns that might be affected by the impacts of climate change include socioeconomic issues relating to developed versus developing areas and rich versus poor. Because the developing countries and poorer populations tend to have weaker infrastructure in place to begin with, their vulnerability to climate change effects is expected to be higher and their capacity to cope or adapt are expected to be lower than developed countries and wealthier populations (Wilbanks et al., 2007).

#### 4.5.7.2.1 Projected Impacts of Climate Change for the United States

The research literature on climate impacts on United States industry, settlements, and society is relatively sparse. "At the current state of knowledge, vulnerabilities to possible impacts are easier to project than actual impacts because they estimate risks or opportunities associated with possible consequences rather than estimating the consequences themselves" (Gamble et al., 2008, Ch. 3, p. 4). In general, "climate change effects on human settlements in the United States are expected to occur as a result of interaction with other processes" (USCCSP, 2008, p. 159). These effects include those on health, water resources, physical infrastructure (notably transportation systems), energy systems, human settlements, and economic opportunities.

Impacts on human health and human health care systems are expected to arise because of temperature-related stress. Increases in cases of respiratory illness associated with high concentrations of ground-level ozone; water-, food-, and vector-borne diseases; and allergies related to higher concentrations of plant species are expected.

Effects on water are expected to include reductions in snowpack, river flows, and groundwater levels, saline intrusion in rivers and groundwater, an increase in water demand due to increasing temperatures, and impacts on sanitation, transportation, food and energy, and communication infrastructures from severe weather events.

The United States coastline, deltas, and coastal cities such as the Mississippi Delta and surrounding cities, are vulnerable to sea level rise. "Rapid development, including an additional 25 million people in the coastal United States over the next 25 years will further reduce the resilience of coastal areas to rising sea levels and increase the economic resources and infrastructure vulnerable to impacts" (Field et al., 2007 in USCCSP, 2008, p. 162).

Effects on other key human systems are discussed in greater detail below. Because this section deals with such a broad set of human systems, the potential impacts of climate change and potential adaptations available to key human systems are discussed together. Given the enormous range of human systems that could be affected by climate change, the discussion here is focused on a few key systems where impacts can best be characterized or supported by sufficient information.

### Impacts on Transportation Infrastructure

Climate affects the design, construction, operation, safety, reliability, and maintenance of transportation infrastructure, services, and systems. The potential for climate change raises critical questions about how changes in temperature, precipitation, storm events, sea level rise, and other climate variables could affect the system of roads, airports, rail, public transit, pipelines, ports, waterways, and other elements of the nation's and the world's complex transportation systems.

Climate changes anticipated during the next 50 to 100 years include higher temperatures, changes in precipitation patterns, increased storm frequency and intensity, and rising sea levels globally, resulting from the warming of the world's oceans and decline in polar ice sheets. These changes may affect the transportation system in a wide variety of ways. Those of greatest relevance for the United States are summarized below.

- **Increases in very hot days and heat waves.** It is *very likely* that heat extremes and heat waves will continue to become more frequent, more intense, and last longer in most regions during the 21st century. This may increase the cost of transportation construction, operations, and maintenance.

- **Increases in Arctic temperatures.** Arctic warming is *virtually certain* as temperature increases are expected to be greatest over land and at most high northern latitudes. As much as 90 percent of the upper layer of permafrost could thaw under more pessimistic emission scenarios.

- **Rising sea levels.** It is *virtually certain* that sea levels will continue to rise in the 21st century as a result of thermal expansion and loss of mass from ice sheets. This may make much of the existing transportation infrastructure in coastal areas prone to frequent, severe, and/or permanent inundation.

- **Increases in intense precipitation events.** It is *very likely* that intense precipitation events will continue to become more frequent in widespread areas of the United States. Transportation networks, safety, and reliability may be disrupted by visibility problems for drivers, and by flooding, which may result in significant damage to the transportation system.

- **Increases in hurricane intensity.** Increased tropical storm intensities, with larger peak wind speeds and more intense precipitation are *likely*, which may result in increased travel disruption, impacts on the safety and reliability of transportation services and facilities, and increased costs for construction, maintenance, and repair (Transportation Research Board, 2008).

Numerous studies have examined ways of mitigating the transportation sector's contribution to global warming from GHG emissions. However, far less attention has been paid to the potential impacts of climate change on United States transportation and on how transportation professionals can best adapt to climate changes that are already occurring, and will continue to occur into the foreseeable future even if drastic mitigation measures were taken today. Since GHGs have long life spans they continue to impact global climate change for decades (Transportation Research Board, 2008).

Scientific evidence confirms that climate change is occurring, and that it will trigger new, extreme weather events and could possibly lead to surprises, such as more rapid than expected rises in sea levels or temperature changes. Every mode of transportation will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers (Transportation Research Board, 2008).

Consideration of climate change-related factors in transportation planning and investment decisions should lead to a more resilient, reliable, and cost-effective transportation system in the coming decades. When decision makers better understand the risks associated with climate change, they can make better decisions about potential adaptation strategies and the tradeoffs involved in planning, designing, constructing, operating, and maintaining transportation systems (Transportation Research Board, 2008).

Projected climate changes have profound implications for transportation in the United States (Transportation Research Board, 2008). Climate change is likely to increase costs for the construction and maintenance of transportation infrastructure, impact safety through reduced visibility during storms and destruction of elements of the transportation system during extreme weather events, disrupt transportation networks with flooding and visibility problems, inundate significant portions of the transportation system in low lying coastal areas, increase the length and frequency of disruptions in transportation service, cause significant damage and incur costly repairs to transportation infrastructure, and impact the overall safety and reliability of the nation's transportation system (Transportation Research Board, 2008).

Transportation systems across the United States are projected to experience both positive and negative impacts from climate change over the next century; the degree of impacts will be determined, in part, by the geographic region (Transportation Research Board, 2008). Coastal communities are especially vulnerable to impacts associated with sea level rise, increased frequency or intensity of storms, and damage to the transportation system due to storm surges and flooding. The literature indicates that the intensity of major storms could increase by 10 percent or more, which could result in more frequent Category 3 (or higher) storms in the Gulf Coast and along the Atlantic coast (Transportation Research Board, 2008).Warming temperatures might require changes in the kinds of materials used for construction of transportation facilities, and in the operation and maintenance of transportation facilities and services. Higher temperatures could require the development and use of more heat-tolerant materials (Transportation Research Board, 2008). Restrictions on work rules could increase the time and costs for labor for construction and maintenance of transportation facilities. Rail lines could be affected by higher temperatures and more frequent rail buckling, which would affect service reliability, safety and overall system costs and performance. Costs could increase for ports, maintenance facilities, and transportation terminals if higher temperatures require an increase in refrigeration and cooling (Transportation Research Board, 2008); and higher temperatures could affect aircraft performance and the runway lengths required for safe operation (Transportation Research Board, 2008). On the positive side, higher temperatures might open up northern transportation routes for longer periods of time and allow more direct routing for marine transportation (Transportation Research Board, 2008).

Changes in precipitation patterns may increase short-term flooding, resulting in decreased safety, disruptions in transportation services, and costly damage to transportation infrastructure. Hotter climates may exhibit reduced soil moisture and average run-off, which might require changes in the management and maintenance of publicly owned right-of-way. The potential increase in heavy rainfall may exceed the capacity of existing drainage systems, resulting in more frequent flooding and associated disruptions in transportation system reliability and service, increased costs for maintenance of existing facilities, and increased costs for construction of new facilities (Transportation Research Board, 2008).

Relative sea level rise may inundate existing transportation infrastructure and significantly increase the cost of provision of new transportation facilities and services. Some portions of the transportation infrastructure in coastal areas, or in areas prone to flooding, may have to be protected with dikes or levees – increasing the cost for construction and maintenance, and the potential for more serious flooding incidents associated with the failure of such dikes and levees (Transportation Research Board, 2008).

Increased storm frequency and intensity may lead to greater transportation service disruption, and damage to transportation infrastructure in coastal and inland areas. Model results for the study of the Gulf Coast conservatively estimated a 22- to 24-foot potential surge for major hurricanes (Transportation Research Board, 2008). During Hurricane Katrina (a Category 3 storm at landfall) surges exceeded these heights in some locations (Transportation Research Board, 2008). While the specific location and strength of storm surges are difficult to predict due to the variation of the scale and trajectory of individual tropical storms, substantial portions of the coastal infrastructure across the United States are vulnerable to increased damage resulting from the impacts of climate change (Transportation Research Board, 2008).

Disruptions in transportation system availability could result in substantial economic impacts associated with increased costs to construct or repair transportation infrastructure, and costs associated with disruptions in transportation for goods and services. Increasing fuel costs and delays in transportation service result in increased transport costs, which are then passed on to consumers. A significant disruption in transportation (e.g. destruction of major transportation facility by hurricane, flood, or other extreme weather event) may affect the regional economy in many different ways. Communities are likely to require long periods of time to recover from these events, and some communities could be permanently affected (Transportation Research Board, 2008).

The analysis to date raises clear cause for concern regarding the vulnerability of transportation infrastructure and services in coastal areas, and across the United States. Addressing the risks associated with a changing climate in the planning and design of transportation facilities and services can help public agencies and private investors to minimize disruptions to the smooth and safe provision of transportation services; and can protect the substantial investments made in the nation's transportation infrastructure now and in the future (Transportation Research Board, 2008).

According to the USCCSP's *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure Report* (Transportation Research Board, 2008), four key factors are critical to understanding how climate change might affect transportation:

- **Exposure.** What is the magnitude of stress associated with a climate factor (sea level rise, temperature change, severe storms, and precipitation) and the probability that this stress will affect a transportation segment or facility?

- **Vulnerability.** Based on the structural strength and integrity of the infrastructure, what is the potential for damage and disruption in transportation services from this exposure?

- **Resilience.** What is the current capacity of a system to absorb disturbances and retain transportation performance?

- **Adaptation.** What response(s) can be taken to increase resilience at both the facility (e.g., a specific bridge) and system levels?

New approaches to address climate change factors in transportation planning and decision making may include:

- **Extending planning timeframes.** In order to address the long timeframe over which climate changes and environmental processes occur, planning timeframes may need to be extended beyond the typical 20- to 30-year planning horizon. The fact that transportation infrastructure can last for many decades (or even more than 100 years) argues for planning for much longer timeframes to examine the potential impacts of climate change and other elements of the natural environment on the location, construction techniques, and costs for transportation infrastructure investments that are expected to last for many decades (Transportation Research Board, 2008).

- **Conducting risk assessment analysis for transportation investments**. Transportation investments face many uncertainties, including the potential impacts of climate change on construction, operation, and maintenance. Planners and decision makers can use iterative risk management analysis to evaluate potential risks of all types, and to identify potential ways to minimize the risks and increase the resiliency of transportation infrastructure. Transportation structures and facilities can be hardened, raised, or even relocated if needed. Where it is critical to safety, reliability and mobility, redundant systems may need to be provided for the most critical elements of the transportation system (Transportation Research Board, 2008).

### Impacts on Energy Systems

Although the energy sector has been seen as a driver of climate change, the energy sector is also subject to the effects of climate change (Wilbanks et al., 2007). All major energy sources are subject to a variety of climate change effects, including temperature, wind, humidity, precipitation, and extreme weather events (Bhatt et al, 2007). The most direct climate change impacts for fossil fuel and nuclear power plants, for example, are related to power plant cooling and water availability (Bhatt et al., 2007). Each kilowatt of electricity generated by thermoelectric generation requires about 25 gallons of water. Power plants rank only slightly behind irrigation in terms of freshwater withdrawals in the United States (USGS, 2004 cited in Bhatt et al., 2007). In addition, about 10 percent of all United States coal shipments were delivered by barge in 2003, and consequently low river flows can create shortfalls in coal supplies at power plants (Bhatt et al., 2007).

USCCSP identified potential effects of climate change on energy production and use in the United States, which are stated in terms of likelihood (Wilbanks et al., 2007). Principal impacts and their likelihood are listed below:

- Climate change will reduce total energy demand for space heating; effects will differ by region (*virtually certain*).
- Climate change will increase total energy demand for space cooling; effects will differ by region (*virtually certain*).
- Net effects on energy use will differ by region. Overall impacts will be affected by patterns of interregional migration – which are likely to be in the direction of net cooling load regions – and investments in new building stock (*virtually certain*).
- Temperature increases will increase peak demands for electricity (*very likely*).
- Changes in the distribution of water availability will affect power plants; in areas with decreased water availability, competition for water supplies between energy and other sectors will increase (*virtually certain*).
- Temperature increases will reduce overall thermoelectric power generation efficiency (*virtually certain*).
- In some regions, energy resource production and delivery systems will be vulnerable to the effects of sea level rise and extreme weather events, especially the Gulf Coast and the East Coast (*virtually certain*).
- Hydropower production will be directly and significantly affected by climate change, especially in the West and Northwest (*very likely*).
- Climate change concerns will affect perceptions and practices related to risk management behavior in investment by energy institutions (*very likely*).
- Climate change concerns are almost certain to affect public and private sector energy technology research and development investments and energy resource and technology choices by energy institutions, along with associated emissions (*virtually certain*).

USCCSP concluded that there is very little literature on adaptation of the energy sector to effects of climate change, and their following discussion is therefore largely speculative (Wilbanks et al., 2007). Both energy users and providers are accustomed to changing conditions that affect their decisions. The energy sector is among the most resilient of all economic sectors in terms of responding to changes within the range of historical experience (Wilbanks et al., 2007). Adaptations to the effects of climate change on energy use may focus on increased demands and rising costs for space cooling; likely responses include investing in more efficient cooling equipment and building envelopes. Increased demands for both peak and average electricity demands may lead to contingency planning for load-leveling, more efficient and expanded generation capacity, expanded inter-ties, and increased storage capacity (Wilbanks et al., 2007).

In terms of energy production and supply, the most likely near-term adaptation is expected to be an increase in perceptions of uncertainty and risk in long-term strategic planning and investment; with investors seeking to reduce risks through such approaches as diversifying supply sources and technologies, and risk-sharing arrangements (Wilbanks et al., 2007).

### Impacts on Human Settlements

The impacts of climate change on human settlements are expected to be significant in a number of ways. "Settlements are important because they are where most of the [United States] population lives, often in concentrations that imply vulnerabilities to location-specific events and processes" (Wilbanks et al., 2007, p. 371). Among the general effects of climate change are increased stress on human settlements due to higher summer temperatures and decreased stress associated with warmer winter weather. Changes in precipitation and water availability, rising sea levels in coastal regions, and greater risks from extreme weather events such as storms, flooding, and droughts are also expected to affect human settlements to various degrees. At the same time, stresses due to cold weather extreme events, such as blizzards and ice storms, are expected to decrease (Wilbanks et al, 2007).

Predicting climate change impacts on United States settlements is difficult because climate change is not forecast on a scale that is appropriate for local decision making, and because climate is not the only change that settlements are confronting. A key example is the continuing population shift, particularly among persons who have reached retirement, toward the Sun Belt and coastal areas. This means an ever larger elderly population could be at risk especially from extreme weather events such as tropical storms, as well as some types of vector-borne diseases and heat related illnesses (USCCSP, 2008).

Anticipated human impacts include the following:

- Increased respiratory and cardiovascular problems (Patz and Baldus, 2001 in USCCSP 2007).
- Changes in mortality rates caused by temperature extremes (Rozenzweig and Solecki, 2001 in USCCSP 2007).
- Increased water demands associated with warming accompanied by changes in precipitation that alters access to water (Gleick et al, 2000; Kirshen, 2002; Ruth et al., 2007 in USCCSP 2007).
- Damages or disruptions to services associated with urban infrastructure such as sanitation systems, electricity transmission networks, communication systems, and the like could occur as a result of storms, floods, and fires (USCCSP, 2008).
- Sea level rise could jeopardize many of the 673 coastal counties and threaten population centers (Neumann et al., 2000; Kirshen et al., 2004 in USCCSP 2007).
- Vulnerable populations such as the poor, elderly, those in ill health, the disabled, persons living alone, and individuals with limited rights (e.g., recent migrants) are expected to be at greater risk from climate change (USCCSP, 2008).

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

The vulnerability of human settlements and infrastructure in coastal areas to natural disasters such as hurricanes and tropical storms was demonstrated through the damages incurred by Hurricanes Katrina and Rita in the Southeastern region of the United States  After Hurricane Katrina struck, a total of 90,000 square miles was declared a Federal disaster area, 80 percent of New Orleans was flooded, more than 1,700 lives were lost, 850,791 housing units were damaged, 2,100 oil platforms and over 15,000 miles of pipeline were damaged (Petterson et al. 2006 in CIER 2007).

There are various possible adaptation strategies for human settlements.  Assuring effective governance, increasing the resilience of physical and linkage infrastructures, changing settlement locations over a period of time, changing settlement form, reducing heat-island effects, reducing emissions and industry effluents, improving waste handling, providing financial mechanisms for increasing resiliency, targeting assistance programs for especially impacted segments of the population, and adopting sustainable community development practices are some of them (Wilbanks et al., 2005 in Wilbanks et al., 2007).  Land use choices, specifically the discouragement of housing development in flood prone areas including areas below sea level and in deep flow plains, can help protect human settlements and preserve management flexibility for these areas (Isenberg et al., 2008).  The choice of strategies and policies for adaptation depend on their relationships with other social and ecological processes and level of economic development (O'Brien and Leichenko, 2000 in Wilbanks et al., 2007).

### Impacts on Economic Opportunities and Risks

Communities or regions that are dependent on climate-sensitive resources or goods or whose comparative advantage could be affected are expected to be particularly vulnerable to climate change. The insurance sector is an example of an industry that could be highly vulnerable to climate impacts.  If increasing trends of adverse weather events continue, claims made to private and public insurers are expected to climb (NAST 2001 in CIER 2007).  Overall risk exposure of insurers' has grown considerably, e.g., the National Flood Insurance Program's exposure increased four-fold since 1980 to $1 trillion in 2005 and the Federal Crop Insurance Corporation's exposure grew up to $44 billion (U.S. GAO 2007 in CIER 2007).  To the extent that climate change increases costs for insurers or increases the difficulty in forecasting risks, the insurance sector might "withdraw (or make much more expensive) private insurance coverage from areas vulnerable to climate change impacts" (USCCSP, 2008, p. 159).

Trade, retail, and commercial services, and tourism are other economic areas that are expected to be affected by climate change impacts, largely as a result of impacts on the transportation and energy sectors.  For example, impacts on transportation will affect distribution and receipt of goods for retail services.  This could have a particular effect on the Midwest which is a heavy domestic freight and shipping route area.  Approximately "$3.4 billion and 60,000 jobs rely on the movement of goods within the Great Lakes-St. Lawrence shipping route annually" (Easterling and Karl 2001 in CIER 2007, p. 22). A decline in water levels could jeopardize this mode of transporting manufacturing.  In fact, "[s]ystem connectivity is predicted to be come 25 percent impaired causing a loss of $850 million annually" (Easterling and Karl 2001 in CIER, 2007, p. 23).  Dredging 7.5 to 12.5 million cubic yards, costing $85-142 million, may be the only alternative to salvage this system if water levels decline significantly (Great Lakes Regional Assessment Group 2000 in CIER, 2007).

Tourism could be affected by "changes in the landscape of areas of tourist interest" as well as by changes in the availability of resources and energy costs (Wilbanks et al., 2007, p. 368).  In the United States, climate change impacts could affect winter recreation and tourism in the Northeast.  Warmer winters would "shorten the average ski and snowboard seasons, increase snow making requirements, and drive up operating costs", possibly "prompting further closures and consolidation of ski areas northward toward the Canadian border" (Frumhoff et al., 2007, p. 81).

### Historical and Cultural Resources

A variety of cultural and historical resources are at risk from climate change. According to a recent study by UNESCO "The adverse impacts of climate change will have consequences for humanity as a whole including the products of human creativity...these consequences will be manifest in at least two principal ways: (1) the direct physical effects on the buildings or structures and (2) the effects on social structures and habitats" (Colette et al., 2007, p. 64).

Alaska is the region expected to be most affected by climate change largely because of location (warming is more pronounced closer to the poles) and way of life (settlement and economic activities based around Arctic conditions) (Gamble *et al*., 2008, p. 25). Indigenous communities in Alaska are facing major economic and cultural impacts because they depend for subsistence on various climate-sensitive animals such as polar bears, walruses, seals, and caribou (USCCSP Scientific Assessment, 2008, p. 160). "Changes in species' ranges and availability, access to these species, a perceived reduction in weather predictability, and travel safety in changing ice and weather conditions present serious challenges to human health and food security, and possibly even the survival of some cultures" (ACIA, 2004 in USCCSP Scientific Assessment, 2008, p. 160 as cited in ACIA, 2004).

In discussing the impacts of climate change on historic cities and settlements around the world, Colette et al. (2007, pp64-65) list the following potential threats associated with climate change:

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

Climate change could also create pressures that result in migration of populations, which in turn could result in the breakdown of communities and the loss of "rituals and cultural memory" (Colette, et al., 2007, p. 65)

#### 4.5.7.2.2 Projected Global Impacts of Climate Change

As the discussion above suggests, the three major ways in which industry, settlements, and society are vulnerable to climate change are through impacts on economics, infrastructure, and health. The magnitude of impacts on industry, settlements, and society largely depends on location and the level of development of the area or region. The discussion below highlights anticipated impacts on key human systems at the global level.

### Global Energy Sector Impacts

In terms of energy production and use, the expected global impacts will likely be similar to those discussed above for the United States. When the climate warms, less heating will be needed for industrial, commercial, and residential buildings, with changes varying by region and by season (Wilbanks et al., 2007). Electricity is used in areas around the world for cooling; coal, oil, gas, biomass, and electricity provide energy for heating. Regions with substantial requirements for both cooling and heating could see net increases in electricity demands while demands for other energy sources decline (Hadley et al., 2006, in Wilbanks et al., 2007).

According to one study, by 2100 the benefits (reduced heating) will be about 0.75 percent of gross domestic product, and impacts (increased cooling) will be approximately 0.45 percent (Tol, 2002a, 2002b, in Wilbanks et al., 2007). These percentages could be affected by migration from heating-intensive regions to cooling-intensive regions (Wilbanks et al., 2007).

Climate change could also affect global energy production and distribution if extreme weather events become more frequent or intense; and in regions dependent upon water supplies for hydropower or thermoelectric generation if there are significant changes in rainfall/snowfall locations and seasonality. Reduced stream flows are expected to jeopardize hydropower production in some areas, but higher precipitation rates resulting in greater or more sustained stream flows may be beneficial (Casola et al., 2005; Voisin et al., 2006 cited in Wilbanks et al., 2007). More frequent or intense extreme weather events could threaten coastal energy infrastructures including electricity transmission and distribution facilities (Bull et al., 2007).

Warming temperatures resulting in melting of permafrost threaten petroleum production facilities and pipelines, electrical transmission towers, and nuclear power plants in the Arctic region (Nelson et al., 2001 cited in Wilbanks et al., 2007). As with Alaska's North Slope facilities, structural failures in transportation and industrial infrastructure are becoming more common in northern Russia due to melting permafrost (Wilbanks et al., 2007).

### Global Transportation Sector Impacts

The IPCC concludes, with *very high confidence*, that data since 1970 have demonstrated anthropogenic temperature rises have visibly altered ecosystems (Parry et al., 2007). Other stressors on the built environment and the ability of cities and countries to adapt to a changing climate make it difficult to discern the exact impacts of climate change on transportation systems around the world. Additional factors, such as projected population growth, are expected to exacerbate the effects of climate change. Development typically occurs in the coastal regions, especially in the newly developing third world countries. These areas are particularly vulnerable to the impacts of projected increases in extreme weather events such as hurricanes, cyclones, unusually heavy precipitation, and flooding. In addition these developing countries are less able to adapt to expected changes due to their limited resources and other pressing needs (Wilbanks, et al., 2007).

Transportation system vulnerabilities in more developed countries often focus on physical assets and infrastructures and their economic value and replacement costs, along with linkages to global markets. Vulnerabilities in less developed countries often focus on human populations and institutions that are likely to have very different transportation needs and resources (Wilbanks, et al., 2007). A warmer, dryer climate could exacerbate many of the problems of developing countries, including drought and decreases in food production in areas of Africa and Asia (Wilbanks, et al., 2007).

At a national scale, industrialized countries such as the United Kingdom and Norway can cope with most kinds of gradual climate change, but localized differences can show considerable variability in stresses and capacities to adapt (Environment Canada, 1997; Kates and Wilbanks, 2003; London Climate Change Partnership, 2004; O'Brien et al., 2004; Kirshen et al., 2006).

The impacts on the United States transportation systems described above apply in other countries as well. Based on information developed by the Transportation Research Board, 2008, the potential impacts of climate change on transportation fall into the two major categories described below.

- Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days, intense precipitation events, intense hurricanes, drought, and rising sea levels, coupled with storm surges and land subsidence. The impacts will vary by mode of transportation and region, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems.

- Potentially, the greatest impact of climate change on global transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of rising sea levels coupled with storm surges, and exacerbated in some locations by land subsidence (USCCSP, 2008).

Given the global nature of the impacts of climate change and the world economy, coordination within and among nations will become increasingly important (Wilbanks, et al., 2007). Strong and complex global linkages and interactions occur throughout the world today and are likely to increase in the future. Climate change effects cascade through interlinked systems for international trade, migration, and communication patterns producing a variety of direct and indirect effects. Some of these impacts may be anticipated. However, many might not, especially if the globalized economy becomes less resilient and more interdependent (Wilbanks, et al., 2007).

The impacts of an extreme weather event in one location (e.g., Hurricane Katrina in Louisiana) causes ripple effects throughout the transportation system in the United States and in areas around the world linked to the United States through the ports in the affected area (Transportation Research Board, 2008).

There are now incidences in Europe, North America, and Japan, of new transportation infrastructure being designed and constructed with potential climate change in mind. For example, bridges and other infrastructure designed at higher elevations in anticipation of sea level rise over the life span of these transportation system elements (Wilbanks, et al., 2007).

### Global Human Settlements Impacts

Human settlements are vulnerable to the effects of climate change in three major ways: (1) through economic sectors affected by changes in input resource productivity or market demands for goods and services; (2) through impacts on certain physical infrastructure; and (3) through impacts of weather and extreme events on the health of populations. The degree of vulnerability tends to be a function of the location (coastal and riverine areas are most at risk), economy (economies most dependent on weather-related sectors are at the highest risk), and size (larger settlements are at a greater aggregate risk, but they likely have greater resources to prevent the impacts of climate change and respond to events that result from climate changes such as hurricanes, floods, or other extreme weather events) (IPCC, 2007a).

Shifts in precipitation patterns might affect already stressed environments. For example, mean precipitation in all four seasons of the year has tended to decrease in all main arid and semi-arid regions of the world, e.g., northern Chile and northeast Brazil, West Africa, and Ethiopia, drier parts of southern Africa, and western China (Folland et al., 2001 in Wilbanks et al., 2007). Increasing temperature could aggravate ozone pollution in many cities which may affect quickly growing urban areas that, especially those in developing countries, are experiencing more air pollution problems (Wilbanks et al., 2007). Extreme weather events affect settlements and society in developing countries just as they do developed countries, through damage and destruction of infrastructure and loss of human life, although perhaps in slightly different ways. For example, in some urban areas of developing countries, informal settlements develop. These informal settlements are especially vulnerable as they tend to be built on hazardous sites and susceptible to floods, landslides, and other climate-related disasters (Cross, 2001, UN-Habitat, 2003 in Wilbanks et al., 2007). Another example is how “[i]n developing countries, a common cause of death associated with extreme weather events in urban areas is electrocution by fallen power cables” (Few et al., 2004 in Wilbanks et al., 2007, p.371).

#### Global Impacts on Economic Opportunities and Risks

Impacts vary by region and locality and cannot be generalized for all nations. Although impacts are expected to vary, a factor that developed countries have in common is that their access to material and financial resources provides them opportunities to adapt to the effects of a changing climate. By contrast, developing countries are expected to be less able to adapt to climate change because they lack both the physical and financial resources needed to bolster their resilience to the same extent that is possible in industrialized countries.

In developing countries “industry includes a greater proportion of enterprises that are small-scale, traditional, and informally organized…Impacts of climate change on these businesses are likely to depend on… location in vulnerable areas, dependence on inputs sensitive to climate, and access to resources to support adaptive actions” (Wilbanks et al., 2007, p. 366). One specific industry that may become more vulnerable to direct and indirect impacts of climate change is the tourism industry. Impacts on this industry can be “especially significant for smaller, tourist-oriented countries often in the developing world” (Wilbanks et al., 2007, p. 369). It seems “likely that tourism based on natural environments will see the most substantial changes due to climate change… Tropical island nations and low-lying coastal areas may be especially vulnerable as they may be affected by sea level rise, changes in storm tracks and intensities, changes in perceived climate-related risks, and changes in transport costs…” (Wilbanks et al., 2007, p. 380). The implications are most notable for areas in which tourism is a relatively large share of the local or regional economy, and those for which adaptation would represent a relatively significant need and a relatively significant cost (Wilbanks et al., 2007). Trade is another industry that may be affected by extreme weather events that temporarily close ports or transport routes and damage infrastructure critical to trade, both domestic and international. There could be “linkages between climate change scenarios and international trade scenarios, such as a number of regional and sub-regional free trade agreements” (Wilbanks et al., 2007, p. 368). However, research on this topic is lacking.

### 4.5.7.2.3 Adaptation

People and societies have adapted to changing conditions in every phase of human history, and human societies have generally been highly adaptable (Ausubel and Landford, 1977). Adaptation can be anticipatory or reactive, self-induced and decentralized, or dependent on centrally initiated policy changes and social collaboration. Adaptation measures can be gradual, occurring over long periods of time; or evolutionary based on reactions to abrupt changes in settlement patterns or economic activity, or in response to extreme weather events (Wilbanks et al., 2007).

Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions of climate change, its sensitivity to such changes, and its capacities to cope with the changes. Some of the strategies are multisectoral, such as improving climate and weather forecasting at local and regional levels, emergency preparedness, and public education (Wilbanks et al., 2007). These strategies are likely to be more prominent in more fully developed countries, but are important tools to facilitate adaptation in all countries. Awareness, capabilities, and access to resources that facilitate adaptation to climate change are likely to be much less widely available in less developed countries, where industrial production and residential population often locate in areas vulnerable to flooding, coastal erosion, and extreme weather events (Wilbanks et al., 2007).

New warning systems and evacuation procedures are important adaptation strategies. New warning systems in areas prone to extreme weather events such as hurricanes, cyclones, tornados, and flooding can help to prevent weather-related deaths; and minimize damage to community infrastructure, including the transportation system. Adaptation strategies tend to be context-specific, within larger global markets and policy structures, although it generally takes place within the larger context of globalization (Benson and Clay, 2003; Sperling and Szekely, 2005).

“Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions of climate change, its sensitivity to such changes, and its capacities to cope with the changes” (Wilbanks et al., 2007, p. 378). In general, uncertainty about the distribution and timing of climate-change impacts at the local level makes judgments about the scale and timing of adaptation actions very difficult (Wilbanks et al., 2007, p. 378).

### 4.5.8 Human Health

#### 4.5.8.1 Affected Environment

Climate change has contributed to human mortality and morbidity (*very high* confidence; IPCC, 2007) with further projected increases. Climate change may increase the risk of flooding; increase incidence of heat waves; change the severity, duration, and location of extreme weather; increase surface temperature; and alter precipitation intensity and frequency. These events can affect human health either directly through temperature and weather or indirectly though changes in water, air, food quality, vector ecology, ecosystems, agriculture, industry, and settlements. Climate change can also affect health through social and economic disruption. Malnutrition, death, and disease brought on by climate-change are projected to affect millions of people. (IPCC, 2007)

#### 4.5.8.2 Consequences

##### 4.5.8.2.1 Heat Waves

A heat wave is a period of abnormally high temperatures that may be accompanied by unusual humidity. This weather phenomenon is not formally specified by a time period or temperature reading. Conventionally, a heat wave lasts several days to several weeks, though a one-day event can qualify as a heat wave. The temperature to qualify as a heat wave is dependent upon what is considered unusually hot for that region, as increases in mortality can occur below temperatures considered extremely hot (Ebi et al., 2008). IPCC has found the number of hot days, hot nights, and heat-waves to have increased (IPCC, 2007). Global warming has increased intensity of heat waves (Houghton et al., 2001 in Epstein et al., 2006), due in part to the disproportionate warming at night (Easterling et al., 1997, in Epstein et al., 2006). Heat-wave events can trigger poor air quality and forest fires, leading to further increases in human mortality and morbidity (Bates et al., 2005; Goodman et al., 2004; Keatinge and Donaldson 2001; O’Neill et al., 2005; Ren et al., 2006 as cited in Ebi et al., 2008).

The impact of a heat wave on the affected population depends on the current health and economic status. In South Asia, those most sensitive to heat waves include the rural population, elderly, outdoor workers, very young, city-dwellers, those with less education, socially isolated, medicated people, mentally ill, and those without available air conditioning (Chaudhury et al, 2000 in IPCC, 2007; Diaz et al., 2002; Klinenberg, 2002; McGeehin and Mirabelli, 2001; Semenza et al., 1996; Whitman et al., 1997; Basu et al., 2005; Gouveia et al., 2003; Greenberg et al., 1983; O'Neill et al., 2003; Schwartz, 2005; Jones et al., 1982; Kovats et al., 2004; Schwartz et al, 2004; Semenza et al., 1999; Watkins et al., 2001, as cited in Ebi, 2008). People in developed areas can be impacted significantly by heat waves as well. Existing electricity grids in the United States would be severely stressed by a major heat wave, leading to brownouts and blackouts further contributing to increased heat-related illnesses (Epstein et al., 2006).

The urban heat island effect may increase temperatures experienced in cities by 2 to 10º Fahrenheit compared to neighboring rural and suburban areas (EPA, 2005, in Ebi et al., 2008). This increase in temperature occurs, in part, as the city pavement and buildings absorb a greater amount of incoming solar radiation compared to vegetation and trees; in addition, heat is also emitted from buildings and transportation (EPA, 2005; Pinho and Orgaz, 2000; Vose et al., 2004; Xu and Chen, 2004 in Ebi et al., 2008). However, it has been demonstrated that during a heat wave, not all urban areas experience greater heat-related mortality than the surrounding rural and suburban areas (Sheridan and Dolney, 2003 in Ebi et al., 2008).

#### 4.5.8.2.2 Cold Waves

Human mortality and morbidity can also be caused by cold waves. Cold waves affect human health through death, hypothermia, frostbite, damage to organs such as kidney, pancreas, and liver, with greatest risk to infants and the elderly (NOAA, 2001). Cold waves can cause further complications of heavy snow, ice, coastal flooding, and stranded motorists. As with a heat wave, the classification of a cold wave varies by region, with no formal definition for the minimum temperature reached, the rate of temperature fall, or the duration of the event. Populations in temperate countries tend to be more sensitive to cold weather (Honda et al., 1998 in IPCC, 2007). The human health reaction of a population to a cold wave can vary depending on the income, (Healy, 2003 in Ebi et al., 2008), age, topography, climate, (Curriero et al., 2002; Hajat, 2006 in IPCC, 2007), race, (Fallico et al., 2005 as cited in Ebi et al., 2008), sex, (Wilkinson et al., 2004 as cited in Ebi et al., 2008), health, (Wilkinson et al., 2004 as cited in Ebi et al., 2008), dress, (Donaldson et al., 2001 as cited in Ebi et al., 2008), and fuel access (Healy, 2003 in Ebi et al., 2008). Cold days, cold nights, and frost days have become less common (IPCC, 2007) with the winter season projected to continue to decrease in duration and intensity (Alley et al., 2007, in Ebi et al., 2008). This may lead to a decrease in cold-related health impacts, notwithstanding external factors, such as influenza outbreaks (Ebi et al., 2008).

#### 4.5.8.2.3 Extreme Weather Events

Climate change is anticipated to affect the number, severity, and duration of extreme weather events (Fowler and Hennessey, 1995 in Sussman et al., 2008). Extreme weather events include floods, tropical and extra-tropical cyclones, tornadoes, windstorms, and drought. Extreme weather can further trigger additional extreme events such as wildfires, negatively affecting infrastructure including sanitation, human mortality and morbidity, and mental health (IPCC, 2007). The loss of shelter, large-scale population displacement, damage to community sanitation and health care, and reduction in food availability can extend the level of mortality and morbidity beyond the actual event (Curriero et al., 2001 in Sussman et al., 2008). Factors that influence population vulnerability to extreme weather include location, population density, land use, age, income, education, health, health care response, and disaster preparedness (Blaikie et al., 1994; Menne, 2000; Olmos, 2001; Adger et al., 2005; Few and Matthies, 2006; in IPCC, 2007).

Adverse weather conditions create safety hazards and delays in the Nation's transportation systems, especially on the nation's highways. The Federal Highway Administration (FHWA) estimates that about 25 percent of highway crashes occur during adverse weather resulting in about 17 percent of highway fatalities (AMS, 2004), while the Federal Motor Carrier Safety Administration (FMCSA) found that the factor "environmental conditions" was the critical reason[18] for 3 percent of large truck crashes (FMCSA, 2007). Extreme weather events that increase adverse weather conditions on the nation's highways could potentially affect highway safety.

Floods occur with the greatest frequency compared to other extreme weather events (EM-DAT, 2006 in IPCC, 2007). The intensity of a flood is dependent on rainfall, surface runoff, evaporation, wind, sea level, and local topography (IPCC, 2007). Health impacts related to flood events include deaths and injuries sustained during a flood event; increased transmission and prevalence of infectious diseases; and toxic contamination of supplies and food (Greenough et al., 2001; Ahren et al., 2005 in IPCC, 2007, and Hajat et al., 2003, Kalashnikov et al., 2003, Tuffs and Bosch, 2002, in Epstein et al., 2006).

Drought is an abnormal period of dry weather that has led to significant decrease in water availability for a given location (Huschke, 1959). The health impacts associated with a drought include mortality, malnutrition, infectious diseases, and respiratory diseases (Menne and Bertollini, 2000 in IPCC, 2007). Aggravating this situation, malnutrition increases the susceptibility of contracting an infectious disease (IPCC, 2007) and drought-related population displacement can reduce access to adequate and safe water, food, and shelter, leading to increased malnutrition and infectious diseases. Further health impacts can spiral, such as a change in the transmission of mosquito-borne diseases during and after the drought event (IPCC, 2007). Impacts on the agricultural productivity affect health through risk of under- and malnutrition (Epstein et al., 2006), and increased dust storm activity and frequency of forest fires. Drought conditions weaken trees' defenses against pests and can result in increased threats to human health from forest fires (Mattson and Hack, 1987, Boyer 1995, Holsten et al., 2000, in Epstein et al., 2006).

#### 4.5.8.2.4 Air Quality

Climate change can affect air quality through altering local weather patterns and/or pollution concentrations. Ground-level ozone, particulate matter, and airborne allergens contribute to poor air quality, leading to respiratory ailments and premature mortality. Increasing exposure to these pollutants would have significant negative health impacts (IPCC, 2007).

Ground-level ozone contributes to urban smog, and occurs both naturally and as a secondary pollutant formed through photochemical reactions of nitrogen oxides and volatile organic compounds.[19] These reactions are accelerated with increasing sunlight and temperatures; thus ozone concentrations tend to peak during late afternoon and early evening in the warmer season; however, some locations demonstrate no such seasonality in ozone concentration (Bates, 2005 as cited in IPCC, 2007). The concentration of ground-level ozone for a particular location varies as a function of temperature, wind,

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[18] FMCSA conducted the Large Truck Crash Causation Study (LTCCS) sample of 963 crashes involved 1,123 large trucks and 959 motor vehicles that were not large trucks between 2001 and 2003. The LTCCS defines the Critical Reason as the immediate reason for the critical event (i.e., the failure leading to the critical event). The critical reason is assigned to the vehicle coded with the critical event in the crash. It can be coded as a driver error, vehicle failure, or environmental condition (roadway or weather). Other causal coding includes a Critical Event and Associated Factors.

[19] Nitrogen oxides are emitted, in part, through the burning of fossil fuels. Volatile organic compounds are emitted from varying sources including burning of fossil fuels, transpiration, evaporation from stored fuels, solvents and other chemicals.

solar radiation, atmospheric moisture, atmospheric mixing, and cloud cover. Studies have found increasing levels of ground-level ozone in most regions (Wu and Chan, 2001; Chen et al., 2004 as cited in IPCC, 2007). A recent study found increases in $CO_2$ concentrations lead to increases in water vapor and temperatures. These lead to higher ozone concentrations in polluted areas, resulting in an increase in ozone-related deaths by 40 percent (Jacobson, 2008). Climate change is anticipated to increase ozone-related diseases (Sussman et al., 2008).

Ozone exposure is associated with respiratory ailments such as pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis, chest pain, shortness of breath, and premature mortality (Mudway and Kelly, 2000; Gryparis et al., 2004; Bell et al., 2005, 2006; Ito et al., 2005; Levy et al., 2005 in IPCC, 2007; American Lung Association, 2008). Asthmatics are considered a sensitive population (Ebi et al., 2008). Long-term exposure to elevated amounts of ozone has been shown to affect lung efficiency (Ebi et al, 2008; American Lung Association, 2008).

Particulate matter comprises solid and liquid particles suspended in the atmosphere varying in both chemical composition and origin. Concentrations of particulate matter are affected by emission rates and local weather conditions such as atmospheric stability, wind, and topography. Some particulates display seasonal variability directly linked to seasonal weather patterns (Alvarez et al., 2000; Kassomenos et al., 2001; Hazenkamp-von Arx et al., 2003; Nagendra and Khare, 2003; Eiguren-Fernandez et al., 2004 in IPCC, 2007). In Mexico City and Los Angeles, local weather conditions can create a stagnant air mass, restricting dispersion of pollution. Seasonal weather patterns can further enhance the chemical reactions of emissions, thereby increasing secondary particulate matter (Rappengluck et al., 2000; Kossmann and Sturman, 2004 in IPCC, 2007).

Breathing particulate matter can cause respiratory ailments, heart attack, and arrhythmias (Dockery et al., 1993; Samet et al., 2000; Pope et al., 1995, 2002, 2004; Pope and Dockery, 2006; Dominici et al., 2006; Laden et al., 2006 in Ebi et al., 2008). Those populations at greatest risk may include those with heart and lung disease, diabetes, children, the elderly, (Ebi et al., 2008) and high blood pressure (Kunzli et al., 2005 in Ebi et al., 2008). Chronic exposure to PM may decrease lifespan by one to three years (Pope, 2000 in American Lung Association, 2008). Increasing PM concentrations will have a significant adverse impact on human health (IPCC, 2007).

Forest fires contribute to poor air quality conditions. During the 5th largest United States wildfire in 1999, medical visits at the Hoopa Valley National Indian Reservation increased by 52 percent with symptoms affecting lower respiratory tract and preexisting cardiopulmonary conditions (Mott et al., 2002). Human health ailments associated with forest fires include burns, smoke inhalation, mortality, eye illnesses, and respiratory illnesses (IPCC, 2007; Ebi et al., 2008). Certain regions are anticipated to experience an increase in frequency and intensity of fire events with projected changes in temperature and precipitation. Pollution from forest fires along with other pollutants, such as carbon monoxide, ozone, desert dust, mould spores and pesticides, can be transported thousands of kilometers on time scales of 4 to 6 days affecting populations far from the sources (Gangoiti et al., 2001; Stohl et al., 2001; Buchanan et al., 2002; Chan et al., 2002; Martin et al., 2002; Ryall et al., 2002; Ansmann et al., 2003; He et al., 2003; Helmis et al., 2003; Moore et al., 2003; Shinn et al., 2003; Unsworth et al., 2003; Kato et al., 2004; Liang et al., 2004; Tu et al., 2004 in IPCC, 2007).

#### 4.5.8.2.5 Water-borne and Food-borne Diseases

Significant morbidity and childhood mortality has been linked to water- and food-borne diseases. Climate change is projected to alter temperature and the hydrologic cycle through changes in precipitation, evaporation, transpiration, and water storage. These changes, in turn, potentially affect water-borne and food-borne diseases, such as salmonellosis, campylobacter, leptospirosis, and pathogenic species of vibrio. They also have a direct impact on surface water availability and water quality. It has been estimated that over 1 billion people in 2002 did not have access to adequate clean water (McMichael et al., 2003 in Epstein et al., 2006). Increased temperatures, greater evaporation, and heavy rain events have been associated with adverse impacts on drinking water through increased waterborne diseases, algal blooms, and toxins (Chorus and Bartram, 1999; Levin et al., 2002: Johnson and Murphy, 2004 in Epstein, 2006). In the United States, 68 percent of all waterborne diseases between 1948 and 1994 happened after heavy rainfall events (Curriero et al., 2001 in Epstein et al., 2006). Climate change could further impact a pathogen by directly affecting its life cycle (Ebi et al., 2008). The global increase in the frequency, intensity, and duration of red tides may be linked to local impacts already associated with climate change (Harvell et al., 1999 in Epstein et al., 2006); toxins associated with red tide directly affect the nervous system (Epstein et al., 2006).

Many people do not report or seek medical attention for their ailments of water-borne or food-borne diseases; hence, the number of actual cases with these diseases is greater than clinical records demonstrate (Mead et al, 1999 in Ebi et al., 2008). Many of the gastrointestinal diseases associated with water-borne and food-borne diseases can be self-limiting; however, vulnerable populations include young children, those with a compromised immune system, and the elderly.

#### 4.5.8.2.6 Vector-borne Diseases

Infections can be spread by the bite of an infected arthropod (termed vector-borne), such as mosquitoes, ticks, sandflies, and blackflies, or through non-human vertebrates such as rodents, canids, and other mammals. Such diseases include typhus, malaria, yellow fever, dengue fever, West Nile virus, Western Equine encephalitis, Eastern Equine encephalitis, Bluetongue virus, and lyme disease. Increased insect density has been correlated with milder seasonal variability (IPCC, 2007) and tick distributions tend to expand with higher minimum temperatures (Ebi et al., 2008). In general, climate and weather are important constraints on the range of transmission for vector-borne diseases. For example, temperature and flooding are key constraints on the range of mosquitoes, which serve as a primary vector for malaria and other diseases (Epstein et al., 2006). Changes in seasonal duration and increases in weather variability reduce/eliminate these constraints (Epstein et al., 2006). In southern Mozambique a the number of malaria cases increased four to five times over long-term averages in the days and weeks following a severe flooding event in 2000 (Epstein et al., 2006). Temperature and the availability of water can both play key roles in regulating population size as well. For the deer tick, the disease vector for Lyme disease, off-host survival is strongly affected by these two variables, and thus climate is the primary factor determining size and distribution of deer tick populations (Needham and Teel, 1991; Bertrand and Wilson, 1996, in Epstein et al., 2006). Changes in land use practice or to the habitat and behavior of wildlife hosts of the insect can also impact latitudinal or altitudinal shifts in the disease carrying species (IPCC, 2007).

### 4.5.8.3 Projected Health Impacts of Climate Change on the United States

Human health is projected to be adversely affected by rising temperatures, increasing ground-level ozone concentrations, changes in extreme weather events, and increasing food and water-borne pathogens. The impact of the varying health-related event is dependent on location. The United States is anticipated to sustain fewer cases of illness and death associated with climate change compared with the developing world (Gamble et al., 2008). The current health infrastructure along with the United States government's disaster planning and emergency response systems are key assets to enable the United States to meet changing health effect demands associated with climate change. These health impacts will vary in scope across the United States

In the United States, there have been 20,000 heat and solar-related deaths from 1936 to 1975, with the heat wave of 1980 accounting for over 1,250 deaths (NOAA, 2005). A rise in heat-related morbidity and mortality may occur in the coming decades (Gamble et al., 2008) due, in part, to an aging population. By 2010, 13 percent of the United States population is projected to be over the age of 65, and 20 percent by 2030 (Day, 1996 in Ebi et al., 2008). Studies have shown a decline in heat-related mortality over the past decades, possibly due to increased air conditioning usage and improved health care (Davis et al., 2002; Davis et al., 2003a; Davis et al., 2003b; Carson et al., 2006 in Ebi et al., 2008). Heat waves are anticipated to increase in severity, frequency and duration, particularly in the Midwest and Northeast sections of the country (Gambel et al., 2008; Frumkin, 2008).

The northern latitudes of the United States are likely to experience the greatest increases in average temperature and concentrations of many of the airborne pollutants (Gamble et al., 2008). In particular, urban centers in the West, Southwest, Mid-Atlantic and Northeast regions are projected to incur the largest increases in average temperatures (Frumkin, 2008). A regional climate simulation projected air quality to worsen in Texas but to improve in the Midwest in 2045 to 2055 compared with 1995 to 2005 (Leung and Gustafson, 2005 in Ebi et al., 2008). In urban areas, ground-level ozone concentrations are anticipated to increase in response to higher temperatures and increases in water vapor concentration (Gamble, 2008; Jacobson, 2008). Climate change may further cause stagnant air masses that increase pollution concentrations of ground-level ozone and PM in populated areas. For example, one study projected an increase in the upper Midwest stagnant air between 2000 and 2052 (Mickley et al., 2004 in Ebi et al., 2008). Further, Frumkin (2008) found that climate change is likely to alter the air pollution contribution from natural sources and increase the creation of secondary pollutants; however, an alternative study found an increase in evaporative losses from nitrate particles reduces PM levels (Aw and Kleeman, 2003 in Ebi et al., 2008). A recent study concluded that continuous local outdoor $CO_2$ emissions can increase the respective $CO_2$ concentration for that area, thereby increasing ozone levels (Jacobson, 2008).

The spring pollen season has been shown to begin earlier than usual in the Northern Hemisphere (D'Amato et al., 2002; Weber, 2002; Beggs, 2004 in IPCC, 2007). There is further evidence suggesting a lengthening of the pollen season for some plant species (IPCC, 2007). A recent study determined that the density of air-borne pollen for some species has increased, however, it is not understood what the allergenic content of this additional pollen is (Huynen and Menne, 2003; Beggs and Bambrick, 2005 in IPCC, 2007). Additionally, climate change could alter the pollen concentration of a given plant species as the species reacts to increased concentration of $CO_2$. Current findings demonstrate that ragweed pollen production and the length of the ragweed pollen season increase with rising $CO_2$ concentrations and temperatures (Wan et al., 2002; Wayne et al., 2002; Singer et al., 2005; Ziska et al., 2005; Rogers et al., 2006a in IPCC, 2007). Invasive plant species with high allergenic content such as ragweed and poison ivy have been found to be spreading in particular locations around the world, increasing potential health risks (Rybnicek and Jaeger, 2001; Huynen and Menne, 2003; Taramarcaz et al., 2005; Cecchi et al., 2006 in IPCC,).

Extreme weather events are likely to be altered by climate change, though there is uncertainty predicting the frequency and severity of events. Some regions in the United States may incur drought conditions due to the reduction in rainfall, while other sections of the country are likely to experience increased frequency of heavy rainfall events leading to potential flood risk (Frumkin, 2008). On the West coast, water quality may be adversely affected as water supplies reduce with decreases in regional precipitation and depletion of mountain snowpacks (Frumkin, 2008). It is considered *very likely* (>90 percent certainty) that over the course of this century there will be an increase in the frequency of extreme precipitation (IPCC, 2007b in Ebi et al., 2008). The Southeast, Intermountain West and West are likely to experience an increase in frequency, severity and duration of forest fires (Gamble et al., 2008; Brown et al., 2004; Fried et al., 2004 in Ebi et al., 2008). Impacts to respective vulnerable populations may change in the future as shifts occur in population, suburban development, and community preparedness. It is very likely that a large portion of the projected growth of the United States population will occur in areas considered to be at risk for future extreme weather events (Ebi et al., 2008). Hence, even if the rate of health impacts were to decrease, the growth in population in risk areas will still cause an increase in the total number of people affected.

Pathogen transmission is dependent upon many climate-related factors such as temperature, precipitation, humidity, water salinity, extreme weather events, and ecological shifts, and may display seasonal shifts (Ebi et al., 2008). Few studies have projected the health impact of vector-borne diseases. Vector-borne illnesses are likely to shift or expand northward and to higher elevations with the possible introduction of new vector-borne diseases (Gamble et al., 2008; Frumkin, 2008), while decreasing the range of tick-borne encephalitis in low latitudes and elevation (Randolph and Rogers, 2000 in Ebi et al., 2008). Malaria and dengue fever in the United States are unlikely to be affected by climate change variables given the housing quality, land use patterns, and vector control (Frumkin, 2008).

Overall, populations within certain United States regions may experience climate change-induced health impacts from a number of pathways simultaneously. For instance, populations in coastal communities may experience an extreme weather event, such as a tropical cyclone and flooding, adding to health burdens associated with sea level rise or coastal erosion.

#### 4.5.8.3.1 Adaptation

The United States has a number of organizations and activities that identify and plan for the prevention of adverse health impacts associated with weather and climate although recent experiences following extreme weather and vector-borne disease outbreaks have demonstrated there is a need for improvement (Confalonieri et al., 2007 in Ebi et al., 2008). The regions where there is an anticipated increase in the health impacts of climate change are very likely to have a greater proportion of poor, elderly, disabled, and uninsured residents. In addition, the American Academy of Pediatrics has determined children are a vulnerable population, recommending the United States government give children particular attention when developing emergency management and disaster response systems (American Academy of Pediatrics, 2007; McMichael et al., 2001; US Department of Health and Human Services, 2007 in American Academy of Pediatrics, 2007).

The public health sector has divided the activities associated with preventing diseases into one of three classifications: primary, secondary and tertiary. Primary prevention protects the unaffected population from contracting diseases. Secondary prevention focuses on the response action that starts at the onset of a disease. Tertiary prevention deals with an existing disease and focuses on reducing suffering and long-term health difficulties. Primary prevention tends to be the most effective and least costly compared to secondary or tertiary prevention (Ebi et al., 2008).

Adaptation policies and measures to address human health impact due to climate change should be continually managed as climate change is dynamic. Such adaptation may include the:

- Support and maintenance of the public health infrastructure (Frumkin, 2008);
- Improvement and dissemination of preventive care in the public health infrastructure (Frumkin, 2008);
- Continued use of nationwide surveillance as a tool to identify, track and map vector-borne diseases (Frumkin, 2008);

- Utilization of preparedness tools to identify and assist vulnerable populations during extreme weather events (Frumkin, 2008); and

- Strengthening of infrastructure to withstand extreme weather events.

#### 4.5.8.4 Projected Global Health Impacts of Climate Change

Globally, climate change is anticipated to contribute to both adverse and beneficial health impacts. Projected adverse health impacts include malnutrition leading to disease susceptibility (*high confidence*); increased heat-wave, flood, storm and fire-induced mortality (*high confidence*); decrease in cold-related deaths (*high confidence*); increased diarrheal disease burden (*medium confidence*); increased levels of ground-level ozone (*high confidence*); and altered geographic distribution of some infectious disease vectors (*high confidence*) (IPCC, 2007). A decrease in cold-related mortality and some pollutant-related mortality, increased crop yields in certain areas, and restriction of certain diseases in certain areas (if temperatures or precipitation rises above the critical threshold for vector or parasite survival) are examples of projected beneficial health impacts (IPCC, 2007). The adverse impacts, however, greatly outweigh the beneficial impacts, particularly after the mid-century mark (IPCC, 2007).

Regionally, the impact on human health will vary. Some Asian countries may experience increasing malnutrition by 2030 with crop yields decreasing later in the century, rendering the population in the region particularly vulnerable to malnutrition-associated diseases and disorders (IPCC, 2007). Certain coastal areas will experience flooding by 2030 impacting human mortality (IPCC, 2007). By 2080, lyme disease is projected to have moved northward into Canada, due to a two- to four-fold increase in tick abundance (IPCC, 2007). By 2085, climate change is projected to increase the population at risk to dengue fever to a total of 3.5 billion people (IPCC, 2007).

Heat waves have been experienced globally: thousands of deaths incurred in India over the eighteen heat-waves recorded between 1980 and 1998 (De and Mukhopadhyay, 1998; Mohanty and Panda, 2003; De et al., 2004; in IPCC, 2007). In August 2003, approximately 35,000 deaths were linked to a heat-wave experienced in Europe, with France alone incurring over 14,800 deaths (Hemon and Jougla, 2004; Martinez-Navarro et al., 2004; Michelozzi et al., 2004; Vandentorren et al., 2004; Conti et al., 2005; Grize et al., 2005; Johnson et al., 2005; in IPCC, 2007). Around 60 percent of the heat-wave related deaths in France were people at or over 75 years of age (Hemon and Jougla, 2004 in IPCC, 2007). Overall, studies have linked high temperatures to about 0.5-2 percent of annual mortality in the elderly European population (Pattenden et al., 2003; Hajat et al., 2006 in IPCC, 2007).

In 2003, floods in China affected 130 million people (EM-DAT, 2006 in IPCC, 2007). In 1999, storms with floods and landslides in Venezuela killed 30,000 people (IPCC, 2007).

The World Health Organization (WHO) estimates that a high proportion of those in dry regions (approximately 2 billion) experience malnutrition, infant mortality, and water-related diseases (WHO, 2005 in IPCC, 2007). Children in low-income countries are particularly vulnerable to loss of life due to diarrhea. The transmission of the enteric pathogen appears to increase during the rainy season for children in the sub-Saharan Africa (Nchito et al., 1998; Kang et al., 2001 as cited in IPCC, 2007). In Peru, higher temperatures have been linked to periods of increased diarrhea incidence experienced by adults and children (Checkley et al., 2000; Speelmon et al., 2000; Checkley et al., 2004; Lama et al., 2004 in IPCC, 2007).

Cholera outbreaks associated with floods can occur in areas of poor sanitation. A study in Sea surface temperatures in the Bay of Bengal demonstrated a bimodal seasonal pattern that translated to increased plankton activity leading to increases in cholera in nearby Bangladesh (Colwell, 1996; Bouma and Pascual, 2001 in IPCC, 2007).

Dengue is considered the most important vector-borne viral disease (IPCC, 2007). A strong correlation exists between climate-based factors such as temperature, rainfall and cloud cover with the observed disease distribution in Colombia, Haiti, Honduras, Indonesia, Thailand and Vietnam (Hopp and Foley, 2003 in IPCC, 2007). Favorable climate conditions for dengue exist to about one-third of the world's population (Hales et al., 2002; Rogers et al., 2006b in IPCC, 2007).

Malaria is a vector-borne disease spread by mosquitoes. Depending upon location, malaria outbreaks may be influenced by rainfall amounts and sea-surface temperatures in southern Asia, Botswana, and South America (Kovats et al., 2003; Thomson et al., 2005; DaSilva et al., 2004 in IPCC, 2007). A recent study of malaria in East Africa found that the significant warming trend the area has experienced since the 1970s can be correlated with the potential of disease transmission. (Pascual et al., 2006 in IPCC, 2007) However, southern Africa was not shown to exhibit the same trend (Craig et al., 2004 in IPCC, 2007). External factors are also influencing the number of cases of the disease in Africa, such as drug-resistant malaria, and parasite and HIV infection. Studies did not provide clear evidence that malaria in South America or the continental regions of the Russian Federation have been affected by climate change (Benitez et al., 2004; Semenov et al., 2002 in IPCC). In general, however, higher temperatures and more frequent extreme weather occurrences (such as floods and droughts) are predicted to have a stronger influence on the wider spread of malaria with increasing climate change (McMichael et al. 1996, in Epstein et al., 2006).

Temperature has been shown to affect food-borne and water-borne diseases. Several studies have found increases in salmonellosis cases (food poisoning) within 1 to 6 weeks of the high-temperature peaks (controlled by season. This may be due, in part, to the processing of food products and the population varying its eating habits during warmer months (Fleury et al., 2006; Naumova et al., 2006; Kovats et al., 2004a; D'Souza et al., 2004; Naumova et al., 2006 in Ebi et al., 2008). High temperatures have been shown to increase common types of food poisoning (D'Souza et al., 2004; Kovats et al., 2004; Fleury et al., 2006 in IPCC, 2007). Increasing global temperatures could contribute to a rise in salmonellosis cases (Ebi et al., 2008). There is further concern that projected increasing temperatures from climate change will also increase leptospirosis cases, a disease that is resurging in the United States.

The effects of climate change on air quality are expected to adversely impact people suffering from asthma and other respiratory ailments. Increases in temperature, humidity, the prevalence and frequency of wildfires, and other factors are expected to result in more smog, dust, and particulates that exacerbate asthma. Widespread respiratory distress throughout many regions of the world is a possible result of climate change. Current asthma treatment and management plans may be overwhelmed, leading to major increases in asthma-related morbidity and mortality (Epstein et al., 2006).

Warm climates are more apt to support the growth of the pathogenic species of Vibrio leading to shell-fish related death and morbidity that may affect the United States, Japan and South-East Asia (Janda et al., 1988; Lipp et al., 2002 in Ebi et al., 2008, 2-10; Wittmann and Flick, 1995; Tuyet et al., 2002 in IPCC, 2008). If temperatures increase, the geographic range and concentration of the Vibrio species could expand. For example, as the waters of the northern Atlantic have warmed, the concentration of Vibrio species has also (Thompson et al., 2004 in Ebi et al., 2008). Future ocean warming might also lead to the proliferation of harmful algal blooms, releasing toxins that contaminate shellfish and lead to food-borne diseases (IPCC, 2007). Algal blooms such as red tide can also increase if fecal bacteria concentrations and nutrient loading increases from storm water runoff during heavy precipitation events (Frumkin, 2008).

In 2000, WHO estimated that climate change has caused the loss of more than 150,000 lives (Campbell-Lendrum et al., 2003; Ezzati et al., 2004; McMichael, 2004 in IPCC, 2007). The projected risks in 2030 described by the WHO study vary by health outcome and region; most of the increase in disease is due to diarrhea and malnutrition. More cases of malaria are predicted in those countries that are situated at the edge of the current distribution. The projected health impact associated with malaria is mixed, with some regions demonstrating increased burden and others exhibiting decreased burden.

#### 4.5.8.4.1 Adaptation

Climate change is considered to pose a risk to the health of both the United States and global populations (Ebi et al., 2008). Developed societies such as the United States are more likely to implement effective adaptation measures reducing the magnitude of severe health impacts. For example, the risk and impact of floods on a population can be reduced with changes in water management practices, improved infrastructure, and land use practices (EEA, 2005 in IPCC, 2007). Unblocking drains also helps to reduce the transmission of enteric pathogens (Parkinson and Butler, 2005 in IPCC, 2007). However, improvements world-wide in adaptive capacity are needed (*high confidence*; IPCC, 2007). Many governments have increased their efforts to cope with extreme climate events moving from disaster relief to risk management. Efforts in Portugal, Spain, France, UK, Italy and Hungary focus on short-term events such as heat waves (Pascal et al., 2006; Simon et al., 2005; Nogueira, 2005; Michelozzi et al., 2005; NHS, 2006; Kosatsky and Menne, 2005 in IPCC, 2007) while other efforts have undertaken long-term strategies addressing policies for agriculture, energy, forestry and transport (IPCC, 2007).

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# 4.6 ENVIRONMENTAL JUSTICE

## 4.6.1 Affected Environment

Executive Order (EO) 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations, directs Federal agencies to, "promote nondiscrimination in Federal programs substantially affecting human health and the environment, and provide minority and low income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment." EO 12898 also directs agencies to identify and consider disproportionately high and adverse human health or environmental effects of their actions on minority and low income communities, and provide opportunities for community input in the NEPA process, including input on potential effects and mitigation measures. CEQ, the entity responsible for compliance with EO 12898, has provided agencies with general guidance on how to meet the requirements of the EO as it relates to NEPA in *Environmental Justice Guidance Under the National Environmental Policy Act*. This guidance document also defines the terms "minority" and "low income community" in the context of environmental justice analysis. Members of a minority are defined as: American Indian or Alaskan Native, Asian or Pacific Islander, Black, and Hispanic. Low income communities are defined as being below the poverty thresholds from the Bureau of the Census.

In compliance with EO 12898, the agency provides a qualitative analysis of the cumulative effects of the proposed action with climate change and other identified relevant actions on these populations.

In addition to describing the cumulative effects of the proposed action on United States environmental justice populations, NHTSA also describes the global effects of climate change on global vulnerable populations in this DEIS. The agency has conducted this additional review because the global nature of climate change means the effects of this project have repercussion across the entire planet. This global environmental justice analysis examines the impacts of climate change on developing nations as they are more likely to have large numbers of residents living in poverty, and are therefore most closely aligned with the intention of the EO 12898 to examine effects on low-income populations.

Environmental justice populations tend to be concentrated in areas with a higher risk of climate related impacts. USCCSP notes that this geographic placement may put these communities at higher risk, "from climate variability and climate-related extreme events such as heat waves, hurricanes, and tropical and riverine flooding" (Gamble et al 2008, Ch. 5 p. 6).

## 4.6.2 Consequences

### 4.6.2.1 Non-Climate Change Effects

With consideration of the reasonably foreseeable increase in CAFE standards for MY 2016-2020, the minimum threshold for which has already been established by Congress as 35 mpg, a further decrease in oil consumption and production is predicted; these changes would further the trends affecting environmental justice populations described in Section 3.5.

The agency predicts that oil refining would decrease over the reductions predicted to result from the proposed MY 2011-2015 CAFE Standards, which could cause a decrease in related air pollutant discharges and a local improvement in air quality for oil refinery-adjacent residents. This could represent a small positive impact on environmental justice populations near these facilities.

All of the six criteria air pollutants regulated by EPA under the CAA and all but one of vehicle emission toxic air pollutants would decrease overall with adoption of any of the action alternatives and the foreseeable MY 2011-2015 standards (see Section 4.3). However, increases in vehicle miles traveled due to the "rebound effect" are still projected to cause increases in criteria pollutants to levels that exceed the EPA NAAQS in certain areas. The exceedance of the NAAQS in these areas would likely result in adverse impacts on environmental justice communities. It is not, however, possible to determine whether these impacts would represent a disproportionate impact on these communities.

### 4.6.2.2 Effects of Climate Change in the United States

Environmental justice populations in the United States, as defined by EO 12898, would experience the same general impacts as a result of global climate change felt by the United States population as a whole and described in Sections 4.5.6, Food, Fiber, and Forest Products, 4.5.7, Industry, Settlements, and Society, and Section 4.5.8, Human Health. However, the United States Climate Change Science Program notes that the general climate change impacts experienced the United States population may be differentially experienced by environmental justice populations, explaining that, "[e]conomic disadvantage, lower human capital, limited access to social and political resources, and residential choices are social and economic reasons that contribute to observed differences in disaster vulnerability by race/ethnicity and economic status" (Gamble et al 2008, Ch. 4, p. 12). A general description of the potential impacts of climate change on the population of the United States is provided below. These impacts are similar to those that would be experience globally, though the severity of impacts felt by developing countries would likely be disproportional to those experienced in developed nations, such as the United States. The most likely anthroprogenic climate change impacts include:

- **Human Health –** increased mortality and morbidity due to excessive heat, increases in respiratory conditions due to poor air quality, increases in water and food-borne diseases and changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition (see Section 4.5.7 for details)

- **Services –** disruption of ability to transport goods and services, shifts in the location of certain crops, disaster related damage to transportation infrastructure (roads, rail, ports), tourism location shifts, insurance premium increases (see Section 4. 5.6 for details)

- **Utilities and Infrastructure –** more frequent droughts and increases in irrigation/drinking water demand, flooding-related impacts on sewage systems with potential water quality impacts, and disaster related damage to transportation, power and communications systems (see Section 4.5.6 for details)

- **Human Settlement –** synergistic effects with existing resource scarcities (for example energy and water), inundation of inhabited coastal areas due to sea level rise, urban temperature increases (see Section 4.5.6 for details)

- **Social Issues –** increased stress on public services and disruptions to traditional cultures (see Section 4.5.6 for details)

- **Agriculture –** changes in crop yields, more intense droughts and floods, changes in the length of growing seasons (see Section 4.5.6 for details)

- **Forest and Ecosystem Service –** increased risk of forest fires, redistribution and extinction of economically or culturally significant wildlife species, expanded ranges for pests and invasive species (see Section 4.5.6 for details).

Environmental justice populations would likely be disproportionately affected by some of these potential impacts. The remainder of this section discusses, qualitatively, the most significant areas of potential disproportionate impact for these populations in the United States.

#### 4.6.2.2.1 Human Health

Low income and minority communities exposed to the direct effects of extremes in climatic conditions may also experience synergistic effects with pre-existing health risk factors, such as limited availability of preventative medical care and inadequate nutrition (Gamble et al. 2008).

As stated in Section 4.5.7, increases in heat related morbidity and mortality as a result of higher overall and extreme temperatures is likely to disproportionately affect minority and low income populations, partially as a result of limited access to air conditioning and high energy costs (Gamble et al. 2008; O'Neill et al. 2005). Urban areas, which often have relatively large environmental justice populations, will likely experience the most significant temperature increase due to the urban "heat island" effect and could be particularly vulnerable to this type of health impact (Gamble et al. 2008; Knowlton et al. 2007).

Increasing temperatures could also lead to expanded ranges for a number of diseases (Gamble et al. 2008). As described in Section 4.5.8, the number and severity of outbreaks for vector-borne illnesses, such as the West Nile Virus, could become more frequent and severe in the future. Because the vectors of these diseases (such as mosquitoes) are more likely to come into contact with environmental justice populations, disproportionate impacts may occur. For example, an outbreak of the mosquito-borne dengue fever in Texas impacted primarily low income Mexican immigrants living in lower quality housing without air conditioning, leading a team researching the outbreak to conclude that the low prevalence of dengue in the United States is primarily due to economic, rather than climatic, factors (Reiter et al. 2003).

#### 4.6.2.2.2 Land Use

In the United States, two primary types of geographical environmental justice communities are likely to be affected by global climate change: urban areas, because of their relatively high concentrations of low-income and minority residents, and indigenous communities. Environmental justice communities in urban areas, because of previously mentioned heat exposure and health issues, are likely to experience climate change impacts more acutely. Additionally, environmental justice populations in coastal urban areas (vulnerable to increases in flooding as a result of projected sea level rise, larger storm surges, and human settlement in floodplains) are less likely to have the means to quickly evacuate in the event of a natural disaster (Gamble et al. 2008; USCCSP 2007). USCCSP, as an example, notes that flooding in Louisiana following the 2005 Hurricane Katrina primarily killed poor and elderly residents without the means to flee (USCCSP 2008). As stated in Section 4.5.7, Industry, Settlements, and Society, traditional communities in the United States, particularly Alaska, could face major impacts on their subsistence economy from climate change. These impacts result from the indigenous communities' partial reliance on arctic animals, such as seals and caribou, for food and the potential destruction of transportation infrastructure due to ground thaw.

In coastal and floodplains areas prone to flooding because of larger storm surges and generally more extreme weather, increases in flood insurance premiums could disproportionately affect environmental justice populations unable to absorb the additional cost. Lack of sufficient insurance coverage could leave these populations more financially vulnerable to severe weather events.

Potential food insecurity as a result of global climate change, particularly among low-income populations in the United States and abroad, is an often mentioned concern (Wilbanks et al. 2007; Gamble et al. 2008). Climate change is likely to affect agriculture by changing the growing season, limiting rainfall and water availability, or increasing the prevalence of agricultural pests (see Section 4.5.6 for more information). In the United States, the most vulnerable segment of the population to food insecurity is likely to be low-income children (Cook et al., 2007 as cited in Gamble et al. 2008).

### 4.6.2.3 Effects of Global Climate Change

EO 12898, which requires Federal agencies to consider high and adverse disproportionate impacts of their actions on environmental justice populations, does not apply to areas outside of the United States or its territories and possessions; however, because of the global impact of climate change, the agency feels that its cumulative impacts assessment should include impacts on vulnerable global populations as well. This global, qualitative environmental justice analysis examines potential climate change impacts on developing nations.

Generally, low-income and other vulnerable populations would experience the same impacts from climate change as populations in comparable geographic areas described in the global impacts sections of 4.5.6, Food, Fiber, and Forest Products, 4.5.7, Industries, Settlements, and Society, and 4.5.8, Human Health. However, as with environmental justice populations in the United States, climate change impacts would likely be differentially experienced by vulnerable populations. The magnitude of climate change impacts on citizens of developing countries would be expected to be greater. For example, IPCC notes that the continent of Africa's, "major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change" (Wilbanks et al., 2007, p. 435).

#### 4.6.2.3.1 Human Health

As discussed in Section 4.5.7, the danger to human health from climate change will differentially affect developing countries. The IPCC states that, "Adverse health impacts will be greatest in low-income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers, and coastal populations" (Wilbanks et al. 2007, p. 393). Section 4.5.8 describes in detail the potential health effects from climate change on developing countries; these impacts include:

- increases in malnutrition, and related health impacts, in developing regions of the world due to declining crop yields;
- potential increases in water-related diseases, such as diarrhea causing pathogens, due to higher temperatures;
- potential for continuation of upward trends in certain vector-borne diseases, such as malaria in Africa, which have been attributed to temperature increases; and
- increases in temperature leading to increased ozone and air pollution levels in large cities with vulnerable populations.

#### 4.6.2.3.2 Land Use

Section 4.5.6 and 4.5.7 describes the effects of climate change on developing countries that would differ or be substantially more severe than similar effects experienced by developed nations. Because the developing world tends to have a greater reliance on small scale farming and subsistence economic activities, individuals in these areas will be disproportionately affected by climate change impacts on agricultural and subsistence resources. In particular, these impacts could include:

- decreases in precipitation in developing parts of the world, such as southern Africa and northern South America, leading to decreases in agricultural production and increased food insecurity;
- significant potential for impacts on small-scale subsistence farmers resulting from increases in extreme weather events projected under global climate change, reducing agricultural production in some areas of the globe;
- changes in the range of fish and animals and species extinctions, affecting populations in developing nations that are economically dependent on these resources;
- declines in tourism, especially to coastal and tropical areas heavily affected by sea level rise, with severe economic consequences for smaller, developing nations; and
- sea level rise and severe weather-related events affecting the long-term habitability of atolls (low coral reef-formed islands) (Barnett and Adger 2003).

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## 4.7 NON-CLIMATE CUMULATIVE IMPACTS OF $CO_2$

### 4.7.1 Affected Environment

In addition to its role as a GHG in the atmosphere, $CO_2$ is exchanged from the air to water, plants, and soil. $CO_2$ dissolves easily in water and more easily in salt water such as oceans. In water, $CO_2$ combines with water molecules to form carbonic acid. The amount of $CO_2$ dissolved into oceans is related to the concentrations in the air. This process reduces $CO_2$ available in the atmosphere as a GHG, but also increases the acidity of the ocean. Increasing levels of $CO_2$ are having a global effect on our oceans. By 2100, ocean pH could drop 0.5 units from pH levels seen in the 1900s (Hall-Spencer, et al., 2008).

Plants take $CO_2$ from the air through photosynthesis, and use the carbon for plant growth. This uptake by plants can influence annual fluctuations of $CO_2$ on the order of 3 percent from growing season to non-growing season (Schneider and Londer 1984 as cited in Perry 1994). Increased levels of $CO_2$ essentially act as a fertilizer influencing normal annual plant growth.

In addition, $CO_2$ concentrations affect soil microorganisms. Only recently have the relationships between above-ground ecosystems and below-ground components of ecosystems been considered significant; there is increasing awareness of the fact that feedbacks between the above-ground/below-ground components play a fundamental role in controlling ecosystems processes. For example, the organic carbon required for below-ground decomposition is provided by plants. Plants also provide the resources for root-associated microorganisms (Wardle, et al., 2004). The “decomposer subsystem in turn breaks down dead plant material and indirectly regulates plant growth and community composition by determining the supply of available root nutrients” (Wardle, et al., 2004, p. 1).

Specific plant species, depending on the quantity and quality of resources provided to below-ground components, may have greater impacts on soil biota and the processes regulated by those biota than do other plants. Variation in the quality of forest litter produced by co-existing species of trees, for instance, “explains the patchy distribution of soil organisms and process rates that result from ‘single tree’ effects” (Wardle, et al., 2004, p. 2). The composition of plant communities has a consistent and significant impact on the composition of root-associated microbes; however, the effects of plant community composition on decomposer systems are apparently context-dependent. In one example cited, manipulating the composition of plant communities in five sites in Europe produced distinctive effects on decomposer microbes while root-related soil microbes experienced no clear effect (Wardle, et al., 2004).

The amount of carbon stored in soils of temperate and boreal forests is about four times greater than the carbon that is stored by vegetation and is “33 percent higher than total carbon storage in tropical forests” (Heath, et al., 2005, p. 1711). Terrestrial communities contain as much carbon as the atmosphere. Forest soils are also the longest-lived carbon pools in terrestrial ecosystems (King, et al., 2004, p. 1027). Several experiments involving increases of atmospheric $CO_2$ resulted in increasing carbon mass in trees, but a reduction of carbon sequestration in soils. This is associated with increasing soil microorganism respiration (Heath, 2005; Black, 2008 (online)); respiration is associated with “root herbivory, predation, consumption of root exudates, and the decomposition of root and leaf litter” (King, et al., 2004, p. 1028). In future real-world scenarios, however, it is possible that the reduction of soil carbon via increased soil respiration could be countered by an increase in litter on the forest floor.

### 4.7.2 Consequences

One of the large-scale non-climatic effects of an increase in $CO_2$ emissions is the potential for ocean acidification. The ocean exchanges huge quantities of $CO_2$ with the atmosphere, and when atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere into the oceans. This lowers the pH of the oceans (more acidic water), which reduces the ability of shell-forming organisms to produce their shells. Most shells are made of calcium carbonate, which dissolves under acidic conditions (Hall-Spencer, 2008, et al; Kleypas, et al, 2006). According to Kleypas, et al (2008), under increasing atmospheric $CO_2$, “A variety of evidence indicates that calcification rates will decrease, and carbonate dissolution rates increase, as $CaCO_3$ (calcium carbonate) saturation state decreases.”

In conjunction with rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Reef building and reef dissolution is always occurring, but dissolution of coral reefs is expected to increase, and surpass reef building, as anthropogenic $CO_2$ in the atmosphere increases. If the water column above reefs becomes saturated with the $CO_2$ from the atmosphere, the water could be less able to hold the $CO_2$ respired by microorganisms in the reef environment. Although the interactions are complex and difficult to project, a possible scenario is that the excess of $CO_2$ in the reef environment could prevent reef-building. Thresholds for calcium carbonate dissolution exceeding calcification will vary for different reef systems (Kleypas, et al, 2006).

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. Plants use $CO_2$ as an input to photosynthesis. The IPCC Fourth Assessment Report (WGI, Chapter 7) states that “On physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to rising $CO_2$, referred to as ‘$CO_2$ fertilization’” (Denman et al. 2007, p. 562).

Under bench-scale and field-scale experimental conditions, a number of investigators have found that higher concentrations have a fertilizing effect on plant growth (e.g., Long et al. 2006; Schimel et al. 2000). IPCC reviewed and synthesized field and chamber studies, finding that:

> There is a large range of responses, with woody plants consistently showing net primary productivity (NPP) increases of 23 to 25 percent (Norby et al., 2005), but much smaller increases for grain crops (Ainsworth and Long, 2005) … Overall, about two-thirds of the experiments show positive response to increased $CO_2$ (Ainsworth and Long, 2005; Luo et al., 2005). Since saturation of $CO_2$ stimulation due to nutrient or other limitations is common (Dukes et al., 2005; Koerner et al., 2005), is the magnitude, and effect of the $CO_2$ fertilization is not yet clear.

The $CO_2$ fertilization effect could potentially mitigate some of the increase in atmospheric $CO_2$ concentrations by resulting in more storage of carbon in biota.

As with the climatic effects of $CO_2$, the changes in non-climatic impacts associated with the regulatory alternatives is difficult to assess quantitatively. In the base case, atmospheric $CO_2$ concentrations increase from current levels of about 380 ppm to as much as 800 ppm in 2100 (Kleypas, et al, 2006). It is not clear whether the distinction in concentrations is significant across alternatives, as the damage functions and potential existence of thresholds for $CO_2$ concentration are not known. However, it is clear that a reduction in the rate of increase in atmospheric $CO_2$ would reduce the ocean acidification effect, as well as the $CO_2$ fertilization effect.

#### 4.7.2.1 Soil Organisms

The current annual exchange in $CO_2$ between the atmosphere and terrestrial ecosystems is approximated as being nine to ten 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 significant impact on atmospheric $CO_2$ concentration (Heath, et al., 2005, 1712). The above-ground/below-ground processes and components in terrestrial ecosystems typically act to sequester carbon. Studies are now confirming that variations in atmospheric $CO_2$ have impacts not only on the above-ground plant components, but also on the below-ground microbial components of these systems.

In one study, $CO_2$ levels were artificially elevated in a forest for the purpose of studying the effect of atmospheric $CO_2$ on soil communities. An *indirect* impact of the increased $CO_2$ was that there were distinct changes in the composition of soil microbe communities as a result of increased plant detritus (BNL, 2007; Science Daily, 2007). In another study, an increase in $CO_2$ *directly* resulted in increased soil microbial respiration. However, after four to five years of increased exposure to $CO_2$, "the degree of stimulation declined" to only a 10 to 20 percent increased in respiration over the base rate (King, et al., 2004, p. 1033). Additionally, the degree of stimulation was linked to variability in seasonal and interannual weather (King, et al., 2004).

The increase in microbe respiration could, therefore, have the effect of diminishing the carbon sequestration role of terrestrial ecosystems. Upon reaching a certain level of $CO_2$ in the atmosphere, carbon sinks in soils could become net carbon emitters (Heath, et al., 2005; Black, 2008). Because of the number of factors involved in determining soil respiration and carbon sequestration, the threshold for significant changes in these activities varies spatially and temporally (King, et al., 2004).

# Chapter 5 Mitigation

The Council on Environmental Quality (CEQ) regulations implementing the National Environmental Policy Act (NEPA) require that the discussion of alternatives in an Environmental Impact Statement (EIS) "[i]nclude appropriate mitigation measures not already included in the proposed action or alternatives" (40 CFR § 1503.14[f]). In particular, an EIS must discuss the "[m]eans to mitigate adverse environmental impacts" (40 CFR § 1503.16[h]). As defined in the CEQ regulations (Sec. 1508.20); mitigation includes:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

The proposed action is the implementation of Corporate Average Fuel Economy (CAFE) standards for model year (MY) 2011–2015, as required by the Energy Independence and Security Act of 2007 (EISA). The cumulative impacts analysis considers the implementation of CAFE standards for MY 2011–2015 and the implementation of CAFE standards for MY 2016-2020.[1] Under the No Action Alternative the National Highway Traffic Safety Administration (NHTSA) would not implement the MY 2011–2015 CAFE standards, and NHTSA would issue a rule providing that the MY 2010 CAFE standards would continue to be implemented in MY 2011–2015. Each of the six alternatives to the No Action Alternative would result in a decrease in $CO_2$ emissions and associated climate change effects, an overall decrease in criteria air pollutant emissions and toxic air pollutant emissions, and a decrease in energy consumption as compared with the No Action Alternative. Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas (NAAs) as a result of implementation of the CAFE standards under the action alternatives. These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards. Under the No Action Alternative, $CO_2$ emissions and energy consumption would continue to increase; thus the proposed standard has a beneficial effect that would not need mitigation. Federal Highway Administration has funds dedicated to the reduction of air pollutants in non-attainment areas providing state and local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in non-attainment areas that would be observed under the proposed standard. Further, the U.S. Environmental Protection Agency (EPA) has authority to continue to improve vehicle emissions standards.

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[1] While NHTSA will set CAFE standards for MY 2016-2020 in a future rulemaking, NHTSA's NEPA analysis makes assumptions about the MY 2016-2020 standards based on the proposed MY 2011-2015 standards and alternatives, as well as EISA's requirements.

# Chapter 6 Unavoidable Adverse Impacts; Short-term Uses and Long-term Productivity; Irreversible and Irretrievable Commitment of Resources

## 6.1 UNAVOIDABLE ADVERSE IMPACTS

The proposed action is the implementation of Corporate Average Fuel Economy (CAFE) standards for model year (MY) 2011-2015. The cumulative impacts analysis considers implementation of CAFE standards for MY 2011-2015 and implementation of CAFE standards for MY 2016-2020.[1] Under the No Action Alternative the National Highway Traffic Safety Administration (NHTSA) would not implement the MY 2011-2015 CAFE standards, and NHTSA would issue a rule providing that the MY 2010 CAFE standards would continue to be implemented in MY 2011-2015. Each of the six alternatives to the No Action Alternative would result in a decrease in carbon dioxide ($CO_2$) emissions and associated climate change effects, a decrease in criteria air pollutant air emissions and toxic air pollutant emissions, and a decrease in energy consumption as compared to the No Action Alternative.

Based on our current understanding of global climate change, certain effects are likely to occur due to the sum total of GHG emissions going into the atmosphere. This proposed action or its alternatives would not prevent these effects. As described in Section 4.4 and 4.5, it may diminish the effects of climate change and contribute to global greenhouse gas (GHG) reductions.

Localized increases in criteria and toxic air pollutant emissions could occur in some nonattainment areas (NAAs) as a result of implementation of the CAFE standards under the action alternatives, largely due to increased vehicle miles traveled (VMT). These localized increases represent a slight decline in the rate of reductions being achieved by implementation of Clean Air Act standards.

## 6.2 THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The six proposed action alternatives would result in a decrease in energy (crude oil) consumption, and reductions in $CO_2$ emissions and associated climate change impacts over those of the No Action Alternative. Manufacturers would need to apply various technologies to the production of passenger cars and light trucks in order to meet the MY 2011-2015 CAFE standards under the six action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the six action alternatives; however, existing technologies and existing vehicle production facilities can be applied to meet the standards under the six action alternatives. Some vehicle manufacturers may need to make additional resource commitments to existing, redeveloped, or new production facilities to meet the CAFE standards. Such short-term uses of resources by the vehicle manufacturers to meet the CAFE standards would enable the long-term reduction of national energy consumption and would enhance long-term national productivity.

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[1] While NHTSA will set CAFE standards for MY 2016-2020 in a future rulemaking action, NHTSA's NEPA analysis makes assumptions about the MY 2016-2020 standards based on the proposed MY 2011-2015 standards and alternatives, as well as EISA's requirements.

## 6.3 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES UNDER THE ACTION ALTERNATIVES

United States energy consumption would decrease under all action alternatives as compared to the No Action Alternative. Energy consumption under each alternative is summarized in Table 3.2-2 for passenger cars and in Table 3.2-3 for light trucks. For the Optimized Alternative the fuel savings over the No Action Alternative in 2050 would be 11.1 billion gallons for passenger cars and 17.3 billion gallons for light trucks. For the Technology Exhaustion Alternative, the fuel savings over the No Action Alternative in 2060 would be 21.3 billion gallons for passenger cars and 27.5 billion gallons for light trucks.

As discussed above, manufacturers would need to apply various technologies to the production of passenger cars and light trucks in order to meet the MY 2011-2015 CAFE standards under the six action alternatives. NHTSA cannot predict which specific technologies manufacturers would apply to meet the CAFE standards under any of the six action alternatives. Existing technologies and existing vehicle production facilities can be applied to meet the CAFE standards under the six action alternatives; however, some vehicle manufacturers may need to make additional resource commitments to existing, redeveloped, or new production facilities to meet the standards. The total cost to manufacturers of meeting the MY 2011-2015 CAFE standards would be $16 billion for passenger cars as compared to the costs manufacturers would incur in continuing MY 2010 CAFE standards under the No Action Alternative (Notice of Proposed Rulemaking [NPRM] Section VI.C.2.). The specific amounts and types of irretrievable resources (e.g., electricity and other energy consumption) that manufacturers would expend in meeting the CAFE standards would depend on which specific methods and technologies manufacturers choose to implement. Commitment of resources for manufacturers to comply with the CAFE standards would be offset by the fuel savings from implementing the standards.

# Chapter 7 Preparers

## 7.1 NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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| Kevin Wang | J.D. Candidate, University of Maryland School of Law; B.S. Civil Engineering, University of California, Davis<br>2 years of experience in structural, hydraulic, and environmental engineering, and less than 1 year legal experience with NHTSA. |

## 7.2 CONSULTANT TEAM

ICF International was responsible for supporting the National Highway Traffic Safety Administration (NHTSA) in conducting its environmental analysis and preparing the Draft Environmental Impact Statement (DEIS) for the Corporate Average Fuel Economy (CAFE) Rulemaking Standards.

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| Ralph Grismala, P.E., Quality Control | M.S., Civil Engineering, Massachusetts Institute of Technology, B.S., Civil Engineering, Massachusetts institute of Technology<br>30 years of experience in geothermal and environmental impact analyses. |
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| John Hansel, Senior NEPA Advisor | J.D., cum laude, American University; B.A., Economics, University of Wisconsin at Madison<br>30 years of experience managing the preparation of NEPA documents. |
| Melinda Harris, Climate Change Cumulative Impacts Analysis Lead | M.A., Economics, University of Maryland; B.A., Economics, University of Maryland<br>20 years of experience analyzing economics and environmental policy analysis, including 12 years in assessing climate change impacts. |

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# Chapter 9 Distribution List

The National Environmental Policy Act (NEPA) regulations identify appropriate distribution (40 CFR Part 1500 to 1508). This chapter lists the agencies, officials, and other interested persons receiving this Draft Environmental Impact Statement (DEIS).

## 9.1 FEDERAL AGENCIES

- Advisory Council on Historic Preservation
- Centers for Disease Control and Prevention
- Council on Environmental Quality
- Delaware River Basin Commission
- Denali Commission
- Environmental Protection Agency
- International Boundary and Water Commission, Environmental Management Division
- Marine Mammal Commission
- National Capital Planning Commission, Office of Urban Design and Plan Review
- National Oceanic and Atmospheric Administration
- National Park Service
- National Science Foundation, Office of General Counsel
- Office of Science and Technology Policy, National Science and Technology Council
- Presidio Trust
- Susquehanna River Basin Commission
- Tennessee Valley Authority
- U.S. Agency for International Development , Bureau for Economic Growth, Agriculture and Trade
- U.S. Department of Agriculture, Agricultural Research Service
- U.S. Department of Agriculture, Animal and Plant health Inspection Service
- U.S. Department of Agriculture, Cooperative State Research, Education and Extension Service
- U.S. Department of Agriculture, Farm Service Agency
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Department of Agriculture, Rural Business-Cooperative Service
- U.S. Department of Agriculture, Rural Housing Service
- U.S. Department of Agriculture, Rural Utilities Service
- U.S. Department of Agriculture, U.S. Forest Service
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration
- U.S. Department of Commerce, Economic Development Administration
- U.S. Department of Commerce, National Marine Fisheries Service
- U.S. Department of Defense
- U.S. Department of Defense, Army Corps of Engineers
- U.S. Department of Energy, Office of NEPA Policy and Compliance
- U.S. Department of Energy, Office of Climate Change Policy
- U.S. Department of Health and Human Services, Office of the Secretary
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention
- U.S. Department of Health and Human Services, Food and Drug Administration (FDA)
- U.S. Department of Health and Human Services, FDA, Center for Food Safety and Applied Nutrition
- U.S. Department of Health and Human Services, Health Resources and Services Administration

- U.S. Department of Health and Human Services, Indian Health Service
- U.S. Department of Health and Human Services, National Institutes of Health
- U.S. Department of Homeland Security, Office of Safety and Environment
- U.S. Department of Homeland Security, Federal Emergency Management Agency
- U.S. Department of Homeland Security, U.S. Coast Guard
- U.S. Department of Housing and Urban Development
- U.S. Department of Interior, Office of Environmental Policy and Compliance
- U.S. Department of Justice, Environment and Natural Resources Division
- U.S. Department of Labor, Mine Safety and Health Administration
- U.S. Department of Labor, Occupational Safety and Health Administration
- U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs
- U.S. Department of Transportation, Secretary for Policy
- U.S. Department of Transportation, Federal Aviation Administration
- U.S. Department of Transportation, Federal Highway Administration
- U.S. Department of Transportation, Federal Motor Carrier Safety Administration
- U.S. Department of Transportation, Federal Railroad Administration
- U.S. Department of Transportation, Maritime Administration
- U.S. Department of Transportation, Federal Transit Administration
- U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration
- 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
- U.S. Environmental Protection Agency, Office of Federal Activities
- U.S. Environmental Protection Agency, NEPA Compliance Division
- U.S. Federal Energy Regulatory Commission, Office of Energy Projects
- U.S. Federal Energy Regulatory Commission, Division of Hydropower, Environment and Engineering
- U.S. Federal Energy Regulatory Commission, Division of Gas – Environmental and Engineering
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Institute for Environmental Conflict Resolution
- Valles Caldera Trust

## 9.2 STATE AGENCIES

- Alabama Department of Environmental Management
- California Office of Attorney General
- Connecticut Office of Attorney General
- Florida Department of Environmental Protection
- Florida Department of Transportation
- Florida Energy Office
- Hawaii Department of Transportation
- Maryland Historical Trust
- Massachusetts Office of Attorney General
- Minnesota Pollution Control Agency
- Missouri Department of Natural Resources
- Montana Department of Transportation
- New Jersey Department of Environmental Protection
- New Jersey Office of Attorney General

- New Mexico Department of Attorney General
- New York State Department of Transportation
- New York State Office of Attorney General
- Nevada Department of Transportation
- Nevada Division of Environmental Protection
- Oregon Department of Attorney General
- Oregon Department of Environmental Quality
- Pennsylvania Department of Environmental Protection
- Rhode Island Department of Attorney General
- Rhode Island Department of Environmental Management
- South Carolina Department of Transportation
- South Dakota Department of Environmental & Natural Resources
- Tennessee Department of Transportation
- Vermont Agency of Natural Resources
- Vermont Office of Attorney General
- Washington State Department of Ecology

## 9.3 ELECTED OFFICIALS

- The Honorable Sarah Palin, Governor of Alaska
- The Honorable Togiola T.A. Tulafono, Governor of American Samoa
- The Honorable Janet Napolitano, Governor of Arizona
- The Honorable Mike Beebe, Governor of Arkansas
- The Honorable Bill Ritter, Governor of Colorado
- The Honorable Ruth Ann Minner, Governor of Delaware
- The Honorable Sonny Perdue, Governor of Georgia
- The Honorable Felix P. Camacho, Governor of Guam
- The Honorable C.L. “Butch” Otter, Governor of Idaho
- The Honorable Rod R. Blagojevich, Governor of Illinois
- The Honorable Mitchell E. Daniels, Governor of Indiana
- The Honorable Chet Culver, Governor of Iowa
- The Honorable Kathleen Sebelius, Governor of Kansas
- The Honorable Steve Beshear, Governor of Kentucky
- The Honorable Bobby Jindal, Governor of Louisiana
- The Honorable John E. Baldacci, Governor of Maine
- The Honorable Martin O’Malley, Governor of Maryland
- The Honorable Jennifer M. Granholm, Governor of Michigan
- The Honorable Tim Pawlenty, Governor of Minnesota
- The Honorable Haley Barbour, Governor of Mississippi
- The Honorable Dave Heineman, Governor of Nebraska
- The Honorable John Lynch, Governor of New Hampshire
- The Honorable Bill Richardson, Governor of New Mexico
- The Honorable Michael F. Easley, Governor of North Carolina
- The Honorable John Hoeven, Governor of North Dakota
- The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana Islands
- The Honorable Ted Strickland, Governor of Ohio
- The Honorable Brad Henry, Governor of Oklahoma
- The Honorable Edward G. Rendell, Governor of Pennsylvania
- The Honorable Aníbal Acevedo-Vilá, Governor of Puerto Rico
- The Honorable Rick Perry, Governor of Texas

- The Honorable Jon Huntsman, Jr., Governor of Utah
- The Honorable John P. deJongh, Jr.,Governor of the United States Virgin Islands
- The Honorable Timothy M. Kaine, Governor of Virginia
- The Honorable Joe Manchin III, Governor of West Virginia
- The Honorable Jim Doyle, Governor of Wisconsin
- The Honorable Dave Freudenthal, Governor of Wyoming

## 9.4 NATIVE AMERICAN TRIBES

- Atmautlauk Traditional Council
- Big Pine Paiute Tribe of the Owens Valley
- Bois Forte Band of Chippewa
- Buckland Fuel Project
- Chalkyitsik Village Council
- Chickasaw Nation
- Enterprise Rancheria
- Flandreau Santee Sioux Tribe
- Fond du Lac Reservation
- Goshute Business Council
- Greenville Rancheria
- Holy Cross Village
- Jena Band of Choctaw Indians
- Kaibab Paiute Tribe
- Kokhanok Village Council
- Leech Lake Band Ojibwe
- Leisnoi Village aka Woody Island Tribal Council
- Lime Village Traditional
- Louden Tribal Council
- Miami Tribe of Oklahoma
- Mille Lacs Band of Ojibwe
- Minto Village Council
- Modoc Tribe
- Native Village of Atka
- Native Village of Buckland
- Native Village of Savoonga
- Native Village of Wales
- Nightmate Traditional Council
- Pinoleville Domo Nation
- Pueblo de San Illdefonso
- Red Cliff Tribe
- Skagway Traditional Council
- Swinomish Indian Tribal Community
- Tatitlek Village IRA Council
- Wiyot Tribe
- Yakutat Tlingit Tribe

## 9.5 COUNTY/LOCAL GOVERNMENTS

- Knox County, TN Department of Air Quality Management
- City of New York Environmental Law Division

## 9.6 STAKEHOLDERS

- Alliance of Automobile Manufacturers
- American Association of Blacks in Energy
- American Council for an Energy-Efficient Economy
- American International Automobile Dealers Association
- BMW (US) Holding Corp.
- California Air Pollution Control Officers Association
- Center for Biological Diversity
- Chrysler, LLC
- Conservation Law Foundation
- Daimler
- Environmental Council of the States
- Environmental Defense Fund
- Ford Motor Co.
- General Motors Corporation
- Gibson, Dunn & Crutcher LLP
- Insurance Institute for Highway Safety
- Kirkland & Ellis LLP
- National Automobile Dealers Association
- National Tribal Environmental Council
- Natural Resources Canada
- Natural Resources Defense Council
- Nissan North America, Inc.
- Northeast States for Coordinated Air Use Management
- Fuji Heavy Industries USA/Subaru
- University of Colorado School of Law
- Volkswagen Group of American
- Western Regional Air Partnership
- Yuli & Susan Chew
- Joan Claybrook

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